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of the
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A Brief Story of the Geology of Yosemite Valley

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Introduction

Prior to 1913, some twelve theories existed explaining the origin of Yosemite Valley. One widely believed explanation was that a large block of the earth's crust was down-faulted, forming Yosemite Valley, while another theory explained the Valley as the result of a great earthquake which split the rocks in two. Controversy raged over Whitney's block fault hypothesis and John Muir's belief that glaciers were largely responsible. Mainly in response to public demand, the United States Geological Survey undertook the task of working out the geologic history of the Valley. Francois E. Matthes and Frank C. Calkins were assigned to the problem, and, in the course of several field seasons, covered practically every foot of the Yosemite region. The present story, consequently, is based on actual field evidence and is generally accepted by scientists. It is condensed from Mr. Matthes' Geologic History of the Yosemite Valley, Professional Paper No. 160 of the U. S. Geological Survey. The manuscript for this special number was reviewed by Mr. Matthes and has his approval.

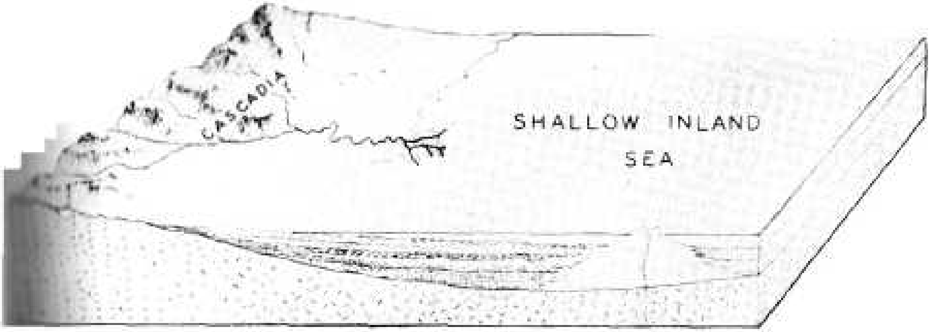
Earlier Mountain Ranges

More than two hundred million years ago the area now occupied by the Sierra Nevada was covered by a shallow arm of the Pacific Ocean. Sediments, mainly outwash from the adjoining land masses, accumulated to thicknesses of thousands of feet on the ocean bed. During the Permian epoch, near the end of the Paleozoic era, these sediments were uplifted and folded into the form of mountain ranges comprised of slate, shale, sandstone, alternating with thick beds of limestone. (See table of sequence of geologic events on next page.)

In the long period of time that followed, these mountains were in large part worn away, and the region again became inundated by the ocean. For millions of years, new layers of mud, silt, and sand, together with beds of volcanic mater-

SEQUENCE OF EVENTS IN THE YOSEMITE REGION

PERIOD	EPOCH	NATURE OF EVENTS (Read from bottom of chart to top for sequence)	Approximate Duration in Years
Quaternary	Recent	Postglacial time. Return to normal climatic conditions. Lake Yosemite formed and filled in, forming present level valley floor.	20,000
	Pleistocene	The Great Ice Age. Second series of uplifts pushed Sierra Nevada up to its present height of over 14,000 feet. Yosemite Valley invaded three times by glaciers.	1 to 2 million
Tertiary	Pliocene	Period of relative stability in which the Merced River developed a rugged mountain valley more than a thousand feet in depth.	10 million
	Miocene	Volcanic eruptions begin anew, following which the first major series of uplifts caused the Sierra Nevada to stand out as a block range. Merced River accelerated.	12 million
	Oligocene Eocene	The region, together with the country to the east of it, is slowly upwarped to moderate heights. Volcanic activity in the north part of the range. Continued land erosion. Birth of Merced River.	40 million
Cretaceous		Mountain ranges gradually worn down and bulk of sedimentary rock carried away by streams, uncovering the granite over large areas.	75 million
Jurassic		Continued deposition of sediments on ocean bed, followed by folding of strata into northwestward-trending mountain ranges. (Mariposa formation). Intrusion of molten granite into the folds from below.	40 million
Triassic		Mountains worn down to hills and land finally sinks below the sea. New sediments deposited.	40 million
Carboniferous	Permian	Sediments uplifted and folded into mountain ranges. (Calaveras formation.)	415 million
Pre Carboniferous		Sediments accumulate on floor of Pacific Ocean.	

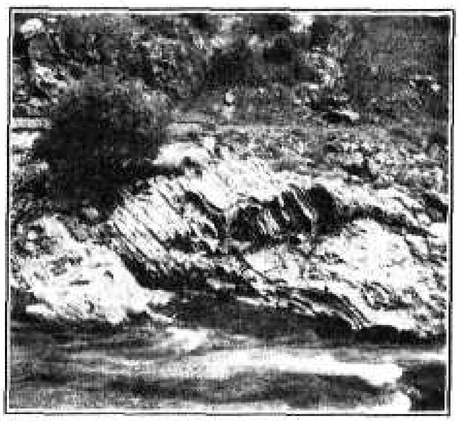


al accumulated upon the submerged remnants of the first mountain system. Then, at the end of the Jurassic period about 130 million years *ago, these new strata* were folded and crumpled and invaded by molten granite from below. Thus a secondary system of mountain ranges was formed that occupied most of eastern California and large areas in adjoining states.

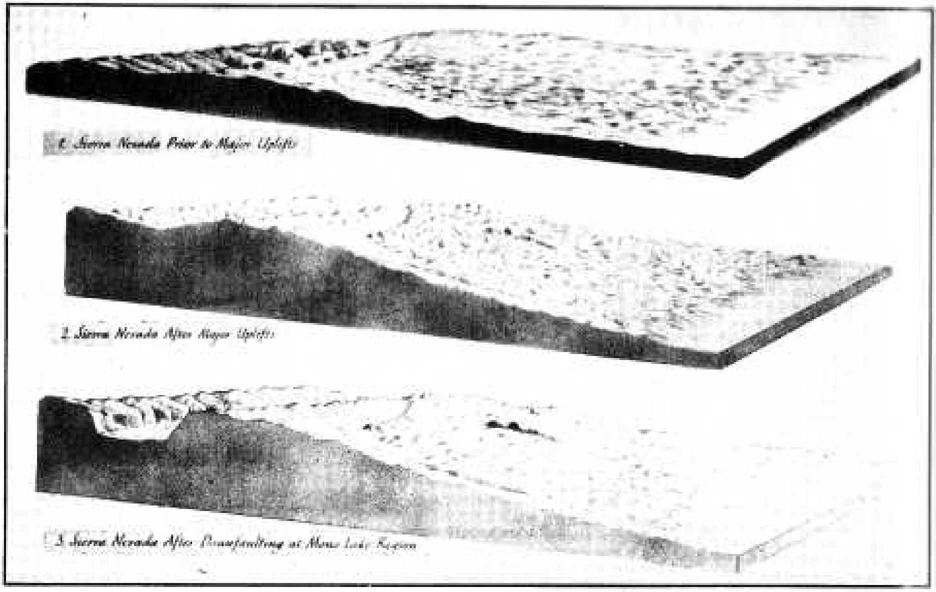
Throughout the Cretaceous period, which *followed the Jurassic,* the second mountain system was being gradually worn down until by the beginning of the Tertiary period only ridges of moderate height were left. The bulk of the original sedimentary material was thus stripped away and the granites exposed over large areas. Remnants of the older sediments, now considerably altered and folded, still exist today, particularly along the crest of the Sierra and in the lower foothills. A geological marker has been placed at one of these sites on the all-year highway from Merced to Yosemite about ten miles west of Arch Rock Entrance Station. There may be seen the broken and intensely folded strata that represent the oldest rocks of the Yosemite region.

Rise of the Sierra Nevada

During the early part of the Tertiary period, the area now occupied by the Sierra Nevada first acquired an appreciable slant to the southwest. For a long period, the region was gently upwarped to moderate heights. In late Tertiary time, a series of uplifts raised the eastern edge of the Sierra region several thousand feet and steepened its western slope.



Oldest Rocks of the Yosemite Region



Diagrammatic cross section of the Sierra block showing Rise of the Sierra Nevada and down-faulting of the Mono Lake Region.

A second series of uplifts occurred during the early part of the Ice Age (Pleistocene), which raised the eastern margin of the range to its present height of over 14,000 feet and again steepened the grade to the west. Following this, the Owens Valley-Mono Lake region was down-faulted, causing the Sierra Nevada to stand out as a lofty block range with a steep eastern front.

The Cutting by the Merced River

Prior to the uplifting of the Sierra, the principle drainage was approximately north and south. As the area was tilted to the west, the drainage was rearranged and new streams started flowing down the western slope. One of these master streams, the Merced River, was responsible for most of the early cutting of Yosemite Valley. Evidence shows three distinct stages of river cutting corresponding to successive uplifts of the range. The first or Broad Valley stage represents the time when the Sierra was still relatively low and for a long time the Merced River flowed sluggishly, meandering back and forth, forming a broad but shallow valley. El Capitan at this time was probably a rounded, wooded hill, rising about 900 feet above the valley floor.

Following the first strong tilting of the Sierra block, the Merced River was accelerated. The stream aban-

Broad Valley Stage

doned its meandering habit and began vigorously to deepen its bed. This resulted in the second or Mountain Valley stage of river cutting. By the end of Pliocene (epoch prior to Ice Age), a deeper and narrower valley had been cut by the Merced River. El Capitan was now about 1600 feet above the valley floor but

Mountain Valley Stage

still retained its rounded, wooded form.

It was during this stage that the waterfalls of the valley came into being, not as the straight sheer drops you see today, but as cascades tumbling down the sloping sides of the river-cut canyon. Their origin was due to the inability of the tributary streams to cut as rapidly as the Merced River, not being benefited by the westerly tilt of the range.

Canyon Stage

The third or Canyon stage of river cutting took place early in the Ice Age coincident with the strong uptilting that pushed the Sierra up to its present height of over 14,000 feet. The Merced River was accelerated to torrential speed, rapidly cutting a steep-walled inner gorge. El Capitan stood 2400 feet above the bottom of the narrow river-cut gorge, while tributary streams cascaded over a half mile down the V-shaped side walls.

Glaciation of the Sierra Nevada

During the Ice Age, the climate of the Sierra Nevada turned wintry and the higher parts of the range became heavily mantled with snow and ice. More snow fell each winter than could possibly melt during the ensuing summer; and, in the course of time, great fields of compacted snow and, ultimately, glaciers were formed.

Maximum Glacial Stage

Great glaciers descended the main river-cut valleys some 50 or 60 miles to elevations of around 2000 feet above sea level where the temperature was sufficiently high to prohibit their further advance. Yosemite Valley was occupied by a huge trunk glacier, one branch coming down the Merced River canyon over what is now Vernal and Nevada Falls, and the other coming down Tenaya Canyon, the two joining together at the head of the Valley. Evidence shows that Yosemite Valley was invaded by ice at least three times during the Ice Age. The first two invasions were by far the greatest in depth and extent, the ice bodies filling the Valley to the brim and reaching a few miles below El Portal. Glacier Point was covered by 700 feet of glacial ice, but Sentinel Dome, a mile back, was not overridden. Other features never covered were the upper 700 feet of Half Dome, the top of El Capitan, and the highest of the Three Brothers — Eagle Peak.

The last glacier to occupy the Valley was near the close of the Ice Age, and, as a result, was much smaller than the preceding two. It filled the Valley only to a third of its depth and reached only a little below El Capitan.

Last Glacial Stage

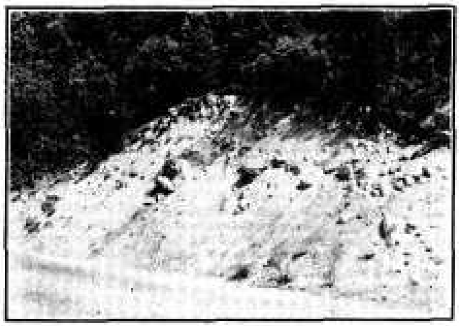
It is difficult to visualize the tremendous crushing and quarrying power of those vast ice bodies as they moved slowly down the river cut canyons. The process whereby glaciers excavate to best effect in hard rocks such as granite is by plucking or "quarrying" entire blocks or slabs. These blocks and slabs are only rarely broken off from sound, unfractured rock. The glaciers take advantage, rather, of the fractures already existing in the rock—the joints by which it is divided into natural blocks and slabs. Where these fractures are close together so that the rock is divided into small, light blocks or slabs, quarrying will proceed with relative ease and rapidity; but where the joints are far apart, the blocks are too large and heavy for even a mighty trunk glacier to dislodge. Therefore, where the granite was massive, as in the case of El Capitan, the glacier could only rasp and polish.

Glacier Polish and Erratics

The structure of the rocks, therefore, played a very important part in the amount of sculpturing accomplished by the ice and explains the variation in appearance of the principal, present-day rock features of the Valley. Considering the Valley as a whole, its profile was changed from a narrow V-shaped gorge into a broad U-shaped trough. It is believed that glaciers were responsible for about a third of the present depth of Yosemite Valley and for the greater part of its present width at the bottom.

Lake Stage

Most of the evidence of glaciation in Yosemite Valley today is from the last glacier which occupied the Valley toward the close of the Ice Age. Glacier polish is still visible at Rocky Point and above



The Bridalveil Moraine

Mirror Lake. A number of moraines in the lower end of the valley mark the recessional stages of the last glacial invasion. One of these, the El Capitan moraine, lies near the narrowest part of the Valley and is responsible for the level Valley floor of today. The remnant of this moraine now visible appears as a high-ridge, railroad-like embankment overgrown with trees and shrubs. Except for a thin veneer of humus and soil, it is composed mainly of boulders of varied size—material that was deposited by the glacier while it occupied this constricted area. At the close of the Ice Age, the tremendous volume of water issuing from the melting glacier was impounded by this morainal obstruction; and, as a result, the Valley floor was flooded, forming a huge lake. How long ancient Lake Yosemite existed is not known, but it was only a short time geologically, as lakes have a comparatively short

Lake Stage

existence. The great load of silt, sand, and rock material carried down by postglacial streams filled the lake rapidly. Eventually the water broke through the morainal obstruction and drained away. Ordinarily, a glaciated valley has a rounded, U-shaped bottom; but in Yosemite Valley, the glaciated rock floor is covered with hundreds of feet of morainal material and lake sediment, which account for the present level, park-like valley floor. Recent studies carried on by geologists of the California Institute of Technology by means of seismograph sound waves indicate that the depth of the fill varies from only a few hundred feet at the lower end of the Valley to more than 1000 feet between Government Center and Camp Curry.

Due to the prevalence of vertical jointing in the rocks surrounding Yosemite Valley, the glaciers were able to produce, in many places, nearly vertical side walls. This changed the cascades of many of the tributary streams to sheer vertical plunges. The hanging valley of Yosemite Creek stands over 2500 feet above the Valley floor, and the upper Yosemite Fall has the distinction of being one of the world's highest, free-leaping waterfalls.

Recent

With the exception of the forming of Lake Yosemite and its rapid disappearance, little change has taken place in the appearance of Yosemite Valley since the close of the Ice Age nearly 20,000 years ago. Earthquakes have played only a minor part in the accumulation of rock material at the base of the cliffs; the bulk of such material having resulted from the natural weathering and breaking down of the side walls. Minor changes are taking place every year in the cliff features as the work of weathering and erosion continues.