Geology of Western National Parks: Yosemite, CA

presentation with Kirt Kempter

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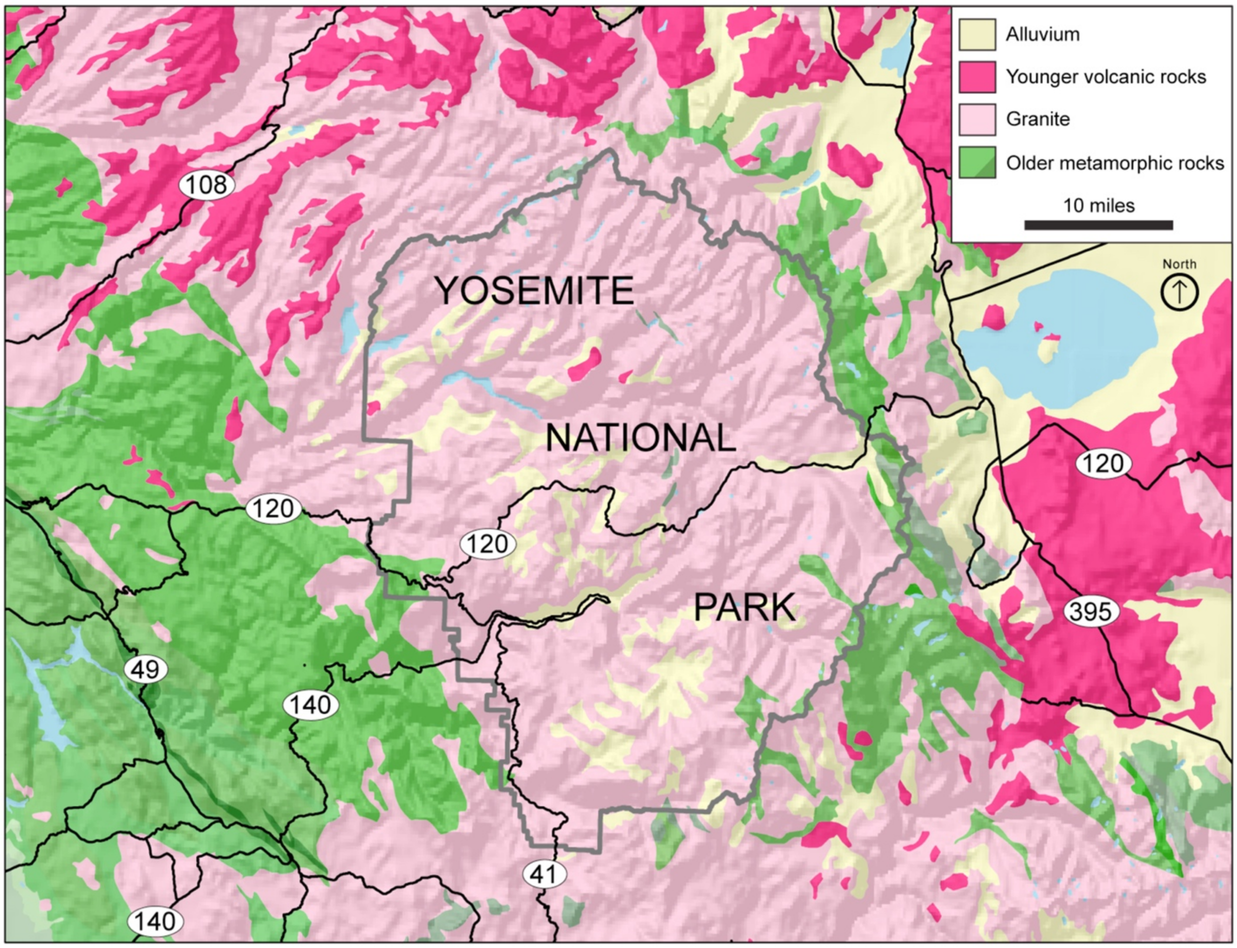

Simplified geologic map of the Yosemite Region

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Geography

The Sierra Nevada (Spanish for "snowy mountain range") is the largest fault-block mountain range in the United States, traversing northwest-southeast along half the length of California [more than 480 km (300 mi)]. The massive block of crust was uplifted along a northwest-trending fault system now forming the border between the mountain range and the basins to the east. The High Sierra refers to the 40-km (25-mi) wide, rugged central plateau of the Sierra Nevada that extends approximately 160–260 km (100–160 mi) north from Mt. Whitney. Peaks of the High Sierra line the park's eastern border. Mount Lyell, the highest peak in Yosemite National Park, rises

3,997 m (13,114 ft) above sea level. Elevations of Mt. Dana and Kuna Peak surpass 3,960 m (13,000 ft). An additional eighteen named and several unnamed peaks rise above 3,660 m (12,000 ft). Mt. Hoffman, at an elevation of 3,307 m (10,850 ft), lies in the approximate geographic center of the park. In Sequoia and Kings Canyon National Parks to the south, Mount Whitney's summit [4,417 m (14,491 ft)] forms the highest elevation in the contiguous United States. Approximately 65–130 km (40–80 mi) wide, the Sierra Nevada has a long, gentle western slope and an incredibly steep eastern escarpment that rises abruptly, along a normal fault system, from the Owens and Mono basins. For example, over a straight-line horizontal distance of about 13 km (8 mi), the elevation changes nearly 1,000 m (3,300 ft) from 2,067 m (6,781 ft) at Lee Vining, California, on the shores of Mono Lake, to 3,031 m (9,943 ft) at the Tioga Pass entrance station. Before the road was paved, this trip up the eastern face of the Sierra Nevada presented a mixture of white-knuckle driving and fantastic scenery. The paved road has removed the driving challenge, but the unsurpassed scenery remains.

Overview of Yosemite's Geology

Of the three main categories of rock (igneous, sedimentary, and metamorphic), igneous rocks are most common at Yosemite National Park, including the granitic salt-and-pepper-colored rocks that form such features as Half Dome, El Capitan, and the cliffs of Yosemite Valley. The park's granitic rocks can be classified more specifically as granite, granodiorite, and tonalite. These plutonic (intrusive) igneous rocks formed when magma (molten rock) cooled and solidified within Earth's crust, and thus contain individual crystals and primary minerals that are often visible to the unaided eye. In contrast, volcanic (extrusive) igneous rocks form when magma cools and solidifies rapidly on Earth's surface. Because rapidly-cooling crystals have less time to grow, most mineral grains in volcanic rocks are too small to be distinguished without a microscope. Plutons (large, discrete masses of plutonic rock) form the 100-km (40-mi)-wide Sierra Nevada Batholith (from the Greek words bathos, deep, and lithos, rock), the core of the Sierra Nevada. More than 100 plutons representing separate episodes of magma intrusion and solidification shape the batholith in the vicinity of Yosemite National Park. Once thought to have originated as a simple emplacement of magma, the Sierra Nevada Batholith is now known to record a complex history of pluton emplacement associated with subduction zone volcanism that took place 220–85 million years ago during the Mesozoic era, although the majority of granites in Yosemite National Park are between 105 and 85 million years old.

Most granitic rocks in Yosemite National Park are medium to coarse grained with crystals that are relatively equal in size. However, some units contain larger mineral crystals, called phenocrysts, scattered in a surrounding groundmass of smaller crystals. The Cathedral Peak Granite, for example, includes characteristically large orthoclase (potassium) feldspar phenocrysts among smaller crystals of quartz, feldspar, and biotite that comprise the groundmass. Rock climbers utilize the larger mineral crystals as hand and foot holds. Although Proterozoic- and Paleozoic-age sedimentary rocks are exposed in the White and Inyo mountains, east of the Sierra Nevada Batholith, all sedimentary rocks in Yosemite National Park have been metamorphosed, or transformed by increasing heat and pressure to form new minerals or fuse individual mineral grains. If the original rock type is known, these metamorphic units may be identified by the prefix "meta." Linear, northwest-trending belts of metasedimentary and metavolcanic rock outcrop along the western and eastern borders of Yosemite National Park.

The western metamorphic belt contains strongly-deformed, weakly metamorphosed rocks that range in age from about 500 million years (Early Cambrian) to approximately 150 million years (Upper Jurassic). Tectonic plate collisions during the Paleozoic and Mesozoic transported these units from their original deep-marine depositional sites and compressed them onto the western margin of North America. In contrast, the metavolcanic and metasedimentary rocks east of the Sierra Nevada Batholith have not been displaced very far from their original sites of deposition. A few remnants of metamorphic rocks also lie within the batholith and provide clues to deformation in central California prior to batholith emplacement. The andesitic lava of Little Devils Postpile, located along the Tuolumne River in Yosemite National Park, solidified about 8 or 9 million years ago and attests to volcanic activity that occurred prior to Pleistocene glaciation. The impressive columnar joints of the Postpile represent solidified magma in a conduit that once fed an ancient volcano.

In the Cenozoic, the Sierra Nevada Batholith was uplifted and tilted to the west, allowing ice age alpine glaciers to carve these dense, hard plutonic rocks into the iconic landscape seen today in Yosemite National Park. The cirque basins, alpine lakes, U-shaped and hanging valleys, polished granitic domes, spectacular waterfalls, unusual glacial erratics, glacial moraines, and other glacial features originated in the dynamic processes of Pleistocene (ice age) glaciers that first impacted the region about 1.5 million years ago. Glaciers straightened, deepened, and widened previously stream-cut valleys and filled them with sediment. Most of the glacial features in the park reflect the most recent major episode of glaciation, called the Tioga, which began about 26,000 years ago and reached its maximum extent about 18,000 years ago. The scoured cliffs in Yosemite National Park contrast sharply with the jagged peaks, spires, and pinnacles that stood above the glacial ice. The joints (fractures) in the park's granitic bedrock significantly influenced glacial activity in this otherwise homogeneous, erosion-resistant landscape. Glaciers plucked and gouged highly-jointed granitic bedrock much more easily than massive, relatively joint-free plutons. Yosemite National Park contains three primary joint patterns: two nearly vertical and perpendicular joint sets that trend northwest and northeast and exfoliation joints that form parallel, sheet-like layers on the surface of granitic exposures. These joints not only influence modifications in the park's landscape, but also pose potential safety hazards by triggering rockfalls. The modern glaciers in the Sierra Nevada are not remnants of Pleistocene glaciation, but are the product of post-Pleistocene (Neoglacial) events. Warming temperatures at the end of the Pleistocene and beginning of the Holocene (11,000 years ago) reached a maximum about 5,000 years ago, when most, if not all, glaciers in the Sierra Nevada had melted. Since then, global climate has fluctuated through relatively minor warming and cooling cycles.

The Sierra Nevada continues to rise. Today, the estimated rate of uplift at Mount Dana is about 4 cm (1.5 in) per 100 years, which exceeds the rate of beveling by erosion, resulting in a net increase in elevation. Rockfalls continue to modify canyon walls while rivers incise valley floors. Sediment slowly fills alpine lakes, and cirque glaciers, although melting at a rapid rate, continue to add material to terminal moraines while scouring and polishing bedrock. From its granitic domes and waterfalls to its sediment-filled valleys, Yosemite National Park exhibits the past processes of plate tectonics and glaciation along with ongoing weathering and erosion that continue to shape one of America's most impressive landscapes.