



# California Geologic Map



## California Geology

Geologic History of California

A Generalized geologic history of the southwestern United States

Precambrian History

Achaean: Current theory suggests that the Earth formed in a stellar cloud around our newly formed sun in the range of about 4.5 billion years ago. Heat-driven mantle convection and asteroid collisions recycled or destroyed the oldest crustal material that may have formed during Earth's earliest history. The oldest rocks in North America are of Late Achaean age and are found in the Canadian Shield region and locally elsewhere in the Rocky Mountain region. The oldest known rocks of this age in the West crop out in core of mountain ranges in western Wyoming—some are estimated to be older than 3 billion years. Rocks as old as 2 billion years crop out in the deepest part of the Grand Canyon. No rocks of this age are known in California.

Early to Middle Proterozoic: The oldest rocks preserved in California are metamorphic rocks in the Mojave Desert region and are Early Proterozoic age, ranging from about 1600 to 1800 million years old. These metamorphic rocks were derived from older sedimentary, igneous, and metamorphic rocks but were subjected to high heat, pressure, and partial melting and recrystallization during a period of mountain building associated with continental collisions of tectonic plates that resulted long ago in Earth's history. Rocks of similar age and character are perhaps best known from the bottom of the Grand Canyon. These rocks could best be simply described as having formed long ago, far away, and having been altered from burial deep in the crust before finally coming to rest attached to the North American continent.

Late Proterozoic: Following the formation of the metamorphic and igneous basement rocks in Early to Middle Proterozoic time, the region that is now the Mojave Desert experiences extensive uplift and erosion that wore down ancient mountain ranges to what was probably a gentle regional plain or rolling pediment. By late Proterozoic time, about 1 billion years ago, the landscape had worn down enough for shallow seas to transgress across the region. Sedimentary deposits (mostly quartz sandstone and limestone) accumulated on a broad continental shelf or continental margin setting. The record of this is preserved as the Elko Unconformity between underlying crystalline basement and overlying sedimentary rocks of Late Proterozoic Age (see Fig. 2). Over time, the seas advanced and retreated leaving behind thick beds of sandstone, limestone, dolomite, and shale (and their metamorphic equivalents—quartzite, marble, and slate). Today these rocks are locally exposed in the eastern Mojave and Death Valley regions. Passive-margin-style deposition continues along the California margin through the end of Proterozoic time into the following Cambrian Period of the Paleozoic Era.

Paleozoic History

A massive sequence of Paleozoic-age sedimentary formations are preserved in California's mountain ranges in the eastern Mojave Desert and the Death Valley region. These rocks, consisting mostly of limestone and dolomite, preserve evidence of the evolution of marine life forms. The oldest sedimentary rocks of the Cambrian Period preserve an abundance of fossil algae (stromatolites) and locally contain an abundance of early invertebrate fauna, including trilobites. Changing sea-level conditions caused the seas to advance and retreat numerous times across the region. By middle Paleozoic time (Devonian and Mississippian times), the rocks in the Death Valley region preserve evidence of the formation of carbonate reefs along the margin of an ancient tropical marine shelf. These reef deposits preserve an abundance of fossil corals, brachiopods, and other invertebrates.

The seas continued to advance and retreat across the region through the Late Paleozoic Era, resulting in the formation of more fossiliferous limestones of Pennsylvanian and Permian age. Farther to the west, deeper water conditions prevailed. Marine shale and sandstones of Paleozoic age accumulated in deep water settings, but these rocks were mostly altered by metamorphism, destroyed or displaced by plate-tectonic subduction, igneous intrusion, or uplift and erosion in the following Mesozoic and Cenozoic eras. Large portions of the ancestral California continental margin bearing rocks of Paleozoic age were ripped away and carried northward along the Pacific margin and metamorphosed, buried, subducted, and accumulated as accreted terranes in the Pacific Northwest, possibly even into the Alaska region. However, great fault-bounded blocks of Paleozoic age rocks remain in the Mojave Desert region and are particularly well exposed in Death Valley National Park and around the Mojave National Preserve.

Much of the western margin of the North American continent was subjected to mountain building (orogenesis) in the middle of the Paleozoic Era. Evidence of the Ancestral Orogeny is preserved as complex fault and structural features preserved in sedimentary and metamorphic rocks of Devonian age throughout what is now Nevada. This was followed by the Sonoma Orogeny throughout the western region during the Permian and Triassic periods. During these orogenies, small land masses (terranes) were accreted onto the Cordilleran margin, with the largest accretionary event involving the addition of the Sonoma island arc (landmass) mostly into what is now Nevada. Current thought is that prior to the Sonoma Orogeny subduction was occurring in the eastern Pacific in a westward-dipping direction (forming Sonoma and other ancient island arcs). Once oceanic crust beneath a moderately shallow seaway basin was consumed by subduction, the Sonoma landmass collided with western North America. What followed was a change to eastward-dipping subduction on the western side of the newly accreted Sonoma terrane. This new configuration of subduction lead to the formation of the great series of island arcs that developed in the Mesozoic era in the Cordilleran region.

Mesozoic History

Triassic-Jurassic-Cretaceous Periods: The Mesozoic Era was a tumultuous time in California's geologic past. In early Triassic time, an extensive volcanic-arc system began to develop along the western margin of the North American continent. In Southern California, this volcanic arc would develop throughout the Mesozoic Era to become the geologic regions known as the Sierra Nevada Batholith, the Southern California Batholith (in the Peninsular Ranges), and other plutonic and volcanic centers throughout the greater Mojave region. These massive belts of plutonic (intrusive) and volcanic (extrusive) regional belts and isolated centers developed as plate convergence and subduction took place farther west along the western continental margin. These igneous provinces shed vast quantities of sediment both eastward into the Western Interior Seaway and westward into Pacific margin basin. At the same time, older sedimentary materials and rocks were subjected to regional metamorphism throughout much of Southern California. In the region today, granitic rocks of Mesozoic age dominate the bedrock exposed in the Peninsular Ranges, western Transverse Range, the southern Sierra Nevada, and the greater Mojave region.

Although igneous activity in the Southern California region was ongoing throughout the Mesozoic Era, the peak of the plutonism in the southern Sierra Nevada region was in the Late Cretaceous, about 100 to 80 million years ago. In addition, thick sequences (accumulations) of Mesozoic-age sedimentary rocks—mostly marine shales and sandstones of Jurassic and Cretaceous age—are locally preserved along the western side of the Peninsular Ranges and throughout the western Transverse Ranges in the Santa Monica Mountains and mountainous Los Padres National Forest region north of Santa Barbara. A thick sequence of terrestrial sedimentary rocks are also preserved in the McCoy Mountains region near Blythe, California. Except for the sedimentary rocks mentioned above, most of the Mesozoic-age rocks in preserved in Southern California display intermediate to high grades of metamorphism, typical of material that may have been buried to mid-crustal depths (probably in a range of 10 to 20 kilometers). Although the region was no doubt extensively covered with terrestrial and marine sedimentary deposits that inter-fingered volcanic deposits from the volcanic centers, most of this material was stripped away by erosion following regional uplift that continued into the following Cenozoic Era.

Rocks of Mesozoic age crop out extensively through the coast ranges of Central and northern California. In the San Francisco Bay region, rocks assigned to the Franciscan Formation consist of rocks in the Pacific Ocean basin and along the western continental margin. The Franciscan Formation, sometimes referred to as an "assemblage" or "basement" complex consist of rock sequences derived from throughout the Pacific Basin region and carried by plate-tectonic motion as fault-bounded terranes that were accreted onto the continental margin over time. Portions of the Southern California batholith were ripped off and carried northward along the California margin, this process has been ongoing into the present via the extensive greater California fault system (which includes the more modern San Andreas Fault).

Cenozoic History (Tertiary and Quaternary Periods)

Paleocene-Eocene-Oligocene: During the early Tertiary Period, subduction continued along the western North American continental margin. However, volcanic-arc style igneous activity that had occurred earlier (during the Mesozoic Era) in the Sierra Nevada and Peninsular Ranges region had diminished or ceased. Instead, volcanic activity occurred in region much farther east (in the Rocky Mountains region). Much of the region that is now Southern California underwent extensive uplift and erosion, and over time the landscape wore down and probably became an extensive pediment (rolling lowlands with a few mountains) bordered on the west by a coastal plain, shallow embayments, and coastal uplands. Rivers and stream carried vast quantities of sediments and deposited them in offshore basins along the continental margin. Great fault systems that predate the modern San Andreas Fault system carried great blocks of crystalline basement rocks and their overburden of sedimentary materials derived from the Southern California northward into the Central Coast region and beyond.

Miocene: In early Miocene time, subduction along the western margin of the North American Continent slowly shifted to transform faulting. This gradually occurred as the ancient Farallon Plate disappeared into the subduction zone and the North American Plate came in contact with the Pacific Plate (click here for more detailed information about the formation of the San Andreas Fault). By late Miocene time, the shoreline geometry of southern California changed significantly as mountain ranges began to rise along the coastline, exposing marine sedimentary deposits that had accumulated in offshore continental shelf and marine basin environments. These sedimentary basins filled with sediments derived from the land and from organic remains deposited in the sea. These organic materials would become the major source of California's modern petroleum resources (oil and gas). Volcanism, tectonic uplift and crustal extension in the eastern Mojave and Great Basin regions are responsible for the formation of the basin-and-range landscape features and formation of the arid, isolated interior-draining basins. In late Miocene time the Baja Peninsula began to separate from mainland Mexico and begin its gradual migration northward. The rift valley between the Mexican mainland and Baja California eventually flooded with marine-water conditions extending northward in the Salton Trough region.

Pliocene: Climate cycles associated with ice ages began to affect the region. Uplift in the Peninsular, Transverse, and Coastal Ranges, and the Sierra Nevada and eastern Mojave region, start to shape the height and extent of mountain ranges visible today. With the cooling of the climate, great lakes started to form in the interior basins of the Mojave, Death Valley, and Great Basin regions.

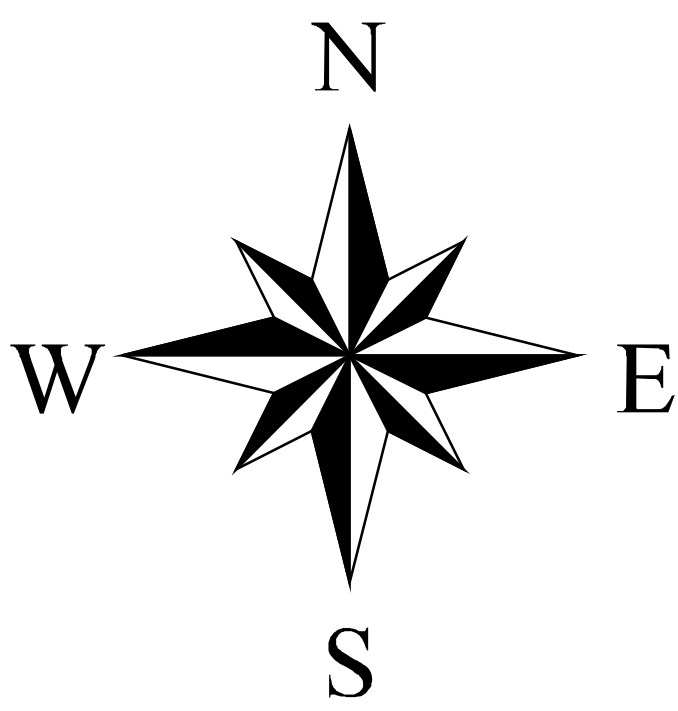
Pleistocene: Climate fluctuation caused intermittent periods of ice ages and warm periods. During cool, wet periods, alpine glaciers carved canyons in the Sierra Nevada and back-filled with sediments. Sea level rose and fell with each glacial cycle. During low sea level periods streams carved downward into their valleys, and during high sea level periods coastal valley became flooded and back-filled with sediments. During high-standing seas, ocean embayments covered the coastal plains and basins along the coast. During low-stand seas, the shoreline extended to the margin of the modern continental shelf and many of the islands now offshore were connected via peninsulas to the mainland. Ongoing tectonic forces (faulting and folding) helped shape the uplifts and basins visible on the landscape as they appear today. Uplift and subduction was particularly active in the Coast Ranges, Transverse Ranges, and Peninsular Ranges west of the San Andreas Fault. Volcanism occurred along the eastern Sierra Nevada region and in the Death Valley and Mojave regions. During the Pleistocene Period, modern river systems of the region (including the Mojave and Colorado Rivers) developed at the expense of older drainage systems that were captured or diverted by tectonic uplift, volcanicism, or as interior basins filled and spilled over into adjacent valleys.

Holocene: Sea level continued to rise following the peak of continental glaciation during the last ice age (Weichselian age, about 15,000 years ago) when sea level was as much as 350 to 400 feet (~120 meters) lower than present levels. Early human populations migrated into the California region starting about 10,000 years ago (possibly earlier). Many large mammalian species that lived in the region became extinct at the beginning of the Holocene Epoch. The California Gold Rush beginning in 1848 initiated one of the greatest human migrations in modern history (the "Anthropocene" begins—human activities (mining, agriculture, and construction) surpasses the effects of natural erosion, deposition, and other processes in increasing areas on the landscape).

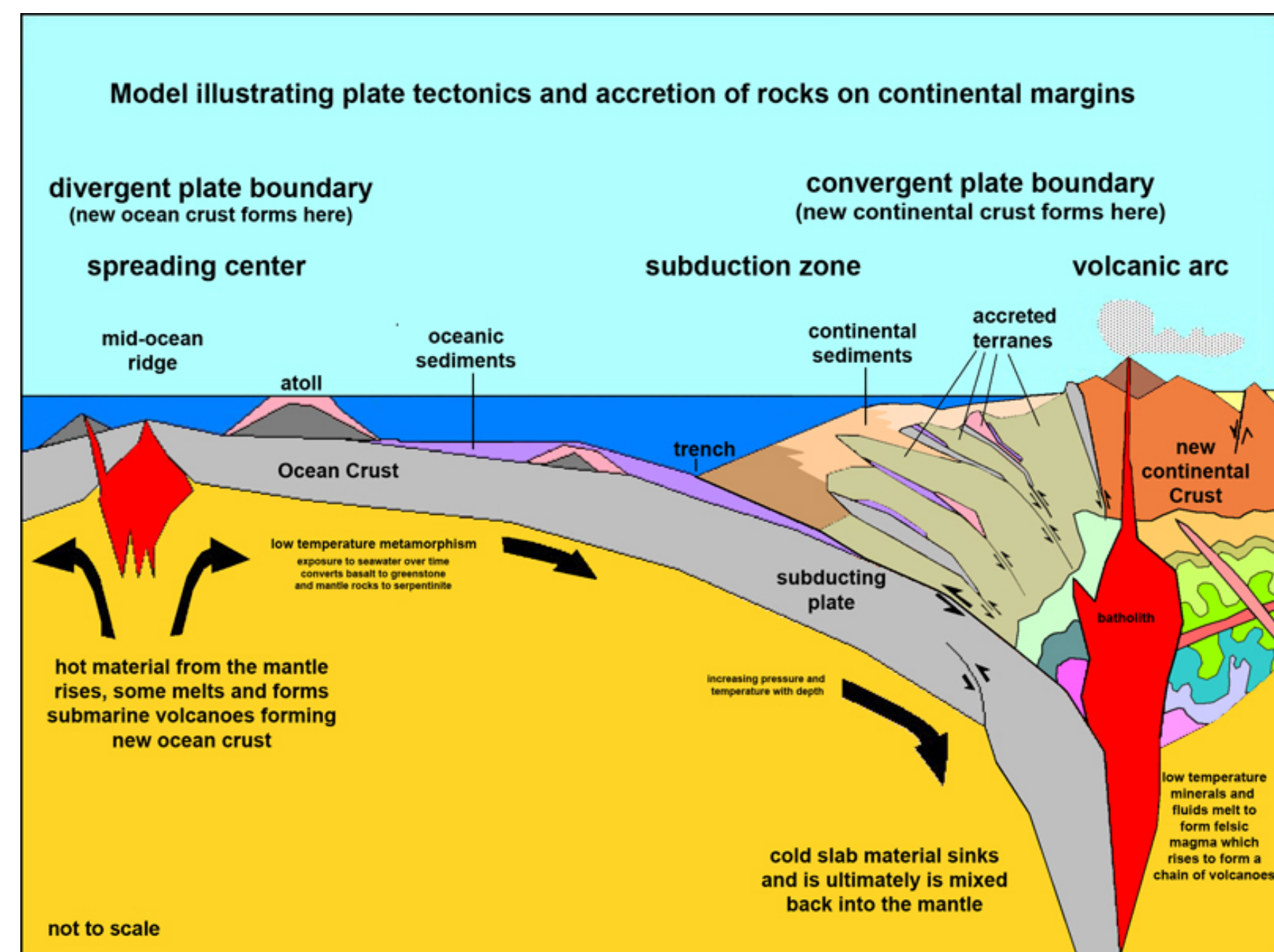
## Legend:

### Lithology

- Sandstone
- Water
- Granodiorite
- Alluvium
- Andesite
- Rhyolite
- Mudstone
- Schist
- Gneiss
- Basalt
- Limestone
- Gabbro
- Conglomerate
- Glacial Drift
- Serpentinite
- Plutonic Rock (Phaneritic)
- Peridotite
- Greenstone
- Intermediate Volcanic Rock
- Argillite
- Felsic Volcanic Rock
- Tonalite
- Dolostone (Dolomite)
- Dune Sand
- Melange
- Diorite
- Granite
- Slate
- Mafic Volcanic Rock
- Tephrite (Basanite)
- Shale
- Dacite
- Blueschist
- Mica Schist
- Hornfels
- Marble
- Quartz Monzonite
- Landslide
- Metasedimentary Rock
- Pelitic Schist
- Metavolcanic Rock
- Anorthosite
- Phyllite
- Quartz Diorite
- Chert
- Orthoquartzite
- Siltstone
- Trachybasalt
- Greenschist
- Sand
- Quartzite
- Peraluminous Granite



50 0 50 100 150 Miles



Geologic Time Table

EOH/ERA	PERIOD	EPOCH	Ma
Cenozoic	Quaternary	Holocene	0.01
		Plistocene	0.8
		Pliocene	1.8
		Early	3.6
		Late	5.3
	Tertiary	Miocene	11.2
		Early	14.4
		Middle	23.7
		Late	25.2
		Oligocene	28.5
	Paleocene	Early	33.7
		Middle	41.3
		Late	49.0
		Early	54.8
		Middle	61.0
Phanerozoic	Mesozoic	Cretaceous	65.0
		Early	144
		Late	196
		Jurassic	180
		Early	227
	Triassic	Early	242
		Late	248
		Permian	256
		Early	293
		Mississippian	323
Paleozoic	Devonian	Late	354
		Middle	370
		Early	417
		Silurian	423
		Early	443
	Ordovician	Early	456
		Middle	470
		Late	490
		Early	512
		Early	520
Precambrian	Achaean	Late	900
		Middle	1600
		Early	2500
		Early	3000
		Early	3400

Evidence for interpreting the geologic history are deciphered from clues provided by rocks, fossils, and landscape features. Not all rocks in the western region share a common history or formed at the same time or in their current location. The modern landscape reflect the cumulative history of the rocks observable in disparate outcropping along the western margin of the North American continent. The region has experienced, and continues to experience, mountain building, faulting (earthquakes), volcanism, weathering, erosion, and deposition. These events processes occur gradually or episodically, sometimes as catastrophic events. More recent activity discloses or removes evidence of earlier geologic events. However, through the study of rocks, fossils, and field mapping earth scientists over the decades have unraveled a remarkable story. The study of rocks in one area can be implied or inferred to other areas where rocks of different ages are not preserved or are buried by younger deposits. This is a short summary of current thought about the geologic origins of our western landscape, focus in California.

