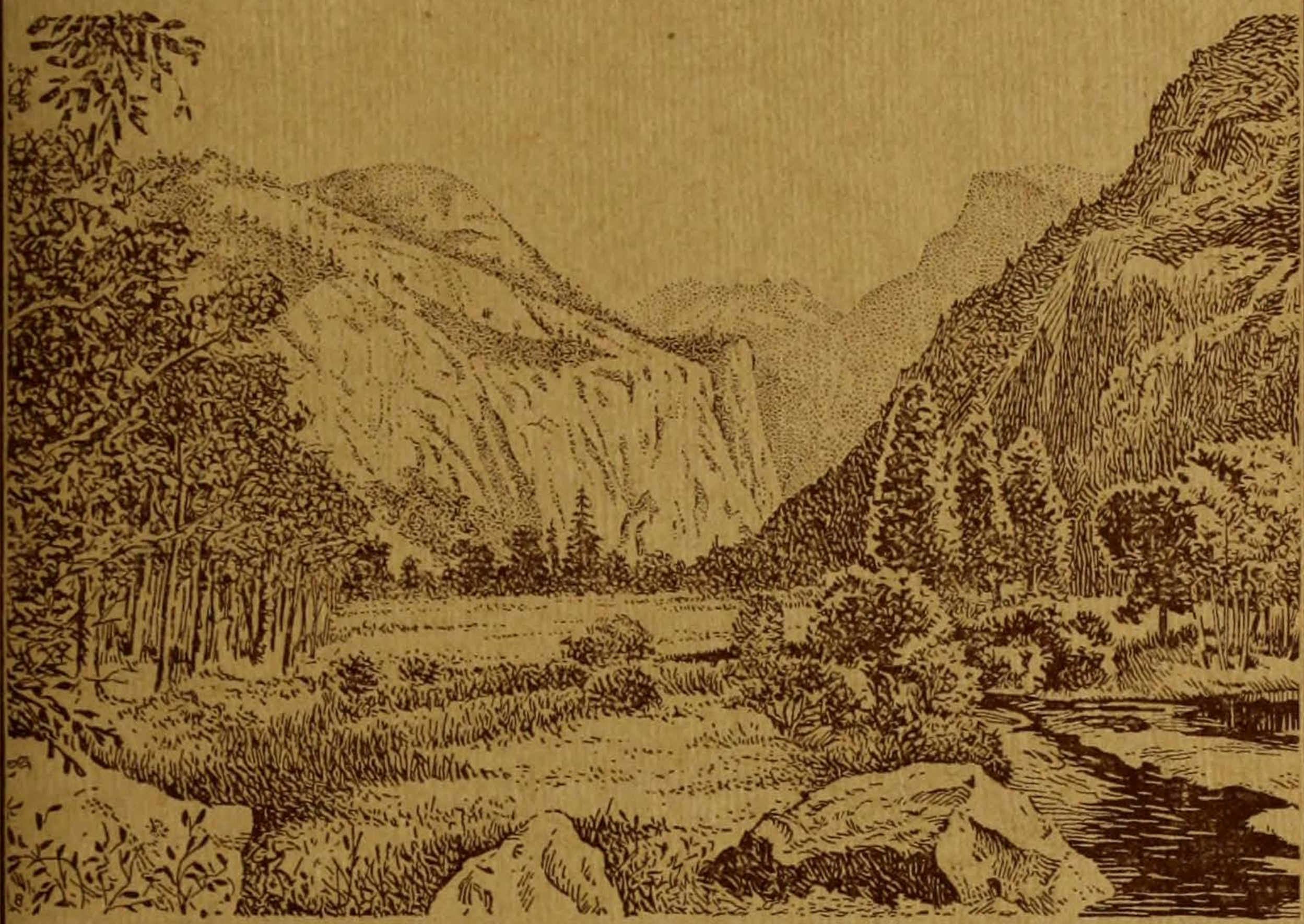
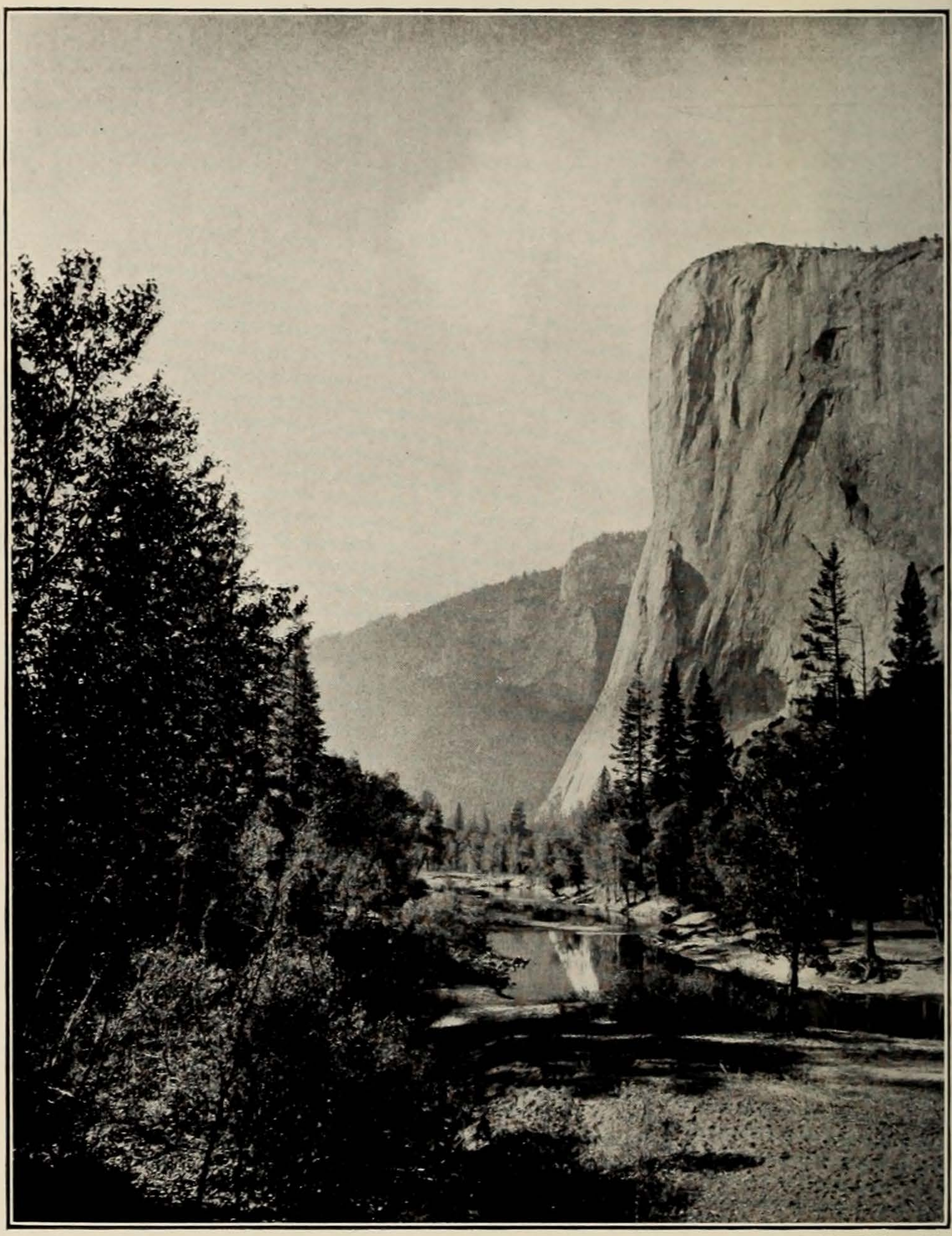
THE AMERICAN MUSEUM OF NATURAL HISTORY

THE STORY OF THE YOSEMITE VALLEY



By FRANÇOIS E. MATTHES, Ph. D.

GUIDE LEAFLET No. 60



J. K. Hillers Pho

EL CAPITAN, THE NOBLEST CLIFF IN YOSEMITE VALLEY

The view shows the bold profile of the 3,000-foot cliff as it appears from the ea at a distance of one and a half miles. Beyond El Capitan are the lesser cliffs that flan the recess of the Ribbon Falls.

THE STORY OF THE YOSEMITE VALLEY

By FRANÇOIS E. MATTHES, Ph. D.

American Museum of Natural History
Guide Leaflet No. 60
New York, July, 1924

The model of the Yosemite Valley and vicinity is one of a series of fifteen relief models of geologically important areas of the United States, representing the existing topography surface of the areas chosen. The hard-rock or underlying geology is represented by colors and patterns taken from the rocks themselves, except in the Watkins Glen-Seneca Lake and the Niagara Falls models, where the superficial Glacial deposits are shown, and in the Porto Rico model, where the scale of the map is too small to permit such treatment. The painted background of each model represents the present day scenery of the surrounding country, and the sky depicts different meteorological conditions as far as practicable.

With the exception of the Yosemite Valley and the Mount Washington models the subjects of these models and their location in the hall were suggested by Associate Curator C. A. Reeds. The construction of all the models has been done under the direction of Curator E. O. Hovey, except that the core of the Grand Canyon model was begun by Doctor Reeds. The cores of the models have been built at the Museum and have been based on the topographic sheets issued by the United States Geological Survey, and the United States Coast and Geodetic Survey, except for Porto Rico, based upon a compilation by C. A. Reeds, and Mount Washington, based upon the maps by the State of New Hampshire and the Appalachian Mountain Club. The modeling and painting have been done by Lester Morgan of Morgan Brothers, following published geological maps of the regions and photographs from several sources. In the Yosemite Valley model the geology has been represented according to unpublished maps and other data furnished by the U. S. Geological Survey.

THE STORY OF THE YOSEMITE VALLEY[1]

By François E. Matthes, Ph.D.

UNITED STATES GEOLOGICAL SURVEY

If you should start from San Francisco in an airplane and fly due east you would pass first over the wooded crests of the Coast Ranges; next over the broad, level expanse of the Great Valley of California, checkered with irrigated fields, vineyards, and orchards; and then, after a flight of about a hundred miles, you would come to a huge mountain barrier, stretching north and south at right angles to your course and rising in a long, gradual slope to a resplendent row of snow-flecked peaks. This is the Sierra Nevada, the longest, the highest, and the grandest single mountain range in the United States.

Deeply carved in its western flank, about midway between the torrid foothills and the wintry summits, in the genial middle zone of majestic forests, you would discover the Yosemite Valley, the chasm that has become renowned the world over for its towering cliffs, its stately trees, and its delightful climate, but, above all, for its sublime waterfalls. If "Yellowstone" spells "geysers," "Yosemite" spells "waterfalls."

As you fly over the valley you may at first be surprised to find that it is no larger. It measures only 7 miles in length and 1 mile in width and is really but a widened part of a narrow canyon that furrows the range from crest to base,—the canyon of Merced River. Indeed, the valley is only one of a great many features—though by far the most wonderful—of the Yosemite National Park, which embraces a part of the western flank of the

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[1]Guide Leaflet No. 59 of the American Museum series.—Text kindly furnished through the courtesy of the United States Geological Survey.

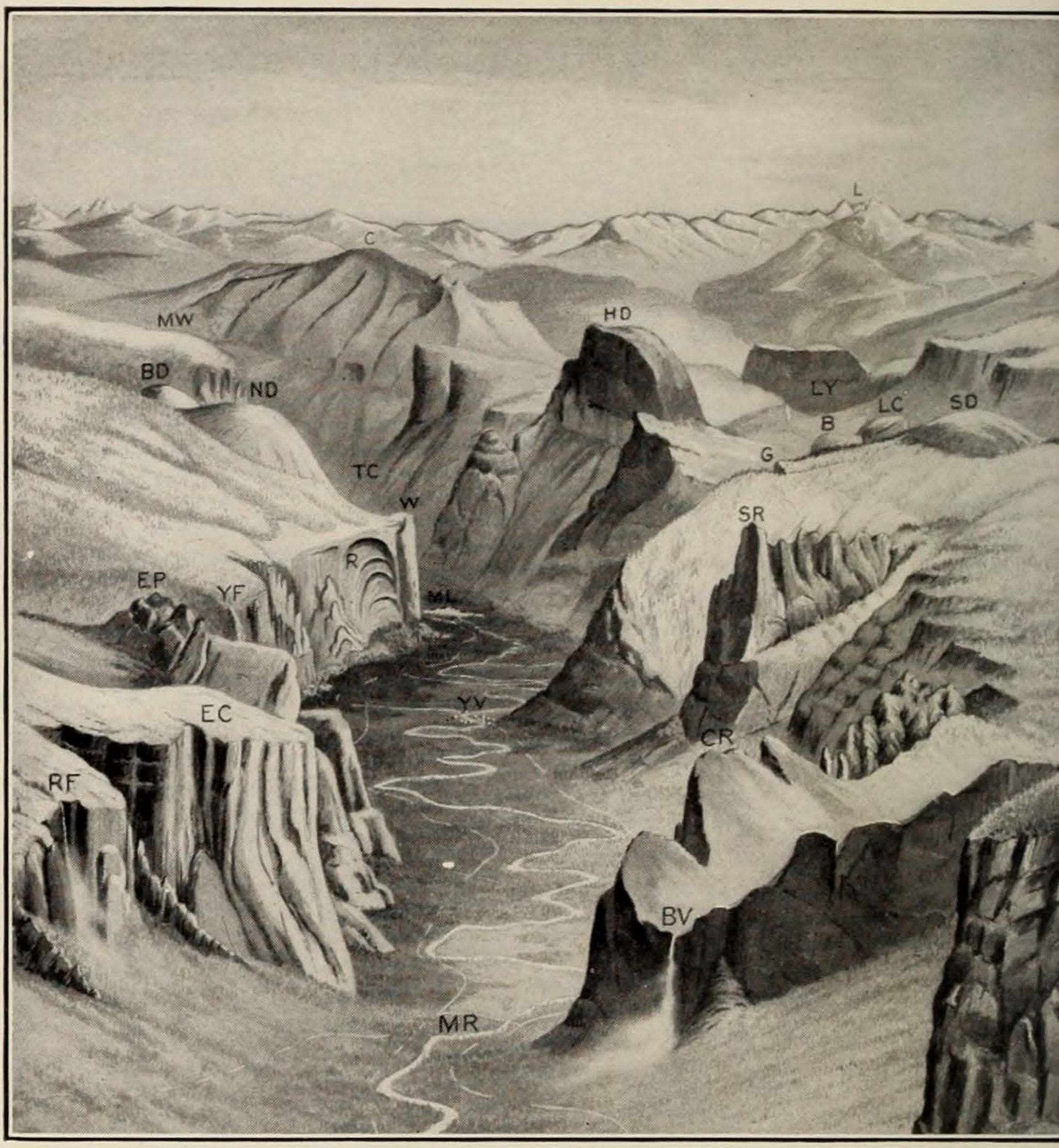


FIG. 1. BIRD'S EYE VIEW OF YOSEMITE VALLEY AND THE HIGH SIERRA BEYOND

R F	Ribbon Falls.	N D	North Dome.	B	Mount Broderick.
E C	El Capitan.	B D	Basket Dome.	G	Glacier Point.
E P	Eagle Peak.	M W	Mount Watkins.	S D	Sentinel Dome.
Y F	Yosemite Falls.	C	Clouds Rest.	S R	Sentinel Rock.
R	Royal Arches.	H D	Half Dome.	C R	Cathedral Rocks.
W	Washington Column.	L	Mount Lyell.	B V	Bridal Veil Falls.
M	Mirror Lake.	L Y	Little Yosemite.	Y V	Yosemite Village.
T C	Tenaya Canyon.	L C	Liberty Cap.	M R	Merced River.

Sierra Nevada almost as large as the State of Rhode Island, that is studded with peaks, domes, and spires and sculptured by valleys, gorges, and canyons. Among the canyons is the Grand Canyon of Tuolumne River, which lies 12 miles north of the Merced Canyon and parallel to it and which also has a Yosemite-like widened part—the beautiful Hetch Hetchy Valley.

But when finally you descend into the Yosemite you at once perceive the reason for its world-wide fame. No other valley is so remarkably fashioned; no other valley holds within so small a compass so astounding a wealth of striking and distinctive scenic features. As a whole, it is a broad rock-hewn trough with parallel sides, boldly sculptured and ornamented with silvery cataracts. The level floor, whose groves and meadows afford ideal places for camping and other forms of recreation, lies 4,000 feet above the sea, and the forested uplands on either side rise 3,000 to 4,000 feet higher.

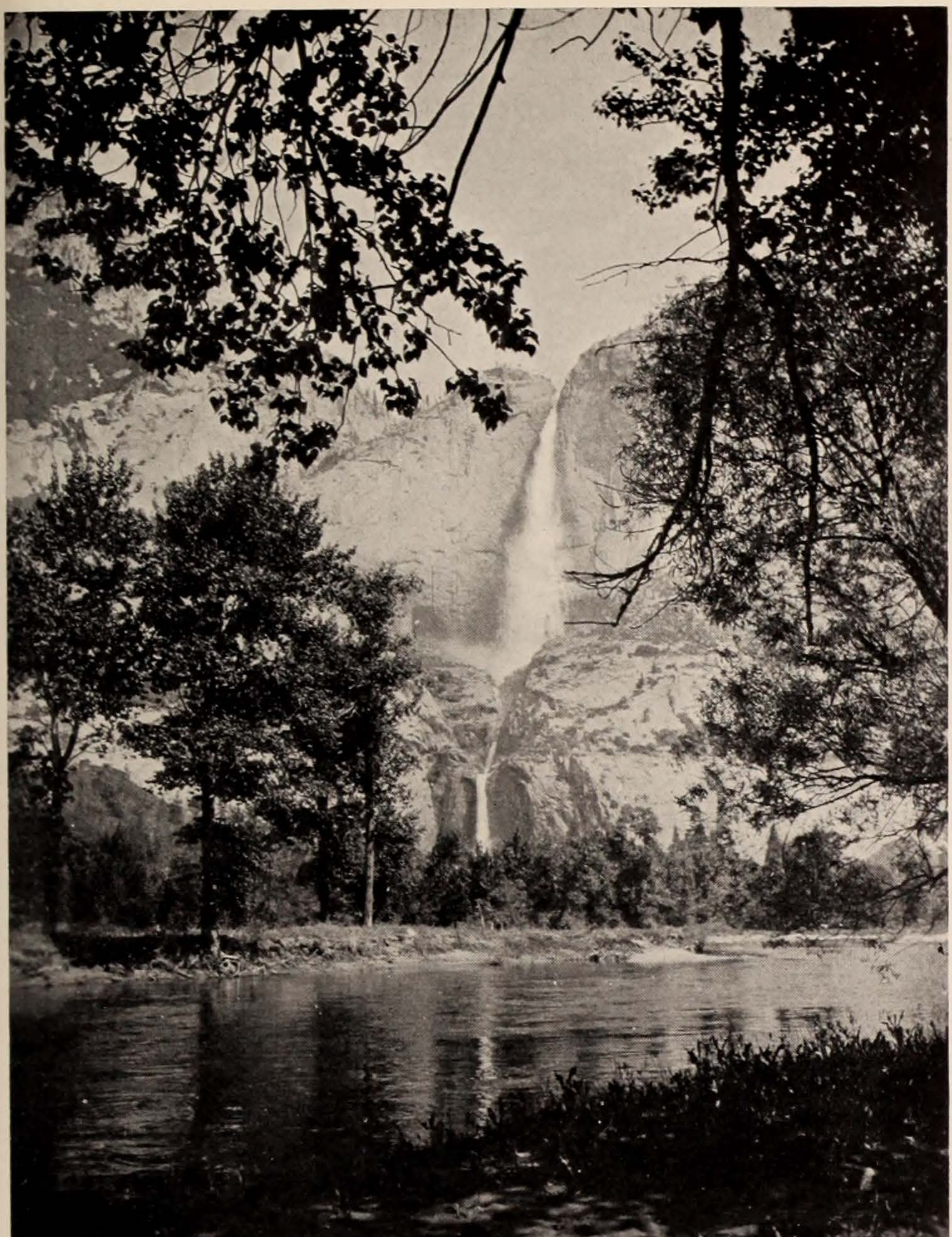
As you look eastward up the valley from its lower end your eye is at once attracted by the sheer profile of El Capitan, the most majestic cliff in the Yosemite and perhaps in the world. It projects from the north wall, its top fully 3,000 feet above the valley floor. Directly opposite stand the three Cathedral Rocks, of nearly equal height, which form the only promontory that juts far out into the valley. From the west end of this promontory leaps the Bridal-Veil Falls, 620 feet in height, its spray suffused with the glory of the rainbow.

Eastward beyond El Capitan and the Cathedral Rocks the valley abruptly regains its full width, and you behold in an embayment on the right the two Cathedral Spires, the frailest rock shafts in the valley. On the left are the Three Brothers, whose gabled summits rise one above another, all built on the same angle, as if designed

by an architect. The highest, known as Eagle Peak, rises 3,800 feet above the valley. Opposite them stands Sentinel Rock, a finely modeled obelisk with a pointed top.

Bridal Veil Falls
620 feet high

A mile beyond the base of Sentinel Rock nestles Yosemite Village, the main tourist center of the park, and just across the valley, booming amid clouds of pearly



F. E. Matthes, Photo

YOSEMITE FALLS, FROM THE BANKS OF MERCED RIVER

The upper fall, 1,430 feet in height, is probably the highest fall of its kind in the world. The lower fall is 320 feet high, and the total descent of the water from the brink of the upland to the floor of the valley is 2,565 feet. The lower fall as seen above is three-fourths of a mile from the camera; the upper fall is nearly one and a half miles distant.

mist, are the Yosemite Falls, most glorious of all the cataracts in the valley. The upper fall, 1,430 feet high, would alone make any valley famous—it is the highest unbroken leap of water on the continent, perhaps the highest in the world. The lower fall, which descends 320 feet, seems insignificant in comparison, yet it is twice as high as Niagara. The entire chain of falls and cascades has a height of 2,565 feet.

Farther up, on the north side, are the Royal Arches, sculptured one within another in an inclined rock wall that rises to a height of 1,500 feet. An enormous natural pillar, the Washington Column, flanks them on the right, and above them rises a smoothly curving, helmet-shaped boss of granite called North Dome.

Facing the Royal Arches, on the south side, is Glacier Point, a high promontory that has become a veritable Mecca for tourists by reason of its matchless view and its unique overhanging rock, below which the cliffs fall off sheer 3,200 feet.

The head of the valley is squared off by another rock wall, and above that wall, planted as on a pedestal, stands Half Dome, the most colossal and most strangely modeled rock monument in the Sierra Nevada, smoothly rounded on three sides and cut down sheer on the fourth, like an apple sliced in two. Though it has been inaccessible heretofore, owing to the smoothness of its sides, it may now be easily scaled with the aid of steel cables so hung as to serve as hand rails.

From the summit of Half Dome, 4,850 feet above the valley, you look down, on the south side, into the Little Yosemite, a broad-floored, cliff-girt valley shaped like the Yosemite, though much smaller. It lies at a level 2,000 feet above the main valley, and from its portal, guarded by Liberty Cap, the Merced descends by a cyclopean stairway, making two magnificent cataracts,

the Nevada Falls, 594 feet high, and the Vernal Falls, 317 feet high.

On the north side of Half Dome you look down into Tenaya Canyon, a chasm as profound as the Yosemite itself, yet the pathway of only a small tributary brook. Almost directly under Half Dome, at the canyon's mouth, lies romantic Mirror Lake. To the northeast Clouds Rest, the loftiest summit in the vicinity of the valley, rises 9,929 feet above the sea, and beyond spreads the vast panorama of the High Sierra, its jagged peaks culminating in ice-covered Mount Lyell, at a height of 13,090 feet.

And now, filled with wonder at the marvels of this stupendous scene, you may feel impelled to ask: How was all this created? By what strange forces has the Yosemite been fashioned, and through what happy circumstances has it become endowed with so much charm and grandeur?

This, then, is the story of the Yosemite: Millions of years ago—about at the end of what geologists call the Cretaceous period—all the country reaching from the Pacific coast to the Rocky Mountains began to bulge up as a result of disturbances in the interior of the earth. The movement was slow and intermittent, yet it caused the crust of the earth to be rent by long fractures, or "faults," as they are called by geologists, and broke it into huge blocks that crowded against and slipped on one another. Some of these blocks were gradually forced up and more or less tilted, so that they began to stand out as mountain ranges; other blocks remained low or were depressed and formed valleys and basins. Thus originated the multitude of roughly parallel northward and northwestward trending ranges and intermediate desert basins of western Utah, Nevada, and eastern California.

The westernmost and largest block, 400 miles long and 80 miles broad, was destined to become the Sierra Nevada. It early acquired a feeble slant to the west, its eastern edge being pushed up and its western edge

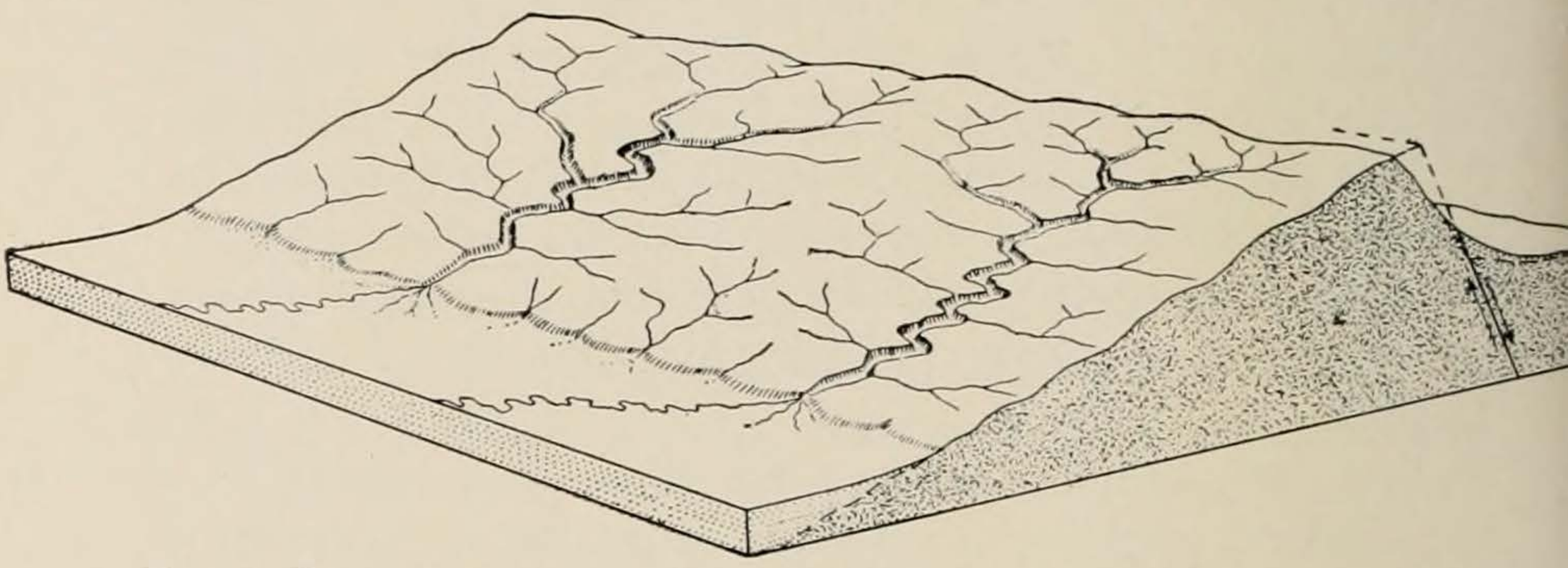


FIG. 2 GENERALIZED DIAGRAM OF A PART OF THE TILTED SIERRA BLOCK

The break, or "fault," that separated it from the next block to the east is shown by a heavy line, and the directions in which the blocks have slipped past each other are shown by arrows. The height and slant of the Sierra block are much exaggerated. In front of the range is a strip of the Great Valley of California, which is underlain by many layers of sand and silt washed down by streams. At the back of the range is a strip of Owens Valley, likewise covered with sediment. The main rivers on the Sierra block have arranged themselves roughly parallel to one another, in the direction of the western slopes, but their lesser tributaries continue to be guided by the irregularities on the surface and flow in diverse directions. The main rivers, having been accelerated by the tilting, have carved deep canyons, but many of their tributaries, and especially those that flow at right angles to the direction of the tilting, have not yet intrenched themselves and still drop into the canyons from "hanging valleys." The conditions shown correspond in a general way to those that prevailed for some time after the first great uplift mentioned in the text.

pulled down. After a great lapse of time—in the latter half of the Tertiary period—the slant of the block was steepened and the eastern edge was raised to a mountain crest several thousand feet high. Still later, about the dawn of the Quaternary period—the last great

division of geologic time, which embraced the Ice Age and witnessed the rise of man—a series of thrusts more vigorous than any that had preceded it tilted the Sierra block still more strongly and lifted it to its present great height—to altitudes ranging from 7,000 feet at the north to more than 14,000 feet at the south.

One effect of the tilting was, naturally, to bring about a rearrangement of the waters on the surface of the

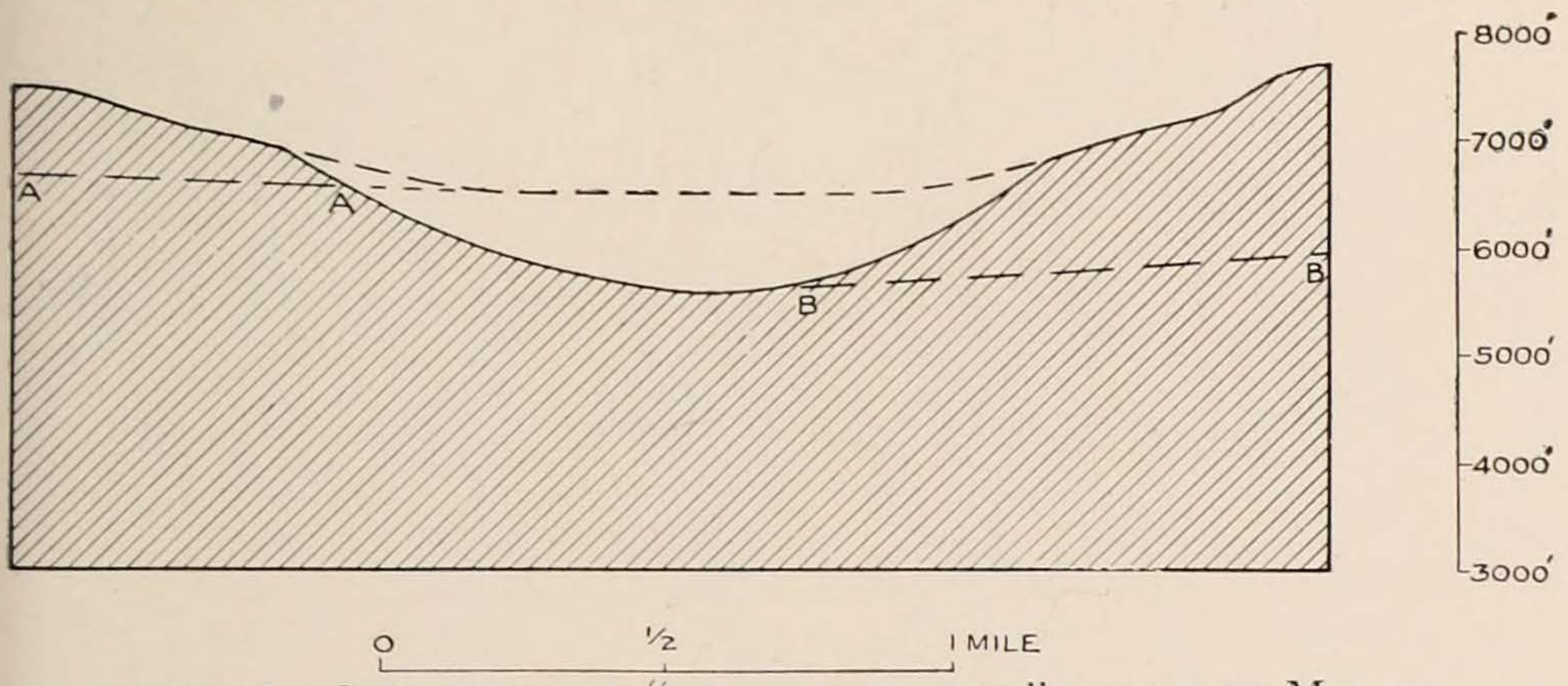


FIG. 3. SECTION OF THE "TWO-STORY VALLEY" WHICH THE MERCED HAD CUT BY THE END OF THE TERTIARY PERIOD.

A–A is the profile of a side stream which was unable to trench as rapidly as the Merced and whose valley has therefore remained "hanging." B–B is the profile of a side stream that succeeded in "catching up" with the trenching of the river. This diagram and the two following are drawn to scale and represent the successive stages in the development of the Yosemite Valley in their true proportions.

Sierra block. The main streams originally flowed in diverse directions, but when, early in the Tertiary period, the Sierra block acquired a considerable slant, they changed their courses and began to flow in the direction of the slant. A series of parallel rivers thus came into existence, all heading at the eastern edge and draining westward, into the Pacific Ocean. The Merced was one of these new rivers.

In the long period of quiet that followed the earlier tiltings the Merced fashioned for itself a broad, level valley, through which it wound sluggishly in serpentine meanders. The valley was flanked as far up as the site of the present Yosemite chasm by rolling hills and occasional ridges a few hundred to a thousand feet in height, all covered with luxuriant semitropical vegetation. The rounded summit of El Capitan was one of the rolling

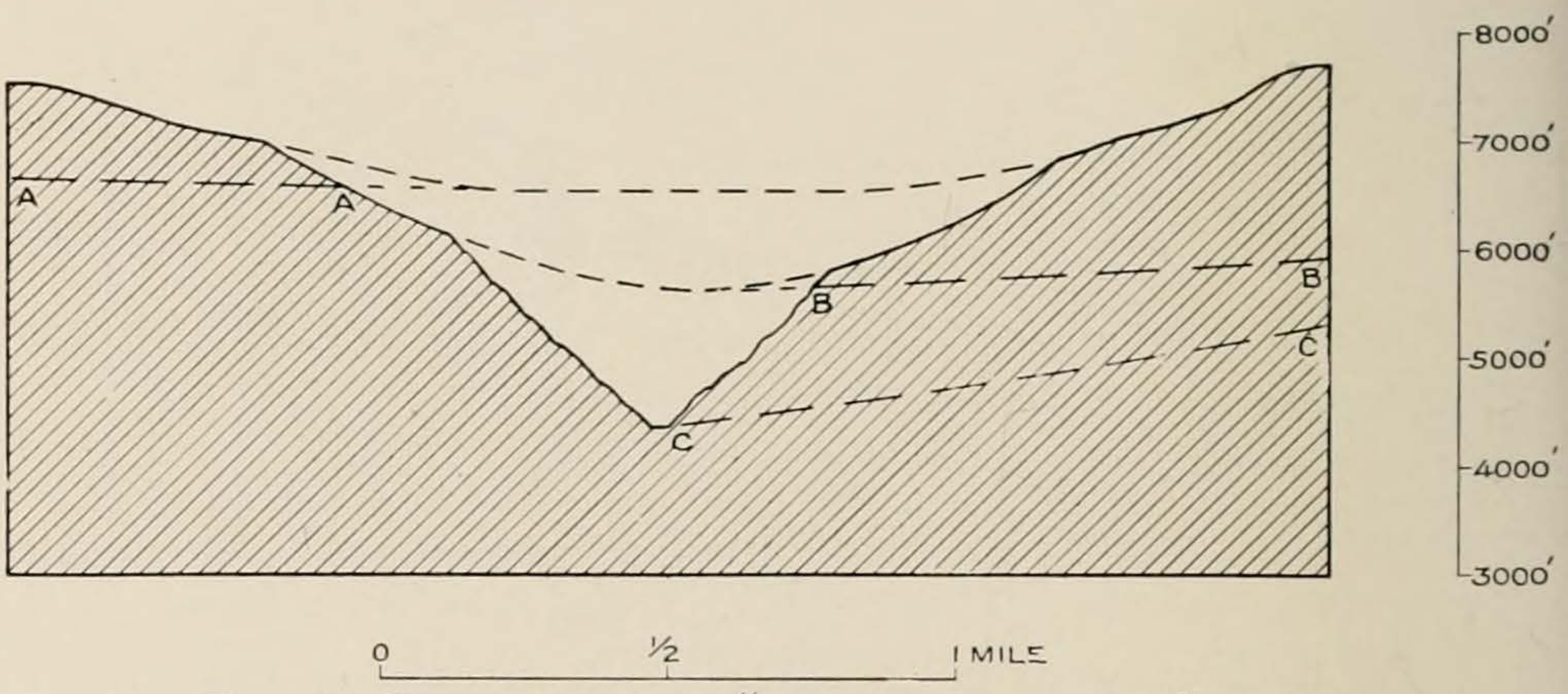


FIG. 4. SECTION OF THE "THREE-STORY CANYON" WHICH THE MERCED OCCUPIED EARLY IN THE QUARTERNARY PERIOD, JUST BEFORE THE ONCOMING OF THE ICE AGE.

The river has cut its inner gorges so rapidly that now the valley of the stream B–B also is left "hanging." But a third stream C–C, more favored than the others because the rock in its path is unresistant, has succeeded in keeping pace with the trenching of the river.

hills; it rose about 900 feet above the Merced. Toward the headwaters of the river the land was more mountainous, but the region as a whole still lay near sea level.

The great uplift of late Tertiary time, which raised the Sierra block to a height of several thousand feet, affected the behavior of the Merced profoundly. The course of the stream now being much steeper than before, its flow became swift and powerful, and, with the sand,

gravel, and boulders that it swept along, it began vigorously to scour and deepen its bed. As time went on it cut in the broad floor of its old valley a narrow, steep-walled gorge—a "gorge within a valley." Although it cut ever more and more slowly as its gradient became flatter and flatter, toward the end of the Tertiary period

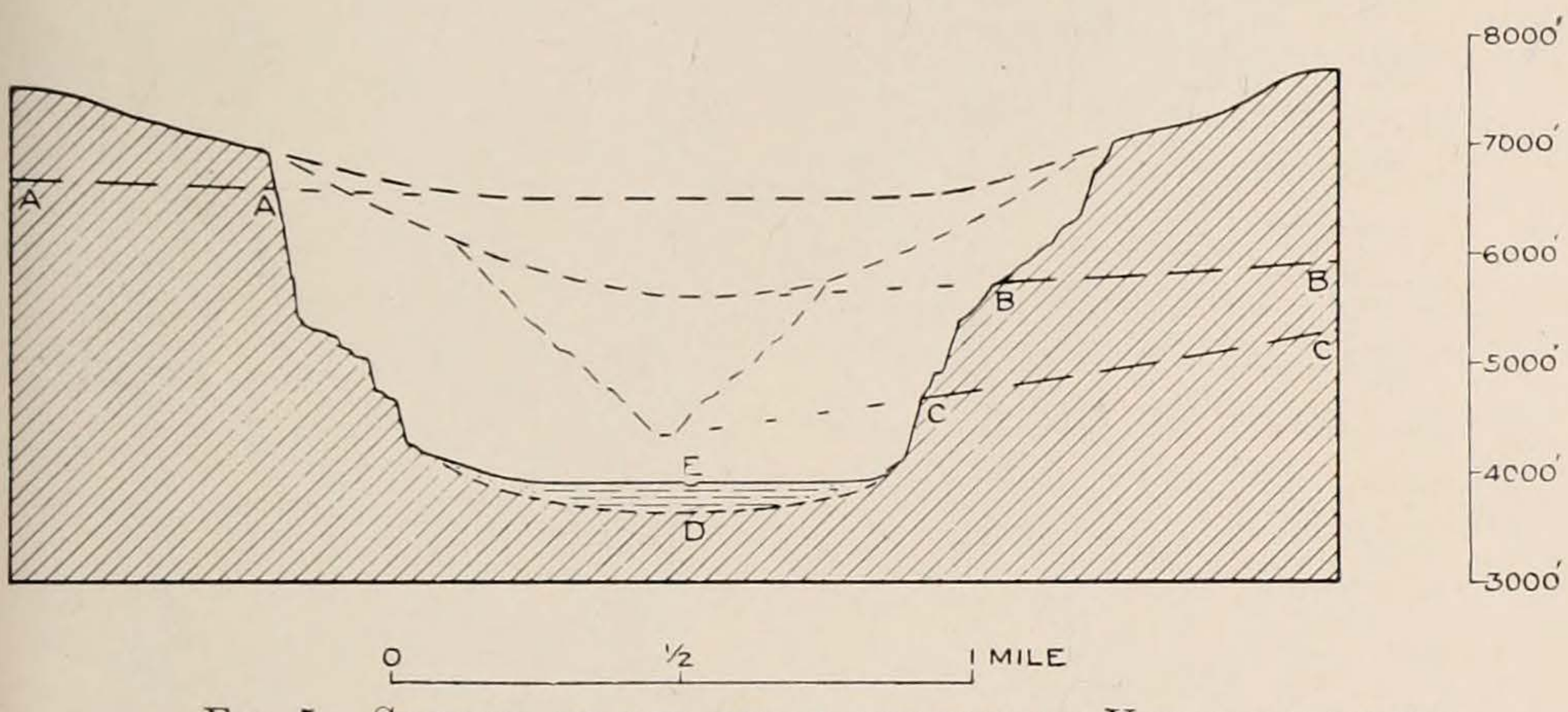


FIG. 5. SECTION OF THE BROAD, STEEP-SIDED YOSEMITE TROUGH AS IT IS TO-DAY.

The transformation from the original "three-story canyon" was accomplished mainly by the quarrying action of the glaciers of the Ice Age. The floor of the glacial trough is at D. The present valley floor is at E, and D–E is the depth of the basin of ancient Lake Yosemite, which now is filled with river-borne sediment. As a result of further deepening of the chasm and of its widening by the ice the valley of the stream C–C now also "hangs," so that there are three sets of "hanging valleys" at different levels, one above another, all having waterfalls pouring from their mouths.

the river had intrenched itself nearly a thousand feet. The gorge, however, had been transformed by that time, through the crumbling of its walls, into a valley with sloping sides, and so the river lay at the bottom of a "valley within a valley"—or a "two-story valley"—such as is outlined in Figure 3.

The side streams were at first unable to trench as rapidly as the Merced. They had smaller volume and therefore less cutting power, and a number of them were handicapped by following courses that lay at right angles to the general course of the river and therefore at right angles to the slope of the Sierra block. These streams were not steepened by the tilting and continued to flow as leisurely as before. As the river cut its gorge deeper and deeper, therefore, the side valleys remained "hanging" at greater and greater heights. They were transformed into what are properly termed "hanging valleys." But later, as the master stream's gradient became flatter and its cutting power waned, most of the side streams by degrees "caught up" with its trenching and the hanging valleys were destroyed—all but a few in the Yosemite region that were underlain by exceedingly resistant, massive granite. These few remained almost untouched and so, at the end of the Tertiary period, the Yosemite was left with several hanging side valleys from whose lips foaming cascades poured. Yosemite Creek, which now produces the great Yosemite Falls, then made a broken cascade 600 feet high. Bridal Veil Creek and Sentinel Creek each cascaded down a vertical distance of 900 feet; Meadow Brook 1,200 feet; Ribbon Creek 1,400 feet.

The last and greatest uplift of the Sierra Nevada, which occurred about the beginning of the Quaternary period, again accelerated the Merced to the swiftness of a mountain torrent—indeed, it gave that stream greater velocity and cutting power than it had ever possessed. What is more, the greatly increased height of the range brought with it a marked change in climate. Deep snows fell on the crest in winter, and the rapid melting of these snows in spring produced freshets of tremendous volume and correspondingly great destruc-

tive power. Thus the river again intrenched itself and with greater rapidity than before carved a new inner gorge, thus producing a "three-story canyon" such as is outlined in Figure 4. In this new inner gorge the river still flows from the lower end of the Yosemite to the foothills. At El Portal, the main gate to the Yosemite National Park, the gorge attains its greatest depth—about 2,000 feet—and the three-story canyon as a whole has a depth of about 3,500 feet.

As happened after the preceding uplift, so after the last, the side streams, and especially those running at right angles to the direction of the tilting, were unable to trench as rapidly as the master stream. And so the new gorge came to have a number of hanging side valleys, and the Yosemite, which already possessed one set of hanging valleys, acquired a second, lower set. To this lower set belong the valleys of Indian Creek and Illilouette Creek. Both of them, as well as some of the hanging side valleys of the lower Merced Canyon, are to-day still well preserved, although they are underlain by less resistant rocks than the older and higher hanging valleys of the Yosemite region. Indeed, so short a period of time, in a geologic sense, has elapsed since the last uplift that only a few of the larger and more favorably situated side streams have succeeded thus far in "catching up" with the trenching of the master stream.

Among these more successful streams are two tributaries of the Yosemite Valley—Tenaya Creek and Bridal Veil Creek. Tenaya Creek had the double advantage of a southwesterly course, following the direction of the tilting, and of being underlain by closely fractured rock and was thus able to trench deeply. Bridal Veil Creek, less advantageously situated, carved only a short, steeply descending gulch—the gulch that now ends abruptly at the precipice of the Bridal Veil Fall. That

cataract, however, was not yet in existence, for the gulch led directly to the bottom of the main chasm. The present lip of the gulch at the top of the waterfall, it is believed, still indicates roughly the level at which the Merced lay in early Quaternary time—that is, just prior to the first great extension of the glaciers of the Ice Age. Evidently the Yosemite then already had a depth of 2,400 feet, measured from the brow of El Capitan. It was, however, a much narrower and less impressive chasm than the Yosemite of to-day; it was a "three-story canyon" no wider at bottom than the channel of the river itself and winding sharply among craggy spurs that projected alternately from either side. But it was adorned by cascades of remarkable height: Illilouette Creek cascaded down 600 feet; Indian Creek 1,500 feet; Yosemite Creek 1,900 feet; Meadow Brook 2,300 feet; Sentinel Creek and Ribbon Creek each 2,400 feet.

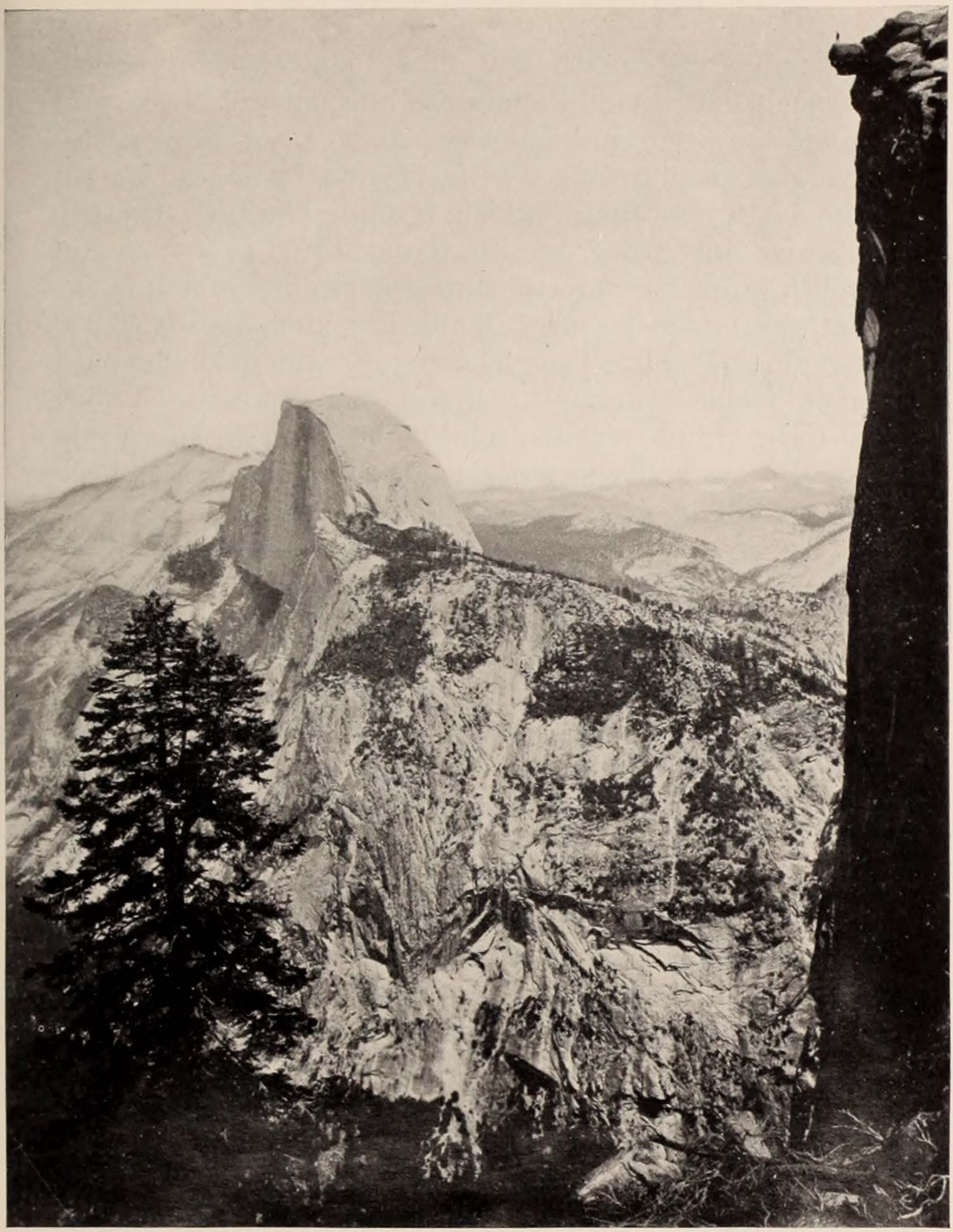
And now came that epoch of cold climate which brought on the great Ice Age. Snow gathered to depths of hundreds and finally thousands of feet in the upper valleys of the range and, becoming compacted to granular ice, formed glaciers that slowly crept down the canyons, moving a few inches to a few feet each day. Small remnants of these ice streams remain to-day on the shaded sides of the highest Sierra peaks, notably on Mount Lyell and its neighbors. Two great glaciers advanced, each more than 2,000 feet thick, one through the Little Yosemite, the other through Tenaya Canyon, and, joining at the head of the Yosemite, formed a mighty trunk glacier that filled the chasm to the brim and extended ten miles down the Merced Canyon.

For hundreds of centuries this glacier held sway, quarrying and scouring the rocky sides and floor of the chasm with tremendous force, due to its weight and its

irresistible forward movement. It excavated the chasm 600 feet more at the lower end and 1,200 feet more at the upper end. It cut off the projecting spurs and wiped the inner gorge out of existence. Then the climate grew milder, the glacier by degrees melted back to its sources on the crest of the range, and for an interval that doubtless also lasted hundreds of centuries the river resumed its work. At the end of this interval the glacial climate returned and the Yosemite again fell under the dominion of the ice. But this time the glacier was much shorter and thinner; it reached no farther than the Bridal Veil Meadow and filled the valley only one-third of its depth. Moreover, the glacier was relatively short lived, and it therefore accomplished much less excavating than its mighty predecessor, whose work, however, it accentuated.

And so, when at length the Ice Age came to a close the narrow three-story canyon had been transformed into a broad U-shaped trough; the craggy slopes had been quarried back to vertical cliffs, and the broken cascades replaced by leaping falls. (See Fig. 4.) Moreover, three new falls of this kind had been created, for in deepening the chasm the glacier had left the gulch of Bridal Veil Creek hanging, thereby causing that stream to leap over a vertical precipice 620 feet high; and in its descent from the Little Yosemite the glacier had hewn a giant stairway down whose steps the Merced now makes two successive leaps, in Nevada and Vernal falls. Finally, a basin had been scooped out in the rock floor of the valley, and in this basin was formed a lake five and a half miles long—ancient Lake Yosemite. Similar but smaller and shallower lake basins were scooped out in the Little Yosemite and in Tenaya Canyon.

The ice was greatly aided in making these prodigious changes in the configuration of the Yosemite Valley by



F. E. Matthes, Photo

THE HALF DOME
From the trail beneath Glacier Point

FOR THE PEOPLE

FOR EDUCATION

FOR SCIENCE