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Geology Inyo-face

The Glacially Sculpted Wonders of Yosemite

The great Sierra Nevada Batholith was created 120 million years ago as the result of the cooling of molten granitic rock. Over time the plutonic rocks were uplifted and expanded outward as the overlying rock eroded. The erosion process continued over the ensuing years, and through faulting and exfoliation, other layers of the Batholith were revealed. Located in the western side of Sierra Nevada, Yosemite Valley is an awe-inspiring formation, with a very unique geological history. Glaciers curved and carved Yosemite Valley but because of its singular, existing rock structure, magnificent domes prevailed, creating unrivaled heights and shimmering polished surfaces.

Most of Yosemite's domes underwent exfoliation, which refers to the sheeting and stripping of layers of rocks just as an onion is peeled. Essential to the makeup of Yosemite Valley, sheeting allows for a round surface to be created as opposed to sharp angular projections. This is in contrast to jointed rocks shaped by faulting which have horizontal and vertical cracks. Mary Hill states: "Sheeting describes the cracking of a rock along curved surfaces parallel to the surface of the rock. Jointing makes sharp, steep faces like the East Side of Mt. Whitney; sheeting provides the magnificent domes of Yosemite" (Hill 69). Mary Hill mentioned that some speculate that rounded sheeting occurred because of the mineral composition of the rock. The Yosemite walls are composed of quartz, feldspar, biotite, and hornblende. Feldspar in particular, when rained upon turns into a clay-like material and swells up, and then crumbles when dried. (Hill 1975) It is suggested that the initial orientation of Feldspar underground influenced

its later orientation towards a rounded peeling. When the glaciers began to sculpt through the boulders in Yosemite, they were only able to carry away jointed rocks, which were more susceptible to erosion. Smooth siliceous walls like El Capitan and Glacier Point in Yosemite remained in place as the glacier swept off those around it. The Bedrock Geology of Yosemite states "...the presence or absence of jointing in the rock determined the effectiveness of the erosive and sculpturing powers of the glaciers.

The Ice Age bore glaciers that covered Eastern North America, Canada, Washington, Idaho, and Montana. The height of the Sierra Nevada did not allow the sheets to incorporate it, but instead gathered glaciers of its own. Ice covered most of the Sierra, sparing only the highest peaks. As the snow melded together it increased in density and force. When the old snow doubled its size it became firn, which is what composes glaciers. After hundreds of years, these glaciers became a form of rock which was nine-tenths as heavy as water. The California glaciers were not as cold as the continental sheets but were closer to the melting point. These temperate glaciers allowed for some of the ice to melt, spurring streams. Glaciers move with their thickest area in the center, allowing water to run towards the sides. Mary Hill states that: "Glaciers can move as solids, by plastic flow, each molecule gliding across its neighbor as the giant ice sheet shuffles along"(Hill 129). This movement occurs when the ice is 100-150 feet thick moving at a rate of several inches per day.

Typically, as a glacier melts, it transforms the valley around it from a V-shape into a soft U-shape, with the head composing a cirque, or a tablespoon-shaped amphitheater. Although glaciers formed Yosemite, it deviates somewhat from the perfect textbook example of a U-shaped valley because it is flat on the bottom. It is uniquely

deeper and wider because its valley rock was easily broken and eroded. As the glacier left, it formed a terminal moraine, which formed a dam for a lake to form. This lake, aptly named Lake Yosemite was crucial in deepening and leveling out the valley. The Roadside Guide to Geology states: “Vertical valley walls give way to a nearly flat valley floor. The flatness itself is a clue that a lake once covered the valley floor. Evidence of the lake has also been found in the form of geophysical measurements indicating as much as 600 meters (2,000 ft) of sedimentary fill in parts of the valley, and well logs that reveal sediments to a depth of at least 300 meters (1,000 ft)”(Wahrhaftig, 1962).

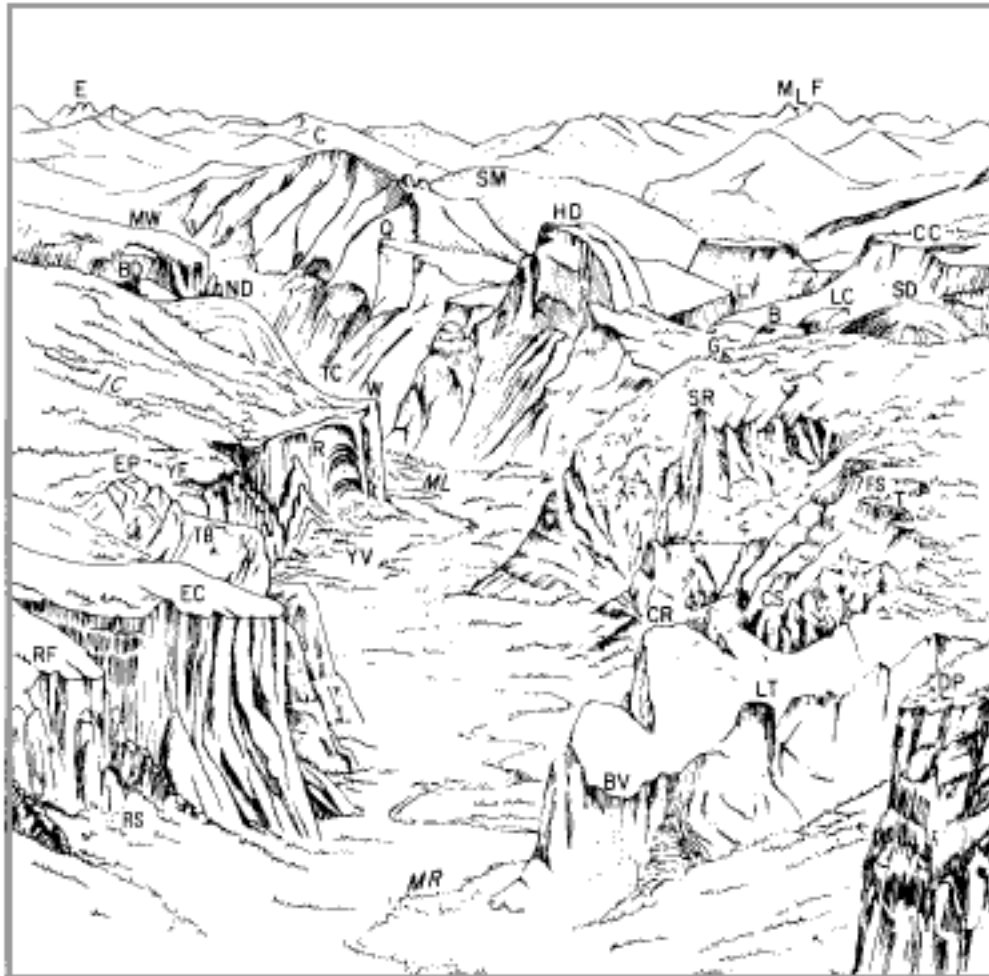


Figure 1. Bird's-eye view of Yosemite Valley, with identification of selected landforms. Sketch by Natalie Weiskal.

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|-----|-----------------------|-----|------------------|-----|------------------|
| RS, | Rockslides | BD, | Basket Dome | B, | Mount Broderick |
| RF, | Ribbon Fall | MW, | Mount Watkins | SD, | Sentinel Dome |
| EC, | El Capitan | E, | Echo Peaks | G, | Glacier Point |
| TB, | Three Brothers | C, | Clouds Rest | SR, | Sentinel Rock |
| EP, | Eagle Peak | SM, | Sunrise Mountain | FS, | Fissures |
| YF, | Top of Yosemite Falls | Q, | Quarter Domes | T, | Taft Point |
| YV, | Yosemite Village | HD, | Half Dome | CS, | Cathedral Spires |
| IC, | Indian Creek | M, | Mount Maclure | CR, | Cathedral Rocks |
| R, | Royal Arches | L, | Mount Lyell | BV, | Bridalveil Fall |
| W, | Washington Column | F, | Mount Florence | LT, | Leaning Tower |
| TC, | Tenaya Canyon | CC, | Cascade Cliffs | DP, | Dewey Point |
| ML, | Mirror Lake | LY, | Little Yosemite | MR, | Merced River |
| ND, | North Dome | LC, | Liberty Cap | | |

Figure 1. This picture depicts the deepened Yosemite Valley right after the Ice Age. Glaciers plowed on the granite, slate, and quartz with a pressure of a thousand tons to the square yard changing the V-shape to a flattened U. Sketch by Natalie Weiskal. Bedrock Geology of the Yosemite Valley

This picture depicts the deepened Yosemite Valley right after the Ice Age. Glaciers plowed on the granite, slate, and quartz with a pressure of a thousand tons to the square yard changing the V-shape to a flattened U.



Figure 2: Yosemite Valley from the Wawona Tunnel Overlook. Half Dome is in the direct center. The towering 7000 ft El Capitan is in the front left. *Roadside Geology of the Sierra Nevada*

Muir observes: “The lure of Yosemite Valley is as much due to its absolutely flat, parklike floor as to its sheer walls”(42)... All the glacier meadows are beautiful, but few are so perfect as this one. Compared with it the most carefully leveled, licked, snipped, artificial lawns of pleasure-grounds are coarse things”(Muir 158).

The individual glaciers to be discussed were from three different ice age eras: Tahoe, 60,000-75,000 years before present, Tenaya, 45,000 years before present, and Tioga, 20,000 years before present. The Tuolumne, Yosemite Creek, Hoffman, Tenaya, South Lyell, and the Illilouete Glaciers, were the principle sculpting agents of the grand Yosemite Valley.

The Tuolumne Glacier was the longest and most influential of all the Sierra ice rivers. It was not restricted to a river canyon, but spread itself out sixty miles and 2000 feet deep. The Tuolumne Glacier produced glacial “*moulin*” or glacial mills, holes formed by carving rocks. Also, it founded Liberty Cap, Mount Broderick, Unicorn, and Cathedral Peaks, “*roches moutonnees*,” or mutton rock, which are huge rounded domes with peaks that survived the glacier’s path.



Figure 3. The sheepish Unicorn Peak rises to the south of Tuolomne Meadows. Yosemitepictures.com

“They [the sheep domes] stood directly in the path of the glaciers and were overridden by them, yet they survived, each as a massive, unsubdued giant”(Hill 139).

Glaciers did not overrun Lembert Dome, Fairview Dome, and Pothole Dome but passing ice streamed as it went uphill and quarried as it descended. The glacier moved upward at a high angle against the back and a slight angle as it descended. The backside therefore was abraded, becoming smooth, while the downstream side was left coarse and mangled.

Glaciers are powerful eroding forces as they pick up sculpting agents when they move. When it encloses around rock it plucks or quarries chunks into its body. The rocks sit in glacial crevasses that range from one inch to fifty feet wide, and from a few feet to hundreds of feet deep. These rocks now act as grinders as it scrapes the floor sometimes

in curving lines upon which it travels. The same rocks it gathers are used to comb out a valley. Muir commented: “Not a peak, ridge, dome, canon, lake-basin, stream or forest will you see that does not in some way explain the past existence and modes of action of flowing, grinding, sculpturing, soil-making, scenery-making ice” (Muir 155). If the glacier collects smaller rocks and sand it becomes ground into sandpaper with which the great Yosemite domes were polished. Hill said: “Polished areas get their patina from the scouring action of minute particles of rock. Such polished areas glisten in the sunlight like old brass”(Hill 130). The polished areas are perfectly preserved since the ice age. Galen Rowell observes: “I used to think of such spots as remnants of some lost age, when the entire high country emerged from ice with a glassy surface, like the polished granite façade of a Manhattan building. My journeys to other great granite ranges of the world that remain locked in ice convinced me otherwise. In the Karakoram and in Patagonia, where retreating modern glaciers are exposing fresh granite as I write these words, the surface is not more evenly polished than this Tuolumne Meadows dome today”(Muir 154).

Fairview Dome, near the Cathedral Peak, is the most preserved out of all the domes. Fairview Dome is “...flat or gently undulating areas of hard resisting granite, which present the unchanged surface upon which with enormous pressure the ancient glaciers flowed”(Muir 156). It glistens with occasional scratches from withstanding the hovering Tuolumne Glacier. Fairview proves survival of the toughest granite, as the Tuolumne Glacier consumed its surrounding, weaker rocks that would later make up its moraine. Darwin’s survival of the fittest rock is displayed all over Yosemite as the Range both to the north and south of this region were composed of less resistant rocks, displayed

by their imperfect patches. Fairview hosts some erratic or foreign boulders that drifted on ice from twelve miles away. The Tuolumne Glacier sculpted Mounts Dana, Lyell, McClure, Gibbs, Conness, and the Hoffman Range. “These bald, westward-leaning rocks, with their rounded backs and shoulders toward the glacier fountains of the summit-mountains, and their split, angular fronts looking in the opposite direction, explain the tremendous grinding force with which the ice-flood passed over them, and also the direction of its flow”(Muir 160).



Figure 4. Fairview Dome stands brilliantly in the sunset to the right. Yosemitepictures.com

The domes unpolished peaks mark the height of the glaciers and the moraines show length of its body. Moraine is the French word for rubble heap, which describes the eclectic combination of scattered rocks it breaks up, holds, and then deposits. During 300 times of freezing and thawing, at the most, ten tons of dust is able to taken from five acres of granite mountains. This combines with debris from rock-slides, falling boulders and avalanches to compose the moraines. Rock ridges along the sides of a glacier are called lateral moraines, and they help to mark the length and width of a glacier. “None of

the commercial highways of the land or sea, marked with buoys and lamps, fences and guide-boards, is so unmistakably indicated as are these broad, shining trails of the vanished Tuolumne Glacier and its far-reaching tributaries”(Muir 160).

The Merced Glacier branched into five tributaries that were responsible for molding the grand valley: Yosemite Creek, Hoffman, Tenaya, South Lyell, and the Illilouete Glaciers. They moved from north-east to south-east and welded together into the Yosemite Glacier moving down into the valley and exiting westward. Only the upper part of the Three Brothers and Sentinel rose above the ice. The valley’s rocks layered in the glaciers to be carried above and out of the valley.

The Yosemite Creek Glacier was fourteen miles long, four miles wide and 500-1000 feet deep. Its tributaries flowed westward and then united curving south to spread two-mile sheets down the north side of Yosemite. Muir comments on the Yosemite Creek Glacier: “Encircling peaks began to overshadow its highest fountains, rock islets rose here and there amid its ebbing currents, and its picturesque banks, adorned with domes and round-backed ridges, extended in massive grandeur down to the brink of the Yosemite walls”(Muir 161). The wide Yosemite Creek glided upward, which contributed to the height of Yosemite Falls. The base of the tributary glacier was a thousand feet higher than the base of the main body. Now, a stream falls starting from the tributary. “Yosemite Falls leaping in three sections over a 1430-foot-high precipice through a raceway 815 feet high, to a final 320 foot plunge to the floor of Yosemite Valley, for a total of 2565 feet is such a ‘hanging’ waterfall”(Hill 135).



Figure 5. Upper Yosemite Falls thundering down it's arduous descent. Yosemitepictures.com



Figure 6. Bridal Veil drops 1612 feet, another example of a hanging waterfall. Yosemite pictures.com

The Hoffman glacier worked on depressing the basin as it declined 5 miles. It combined with the Tenaya Glacier to carve Half Dome, North Dome South Dome and other pieces of the head of the valley. The domes "... are miles in extent, only slightly interrupted by spots that have given way to the weather, while the best preserved portions reflect the sunbeams like calm water or glass, and shine as if polished afresh every day, notwithstanding they have been exposed to corroding rains, dew, frost, and snow measureless thousands of years"(Muir 156). As the glacier moved over Half Dome, it polished its face, and broke off the dome face leaving a steep cliff.



Figure 7. Half Dome from Sentinel Bridge stands alone...its fitting mate fallen to the woo of a powerful glacier. Rick Ellis <http://www.spinics.net/photo/>

South Dome is the only rock that is impossible to traverse by natural means. When the glaciers traveled down to Yosemite Valley they had to crack through a wall of domes from the Mount Starr King to the North Dome. South Dome was one of the first shining survivors as it persevered for tens of thousands of years.

The Tenaya Glacier was fourteen miles long, two miles wide, and 1500-2000 feet deep. It ascended between the Tuolumne and Tenaya basins and flooded over the northeastern rim slamming against Clouds' Rest Ridge. Toward the end of the Ice Age, the body melted which freed surface water. The Tenaya Glacier bore no terminal moraines since its trunk disappeared in a simultaneous setting. Also, its position was too steep to create lateral moraines but deposited rock under the Half Dome and Coliseum Peak.

The Nevada Glacier had three fountains 10,000-12,000 feet above sea, which were all apart of the Merced System. The first one moved from Matterhorn to Cathedral Peak, while the second one was parallel on the left, stretching through Merced. The last one enjoined the first two, from which stationed at a right angle going to the head of the basin. Three ranges of peaks discharged the snow for the fountains creating a rectangular basin. The main glacier body, three-fourths of a mile to a mile and a half wide, fifteen miles long, and from 1000-1500 feet deep departed from the western outlet and initiated its path between the Half Dome and Mount Starr King. On the Nevada Glacier, Muir wrote: "Picturesque rocks of every conceivable form adorned its banks, among which glided the numerous tributaries, mottled with black and red and gray boulders, from the fountain peaks, while ever and anon, as the deliberate centuries passed away, dome after dome raised its burnished crown above the ice-flood to enrich the slowly opening landscapes"(Muir 164). Its lateral moraine extends five miles from the beginning of the first tributary to the Illilouette Canon. The right lateral follows from the Cathedral tributary to the Half Dome mainly composed of porphyritic granite that came from the Feldspar and Cathedral Valleys.

The Illilouette Basin was filled with a glacier that was ten miles long and 1000 feet deep. Its fountains, at 10,000 feet high were stationed to the west of the Merced system where its tributaries flowed westward to conglomerate upon reaching the basin center. The tributary's right lateral moraine is 250 feet high and has three terraces, rising between the Red and Merced Mountains. The oldest, upper terrace is smooth since its rocks have rolled down with time. The Illilouette Basin center contains gravel similar to the debris of the moraines but is more eroded and smooth, being carried further by glacial streams. The north part of the basin is waving, gray granite composing the Starr King. The south wall is gray on top with white symmetrical sides from hydro-thermal alteration. The East fountain peaks have canons with cirques between them.

Yosemite was uniquely sculpted and polished by glaciers, transfiguring into a flat-U-shaped valley. Yosemite's domes' mineral composition affected their round sheeting which made them less susceptible to erosion. The glaciers swept away the angular and weaker rocks, leaving unparalleled domes like El Capitan and Half Dome. These mysterious wonders traveled through Yosemite thousands of years ago and were responsible for the shining high domes and deep valley that exist today. Muir poetically remarks: "But glaciers, back in their white solitudes, work apart from men, exerting their tremendous energies in silence and darkness. Outspread, spirit-like, they brood above the predestined landscapes, work on unwearied through immeasurable ages, until, in the fullness of time, the mountains and valleys are brought forth, channels furrowed for rivers, basins made for lakes and meadows, and arms of the sea, soils spread for forests and fields; then they shrink and vanish like summer clouds"(Muir 167).

Picture of present day glaciers in New Zealand:



Figure 8. Modern day glaciers covering the Grand Plateau, New Zealand. Mt. Cook stands on the left. Thousands of years from now, The Grand Plateau will probably melt into a U-shaped valley like its mirroring historical glacier-valleys. Tom Lowell <http://tv11.geo.uc.edu/ice/Glacier.html>

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