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Geologic Trips, Sierra Nevada

by Ted Konigsmark

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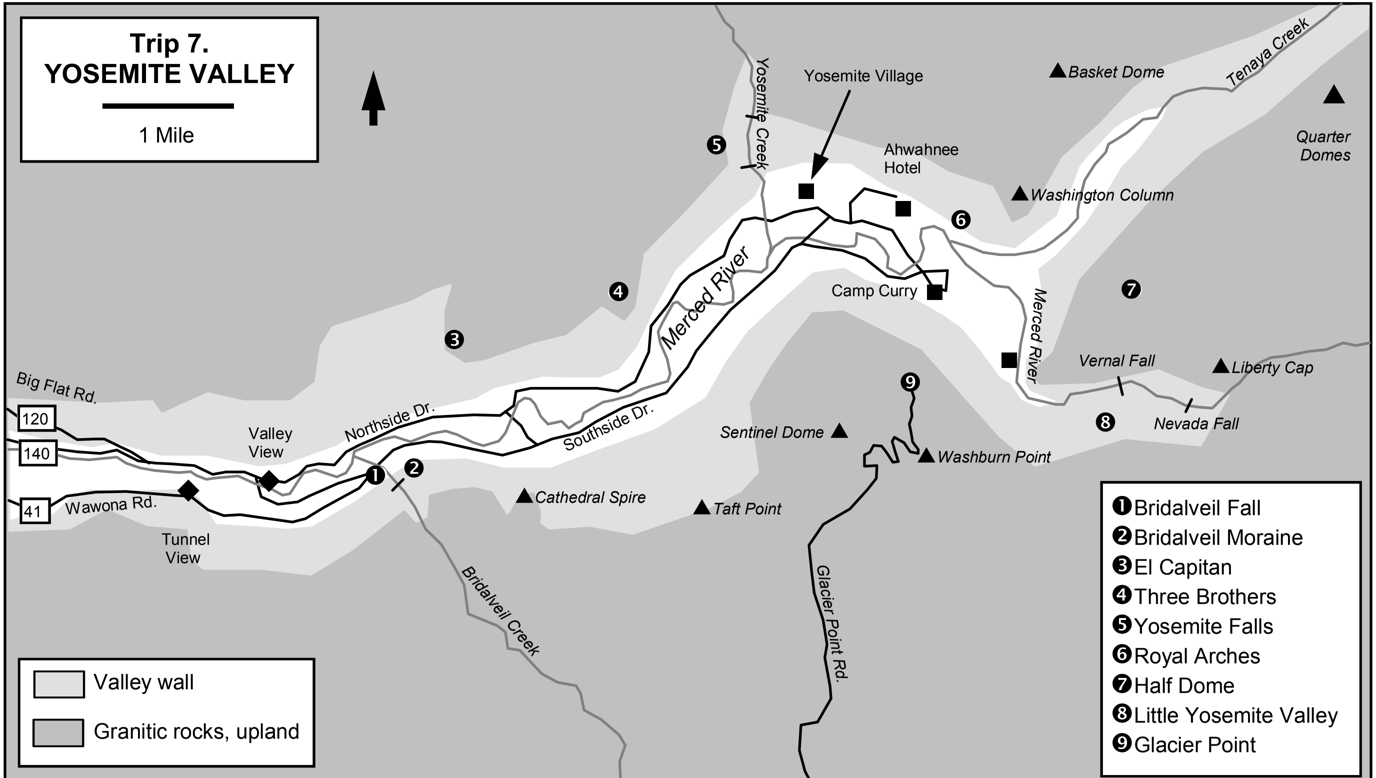

Trip 7.
YOSEMITE VALLEY
1 Mile
Yosemite Creek
Yosemite Village
Ahwahnee Hotel
Basket Dome
Tenaya Creek
Quarter Domes
Washington Column
Merced River
Camp Curry
Merced River
Vernal Fall
Liberty Cap
Nevada Fall
Big Flat Rd.
120
140
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Wawona Rd.
Tunnel View
Valley View
Northside Dr.
Southside Dr.
Sentinel Dome
Washburn Point
Cathedral Spire
Taft Point
Bridalveil Creek
Glacier Point Rd.
Valley wall
Granitic rocks, upland
1 Bridalveil Fall
2 Bridalveil Moraine
3 El Capitan
4 Three Brothers
5 Yosemite Falls
6 Royal Arches
7 Half Dome
8 Little Yosemite Valley
9 Glacier Point

Trip 7

YOSEMITE VALLEY

A Sculpture in Granite

The spectacular scenery in Yosemite Valley didn't just happen. Creation of the cliffs, waterfalls, spires, columns, arches, and domes of Yosemite required just the right type of rock and the right combination of geologic tools to shape the rock. The granitic rocks of the Sierra Nevada batholith were the perfect rocks to use in the sculpture of the valley. Granite is known for its hardness, beauty and enduring qualities. Among all of the rocks of the earth's crust, only granite would produce the scenery of Yosemite. The geologic tools that were used to shape the granite included jointing, exfoliation, river erosion, and glacial erosion. Each tool worked in its own special way on the granite, and it is the combination of these tools that have produced the magnificent scenery of the valley. During the trip to Yosemite, we'll visit many of its best-known scenic features, see examples of the different types of granitic rocks, and examine the tools that were used to form the scenery.

The Granite

At first glance, all of the granitic rocks in Yosemite Valley look alike. However, if you look at the rocks in more detail, you will see that there are several different types of granite. Each type represents a different pluton intruded at a different time and at a different depth, and has its own composition, cooling history, and characteristic minerals. Once you know what to look for, you can easily identify the different plutons. The accompanying table summarizes characteristics of the more important plutons in Yosemite Valley.

Each pluton weathers and erodes in a different manner. Granite that contains relatively large amounts of quartz, like the El Capitan Granite, tends to be massive, and has wide-spaced joints. In contrast, diorite, which has little or no quartz, tends to break into small blocks. The Half Dome Granodiorite tends to be massive with few joints, and is especially prone to developing exfoliation joints. The variety of cliffs, waterfalls, points, and domes that you see along the walls of Yosemite Valley are in large part due to the many variations of the granitic bedrock.

GRANITIC ROCKS Yosemite Valley			
Name	**Age**	**Description**	**Location**
Half Dome Granodiorite	Cret. 87 MYA	Medium to coarse grained, contains well-formed platesof biotite and rods of hornblende.	Half Dome Royal Arches North Dome Nevada Falls Vernal Falls Olmstead Point
Granodiorite of Kuna Crest	Cret. 91 MYA	Darker than Sentinel Granodiorite, streaky appearance, parallel flakes of biotite and hornblende; disc-shaped inclusions.	Glacier Point Washburn Point
Sentinel Granodiorite	Cret.	Medium gray, medium grained, contains poorly formed biotite and hornblende crystals.	Sentinel Rock Sentinel Fall
Taft Granite	Cret.	Similar to El Capitan, but lighter, finer, and no phenocrysts.	Brow of El Capitan Fissures
El Capitan Granite	Cret. 108 MYA	Massive, contains phenocrysts.	El Capitan Three Brothers Cathedral Rocks Leaning Tower Sentinel Dome
Diorite		Mostly plagioclase and dark minerals, little quartz and potassium feldspar.	Rockslides "North America" wall of El Capitan

The Valley Visitor Center in Yosemite Village has maps, books, and excellent displays explaining the scenery, glaciers, and rocks of Yosemite.

For general information about Yosemite, visit the official Yosemite National Park website www.nps.gov/yose. For recorded park information phone 209-372-0200. For information about roads and lodging in the surrounding area go to website www.yosemite.com

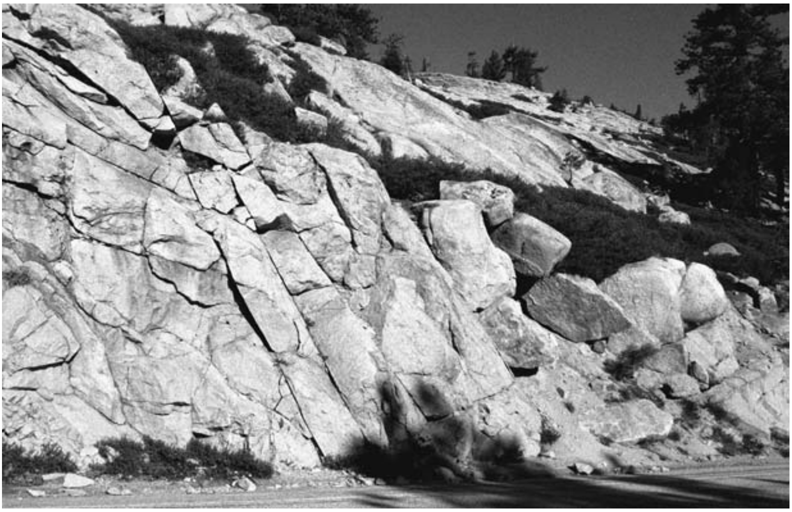
If you are interested in the distribution of the different types of granitic rocks of Yosemite, get a copy of U.S. Geological Survey Map I-1635 *Bedrock Geologic Map of Yosemite Valley.* Also, get the excellent publication *The Geologic Story of Yosemite National Park* by Huber, Both of these publications are available at the visitor center.

Joints

Joints are simply surfaces along which rocks have cracked. Joints may be formed by tectonic stresses or by contraction or expansion of the rocks. When granite solidifies from magma, it is buried at a depth of several miles and is under high pressure. Following uplift and erosion of the overburden, joints typically form in the granite as the rock expands because of release from the pressure of the overlying rocks.

Most joints are flat and parallel and most are nearly vertical. However, joints may also be inclined or even horizontal. Some joints are spaced just a few inches apart. Others are spaced hundreds of feet apart and extend for several miles. There may also be more that one set of joints. Where three sets of joints intersect, the granite is broken into blocks of various sizes, depending on the spacing of the joints.

Joints represent zones of weakness in the rock, and the rocks tend to break, weather, and erode along the joints. Rivers tend to follow joints. Cliffs and ledges are formed by large joints. Sloping ledges are formed by sloping joints. Joints play an important role in shaping all of the major landforms in Yosemite Valley. Where there are few joints, massive features such as El Capitan, Half Dome, and the Royal Arches are formed. Other features, such as Yosemite Falls, Three Brothers and Glacier Point are sculptured by two or three sets of intersecting joints.



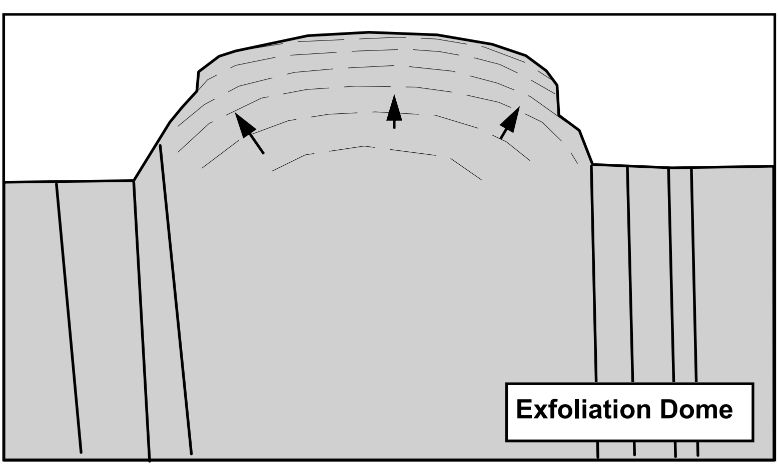
Joints are breaking this granite into large blocks. The blocks at the right side of the roadcut are being rounded into boulders by weathering along the joints.

Exfoliation Domes

Yosemite has a number of large, rounded domes such as Sentinel Dome, Half Dome, and North Dome. These domes were formed by a process referred to as exfoliation. Exfoliation occurs in large masses of homogeneous granite that are unjointed. As the overlying rocks are stripped by erosion, the granite expands. If the granite is jointed, then the expansion is accommodated along the joints. If the granite is not jointed, or has few joints, then the exposed surface of the granite tends to expand faster than the underlying granite. The surface layer of granite, typically a couple of feet thick, separates from the underlying granite along an expansion joint and forms a shell. As the process continues, several concentric shells may form to depths of a hundred feet or more.

Most of the massive chunks of granite that form domes began as large pieces of homogeneous granite that were bounded by large joints. During exfoliation, the sharp corners and flat surfaces along the joints were rounded and the granite was shaped into domes and elongated domes. Most of Yosemite Valley's domes are formed in the Half Dome Granodiorite. This rock is especially homogeneous and has few joints. The sparsity of jointing is probably related to the abundant quartz in the rock.

Some of the more important domes and exfoliation features that formed in the Half Dome Granodiorite include Half Dome, North Dome, Basket Dome, Liberty Cap, and Mt. Starr King. Since these domes were formed from unjointed rocks, they have resisted weathering and protrude above the surrounding landscape.



The Work of the Rivers

Although glaciers often get top billing for the formation of Yosemite Valley, the glaciers could not have done their job without the earlier work done by rivers. Rivers had a huge job to accomplish. During Cretaceous and early Tertiary time, they removed several miles of Tertiary rocks and metamorphic rocks from the top of the granite, and then cut deeply into the granite. By late Miocene time, the granite in the Yosemite area had been worn down to a landscape of low rolling hills with broad river valleys. The river valleys followed the joints in the granitic rocks. The unjointed granitic rocks resisted erosion and formed exfoliating domes that stood above the general landscape. If you want to see what this erosion surface looked like, take the short hike to Taft Point or Sentinel Dome. These trails lie on the Miocene landscape, and this upland surface has probably changed little since Miocene time.

At the beginning of Pliocene time, the Sierra Nevada began to be uplifted and tilted to the west along the Frontal fault system. The gradients of the west-flowing rivers, like the Merced River, were increased by the tilting, and these rivers began to cut deep valleys into the Miocene landscape. However, much of the Miocene landscape was unaffected by the westward tilting. Many of the tributary creeks to the Merced River, such as Yosemite Creek and Bridalveil Creek, flowed north or south. The west tilt of the uplifted Sierra block did not significantly steepen the gradient of these rivers, so there was no extra downcutting. However, when these tributaries reached the lip of the incised Merced River valley, the tributaries suddenly descended into the valley by waterfalls and cascades and then joined the Merced River at the bottom of the valley.

By the beginning of the Pleistocene time, the Merced River had cut a 1,500-foot-deep valley into the Miocene landscape. The valley was V-shaped, with a narrow bottom and steep slopes, and took several jogs as it followed large northeast- and northwest-trending joints. The valley was now ready to receive the glaciers that would apply the final carving and polishing to the granite sculpture.

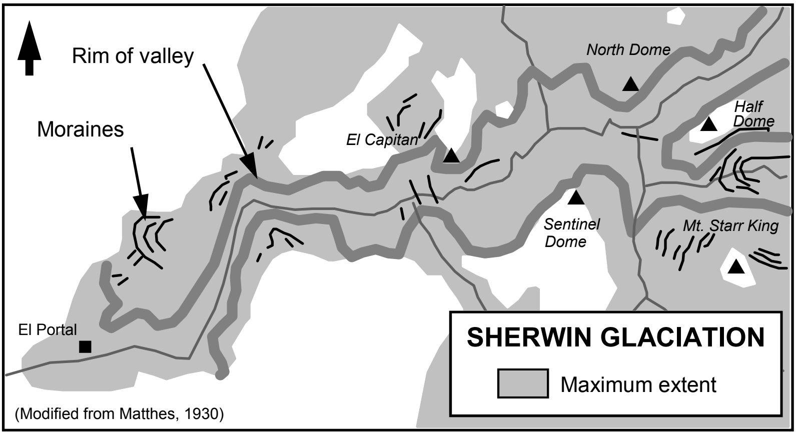
Pleistocene Glaciation

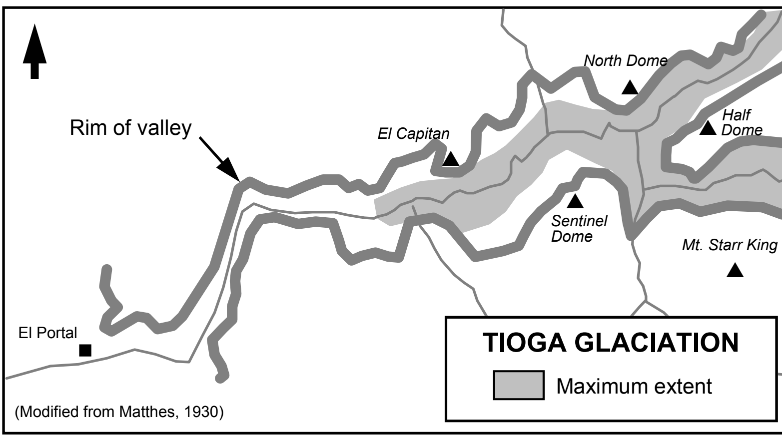
About two million years ago, at the beginning of Pleistocene time, a series of glaciers began their work on Yosemite Valley and profoundly changed the narrow V-shaped valley of the Merced River. The glaciers scooped out the bottom of the valley and removed as much as 2,000 feet of granite. They also excavated the sides of the valley so that the valley had a broad bottom and steep cliffs along the sides. Some of these cliffs were up to 3,000 feet high. Not yet satisfied, the glaciers carved these cliffs into arches, spires, and columns. The glaciers also cut off the lower parts of many of the tributaries to the Merced River so that these tributaries now flowed over the steep sides of the valley as waterfalls and cascades. These truncated tributaries, like Yosemite Falls and Bridalveil Fall, now form some of the highest and most spectacular waterfalls in the world. Enormous quantities of rock were excavated and removed from Yosemite Valley by these glaciers, and the glaciers did a major part of sculpturing nearly all of the scenic features that are characteristic of Yosemite Valley.

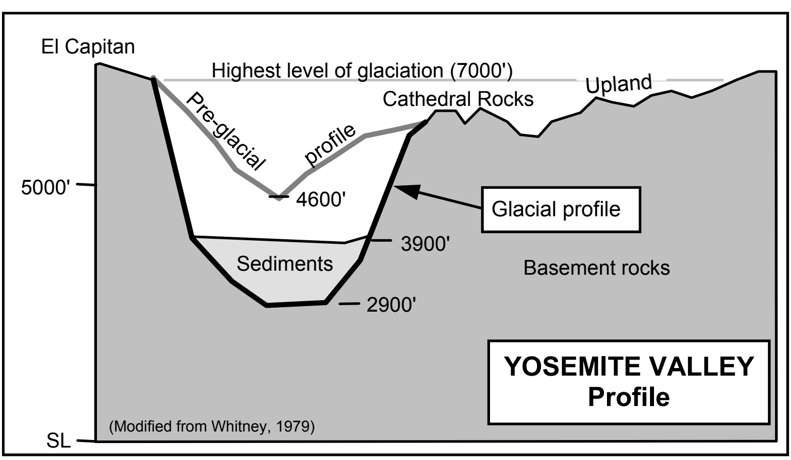
Each of the four major Pleistocene glacial episodes started with formation of a thick icefield that covered the Tuolumne Meadows area. From this icefield, glaciers descended down many of the valleys along the east and west slopes of the Sierra. One of these glaciers went down Tenaya Creek and another went down Little Yosemite Valley. These two glaciers joined at the head of Yosemite Valley and formed the Yosemite Valley glacier. The Yosemite Valley glacier then continued west through Yosemite Valley as far as El Portal.

Each glacial episode produced glaciers of different sizes and characteristics. The largest glacier was formed during the Sherwin glacial episode, about one million years ago. This glacier spilled over the sides of Yosemite Valley and covered Glacier Point, Washington Column, the Royal Arches, Bridalveil Fall, and the Cathedral Rocks. However, the tops of Half Dome, El Capitan, and Sentinel Dome were never covered by this or any other glacier. The Sherwin glacier was nearly 4,000 feet deep at the head of the valley north of Glacier Point. Imagine the tremendous pressure on the underlying rocks and on the rocks along the sides of the valley.

The last of the glacial episodes, the Tioga, reached its maximum about 20,000 years ago. This glacier was much smaller than the Sherwin, and extended west only as far Bridalveil Meadow, where it left a small terminal moraine.


Rim of valley
Moraines
El Capitan
North Dome
Half Dome
Sentinel Dome
Mt. Starr King
El Portal
SHERWIN GLACIATION
Maximum extent
(Modified from Matthes, 1930)


Rim of valley
El Capitan
North Dome
Half Dome
Sentinel Dome
Mt. Starr King
El Portal
TIOGA GLACIATION
Maximum extent
(Modified from Matthes, 1930)


El Capitan
Highest level of glaciation (7000')
Upland
Cathedral Rocks
Pre-glacial profile
5000'
4600'
Glacial profile
3900'
Sediments
Basement rocks
2900'
YOSEMITE VALLEY
Profile
(Modified from Whitney, 1979)
SL

❶ *Bridalveil Fall*

Bridalveil Fall is a classic example of a hanging valley. The valley of Bridalveil Creek lies 850 feet above the floor of Yosemite Valley and the fall leaps over a 650-foot near-vertical cliff where the creek enters the valley. The valley of Bridalveil Creek above the fall slopes very steeply so that the water in the creek is propelled over the edge of the cliff with great force. This large stream of water forms a beautiful parabolic curve if not broken by the wind. If the wind does take hold of the spray, it spreads the water into a beautiful shimmering veil.

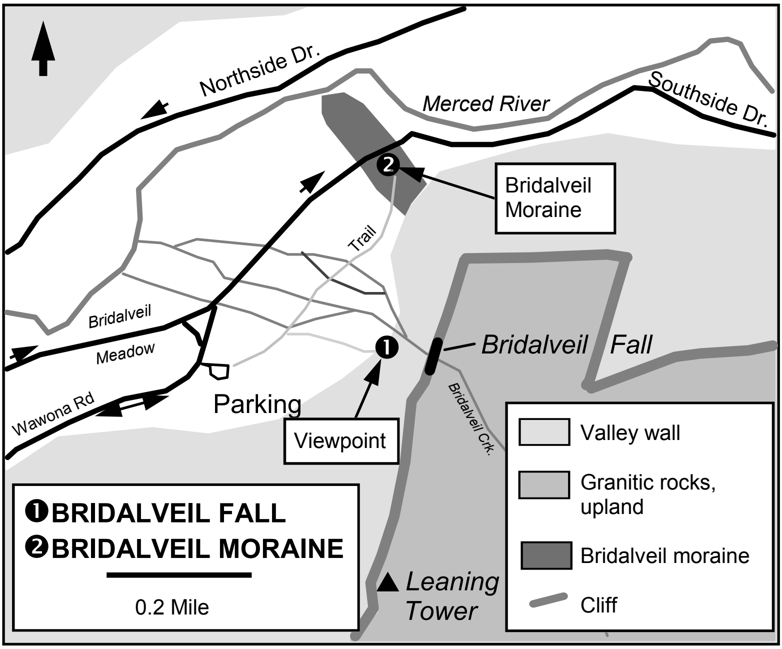
Prior to the Pleistocene glaciation, Bridalveil Creek flowed down a steep slope and joined the Merced River in the bottom of the valley. During the Pleistocene glacial episodes, glaciers deepened and widened Yosemite Valley and cut off the lower part of the creek. When the ice melted, Bridalveil Creek was left hanging high on the side of the valley.

Viewpoint **-** *Park at the Bridalveil picnic area, located on Hwy. 41 (Wawona Rd.) 100 feet S of Southside Dr.; take the short paved trail to the viewpoint at the base of Bridalveil Fall.*

From the Bridalveil viewpoint, you can get a close look at the waterfall. In the spring, when the water is flowing at full force, you can get quite wet here. Along the cliff face at the tip of Bridalveil Fall is a thick horizontal sheet of smooth-weathering Bridalveil Granodiorite. This rock is fine-grained and consists of evenly distributed light and dark minerals, which give the rock a salt-and-pepper appearance. Much of the remainder of the cliff is made up of the Granodiorite of Illilouette Creek.

The vertical face of the cliff is formed by a major north-trending joint that cuts the granodiorite. Moisture from the spray of the falls has accelerated weathering of the granitic rocks at the base of fall, forming a recess in the cliff. Because of this, Bridalveil Fall is steeper now than at the end of the Tioga glacial episode.

Yosemite has many hanging valleys. Almost all of the creeks that entered the valley from the sides are now hanging valleys. Among the most prominent of these are Yosemite Creek with Yosemite Falls, Sentinel Creek with Sentinel Fall, and Ribbon Creek with Ribbon Fall.



Bridalveil Fall is a classic example of a hanging valley. The lower part of Bridalveil Creek was cut off by the Yosemite Valley glacier.

❷ *Bridalveil Moraine*

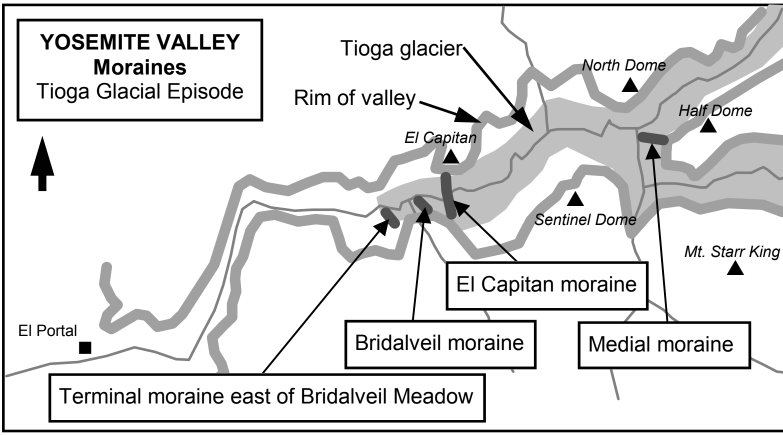
During Pleistocene time, glaciers periodically plowed down Yosemite Valley and left moraines and other glacial deposits on the valley floor as they retreated. Because the valley walls are steep, each glacier swept away the moraines that had been deposited on the valley floor by the previous glacier. Thus, all of the moraines on the present valley floor were deposited during the latest glacial episode, the Tioga.

You can see these moraines in several places on the valley floor. A small terminal moraine along the east side of Bridalveil Meadow marks the furthest westward extent of the Tioga glacier. Another moraine can be found along the south wall of the valley near Bridalveil Fall and is described below. Further east, the El Capitan moraine crosses the valley on the west side of El Capitan Meadow. This recessional moraine served as a dam for Lake Yosemite, which at one time covered much of the valley floor east of the moraine. The lake, which held the waters of the melting Tioga glacier, was rapidly filled by sediments from the retreating glacier and evolved into the meadow that now forms the flat floor of Yosemite Valley.

Another moraine occurs at the head of Yosemite Valley just north of the Pines Campground. This is a medial moraine that was formed where the Tenaya and Little Yosemite Valley glaciers joined at the head of Yosemite Valley. The moraine forms a hummocky ridge 50 to 60 feet high and about half-a-mile long. The road from Happy Isles to Mirror Lake passes through a saddle in this moraine.

Bridalveil Moraine - *From the Bridalveil parking area, go E on Southside Drive 0.3 miles and park near the roadcut on the S side of the road.*

The Bridalveil moraine forms a wooded ridge about 40 feet high that extends northwest from the south wall of the valley across Southside Drive to the bank of the Merced River. The materials that make up the moraine can best be seen in the roadcut on Southside Drive. In this roadcut, you will see many large smooth rounded boulders. Some of these granitic boulders have large feldspar phenocrysts which identify them as the Cathedral Peak Granodiorite. These boulders came from the Tuolumne Meadows area where there are extensive exposures of the Cathedral Peak Granodiorite. The granite boulders are mixed with many angular rock fragments of various sizes and abundant sand and mud. Many of the boulders and cobbles were scratched and grooved during transportation by the glacier.



Glacial outwash exposed along the bank of the Merced River at Bridalveil Meadow. Bridalveil Fall and the Leaning Tower are in the background.

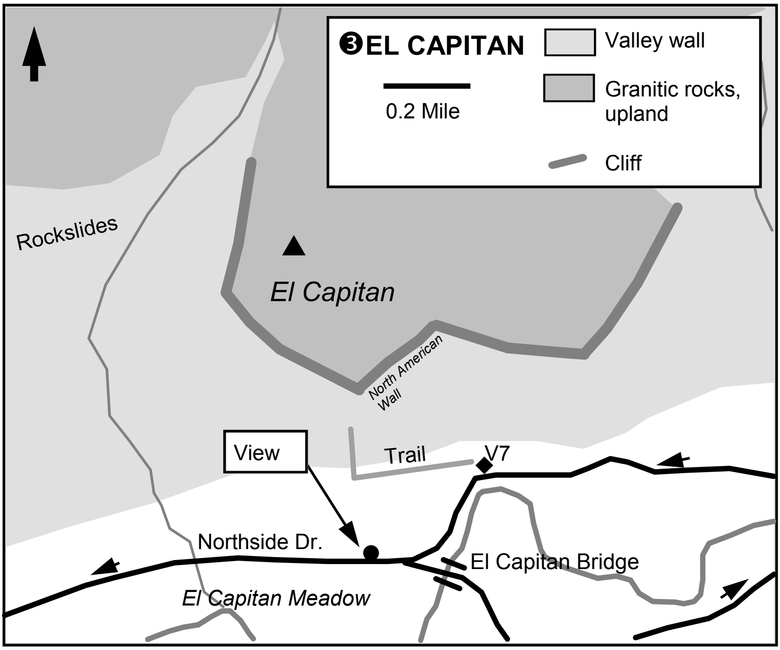
❸ *El Capitan*

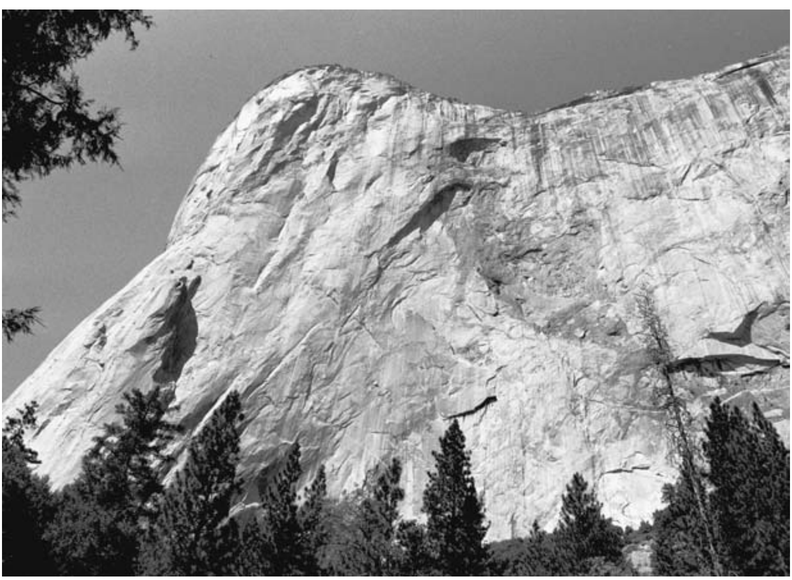
The huge granite monolith of El Capitan is the tallest unbroken cliff in the world, measuring 3,593 feet from base to summit. Although El Capitan stood directly in the path of the many Pleistocene glaciers that carved out Yosemite Valley, the monolith consists of hard unjointed granite and withstood the repeated onslaught of these powerful glaciers.

Most of El Capitan consists of the El Capitan Granite. This granite was ofrmed 108 million years ago and is one of the oldest granites in Yosemite Valley. The grains in the granite are large, and include quartz (30%), potassium feldspar (30%), plagioclase feldspar (30%), and dark grains of biotite and hornblende (10%). Coarse-grained granitic rocks with a high percentage of quartz, such as the El Capitan Granite, tend to be resistant to fracturing and jointing. This resistance to jointing enabled El Capitan to withstand the quarrying action of the glaciers.

Shortly after the El Capitan Granite solidified deep in the earth's crust, it was intruded by the Taft Granite, which is lighter gray, finer grained, and has no phenocrysts. The Taft Granite forms the summit brow of El Capitan. The east face of El Capitan is known as the North American Wall. This wall got its name came from a large irregular mass of dark rock that is exposed on the wall. This dark mass of rock is roughly the shape of North America and consists of diorite that has intruded the El Capitan Granite. Diorite is finer-grained and more mafic in composition than granite, and gives "North America" its dark color. Detailed studies have shown that the granite and diorite magmas mixed along their contacts, forming rocks of intermediate composition. This indicates that the intrusion of the diorite took place when the diorite was extremely hot and before the El Capitan Granite had completely solidified.

> ***View -*** *Park on Northside Drive, immediately W of El Capitan Bridge.*
> From El Capitan Bridge, there are excellent views of the steep face of El Capitan. If you want to get to the base of El Capitan, take the short trail that leaves from the parking area near marker V7. At the base of the cliff, you will see the large rocks that have broken from the cliff. These rocks give a good representation of the rocks that make up the cliff. You may even find some rocks that show the contact between the granite and the dark diorite that intruded the granite. Considering the height of the cliff, there are relatively few rocks at the base, indicating that the cliff is eroding more slowly than most of the other cliffs along the valley. Looking at the rocks at the base of the cliff is a good alternative to climbing the North American Wall.





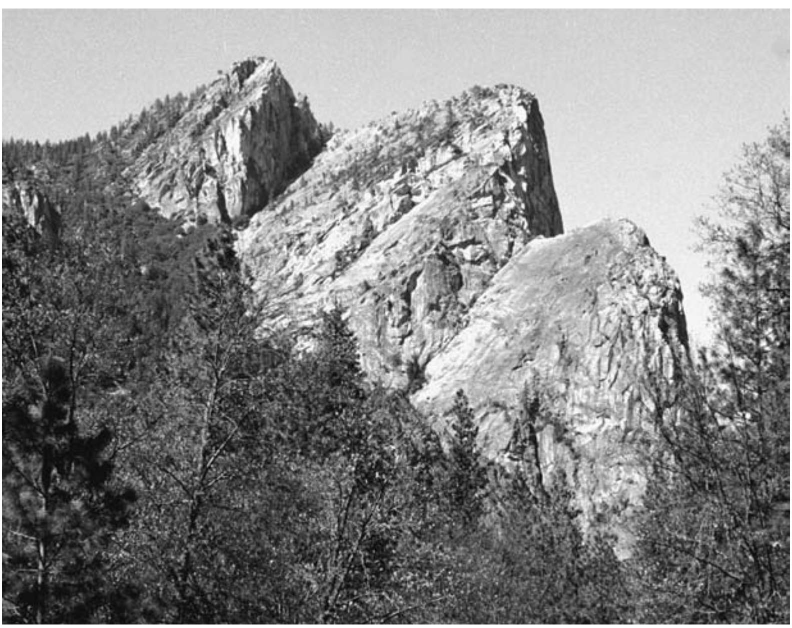
The North American Wall on the southeast face of El Capitan has a large dark area shaped like North America. The dark patch is formed from diorite that intruded the El Capitan Granodiorite during crystallization of the granodiorite.

❹ *Three Brothers*

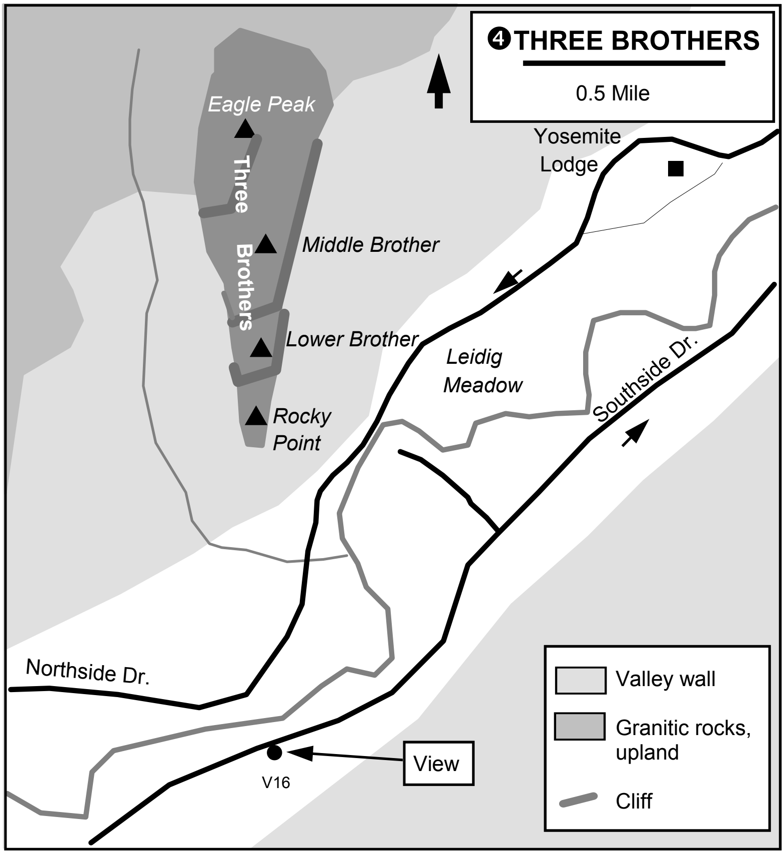
The Three Brothers are a series of three peaks that lie on the north side of Yosemite Valley between El Capitan and Yosemite Falls. The three peaks have similar sloping surfaces, and are obviously related. The Three Brothers were formed by jointing and provide one of the finest examples of jointing that can be seen in Yosemite Valley.

View - *On Southside Dr. 2 mi. E of Bridalveil Fall; marker V16.*

Looking north from this viewpoint you can get a good view of the three successively higher rocky peaks that make up the Three Brothers. The highest point is Eagle Peak. Next are Middle Brother and Lower Brother. The Three Brothers are formed from the El Capitan Granite. The granite is cut by three intersecting sets of wide-spaced joints, and these joints form the outline of each of the three peaks. The most prominent set of joints dips steeply to the west and forms the steep west-sloping roof of each brother. On each roof you can see many thinner parallel slabs of granite formed by the same set of west-sloping joints. Another set of joints forms the near-vertical south face of each peak. The third set of joints is less



The Three Brothers are formed by three sets of intersecting joints and are one of the finest examples of jointing in Yosemite Valley.



regular, but forms the steep east slope of each brother. Ledges and broken rocks follow smaller joints along all three sets of joints.

During Pleistocene glaciation, the glaciers that moved west down the valley covered much of the Three Brothers from time to time, although they never covered the top of Eagle Peak. As the glaciers moved down the valley they removed large blocks of granite from the three sets of joints. The quarry action of the glaciers worked especially well on the west sides of the peaks and the glaciers were very efficient at removing the flat slabs of rock that form the roofs of the Three Brothers.

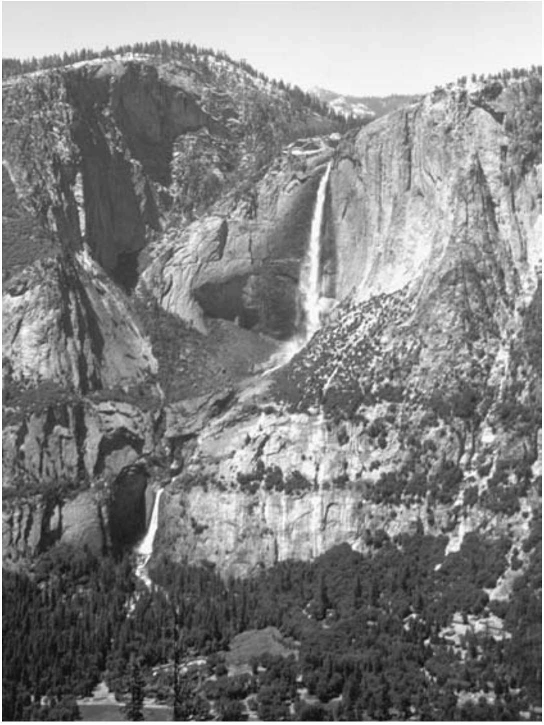
The same three sets of joints that are responsible for the Three Brothers can be seen on the south side of the valley, where they form asymmetric spurs and slanting rock surfaces near Taft Point.

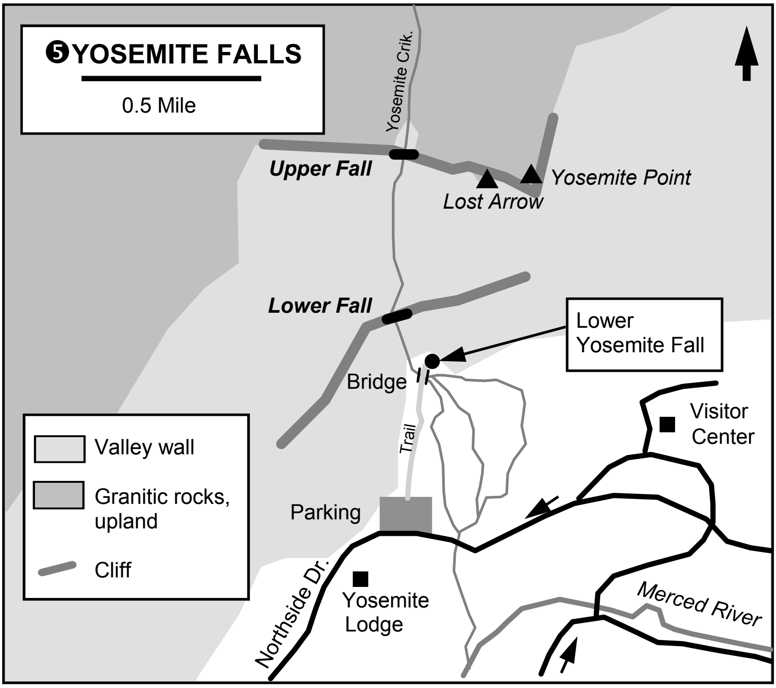
❺ *Yosemite Falls*

Yosemite Falls are one of the main scenic attractions of Yosemite Valley. At the top of the Upper Fall, the water from Yosemite Creek descends 70 feet through a chute worn in the top of the cliff. When the water leaves the chute, it leaps clear of the cliff and descends 1,430 feet in a broad parabolic curve to the base of the Upper Fall. This is reportedly the highest leaping waterfall in the world. After collecting itself at the base of the Upper Fall, the water descends 675 feet through a chain of cascades to the top of the Lower Fall. The water then drops another 320 feet over the Lower Fall. The combined drop of the falls and cascades is 2,425 feet.

The Upper Fall, like Bridalveil Fall, is a hanging valley. During the Plio-Pleistocene uplift and west tilting of the Sierra Nevada, Yosemite Creek was unable to keep pace with the rapid downcutting of the Merced River and the creek descended into the Merced River Valley in a series of cascades. During Pleistocene glaciation, the wall of Yosemite Valley was steepened by glacial erosion. This erosion removed the cascades and left the valley of Yosemite Creek hanging high above the valley floor.

The steep cliff at Upper Yosemite Fall was formed by a major west-trending vertical joint. The Lost Arrow, to the right of the Upper Fall, is a remnant of a slab of granite that is breaking away from the cliff along the same set of vertical joints. The base of the Upper Fall is on a ledge formed by a near-horizontal joint. The top of the Lower Fall lies on a ledge formed by another horizontal joint. See the cover photo for a closer view of the Lost Arrow.





***Lower Yosemite Fall* -** *Park at the Yosemite Falls parking area 0.5 mi. W of Yosemite Valley Visitor Center; walk N on the paved trail 0.25 mi. to the viewing area and bridge at the base of Lower Yosemite Fall.*

You can get a good view of the Upper and Lower Falls from the trailhead near the parking lot for Yosemite Falls. The Yosemite Falls cliff is made up of light gray El Capitan Granite, which has been intruded by medium to dark gray Sentinel Granodiorite. These rocks are very hard and are sparsely jointed.

The falls are formed by two sets of wide-spaced joints. When the glaciers went through Yosemite Valley, they excavated the granite along these two joint trends. One set of joints is nearly vertical and trends east-west. The steep cliff that supports the Upper Fall was formed along a major joint in this trend. The Lower Fall plunges over still another joint in this trend. The other important set of joints is nearly horizontal. The large, sloping, vegetation-covered ledges at the base of the Upper Fall and the top of the Lower Fall are formed by joints in this trend. Near the bridge at the base of the Lower Fall, there are many granite boulders that have broken from the cliff. Most of these rocks are light gray El Capitan Granite, but you may also find some boulders of dark gray Sentinel Granodiorite.

❻ *Royal Arches*

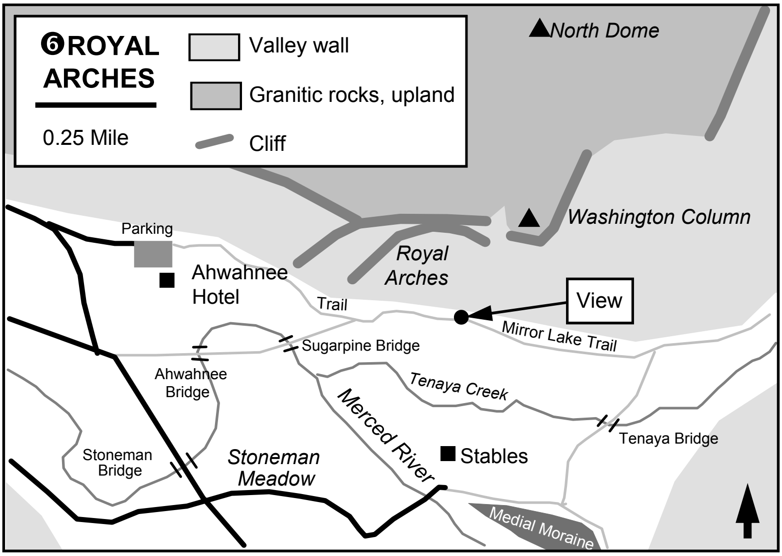
The Royal Arches are a set of large, thick, concentric granite arches that occur on the north wall of Yosemite Valley between the Ahwahnee Hotel and Washington Column. The arches are part of a large exfoliation dome that lies on the north wall of Yosemite Valley. The top of this exfoliation dome is represented by North Dome, and the Royal Arches are on the side of this dome. During the Pleistocene glaciation, glaciers pealed away the outer exfoliation shells along the side of the dome, leaving this series of arches. Since the granite was very homogeneous and very strong, it gave rise to exceptionally smooth, thick, high, and broad arches, and allowed these arches to stand rather than to collapse in a pile of rubble.

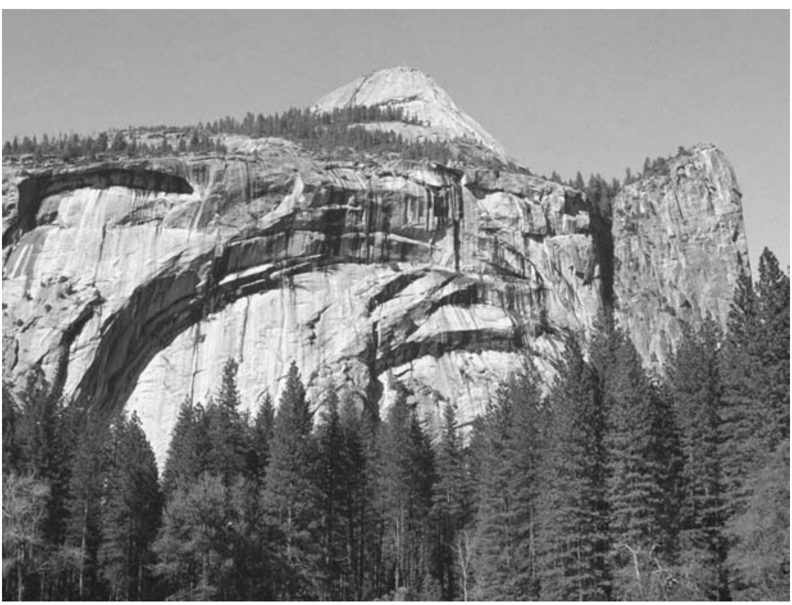
View **-** *Park at the Ahwahnee Hotel; hike 0.5 mi. E on the Mirror Lake Trail to the base of the Royal Arches.*

The Mirror Lake trail from the Ahwahnee Hotel to Mirror Lake follows along the base of the Royal Arches, and from this trail you can appreciate the size of the arches. The main outer arch of the Royal Arches is 1,000 feet high, spans a distance of 1,800 feet, and is about 200 feet thick. Below this arch are a number of smaller arches from 10 to 80 feet thick.

The Royal Arches are formed from the Half Dome Granodiorite. This is one of the youngest granitic rocks in Yosemite Valley and covers much of the head of the valley east of the Ahwahnee Hotel and Curry Village. The Half Dome Granodiorite is coarse-grained and can be distinguished from the other granitic rocks in Yosemite Valley by its well-formed plates of shiny biotite and long rods of black hornblende. This particular rock is especially good at making exfoliation domes. Among its offspring are Half Dome, North Dome, Basket Dome, Liberty Cap, Mount Broderick, Mount Starr King, and Mount Watkins.

The right side of the Royal Arches is abruptly terminated in a steep gully and the Washington Column lies to the right of the gully. Since the Washington Column and Royal Arches are formed from the same rock, the gully does not represent a contact between two different types of rock. Instead, the gully was formed along a major joint within the Half Dome Granodiorite. The stresses that formed the exfoliation slabs at the Royal Arches were apparently relieved along this joint.





The Royal Arches were formed when thick slabs of exfoliating granite were quarried by glaciers that moved down Yosemite Valley. North Dome is seen above the arches and Washington Column lies to the right.

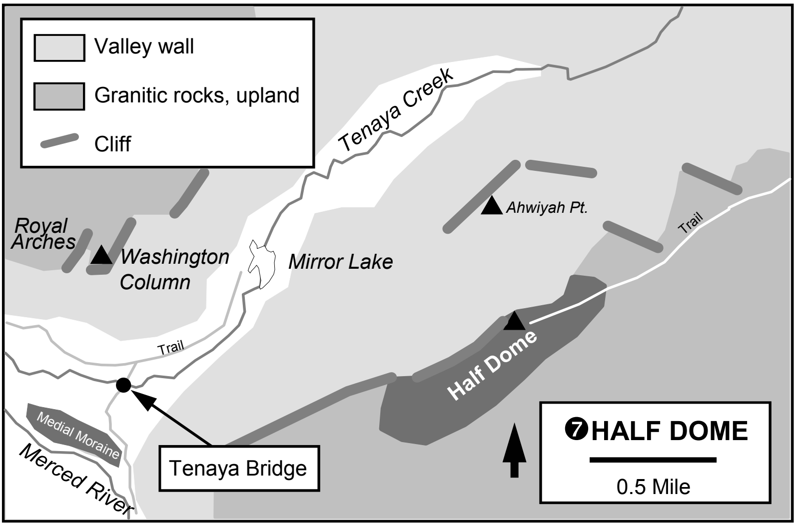
❼ *Half Dome*

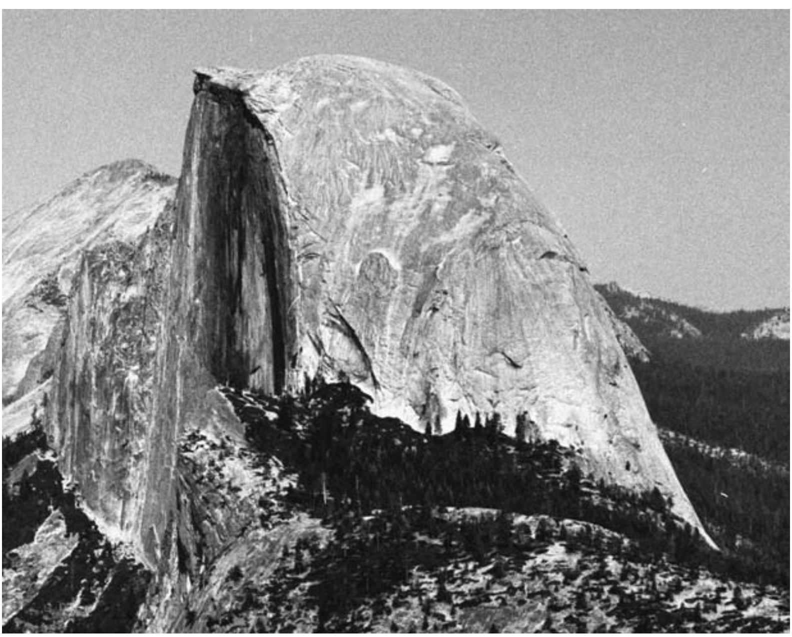
Half Dome, with its sheer northwest face and rounded summit, dominates the head of Yosemite Valley. This is one of the best known and best loved features of Yosemite, and also one of the least understood. From the valley floor, it appears that the dome has been cut in half, and that the missing half has disappeared. Read on if you've ever wondered where it went.

Tenaya Bridge - *From Shuttle Stop 17 follow the trail to Tenaya Bridge.*
From Tenaya Bridge you can get a good view of the steep glaciated northwest face of Half Dome. Half Dome is formed from a large block of unjointed Half Dome Granodiorite that is bounded on the northwest and southeast sides by major joints. This block of granite was extremely resistant to erosion, and stood above the general landscape during most of mid- to late-Tertiary time. During this period, the sharp corners of the block were rounded by exfoliation to form a steep-sided elongated dome.

During the Pleistocene glacial episodes, the largest of the glaciers that flowed down Tenaya Canyon reached to within 700 feet of the summit of the dome, but none of the glaciers ever covered Half Dome. The glaciers did, however, remove the exfoliating rock on the northwest flank of the dome and then began to remove the rock along the existing joint surfaces. The jointed granite above the glacier ice was quarried by the freeze and thaw action of ice along the joints. By the end of the Pleistocene, the joint zone on the northwest flank of the dome had become a steep cliff. The crest and backside of the dome were unaffected by the glaciation, and retained the curved surfaces of the exfoliated granite. The trail to the summit of Half Dome goes up the steep slope of exfoliated granite on the northeast end of the dome.

The exfoliating granite shells on the southeast flank of Half Dome are eroding at a very slow rate. They have been in place so long that furrows several feet deep have been worn into the rock where rain has carried decomposed granite down the side of the dome. The exfoliation shells at the top of Half Dome have also eroded slowly. These shells have accumulated to a depth of 100 feet, since they have not been carried away by gravity. Most of the shells on the top are six to ten feet thick. Some of these exfoliation shells overhang the steep northwest face, forming a visor for the dome. The jointed rock on the precipitous northwest face of the dome was quarried out from under the visor during Pleistocene glaciation.





The steep northwest face of Half Dome is formed by vertical joints. The granite along the joints was removed by glaciers that flowed down Tenaya Canyon. The visor at the top of Half Dome is formed from exfoliated slabs of granite that were undercut by the vertical joints.

❽ *Little Yosemite Valley*

As the Merced River enters Yosemite Valley from Little Yosemite Valley, the river drops 2,000 feet in a series of foaming cascades, rapids, and waterfalls. This turbulent mile-and-a-half stretch of the river begins at Nevada Fall, then passes through the Emerald Pool, across the Silver Apron, over Vernal Fall, and then steeply descends to Happy Isles on the floor of Yosemite Valley. This section of the river crosses the Half Dome Granodiorite where there are few joints in the granite. The Pleistocene glaciers had a hard job cutting into this rock, and left the series of ledges, cliffs, and chutes over which the water now tumbles.

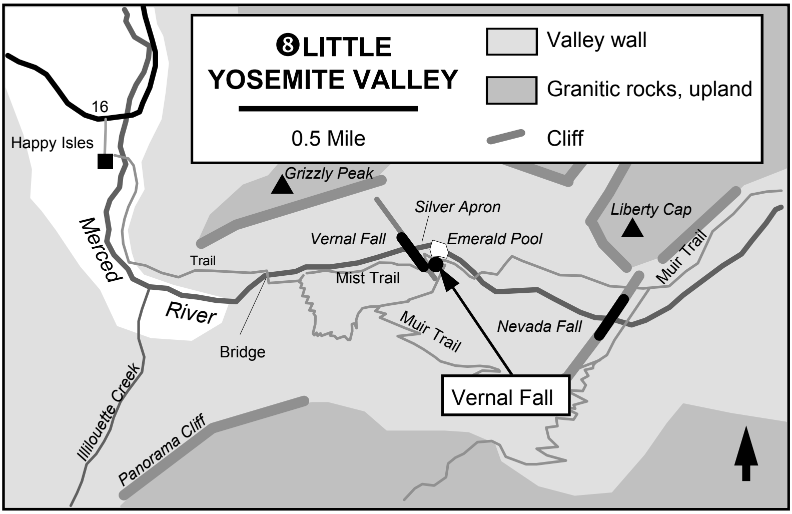
Vernal Fall - *From Happy Isles (Shuttle Stop 16) hike up Little Yosemite Valley to the viewpoint just beyond the bridge over the Merced River; for a closer look, take the 500-step Mist Trail to the top of Vernal Fall, but be prepared to get wet; 3 mi. RT.*

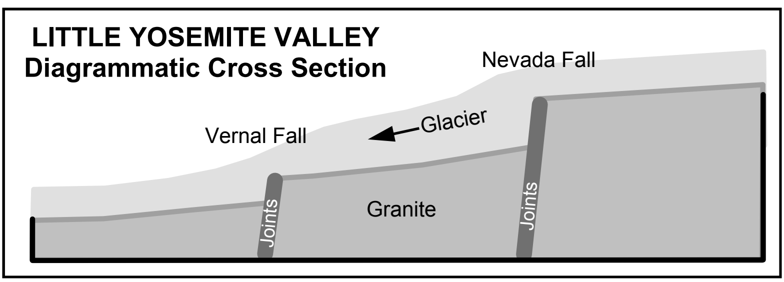
Vernal Fall (317’) flows over a cliff formed by a major northwest-trending joint in the Half Dome Granodiorite. When the Merced glacier encountered this joint, it quarried the jointed rock and carried it downstream, leaving behind the cliff for Vernal Fall. The cliff extends across the entire valley because the glacier covered the entire valley.

Emerald Pool, at the top of Vernal Fall, was formed in unjointed resistant granite that was scoured out and polished by the Merced glacier. From the pool, the Merced River flows across the Silver Apron, then plunges over Vernal Fall. Some of the granite at the Silver Apron still has glacial polish and striations. The granite at the top of Vernal Fall has not been notched by the water flowing over the cliff during the 15,000 years since the glaciers melted because there is little sediment in the Merced River at this point. Most of the sediment dropped out in Merced Lake, eight miles upstream. Without sediment, the water has little cutting power. Further up the valley you can see Nevada Fall (594’). The cliff that forms Nevada Fall trends northeast and was formed along the same set of joints that formed Half Dome. These joints are in a different direction from the joints that formed Vernal Fall.

During the glacial episodes, the Little Yosemite glacier covered much of Little Yosemite Valley, but never covered the top of Half Dome. Liberty Cap, immediately north of Nevada Fall, is a large roche moutonnée and was covered by the larger glaciers that flowed down Little Yosemite Valley.

→This photo of Little Yosemite Valley, taken from Glacier Point, shows Vernal Fall in the lower center and Nevada Fall to the right.


❽LITTLE YOSEMITE VALLEY
0.5 Mile
Valley wall
Granitic rocks, upland
Cliff
16
Happy Isles
Merced
River
Trail
Bridge
Grizzly Peak
Vernal Fall
Silver Apron
Emerald Pool
Mist Trail
Muir Trail
Nevada Fall
Liberty Cap
Muir Trail
Illilouette Creek
Panorama Cliff
Vernal Fall


LITTLE YOSEMITE VALLEY
Diagrammatic Cross Section
Nevada Fall
Glacier
Vernal Fall
Granite
Joints
Joints


Nevada Fall
Vernal Fall

❾ *Glacier Point*

The trip to Glacier Point provides excellent views of Yosemite Valley from several places along the rim of the valley. On this trip you can also see and walk on the old Miocene land surface that existed prior to the Plio-Pleistocene uplift of the Sierra.

Sentinel Dome **-** *From the junction of Hwy. 41 and Glacier Point Rd. go 13 mi. E on Glacier Point Rd. to the parking area for Sentinel Dome and Taft Point; take the trail to Sentinel Dome; 2 mi. RT.*

Sentinel Dome is one of many domes that protrude above the High Sierra landscape. These domes are all made of hard, unjointed granite and have a rounded shape formed by exfoliation of the granite. Sentinel Dome is formed from the El Capitan Granite. Glacier ice covered some of the domes in Yosemite, but Sentinel Dome was always above the glaciers. Moraines from the highest Yosemite glacial stages lap up onto the edge of the dome.

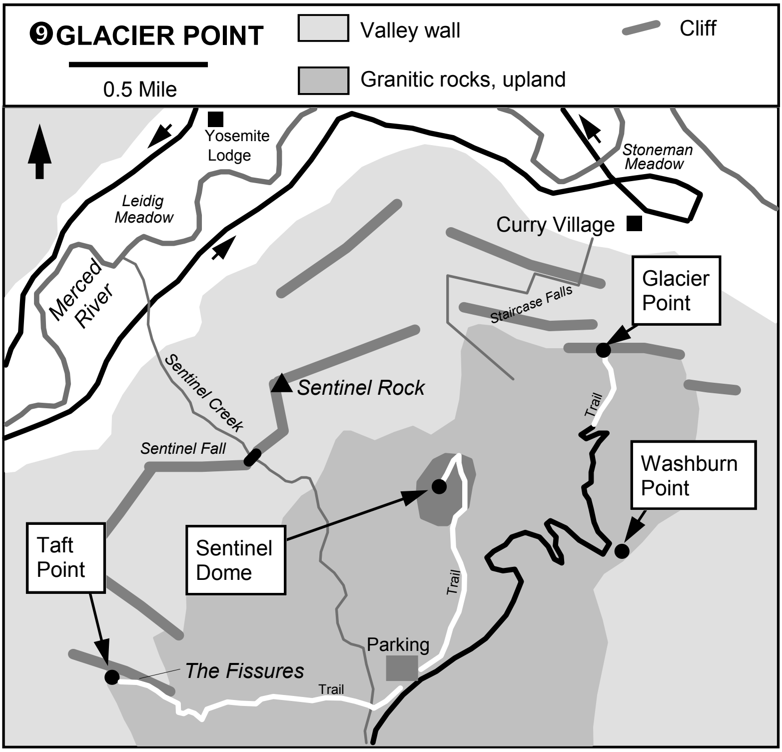
When you hike to the top of Sentinel Dome, you are walking on a land surface that has not changed much since Miocene time. Although the Sierra Nevada block was uplifted about 4,000 feet in this area during Plio-Pleistocene time, Sentinel Dome and the surrounding area looks today much as it did several million years ago. From the top of the dome you will have a 360^0 panoramic view of the park and this highland area.

Taft Point **-** *From the parking area take the trail to Taft Point; 2 mi. RT.*

The first part of the trail to Taft Point goes across the gray weakly foliated Sentinel Granodiorite. This granodiorite forms Sentinel Rock and Sentinel Fall, which lie on the steep wall of Yosemite Valley between Taft Point and Glacier Point.

On the way to Taft Point, you will pass the Fissures. The Fissures were formed from weathering of joints in the granite along the rim of Yosemite Valley. Some of these joints are several feet wide and tens of feet deep and testify to the importance of joints in promoting weathering in granite.

Near Taft Point, the trail crosses into the El Capitan Granite. The outcrops at Taft Point are coarse-grained El Capitan Granite, which is cut by the younger fine-grained light colored Taft Granite, the same granite that forms the summit brow of El Capitan. From Taft Point there are excellent views of El Capitan and the Three Brothers on the opposite side of Yosemite Valley.



View from Taft Point, left, across Yosemite Valley to El Capitan, right center. Note the low relief of the old Miocene land surface above the rim of the valley.

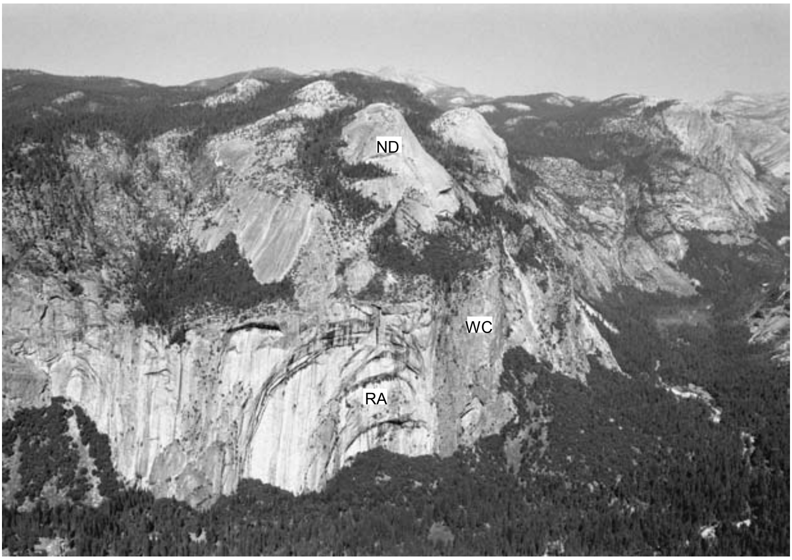
Washburn Point - *From the Taft Point/Sentinel Dome parking area drive N on Glacier Point Rd. 2 mi. to the Washburn Point parking area.*

From Washburn Point, there are excellent views of the High Sierra. Almost all of the rocks east of Washburn Point are granite. From here you can also see how Vernal and Nevada Falls were formed along two different joint trends in Little Yosemite Valley. To the northeast, note the steep sides of Half Dome. The exfoliated backside is nearly as steep as the cliff that faces Yosemite Valley.

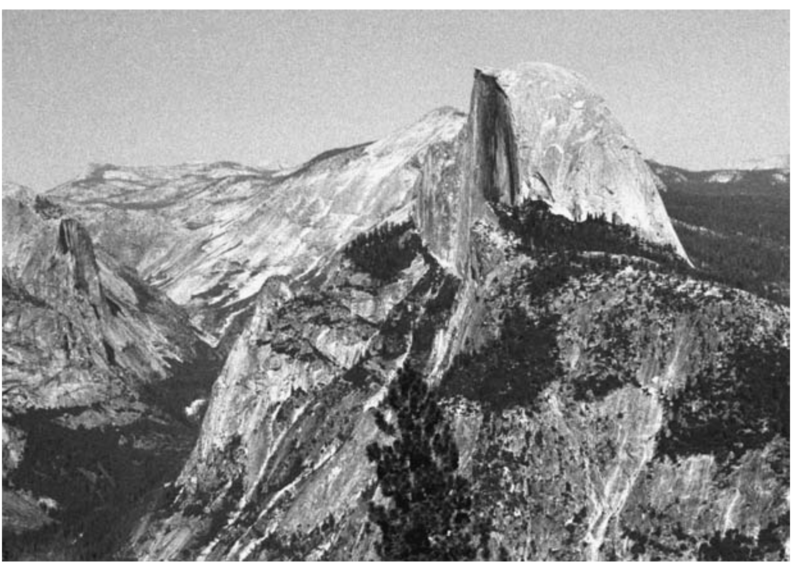
Glacier Point - *From the Washburn Point parking area drive N on Glacier Point Rd. 0.5 mi. to Glacier Point; take the short trail to Glacier Point. While at Glacier Point, visit the hut with exhibits explaining the formation of the Yosemite landscape.*

Both Glacier Point and Washburn Point are formed from the Granodiorite of Kuna Crest. This rock has a streaky appearance, with flakes of biotite and rods of hornblende. The rocks at Glacier Point are moderately jointed, and have three prominent sets of intersecting joints. These joints are responsible for many of the interesting features that can be seen on the steep cliff below Glacier Point. Some of the joints are inclined, and have formed a number of sloping ledges. Staircase Falls step down and move eastward along a series of these ledges. Glacier Point and Washburn Point were both covered at the time of maximum glaciation, so glacial erratics can be found in this area. At the maximum glacial stage, Glacier Point was covered by about 700 feet of ice.

The overhanging ledge at Glacier Point is at the left. Yosemite Falls, on the far side of Yosemite Valley, are dry. Note the long cascade between the Upper Fall and Lower Fall.



The Royal Arches (RA), Washington Column (WC), and North Dome (ND), as seen from Glacier Point. North Dome is an exfoliation dome that was overridden by the largest Pleistocene glaciers.



View of Half Dome from Glacier Point. During Pleistocene glaciation, glaciers that flowed down Tenaya valley (left) did not override Half Dome, but undercut and removed jointed rocks on the northwest side of the dome, leaving the steep cliff that we see today.