Liz Gray
G188 Volcanoes of the Eastern Sierra Nevada

The Glaciation of Yosemite

One of nature's most powerful and influential forces is also one of nature's coldest and slowest processes. These great icy rivers are called glaciers and have formed some of the most beautiful scenery on this planet. These enormous frozen bodies of water are often thousands of feet wide and deep and many miles long. They cover millions of acres of land and drastically change the land into beautiful mountains with many amazing features. One of the areas where glaciers have been most influential is in Yosemite National Park in California. Here almost every glacial feature is shown. However, before this information about glaciers in Yosemite was clear, there was the "Yosemite Controversy" with arguments of different views of how the valley originated. Glaciers are best described in this passage by naturalist John Muir: (Bailey) (Guyton)

> The work of glaciers, especially the part they have played in sculpturing the face of the earth, is as yet but little understood, because they have so few loving observers willing to remain with them long enough to appreciate them. Water rivers work openly where people dwell, and so does the rain and the dew, and the great salt sea embracing all the world; and even the universal ocean of air, though invisible, yet it speaks aloud in a thousand voices, and explains its modes of working and its power. But glaciers, back in their cold solitudes, work apart from men, exerting their tremendous energies in silence and darkness. Outspread, spirit-like, they brood above the long predestined landscapes, working on unwearied though unmeasured ages, until, in the fullness of time, the mountains and valleys and plains are brought forth, channels furrowed for the rivers, basins made for the lakes and meadows and long, deep arms of the sea, soils spread for the forests and the fields—then they shrink and vanish like summer clouds.
> (Muir, 1880, P. 557)

A glacier occurs when the climate of an area is so cold that new snow does not completely melt each summer and more snow is added in the winter. After many winters

the accumulation of this snow becomes compact and re-crystallizes, thus forming a glacier. Currently, glaciers cover about ten percent of the Earth's surface. Yet, in the past, glaciers covered much more land and were thousands of meters thick. (Tierney)

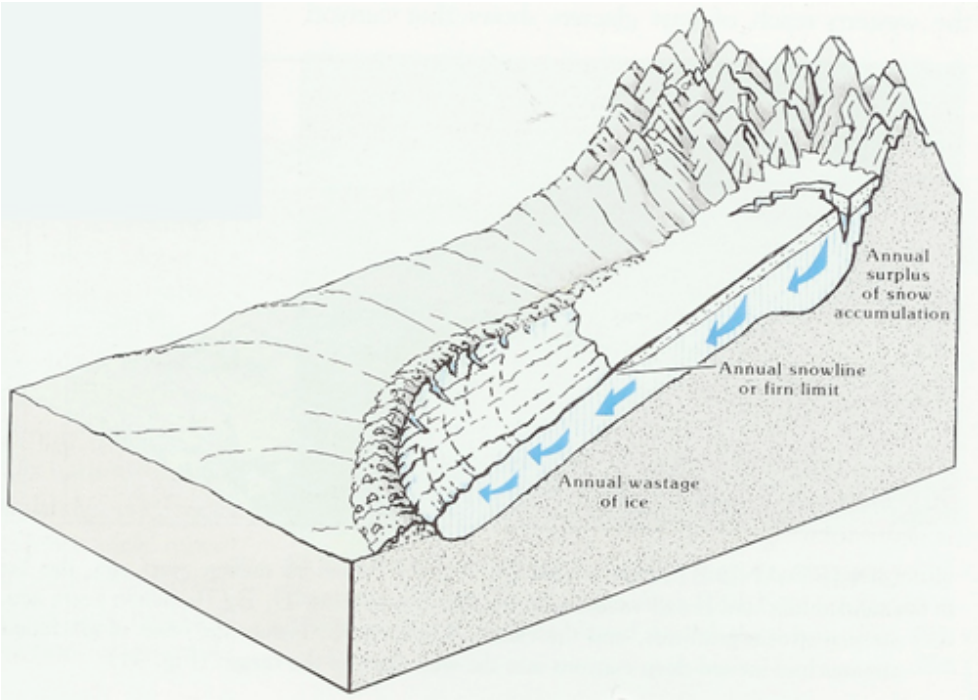
Glaciers take part in two of the Earth's cycles—hydrology and the rock cycle. When precipitation falls at high attitudes where glaciers exist, the rain or snow becomes a part of the glacier and may be stored in the glacier for up to thousands of years. Glaciers move very slow but are very important in erosion of rocks. (Lutgens & Tarbuck)

There are different types of glaciers that exist. Valley or alpine glaciers exist in mountain valleys. They occupy the space where a stream once was and become a glacial stream flowing down the valley. Ice sheets are a very different type of glacier. They are much larger and are at times referred to as continental ice sheets. They flow in all directions and cover the land they are on. An ice cap is another kind of glacier that covers the uplands and plateaus. They cover the surface they are on totally, but are smaller than ice sheets. The final type of glacier is a piedmont glacier. These cover the land at the bases of mountains and are formed when valley or alpine glaciers come out of the mountain valleys. (Lutgens & Tarbuck)

The ice in glaciers becomes under so much pressure that the glacier starts to flow like a very thick liquid. There are two types of flow. Plastic flow is flow within the ice. The other type of flow is when the entire ice mass slides on the ground. The rate of glacial flow varies from one glacier to the next. (Tierney)

Glaciers are always gaining more ice and losing ice. In the zone of accumulation, ice and snow is accumulated and thickens the glacier. There is also a zone of wastage where the old snow and ice melt. Ice is also lost when large masses break off, which is

called calving. This is what creates icebergs in the sea. The movement of a glacier mainly depends on the glaciers budget. When a glacier's zone of accumulation is larger than its zone of wastage, the glacier will move forward. When these two things are balanced a glacier will standstill. If the zone of wastage exceeds the zone of accumulation the glacier will retreat. (Lutgens & Tarbuck)



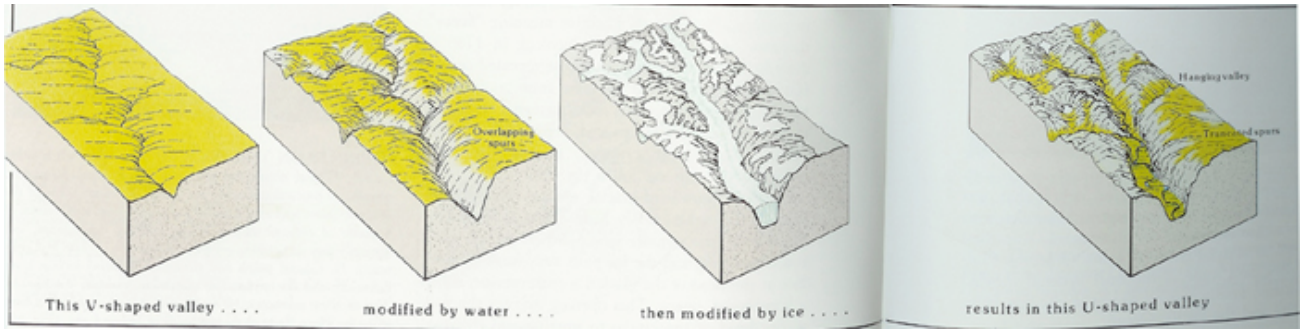
Taken and changed from Huber

Glaciers are key in the process known as erosion. A glacier will flow over bedrock and loosen rock by freezing in fractures and then melt and expand and break the rock. The glacier will pick up any loose chunks of rock and carry it. Glaciers will also smooth and polish the bedrock it passes over. The excess grinded rock is called rock flour and becomes a part of the glacier. Sometimes this rock flour is so abundant in the glacier that it changes the glacier's color to a gray shade. Glaciers may also cause grooves and scratches in the bedrock called glacial striations. (Lutgens & Tarbuck)

Alpine glacial erosion produces many different types of landforms that greatly contribute to the beauty of mountains. These landforms include glaciated valleys, cirques, arêtes and horns, and fiords. (Lutgens & Tarbuck)

Example of glacial polish taken from Hamburger

Before an alpine valley is glaciated, it is V-shaped because of streams that cut through. But, when a glacier enters a mountain valley, the glacier changes the valley. It makes the valley wider and deeper and makes the valley straight. The valley is transformed into a U-shape glacial trough. When a larger glacier cuts a valley deeper than other smaller glaciers, a hanging valley is formed. When the glaciers recede, beautiful waterfalls usually fall from these hanging valleys. (Lutgens & Tarbuck)



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A cirque is found at the head of a glacial valley. They start as an irregularity in a mountainside and are exaggerated by glacial erosion. They are the sides that keep the glacier in the mountain. They often form a huge basin that sometimes becomes a small lake once the glacier recedes. (Lutgens & Tarbuck)

Arêtes and horns are sharp ridges and peaks that project above the glacier. They are formed by the same processes of a cirque. Arêtes are formed when a ridge is made from a widening cirque or when there are two glacial valleys on either side of the arête. Horns are a single peak if rock that is isolated from the other peaks. (Lutgens & Tarbuck)

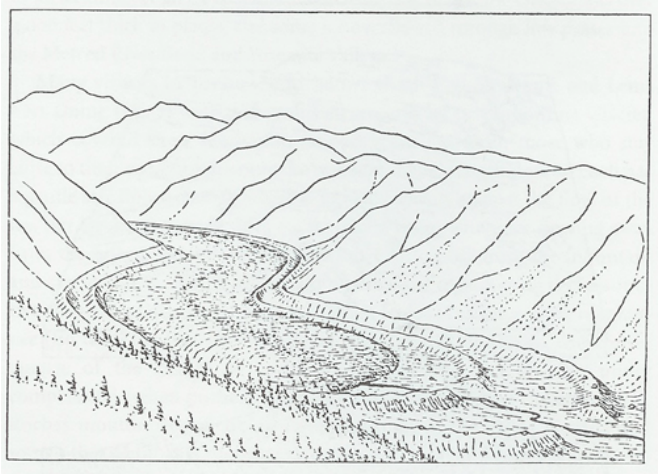
When a mountain is adjacent to an ocean, a fiord is formed. It is a trough that became level with the sea as the glacier melted. The trough becomes filled in by the sea and becomes a part of it. (Lutgens & Tarbuck)

Glaciers pick up and move debris as they flow. Once they melt, they deposit the debris. When glacial sediment is deposited it can change landscapes. This is one of the reasons boulders and rocks are found in fields and other unlikely places. The sediment from glaciers is known as glacial flow. There is till—directly deposited materials by a glacier—and striated drift—sediments from melted glacial water. (Lutgens & Tarbuck)

The most abundant landforms attributed to glaciers are layers of till called moraines. There are lateral and medial moraines which are found in areas where

mountain valleys exist and end, and ground moraines found where ice sheets and valley glaciers existed. (Lutgens & Tarbuck)

A valley glacier accumulates large amounts of debris from valley walls that is left when a glacier recedes. Lateral moraines exist along the sides of valleys while medial moraines are formed when two glaciers come together and their collective debris accumulates in the center of the glacier. Medial moraines are left when the glacier melts. (Lutgens & Tarbuck)



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An end moraine is formed when the zone of accumulation and zone of wastage is balanced. The glacier stands still but the ice moves forward carrying debris with it. The debris is carried to the end of the glacier and deposited and the ice moves back as if on a conveyer belt. This deposit of debris forms an end moraine. When the zone of wastage exceeds the zone of accumulation and the glacier starts to recede, the debris is still moved to the end of the glacier in the conveyer belt like motion. The debris is deposited along the ground because as the debris is coming to the end of the glacier, the glacier is receding and the end of the glacier is moving. This is called a ground moraine. (Lutgens & Tarbuck)

Many of the processes and landforms discussed were formed during a period of time known as the ice age. During this time glaciers covered the Earth much more than they do today. But the ice age was split up by many different periods of warming and cooling. The ice age began between two and three million years ago. Most of the glaciations of the Earth occurred during the geologic time period known as the Pleistocene epoch. There were also two ice ages in the Precambrian time period about two billion years ago and six hundred million years ago. There was also another ice age possibly even before those in the late Paleozoic time period. But, the most influential ice age was the most recent one in the Pleistocene epoch. (Lutgens & Tarbuck)

One of the most interesting and beautiful national parks is Yosemite. The reason it is this way is because of the glaciers that shaped it. But, it took many years for it to be determined that Yosemite was in fact shaped by glaciers. Yosemite was first discovered officially in 1851 by nonnatives. In the 1860s, the California Geological Survey started to study and try to understand Yosemite's origin. Yosemite became a subject of great argument in the 1870s and was known as the "Yosemite Problem" or the "Yosemite Controversy." The first person to give his view on Yosemite's origin was a geologist names Josiah D. Whitney. (Guyton)

Whitney believed that Yosemite Valley was formed by a down-dropping of a big rock that was between two faults. He thought glaciers were not very influential to the land. Whitney was most amazed by the vertical cliffs, the smooth face of Half Dome, and the flat valley floor. There is also a V-shaped valley along Tenaya Creek above Yosemite. Whitney's conclusion was that Yosemite's unique landforms must have been formed by faults: (Guyton)

> We conceive that, during the process of upheaval of the Sierra or, possibly some time after that had taken place, there was at the Yosemite a subsidence of a limited area, marked by lines of "fault" or fissures crossing each other somewhat nearly at right angles. In other and simpler language, the bottom of the Valley sank down to an unknown depth….
>
> (Whitney, 1868, P. 77)

Other geologists of the time—Clarence King, Israel C. Russell, and Andrew Lawson—agreed with Whitney's theory of the origin of Yosemite. They believed glaciers had little impact. But, Whitney did note some evidence he found of glacial activity that, if he had looked at it a little more closely, he might have realized the greater impact glaciers had than he believed. He spoke of one moraine in particular: (Guyton)

> [The moraine] may have acted as a dam to retain the water within the valley, after the glacier had retreated to its upper end, and that it was while thus occupied by a lake that it was filled up with the comminuted materials arising from the grinding of the glaciers above, thus giving it its present nearly level surface.
>
> (Whitney, 1865, P. 423)

Whitney was so close to understanding one of the main points that makes the glaciated valley so unique. There are thick lake sediments that cover the bottom of the U-shaped Yosemite Valley. These sediments make the valley floor flat and the valley looks like a dropped-down fault block or a graben. If there were no lake sediments, the valley would be a magnificent U-shaped valley and Whitney would have immediately realized the importance of glaciers in this place. (Guyton)

Although Yosemite Valley is assumed to be a place of textbook examples of glaciers it is, in fact, not. Yosemite has many landforms that are unique but are not formed from glaciers. North Dome, Sentinel Dome, and Half Dome were formed by weathering and exfoliation. Half Dome also had a vertical joint. El Capitan is beautiful because it has very few joints and is almost vertical. This could be from glacial erosion,

but cliffs are not only formed from glaciers. The Royal Arches, Washington Column, and Three Brothers were shaped by jointing and rock was removed by either rock falls or glacial rock plucking, but it is unsure which. The lake that was in the valley was a glacial lake, but as it appears it is not obviously a glacial lake. It is not unreasonable that Whitney did not notice glacial features. It is remarkable, however, that other people did recognize the glacial evidence such as John Muir. (Guyton)

Painting by Collins taken and changed from Matthes

John Muir was not a geologist or a college graduate. He was a nature lover that lived in Yosemite Valley. He first visited the valley at the age of thirty in 1868. He believed that glaciers were responsible for excavating the valley. He totally disagreed with Whitney's theory about Yosemite: (Guyton)

> The argument advanced to support this view is substantially as follows: it is too wide for a water-eroded valley, too irregular for a fissure valley, and too angular and local for a primary valley originating in a fold of the mountain surface during the process of upheaval; therefore a portion of the mountain bottom must have suddenly fallen out, letting the super-incumbent domes and peaks fall rumbling into the abyss, like coal into the bunker of a ship. This violent hypothesis, which furnishes a kind of Tophet for the reception of bad mountains, commends itself to the favor of many by seeming to account for the remarkable sheerness and angularity of the walls, and by its marvelousness and obscurity, calling for no investigation, but rather discouraging it.
>
> (Muir, in Colby, 1950, P. 18)

Although Muir had no college degree, it was obvious that he was a fit opponent for Whitney. He believed that glaciers were the only thing that shaped Yosemite as well as the entire Sierra Nevada Mountains. He believed that at a point in time, this entire region was cover by a large ice sheet. He thought this ice sheet was responsible for shaping all of the valleys and peaks in the mountains. He also had a theory about the glacial history of Yosemite: (Guyton)

> They number five, and may well be called Yosemite glaciers, since they were the agents by which beauty-loving nature created the grand valley, grinding and fashioning it out of the solid flank of the range, block by block, particle by particle, with sublime deliberation and repose.
>
> The names I have given them are, beginning with the northernmost, Yosemite Creek, Hoffman, Tenaya, South Lyell, and Illillouette [*sic*] Glaciers. They all converged in admirable poise around from north-east to south-east, welding themselves together into one huge trunk which swept down through the valley, filling it brimful from end to end, receiving small tributaries on its way from the Indian, Sentinel, and Pohono Cañons; and at length flowed out of the valley, and on down the range, in a general westerly direction.
>
> (Muir, 1880, P. 553)

The accepted version of the origin of Yosemite Valley is the view of François Matthes. He believed that both rivers and glaciers were responsible for the shaping of the valley. He stated that both rivers and glaciers deepened the valley and that glaciers alone widened the valley. His view is not completely the same as John Muir's, but it does support his view. In 1930 the United States Geological Survey published the first Professional Paper on Yosemite called *160, Geologic History of the Yosemite Valley*. This work was based on years of study by Matthes and others. (Guyton)

Matthes commented on Whitney's and Muir's views saying that they were both admirable for the evidence available to those men at the time. Matthes was able to make

better conclusions because he was better educated with a new topographic map and new ideas on how landscapes form. He made a statement about this issue: (Guyton)

> [S]ince the end of the nineteenth century there had come to maturity a new branch of geologic science—geomorphology, or physiography, as it is also termed—which deals specifically with the origin and development of the surface features of the earth and within whose scope a problem such as that of the Yosemite Valley largely belongs.
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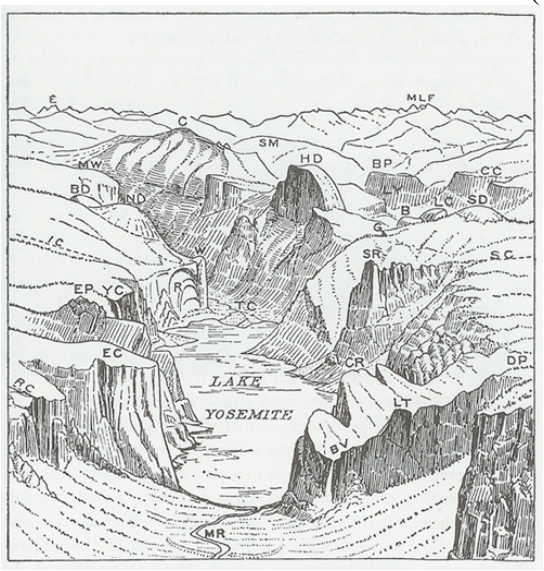
> (Matthes, 1930, P. 6)



Map by Matthes taken from Guyton

Matthes concluded that erosion by the Merced River and different glaciers formed the Yosemite Valley. This is the accepted version. But, since Matthes in 1930, there have been some modifications with new technologies and new information. The origin of Yosemite Valley was a contribution of many people, mainly Whitney, Muir, and Matthes. They made enormous contributions in the field of geomorphology and the geology of the Sierra Mountain region. With all of the information from geologists and new information since Matthes, there is now a complete view of the origin of Yosemite Valley. (Guyton)

25 million years ago, the Sierra Nevada Mountains started to slowly uplift and tilt westward. This caused the Merced River to erode a valley were Yosemite is. This

continued and deepened the valley maybe even 2,000 feet deep below the river valley divides. About 1.5 million years ago, the climate got cold enough for glaciers to form in the Sierras. Glaciers formed about three times (maybe more) in this region and these glaciers started to form a combined trunk glacier. These glaciers widened, straightened, and deepened the river valley and made it U-shaped with vertical cliffs. The most significant glacier occurred about one million years ago. This glacier eroded the east end of the valley to its maximum depth and the glacier totally filled the entire valley. This most influential glacier also created extremely steep valley walls and hanging valleys. When this glacier retreated, it most likely left waterfalls and a large lake that provided the sediments that cover up the U-shaped valley. After that glacier there were about two more but they were not as large. The last glaciation of Yosemite occurred only about 20,000 years ago and was not very big. When this last glacier retreated, it left moraines, Lake Yosemite, and waterfalls such as Yosemite Falls, Bridalveil Fall, Vernal Fall, and Nevada Fall. All of these landforms remain except for Lake Yosemite which was filled with sediment to cover the U-shaped valley even more. Currently, the Merced River runs through the valley. During all of this glacial activity, the Sierra Nevadas continued to uplift causing earthquakes and rock fall which shaped the valley even more. Rockfall has shaped the Royal Arches and Mirror Lake. Recently in July of 1996, there was a large rock fall and in January of 1997 the Merced River flooded proving that the geology of Yosemite is a forever changing process that still goes on to this day. (Guyton)

Taken from Hamburger

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