A Remarkable Geography

To explain California's biodiversity, we must first look at its geography, the basic physical systems that shape California. California is roughly 164,000 square miles in size with 840 miles of coastline. The size and interplay of active physical systems within California has resulted in a landscape of extremely varied geography: the highest and lowest elevations of the contiguous United States are both found in California. We can explain much about the biodiversity of the state by looking at its topography, geology, soils, climate, bathymetry, and ocean currents.

Climate and Topography

California is one of the few places where five major climate types occur in close proximity. Here, the Desert, Cool Interior, Highland, and Steppe climates border a region of Mediterranean climate (see the map on page 15). Perhaps the only other place like California is central Chile, where this convergence is made even more extreme by the dramatic Andean topography.

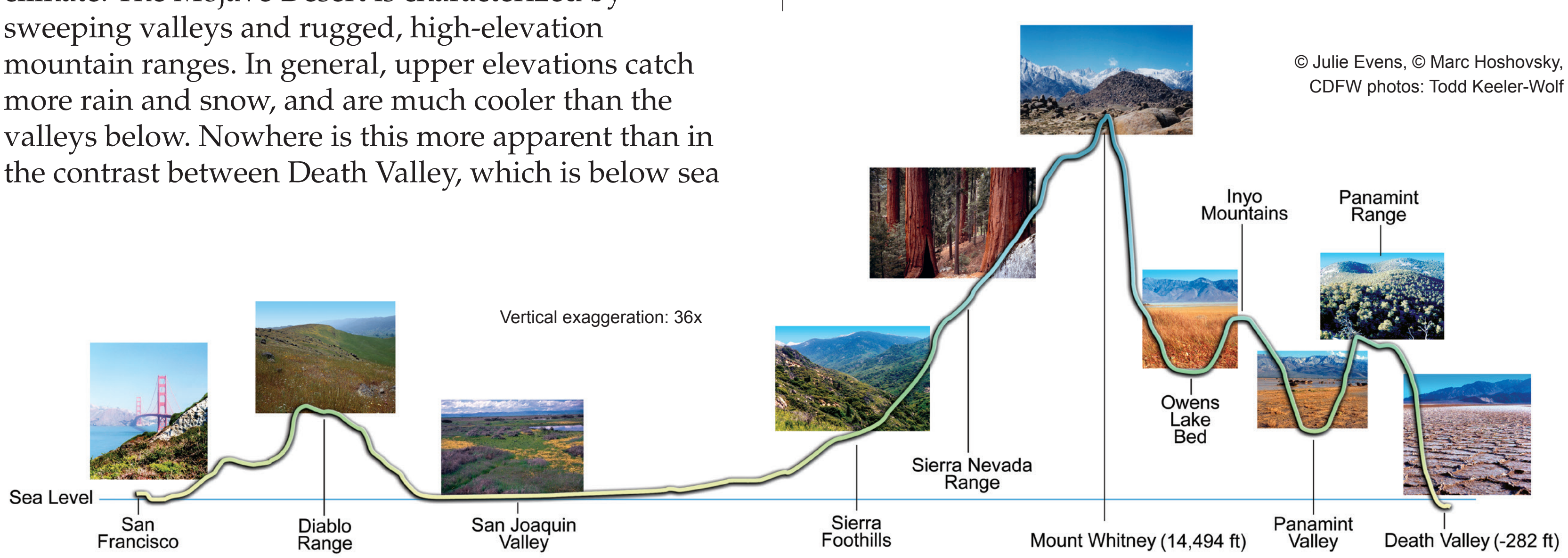
As climates go, the Mediterranean climate is rare. Outside of the Mediterranean Sea region, it is limited to five locations: two in Australia, one in South Africa, one in Chile, and one in California.

In California, the Mediterranean climate has two main variations. One is the temperate climate found along the coast and the western slope of the Sierra Nevada. Summer fog is frequent along the immediate coast due to the influence of the Pacific Ocean. The second variation is an interior valley version with hotter summers and cooler winters. With both types, most of the precipitation falls in winter—not summer—which is unusual for much of the world, where the opposite is true.

The mild temperatures and winter rain of the Mediterranean climate support some of the highest species richness in the state. Interestingly, however, California's Desert climates rival the Mediterranean for plant and animal species richness. For California's deserts, topography comes into play along with climate. The Mojave Desert is characterized by sweeping valleys and rugged, high-elevation mountain ranges. In general, upper elevations catch more rain and snow, and are much cooler than the valleys below. Nowhere is this more apparent than in the contrast between Death Valley, which is below sea level, and the Panamint Range, with peaks as high as 10,000 feet above sea level. In Death Valley, plants and animals may bake in 115 degree summer heat while 12 miles away and 2 miles up, cool breezes blow through the dark green needles of bristlecone pine (*Pinus longaeva*) and the delicate leaves of mountain maple (*Acer glabrum*). California's Steppe climate of the San Joaquin Valley is hot like a desert but averages enough moisture to support grasslands and other vegetation not commonly found in the desert.

California's higher elevations, such as those found on the Modoc Plateau and in the Sierra Nevada, generally have two major climate types: a Cool Interior climate and a Highland climate. In these areas, the conditions that determine most other climates (latitude, prevailing winds, and temperature) are strongly modified by elevation, slope, and aspect. Aspect, or the direction a slope faces, is very important. South-facing slopes catch the sun's rays and heat, making them warmer and drier, while shaded north-facing slopes are cooler and wetter. West-facing slopes tend to catch more precipitation from storms moving inland from the Pacific Ocean. The result is vegetation diversity—even on a single mountain. For example, a ridge may have oaks and open grass areas on one side and a dense canopy of fir or pine trees on the other.

Plants and animals have evolved to thrive in the varied conditions created by the interplay of climate and topography in California.



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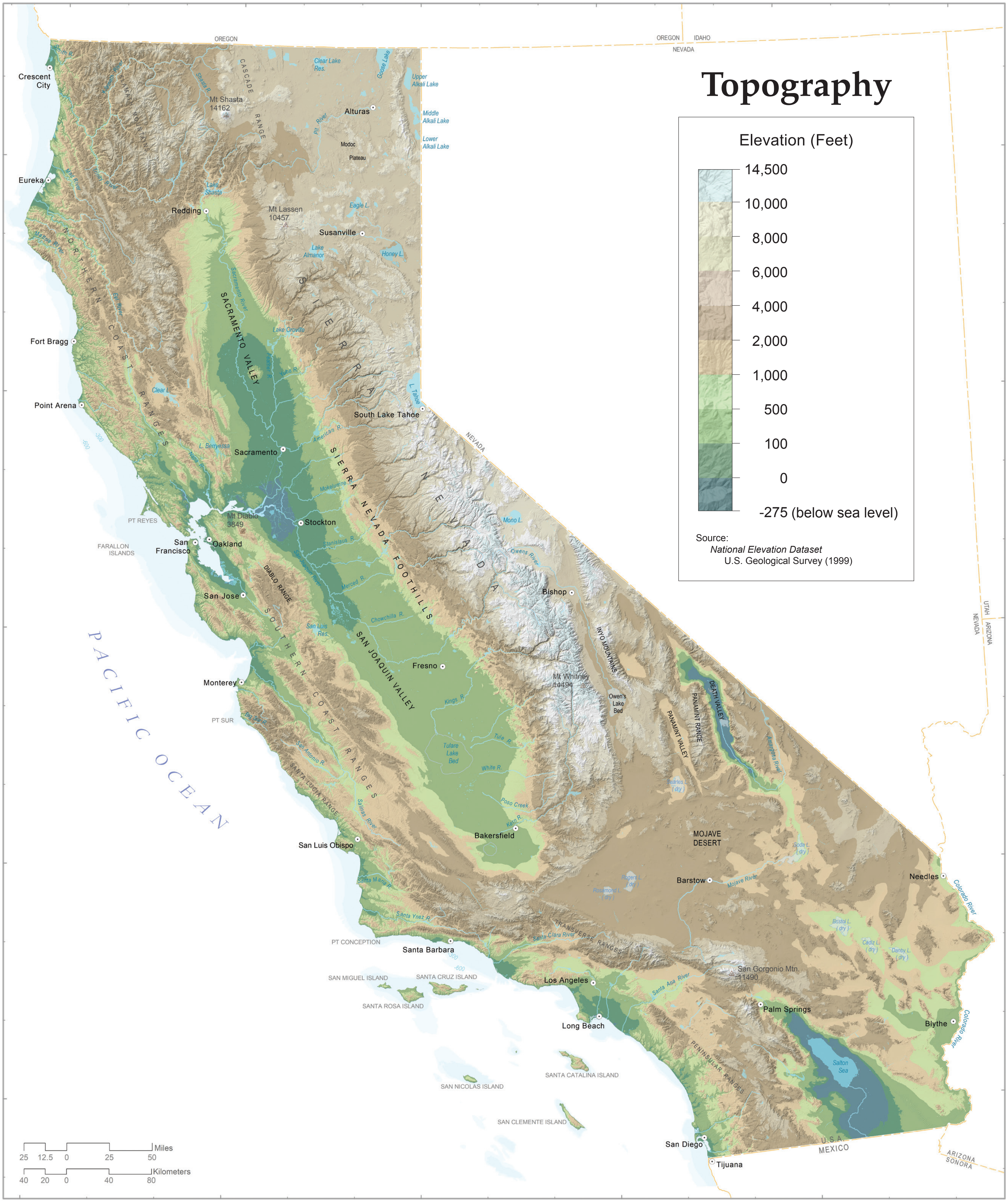
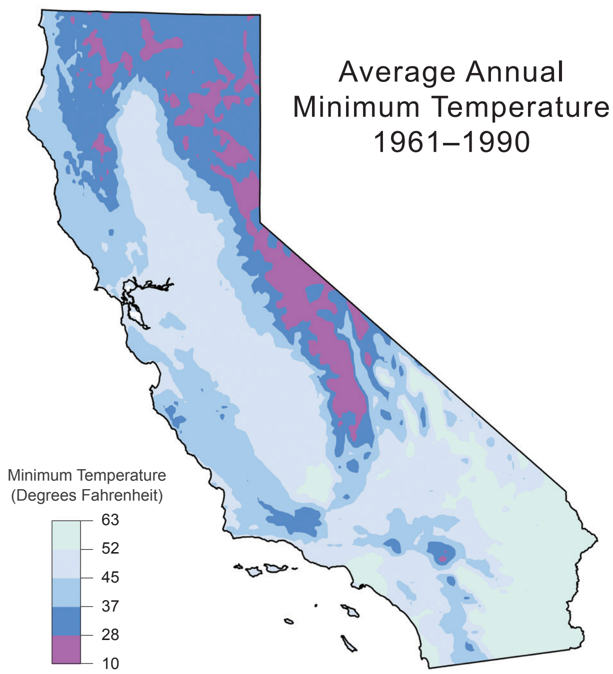
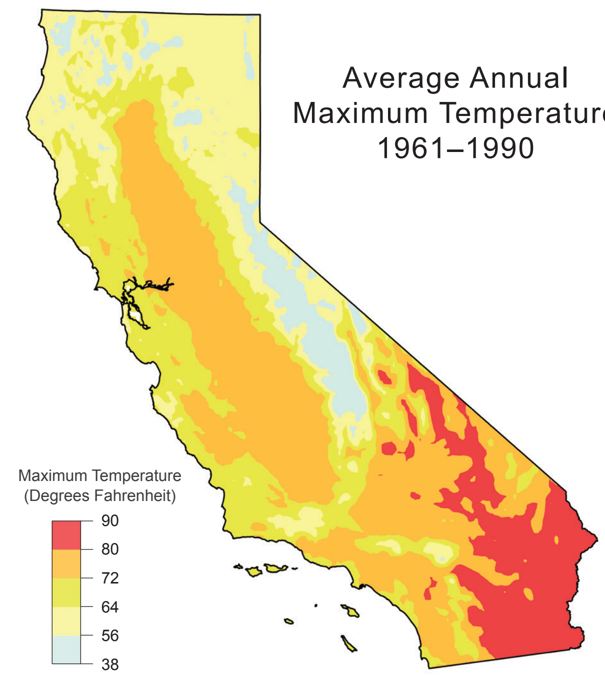

Topography
Elevation (Feet)
14,500
10,000
8,000
6,000
4,000
2,000
1,000
500
100
0
-275 (below sea level)
Source:
National Elevation Dataset
U.S. Geological Survey (1999)
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
114°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
33°0'0"N
OREGON
IDAHO
NEVADA
UTAH
ARIZONA
ARIZONA
SONORA
U.S.A.
MEXICO
Crescent City
Eureka
Redding
Fort Bragg
Point Arena
Sacramento
Stockton
San Francisco
Oakland
San Jose
Monterey
San Luis Obispo
Santa Barbara
Los Angeles
Long Beach
San Diego
Tijuana
Alturas
Susanville
South Lake Tahoe
Fresno
Bakersfield
Bishop
Barstow
Needles
Palm Springs
Blythe
Mt Shasta
14162
Mt Lassen
10457
Mt Diablo
3849
Mt Whitney
14494
San Gorgonio Mtn.
11490
CASCADE RANGE
Modoc Plateau
SIERRA NEVADA
SIERRA NEVADA FOOTHILLS
SACRAMENTO VALLEY
SAN JOAQUIN VALLEY
NORTHERN COAST RANGES
SOUTHERN COAST RANGES
DIABLO RANGE
SANTA LUCIA RANGE
TRANSVERSE RANGES
PENINSULAR RANGES
INYO MOUNTAINS
PANAMINT RANGE
PANAMINT VALLEY
DEATH VALLEY
MOJAVE DESERT
Owen's Lake Bed
Tulare Lake Bed
Salton Sea
Clear Lake Res.
Goose Lake
Upper Alkali Lake
Middle Alkali Lake
Lower Alkali Lake
Eagle L.
Lake Almanor
Honey L.
Lake Shasta
Lake Oroville
Clear L.
L. Berryessa
L. Tahoe
Mono L.
San Luis Res.
Sacramento River
American R.
Stanislaus R.
Merced R.
Chowchilla R.
Kings R.
Tule R.
White R.
Poso Creek
Kern R.
Owens River
Mojave River
Colorado River
Santa Ana River
Santa Clara River
Santa Ynez R.
Salinas River
PT REYES
FARALLON ISLANDS
PT SUR
PT CONCEPTION
SAN MIGUEL ISLAND
SANTA CRUZ ISLAND
SANTA ROSA ISLAND
SANTA CATALINA ISLAND
SAN NICOLAS ISLAND
SAN CLEMENTE ISLAND
PACIFIC OCEAN
25 12.5 0 25 50 Miles
40 20 0 40 80 Kilometers

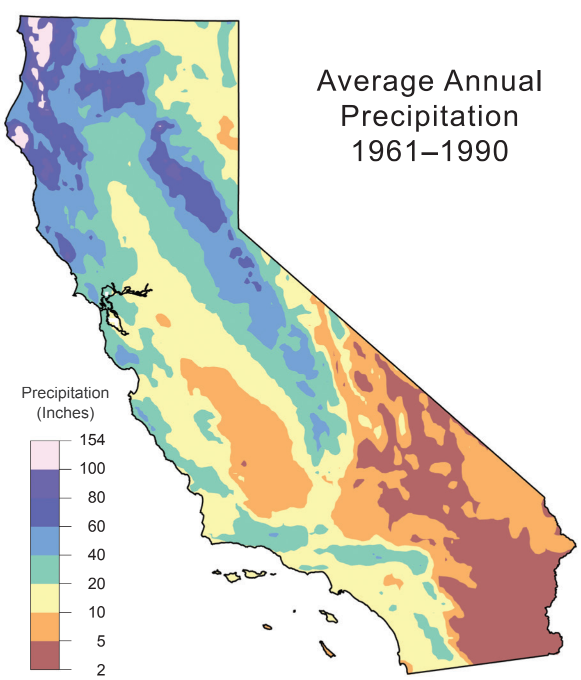
The combination of temperature and precipitation strongly influences the distribution of species across the state. Some species have evolved physical traits or behaviors that allow them to survive the climatic extremes they encounter. For example, desert-adapted mammals may deal with high temperature by having larger ears to cool their bodies or by spending most of their day underground. These adaptations can lead to speciation and contribute to the incredible biodiversity in California.



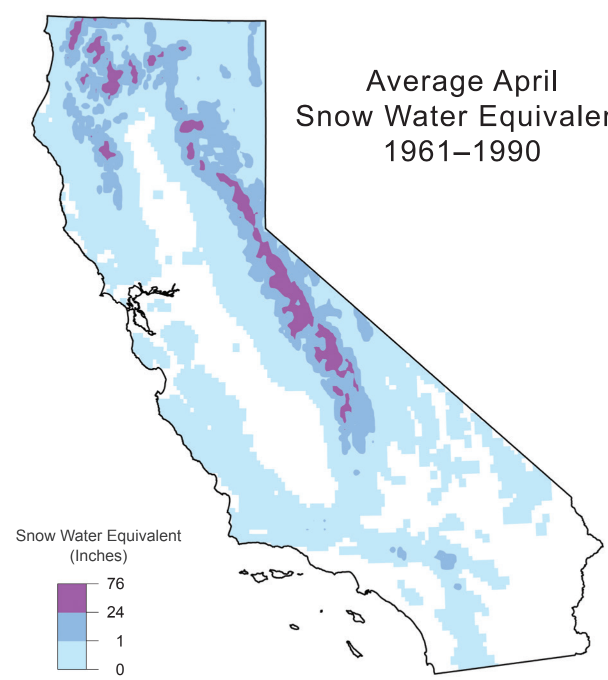
Source:
Annual Average Minimum Temperature, Historical Baseline (1961–1990)
Pierce et al. (2018)



Source:
Annual Average Maximum Temperature, Historical Baseline (1961–1990)
Pierce et al. (2018)

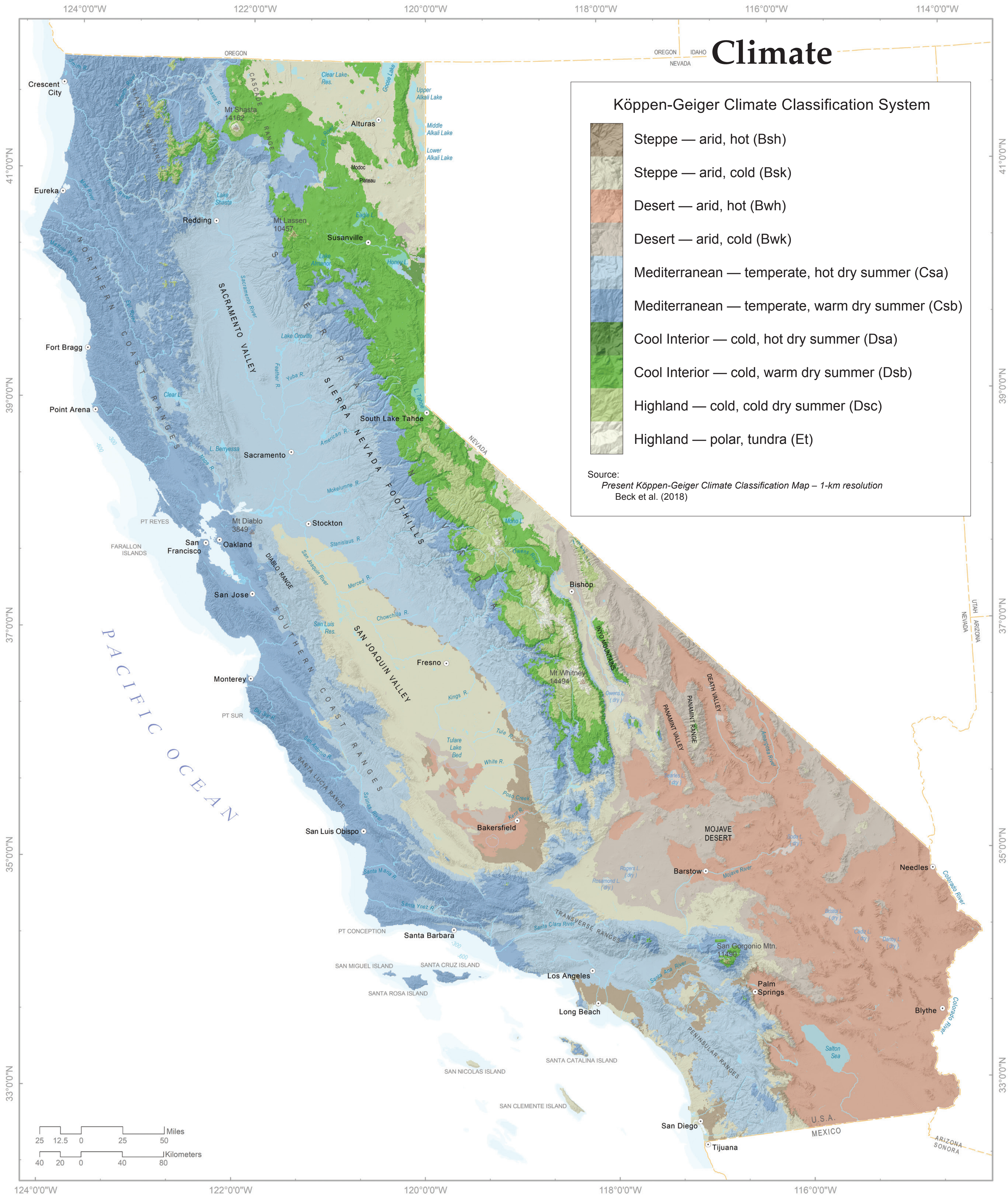


Source:
Annual Average Precipitation, Historical Baseline (1961–1990)
Pierce et al. (2018)

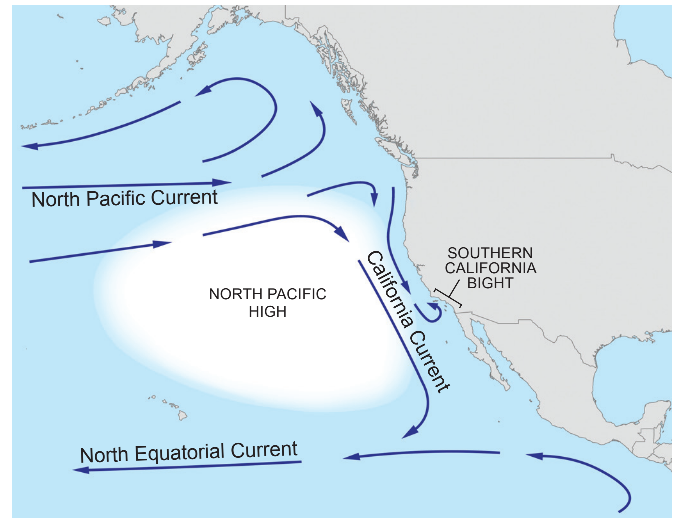


Source:
April Average Snow Water Equivalent, Historical Baseline (1961–1990)
Cal-Adapt (2020a)

Precipitation that accumulates in snowpacks during the winter provides much of the state's water in late spring and summer when it is hotter and drier. The Sierra Nevada snowpack alone is the source of more than one third of California's water supply. Snow water equivalent is the measurement of how much water would be released if the snowpack melted.


Climate
Köppen-Geiger Climate Classification System
Steppe — arid, hot (Bsh)
Steppe — arid, cold (Bsk)
Desert — arid, hot (Bwh)
Desert — arid, cold (Bwk)
Mediterranean — temperate, hot dry summer (Csa)
Mediterranean — temperate, warm dry summer (Csb)
Cool Interior — cold, hot dry summer (Dsa)
Cool Interior — cold, warm dry summer (Dsb)
Highland — cold, cold dry summer (Dsc)
Highland — polar, tundra (Et)
Source:
Present Köppen-Geiger Climate Classification Map – 1-km resolution
Beck et al. (2018)
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
114°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
33°0'0"N
OREGON
IDAHO
NEVADA
UTAH
ARIZONA
SONORA
MEXICO
U.S.A.
PACIFIC OCEAN
Crescent City
Eureka
Redding
Mt Shasta 14162
Mt Lassen 10457
Alturas
Susanville
Modoc Plateau
Fort Bragg
Point Arena
Sacramento
South Lake Tahoe
Stockton
Mt Diablo 3849
San Francisco
Oakland
San Jose
Monterey
Fresno
Bishop
Mt Whitney 14494
San Luis Obispo
Bakersfield
Barstow
MOJAVE DESERT
Needles
Santa Barbara
Los Angeles
Long Beach
San Gorgonio Mtn. 11499
Palm Springs
Blythe
San Diego
Tijuana
Salton Sea
NORTHERN COAST RANGES
SACRAMENTO VALLEY
SIERRA NEVADA
SIERRA NEVADA FOOTHILLS
CASCADE RANGE
DIABLO RANGE
SOUTHERN COAST RANGES
SAN JOAQUIN VALLEY
SANTA LUCIA RANGE
INYO MOUNTAINS
DEATH VALLEY
PANAMINT RANGE
PANAMINT VALLEY
TRANSVERSE RANGES
PENINSULAR RANGES
Tulare Lake Bed
PT REYES
FARALLON ISLANDS
PT SUR
PT CONCEPTION
SAN MIGUEL ISLAND
SANTA CRUZ ISLAND
SANTA ROSA ISLAND
SANTA CATALINA ISLAND
SAN NICOLAS ISLAND
SAN CLEMENTE ISLAND
Miles
25 12.5 0 25 50
Kilometers
40 20 0 40 80

Sea Currents and Temperatures



Northeastern Pacific Currents and High Pressure System
CDFW Graphic: Annie Chang

The California Current System is located off the U.S. West Coast. A key component of this system, the California Current, brings cool waters south from British Columbia, Canada to the Baja California Peninsula, Mexico. Off Southern California, part of the California Current branches off and curls northeast to become the Southern California Eddy.

Conditions within the California Current System are highly dynamic due to various oceanic responses to large-scale atmospheric drivers, such as winds associated with atmospheric pressure systems, and to local perturbations, such as storms. One useful indicator of these changing ocean conditions is sea surface temperature (SST) as captured from satellite imagery. To highlight changes, anomalies between annual SST values and long-term average temperatures are determined and mapped.

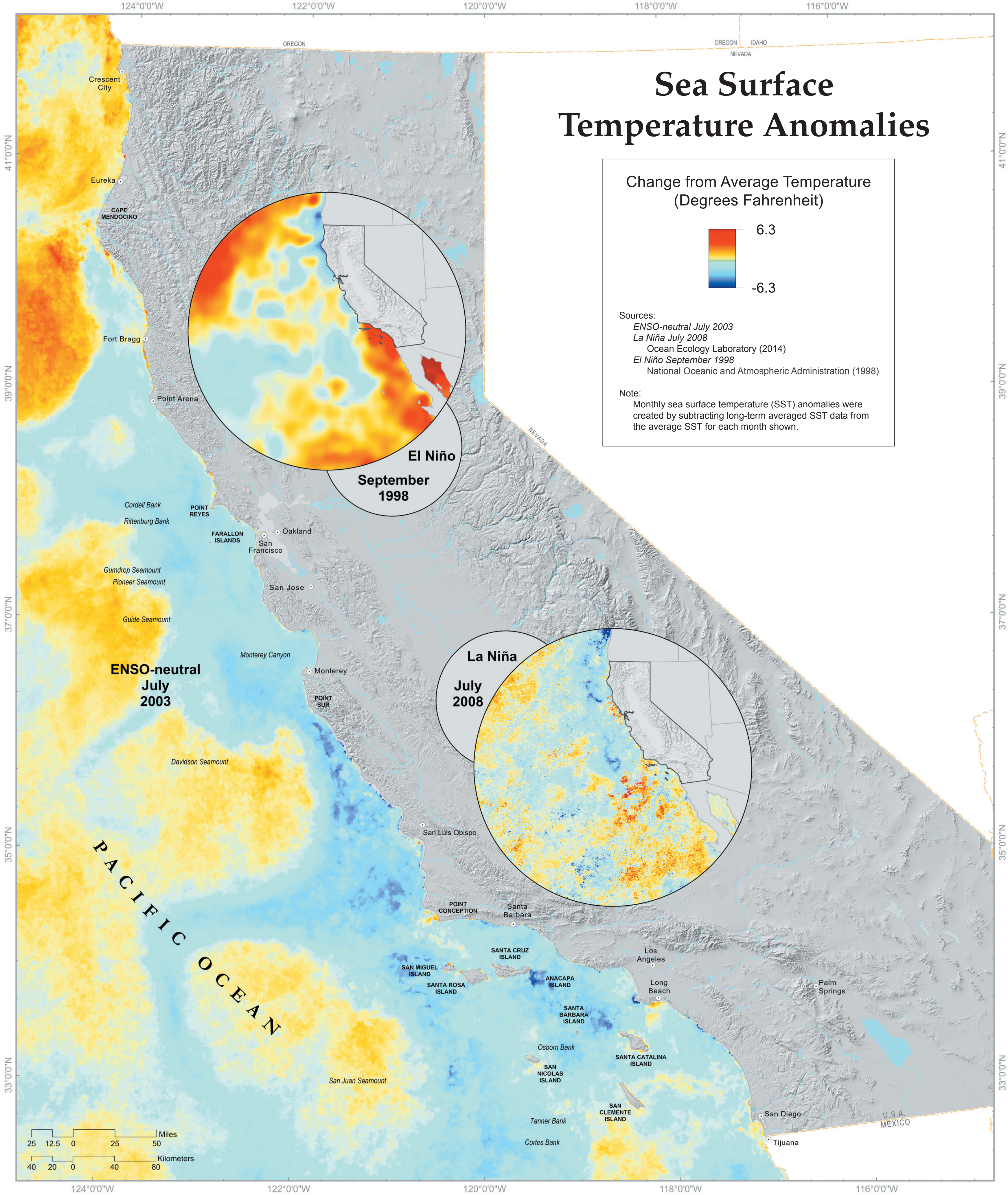
The North Pacific High, a large atmospheric high-pressure system, occurs west of the North American continent. It moves northward in the summer and southward in the winter. It is strongest in the summer and its southward-blowing winds drive the surface waters of the California Current away from the coast. The surface waters are replaced by deeper, colder, nutrient-rich waters in a process called upwelling. These nutrients support high productivity, from abundant phytoplankton to great numbers of fish, marine mammals, and sea birds.

The timing and intensity of upwelling varies along the coast. North of Cape Mendocino, upwelling-favorable winds primarily occur in the summer, while between Cape Mendocino and Point Conception they occur from spring through early fall. Upwelling-favorable winds can be present throughout the year in Southern California, but the region is shadowed from the stronger winds so upwelling is weak. Throughout California, local perturbations such as storms and other changes in the weather can lead to relaxation of favorable winds, reducing upwelling, or even reversal of winds, resulting in local downwelling.

One large-scale atmospheric-oceanic pattern that affects ocean conditions is the El Niño Southern Oscillation (ENSO). The map shows the SST anomalies for July 2003 during an ENSO-neutral state. In this state, the trade winds blow westward across the equatorial Pacific from high pressure in the east to low pressure in the west. When this pressure gradient decreases, the trade winds relax and, through various ocean processes, waters in the eastern equatorial Pacific warm. Along the California coast, upwelling-favorable winds are reduced with the associated weakening of the North Pacific High. Productivity drops as available nutrients decline. These are the conditions observed during an El Niño. Over a period of months, warm waters from the south typically move north into the Southern California Bight and, in the case of very strong El Niños, may move into the Central California region (see El Niño inset). El Niños occur every three to eight years and last from 12 to 18 months, after which conditions may return to an ENSO-neutral state or move into a La Niña.

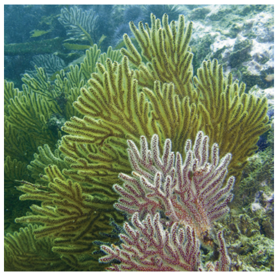
During a La Niña, the opposite happens (see La Niña inset); the trade winds strengthen and waters in the eastern equatorial Pacific cool. The North Pacific High also strengthens, resulting in enhanced upwelling and, at times, increased productivity along the California coast.

Point Conception is a biogeographical boundary between the colder waters off Central California and the warmer waters to the south. The transition zone between these two regions is an area of high diversity. During El Niños, species from more subtropical waters may move into Southern California waters while some species from Southern California may move north along the California coast. Recruitment for species that favor warm waters also may increase. During La Niñas, opposite trends in movement and recruitment may occur.



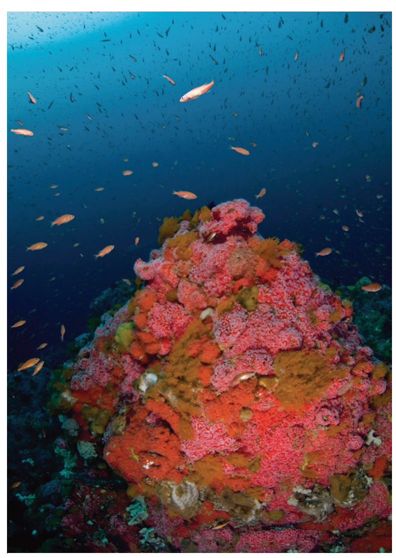
Sea Surface Temperature Anomalies
Change from Average Temperature (Degrees Fahrenheit)
6.3
-6.3
Sources:
ENSO-neutral July 2003
La Niña July 2008
Ocean Ecology Laboratory (2014)
El Niño September 1998
National Oceanic and Atmospheric Administration (1998)
Note:
Monthly sea surface temperature (SST) anomalies were created by subtracting long-term averaged SST data from the average SST for each month shown.
El Niño
September 1998
La Niña
July 2008
ENSO-neutral
July
2003
PACIFIC OCEAN
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
33°0'0"N
OREGON
IDAHO
NEVADA
U.S.A.
MEXICO
Crescent City
Eureka
CAPE MENDOCINO
Fort Bragg
Point Arena
Cordell Bank
Rittenburg Bank
POINT REYES
FARALLON ISLANDS
Oakland
San Francisco
Gumdrop Seamount
Pioneer Seamount
San Jose
Guide Seamount
Monterey Canyon
Monterey
POINT SUR
Davidson Seamount
San Luis Obispo
POINT CONCEPTION
Santa Barbara
SANTA CRUZ ISLAND
SAN MIGUEL ISLAND
SANTA ROSA ISLAND
ANACAPA ISLAND
SANTA BARBARA ISLAND
Los Angeles
Long Beach
Palm Springs
Osborn Bank
SAN NICOLAS ISLAND
SANTA CATALINA ISLAND
San Juan Seamount
SAN CLEMENTE ISLAND
Tanner Bank
Cortes Bank
San Diego
Tijuana
Miles
25 12.5 0 25 50
Kilometers
40 20 0 40 80

Bathymetry


Gorgonians, also called sea fans, are attached to rocky reefs off Santa Catalina Island. CDFW photo: Dianna Porzio

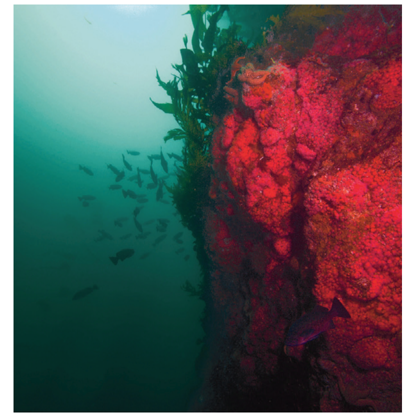
As mountains and valleys define the diverse topography of California, seamounts, banks, submarine canyons, and a narrow continental shelf define its coastal bathymetry. Bathymetry is the measure and study of water depth. This bathymetry map illustrates many fascinating ocean features in remarkable detail.

Seamounts are underwater geologic formations abruptly rising from the seafloor and are typically formed by volcanic activity. They are made of hard, rocky material, provide structure for various forms of marine life to grow on, and are considered biologically diverse hot spots. In Central California, the Davidson Seamount occupies an area 8 miles wide by 26 miles long and rises over 6,500 feet tall, yet its peak remains over 4,000 feet below the sea surface.


Abundant assemblage of invertebrates at Cranes Point in Cordell Bank Photo: Joe Hoyt, NOAA CBNMS

In contrast to seamounts, banks form where the seafloor has been elevated above the continental shelf due to the movement of tectonic plates. Banks are biologically diverse because they provide solid structure among the soft sediments that characterize the continental shelf. Cold, nutrient-rich water flows up their steep slopes, creating conditions that are ideal for benthic organisms, including sponges and corals. Cordell Bank is located 22 miles offshore Point Reyes. It occupies an area 4 miles wide by 7 miles long, is 400 feet tall, and its peak is 115 feet below the ocean surface.

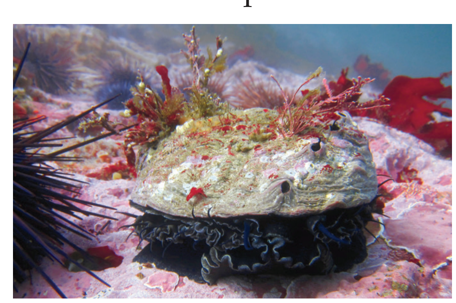
Submarine canyons are deep valleys relative to their immediate surroundings. They can form due to underwater landslides and intense currents, starting as underwater gullies and scarps, then subsequently deepening into canyons. Evidence of this canyon erosion is seen perpendicular to the shoreline up and down the California coast. Prominent examples exist below Cape Mendocino and along the Big Sur Coast (just below Point Sur). The state's largest and most dramatic example is the Monterey Submarine Canyon.

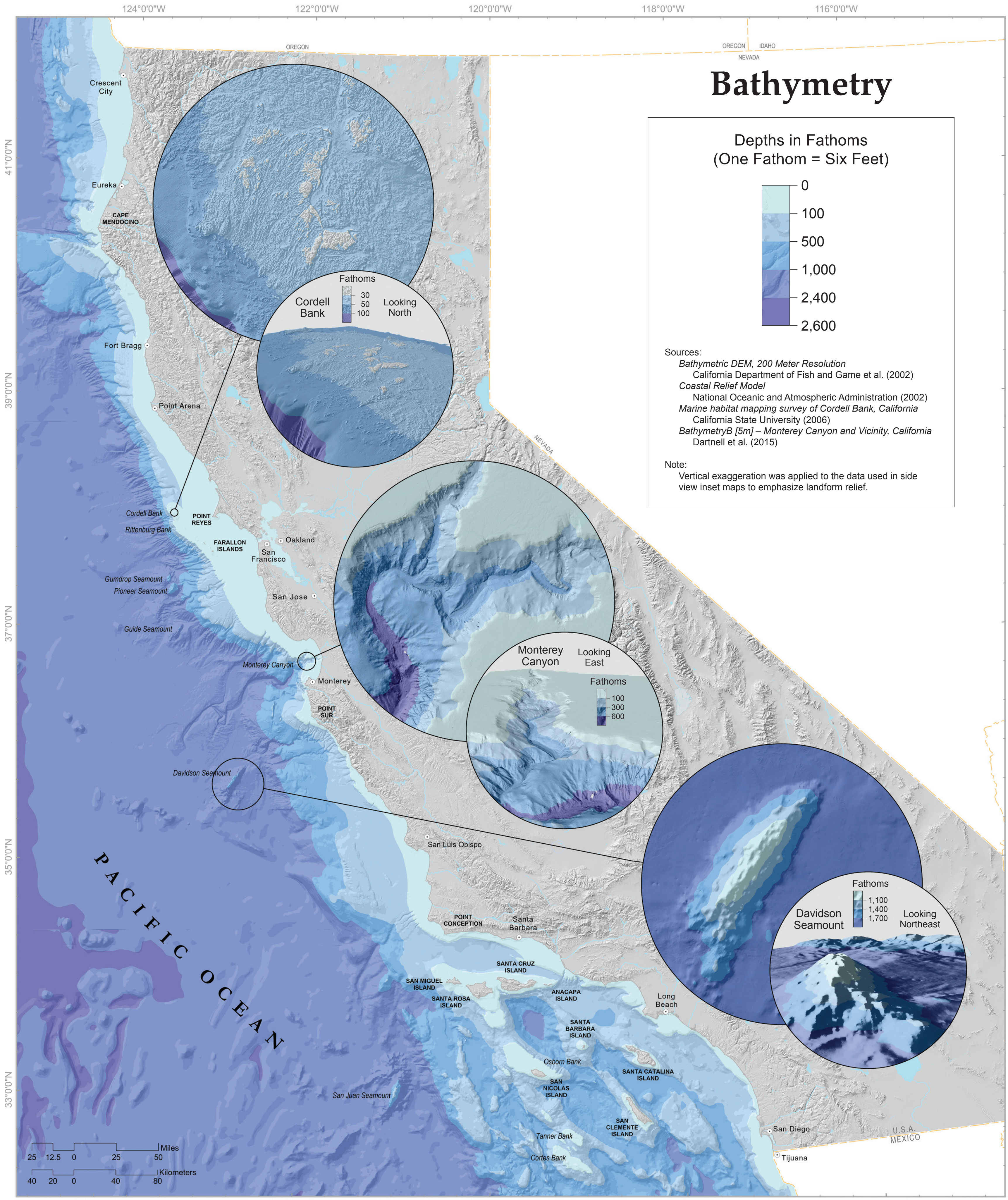

Dali's Wall offshore Pebble Beach characterizes the geologic formations found in the Monterey Area. Photo: Chad King, NOAA MBNMS

Beginning immediately at the shoreline of Moss Landing, it meanders over 100 miles out to sea to a maximum depth over 13,200 feet; this size rivals that of the Grand Canyon. Monterey Bay's distinctive symmetrical mapping profile is the result of this canyon's erosion over time.

The seafloor can also be categorized in terms of its composition, or habitat type. Rocky reefs, boulders, gravel, soft and coarse sediments, silts, clay, and mud are some of the diverse habitats found on California's geologically complex seafloor. In estuaries such as Humboldt Bay (near Eureka), the seabed composition is dominated by soft muds, sands, silts, and clays, and this environment is a nursery to a variety of marine life. In coastal environments around Big Sur, the seabed composition is a mix of coarse and fine sands, rocky reefs, and boulders. These environments are host to iconic marine life including kelp, rockfish, urchins, otters, and abalone.

Bathymetry plays an important role in ocean current dynamics because the structure of the seafloor and its interaction with offshore winds dictate the directional paths of currents. These currents provide necessary nutrient-rich waters to organisms and can create biodiversity hot spots, as seen on seamounts and banks. Bathymetry also impacts various abiotic conditions (temperature, acidity, oxygen concentration) that drive species composition offshore California. Understanding the ocean bathymetry of California is important for understanding biological processes and marine ecosystems.


California's iconic Red Abalone (*Haliotis rufescens*) is typically associated with hard surface and kelp. CDFW photo: Athena Maguire



Bathymetry
Depths in Fathoms
(One Fathom = Six Feet)
0
100
500
1,000
2,400
2,600
Sources:
Bathymetric DEM, 200 Meter Resolution
California Department of Fish and Game et al. (2002)
Coastal Relief Model
National Oceanic and Atmospheric Administration (2002)
Marine habitat mapping survey of Cordell Bank, California
California State University (2006)
BathymetryB [5m] – Monterey Canyon and Vicinity, California
Dartnell et al. (2015)
Note:
Vertical exaggeration was applied to the data used in side view inset maps to emphasize landform relief.
Cordell Bank
Looking North
Fathoms
30
50
100
Monterey Canyon
Looking East
Fathoms
100
300
600
Davidson Seamount
Looking Northeast
Fathoms
1,100
1,400
1,700
PACIFIC OCEAN
OREGON
IDAHO
NEVADA
U.S.A.
MEXICO
Crescent City
Eureka
CAPE MENDOCINO
Fort Bragg
Point Arena
Cordell Bank
Rittenburg Bank
POINT REYES
FARALLON ISLANDS
Oakland
San Francisco
Gumdrop Seamount
Pioneer Seamount
San Jose
Guide Seamount
Monterey Canyon
Monterey
POINT SUR
Davidson Seamount
San Luis Obispo
POINT CONCEPTION
Santa Barbara
SANTA CRUZ ISLAND
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SANTA ROSA ISLAND
ANACAPA ISLAND
Long Beach
SANTA BARBARA ISLAND
Osborn Bank
SAN NICOLAS ISLAND
SANTA CATALINA ISLAND
San Juan Seamount
SAN CLEMENTE ISLAND
Tanner Bank
Cortes Bank
San Diego
Tijuana
Miles
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Kilometers
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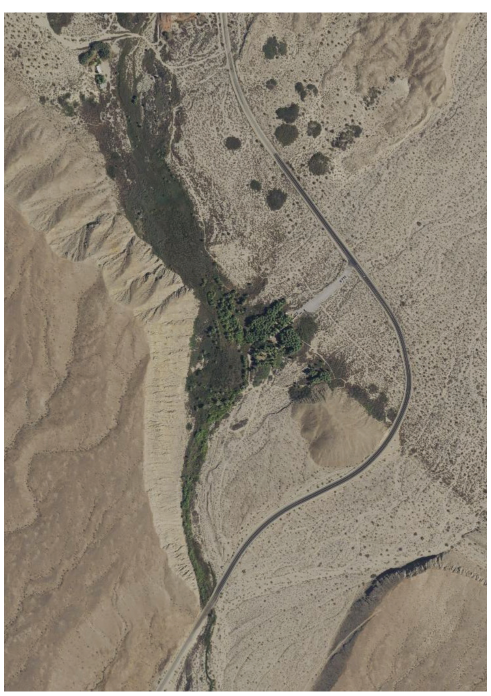
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
33°0'0"N

Geology and Soils

At Wilder Ranch State Park near Santa Cruz, marine terraces formed by wave-cut platforms and sea cliffs represent ancient shorelines that have been uplifted due to relatively slow-moving tectonic activity over time. In the background, another, even older terrace is visible along the horizon. These terraces may vanish over time as sea level rises, unless they are thrust upward by a powerful earthquake. For more information see *Wilder Ranch State Park* (CGS 2015b). Photo: Mike Fuller, California Geological Survey

The broad range of California's elevations and landscape features is a result of an active continental margin where tectonic plates shift the earth's crust. For over a billion years, tectonic processes have layered and altered geologic terrains to shape the present landscapes. Compressional, extensional, and translational faults create the mountains, valleys, and displaced features seen throughout California today.

Movement along faults not only displaces rock units across California over time but also provides planes of weakness in the ground that can act as conduits for root systems and can redirect or impede groundwater flow. This has occurred in the Colorado Desert at the Thousand Palms Oasis, where palm trees grow along a fault line that traps groundwater near the surface. In Northern California, coastal soils form on marine terraces that have been uplifted due to faulting, such as those at Wilder Ranch State Park. The result is referred to as an "ecological staircase," where each step up in elevation reflects longer periods of weathering and soil development. These soils are nutrient-poor, highly acidic, and offer low levels of oxygen, which may result in stunted vegetation called pygmy forests (Schulz et al. 2018).



The Thousand Palms Oasis in the Coachella Valley Preserve is located within the San Andreas fault zone. The linear alignment of vegetation that extends beyond the Thousand Palms Canyon Road indicates the surface trace of the fault. Groundwater is redirected to the surface, providing palm trees with an adequate water supply. Photo: National Agriculture Imagery Program (2018), U.S. Department of Agriculture

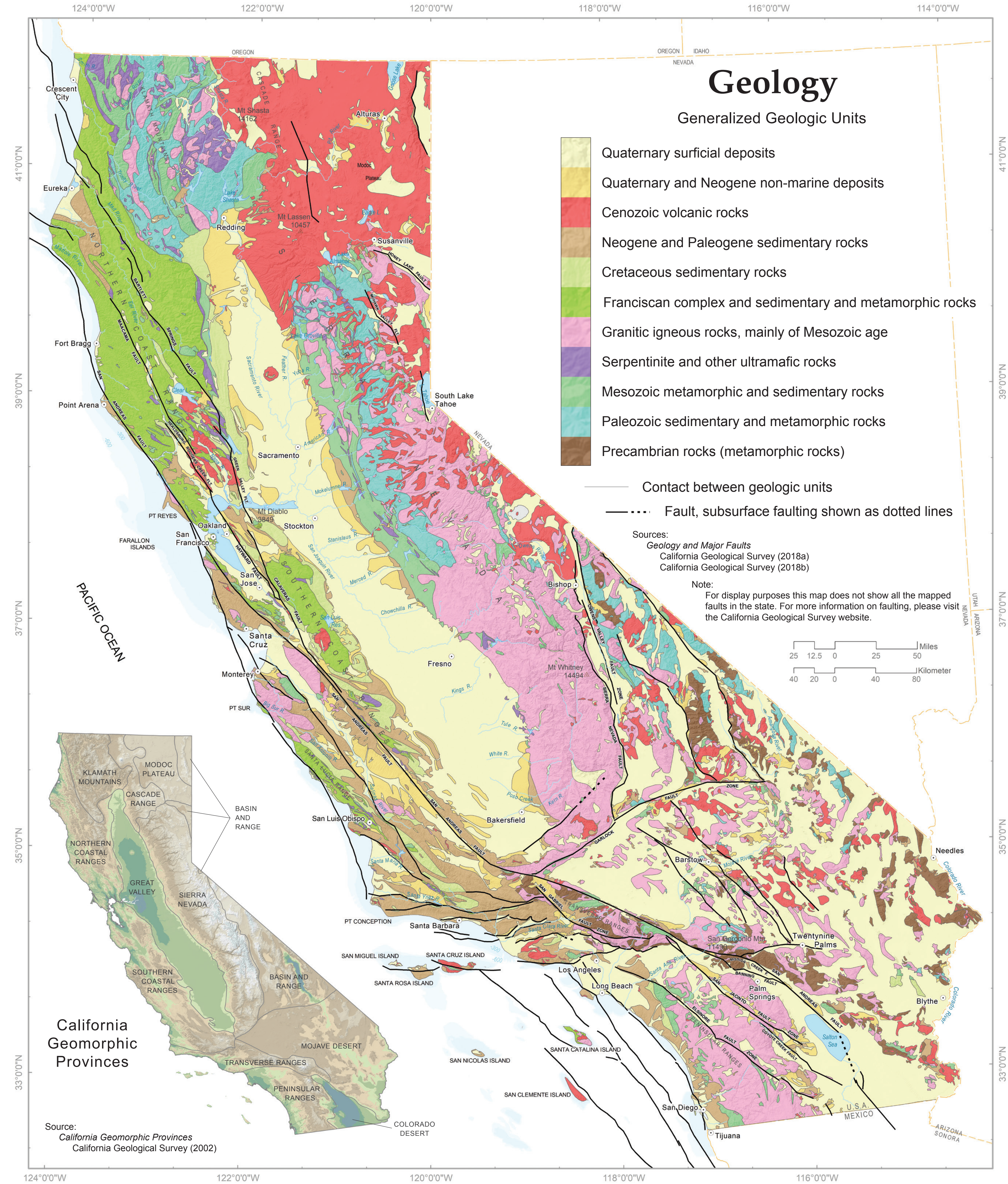
Rocks are described and mapped based on mineralogy and the way in which the they are formed; they are broadly classified as igneous, metamorphic, and sedimentary. Igneous rocks are formed by rapid cooling of lava flows or pyroclastic explosions and ash falls, or by slower cooling of underground magma.

Sedimentary rocks are developed by weathering and erosion of existing rocks and soil, forming deposits such as limestone, shale, sandstone, and conglomerate. When sedimentary or igneous rocks are subjected to high temperatures, pressures, and chemical reactions, they alter to become what are called metamorphic rocks, as found in the Franciscan Complex. The distribution of rock types across California is shown on the geologic map on the right.

Young surficial sediments that have not lithified (solidified into rocks) are mapped as Quaternary deposits. These include alluvium, desert sands, coastal estuary deposits, and beach deposits. As rocks and surficial sediment weather and erode, they break down to form soils with mineral characteristics derived from their parent material. Soils that remain on the landscape for thousands of years develop distinct layers called soil horizons.

California's diverse terrain can be grouped into 12 geomorphic provinces based on landforms and geologic history, as shown in the map inset (CGS 2002). The physical characteristics of each province influence the regional climate which in turn affects the soil development process. These intertwined factors are responsible for the wide variety of habitats that support species throughout California (CGS 2015a, CGS 2020). For example, the Sierra Nevada Province is home to 50 percent of the plant species and 60 percent of the animal species in the state (CWWR 1996).

(continued)


Geology
Generalized Geologic Units
Quaternary surficial deposits
Quaternary and Neogene non-marine deposits
Cenozoic volcanic rocks
Neogene and Paleogene sedimentary rocks
Cretaceous sedimentary rocks
Franciscan complex and sedimentary and metamorphic rocks
Granitic igneous rocks, mainly of Mesozoic age
Serpentinite and other ultramafic rocks
Mesozoic metamorphic and sedimentary rocks
Paleozoic sedimentary and metamorphic rocks
Precambrian rocks (metamorphic rocks)
Contact between geologic units
Fault, subsurface faulting shown as dotted lines
Sources:
Geology and Major Faults
California Geological Survey (2018a)
California Geological Survey (2018b)
Note:
For display purposes this map does not show all the mapped faults in the state. For more information on faulting, please visit the California Geological Survey website.
25 12.5 0 25 50 Miles
40 20 0 40 80 Kilometer
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
114°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
33°0'0"N
OREGON
IDAHO
NEVADA
UTAH
ARIZONA
MEXICO
U.S.A.
SONORA
PACIFIC OCEAN
Crescent City
Eureka
Redding
Mt Shasta 14162
Mt Lassen 10457
Alturas
Modoc Plateau
Susanville
HONEY LAKE FAULT
Fort Bragg
Point Arena
South Lake Tahoe
Sacramento
Mt Diablo 3849
Stockton
PT REYES
FARALLON ISLANDS
San Francisco
Oakland
San Jose
Santa Cruz
Monterey
PT SUR
Fresno
Bishop
Mt Whitney 14494
Bakersfield
San Luis Obispo
PT CONCEPTION
Santa Barbara
SAN MIGUEL ISLAND
SANTA CRUZ ISLAND
SANTA ROSA ISLAND
SAN NICOLAS ISLAND
SANTA CATALINA ISLAND
SAN CLEMENTE ISLAND
Los Angeles
Long Beach
San Diego
Tijuana
Barstow
San Gorgonio Mtn 11499
Twentynine Palms
Palm Springs
Salton Sea
Blythe
Needles
Colorado River
SAN ANDREAS FAULT
HAYWARD FAULT
CALAVERAS FAULT
GARLOCK FAULT ZONE
SAN GABRIEL FAULT ZONE
SAN JACINTO FAULT ZONE
ELSINORE FAULT ZONE
TRANSVERSE RANGES
PENINSULAR RANGES
California Geomorphic Provinces
KLAMATH MOUNTAINS
MODOC PLATEAU
CASCADE RANGE
BASIN AND RANGE
NORTHERN COASTAL RANGES
GREAT VALLEY
SIERRA NEVADA
SOUTHERN COASTAL RANGES
MOJAVE DESERT
TRANSVERSE RANGES
PENINSULAR RANGES
COLORADO DESERT
Source:
California Geomorphic Provinces
California Geological Survey (2002)

Geology and Soils

(Continued from page 20)

Habitats and ecosystems rely on soil to support diverse plants and wildlife. Studies show that soil age, parent material, and soil horizon characteristics affect the sizes, distributions, and physiological responses of plants. Chemical and mechanical weathering of parent material determines the nutrients available in the soil and gives distinct characteristics to the soil horizons (Birkeland 1999). For example, granitic rocks erode to form sandy soils, while fine-grained sedimentary shale deposits erode to form clay-rich soils. Grain size contributes to the ability of water to move through the soil to underlying layers; fine-grained soils retain water, and coarse-grained soils drain rapidly. With time and landscape stability, soil development processes lead toward finer-grained soils with more distinct soil horizons.

An active wind-blown sand sheet encroaches upon the creosote bush at left, Chuckwalla Valley, Mojave Desert.
Photo: Jeremy Lancaster, California Geological Survey

Deserts are dominated by active alluvial surfaces and dunes with geologically young, well-drained sands having little to no soil horizons. Within the Mojave and Colorado deserts, soil age affects the size and density of creosote bush (*Larrea tridentata*). Younger, well-drained sands allow deep roots and robust growth in *Larrea*, whereas older soils limit root growth and size. Lizards, tortoises, and kangaroo rats often seek refuge beneath this shrub and it is a dominant food source for desert woodrats (Marshall 1995).

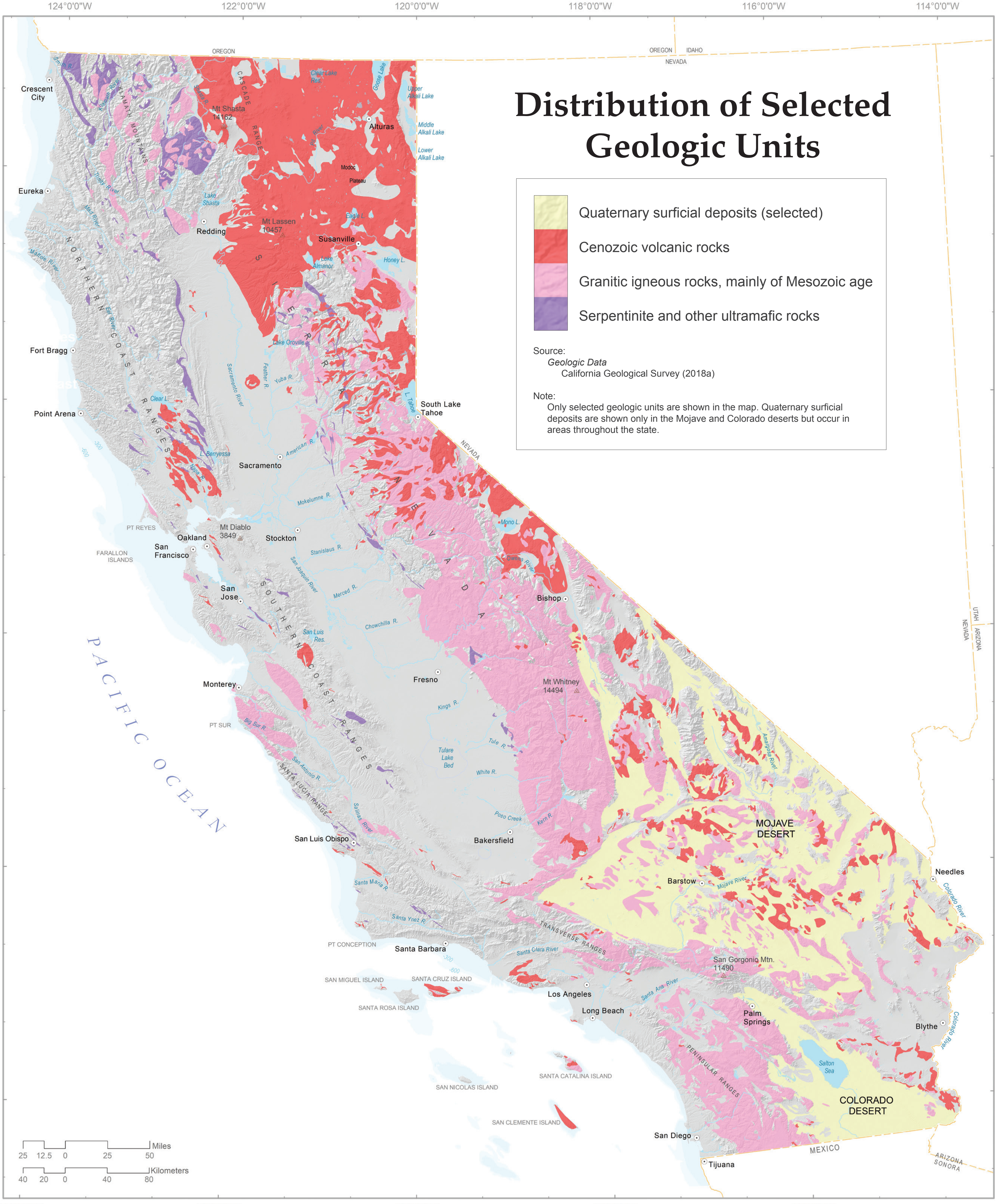
Ultramafic rocks weather into "serpentine" soils that are rich in asbestos, magnesium, nickel, chromium, and other heavy metals but low in nitrogen. This chemical composition can alter cell membranes and reduce root growth, resulting in stunted plants as observed in Jeffrey pine trees (*Pinus jeffreyi*) in the Klamath Mountains. Some adaptive plants thrive in the nitrogen-poor soils, however. The rare carnivorous California pitcher plant (*Darlingtonia californica*), found in serpentine wetlands, catches and decomposes insects to obtain its nitrogen (USFS 2020).

Darlingtonia californica has adapted to serpentine soils by trapping and decomposing insects to obtain nutrients.
Photo: Barry Rice

Where igneous deposits are resistant to erosion, rocky landscapes with little soil are common. In Northern California the whitebark pine (*Pinus albicaulis*) flourishes in coarse granite, basalt, and glacial deposits (Tilley et al. 2011). The giant sequoia (*Sequoiadendron giganteum*) requires moistures and temperatures occurring within 4,600- to 7,100-foot elevations on the western slope of the Sierra Nevada, where coarse soils are derived from granitic and glacial parent material (Weatherspoon 1990, Habeck 1992).

The map on the opposite page shows the locations of serpentine, volcanic, and igneous geologic units that represent the parent materials for serpentine and granitic soils discussed above. The desert soils can be seen on the map as Quaternary surficial deposits in the Mojave and Colorado deserts.

Sequoiadendron giganteum are the largest trees in the world.
Photo: National Park Service


Distribution of Selected Geologic Units
Quaternary surficial deposits (selected)
Cenozoic volcanic rocks
Granitic igneous rocks, mainly of Mesozoic age
Serpentinite and other ultramafic rocks
Source:
Geologic Data
California Geological Survey (2018a)
Note:
Only selected geologic units are shown in the map. Quaternary surficial deposits are shown only in the Mojave and Colorado deserts but occur in areas throughout the state.
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
114°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
33°0'0"N
OREGON
IDAHO
NEVADA
UTAH
ARIZONA
MEXICO
SONORA
PACIFIC OCEAN
Crescent City
Eureka
Fort Bragg
Point Arena
Redding
Alturas
Susanville
South Lake Tahoe
Sacramento
Oakland
San Francisco
Stockton
San Jose
Monterey
Fresno
Bishop
Bakersfield
San Luis Obispo
Santa Barbara
Los Angeles
Long Beach
Barstow
Needles
Palm Springs
Blythe
San Diego
Tijuana
Mt Shasta 14162
Mt Lassen 10457
Mt Diablo 3849
Mt Whitney 14494
San Gorgonio Mtn. 11490
MOJAVE DESERT
COLORADO DESERT
NORTHERN COAST RANGES
SOUTHERN COAST RANGES
SIERRA NEVADA
CASCADE RANGE
KLAMATH MOUNTAINS
TRANSVERSE RANGES
PENINSULAR RANGES
SANTA LUCIA RANGE
Modoc Plateau
PT REYES
FARALLON ISLANDS
PT SUR
PT CONCEPTION
SAN MIGUEL ISLAND
SANTA CRUZ ISLAND
SANTA ROSA ISLAND
SANTA CATALINA ISLAND
SAN NICOLAS ISLAND
SAN CLEMENTE ISLAND
Salton Sea
Mono L.
Lake Tahoe
Lake Shasta
Lake Almanor
Lake Oroville
Clear L.
L. Berryessa
Goose Lake
Honey L.
Eagle L.
Tulare Lake Bed
Sacramento River
San Joaquin River
Colorado River
Mojave River
Miles
25 12.5 0 25 50
Kilometers
40 20 0 40 80

Geography and Vegetation

The relationship between California's geography and its wealth of biodiversity is reflected in its vegetation. Vegetation may be defined as a patchwork of plant species arrayed across the landscape. It includes a variety of life forms such as trees, shrubs, grasses, forbs, and mosses. These life forms are distributed in different combinations and patterns in response to variations in the physical environment, such as climate and geology.

Tall conical spires of Santa Lucia fir (*Abies bracteata*) rise above the rounded crowns of canyon live oak (*Quercus chrysolepis*) on the precipitous misty slopes of Cone Peak in Monterey County. These fir woodlands are completely restricted to the steeper, fire-protected slopes of the Santa Lucia Mountains of California's Central Coast.
Photo © Todd Keeler-Wolf

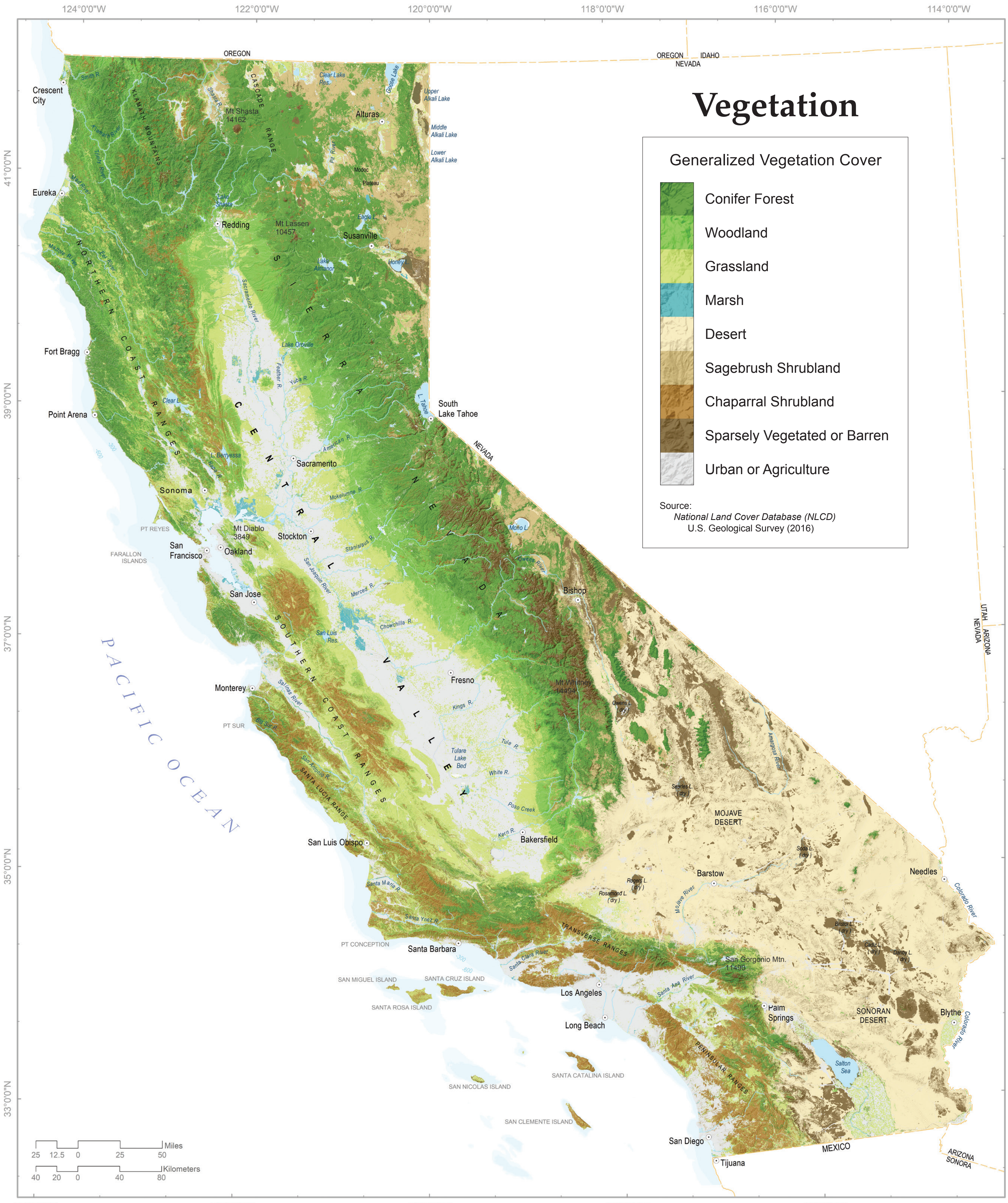
The broad patterns of vegetation in California relate most clearly to the combination of temperature and moisture, which is, in turn, strongly influenced by the state's varied topography (see "Climate and Topography"). These patterns are clearly shown in the map on the facing page. The most extreme climates—the coldest alpine heights of the Sierra Nevada and the driest desert sand dunes—are sparsely vegetated. The cooler and wetter climates, including the North Coast and the mountain ranges, are forested with coniferous trees. The hotter and drier Mojave and Sonoran deserts are covered with desert scrub characterized by small-leaved shrubs and cacti. Areas of intermediate temperature and moisture are carpeted with woodlands, grasslands, chaparral, and coastal scrub. These are found in the Coast Ranges and foothills of the Sierra Nevada, in the valleys and on the edges of the Central Valley, and along the Southern Coast.

A stand of The Cedars manzanita (*Arctostaphylos bakeri* ssp. *sublaevis*), a rare vegetation type forming only on steep serpentine soils at The Cedars, Sonoma County
Photo © Todd Keeler-Wolf

Other important factors that influence vegetation, such as soil fertility and depth, are determined by topography and geology. Within a general area climatically suitable for woodlands, we may see chaparral on shallower, steeper, and rockier soils; grasslands on deeper and less steep clay-rich soils; and woodlands on intermediate soils of gentle and moderate slope. The substrate on which vegetation grows may affect the species composition. For example, vegetation on soils derived from serpentine, our state rock, may often be chaparral, but it will be less dense and composed of very different species than adjacent chaparral on soils derived from non-serpentine rock. These fine-scale patterns are difficult to see on the statewide map at right. An example of a detailed vegetation map is provided in the Mojave Desert chapter.

California's unusual summer-dry Mediterranean climate is another important geographic factor, producing many types of vegetation that are unique to the state. These include drought-deciduous shrublands, where the plants are green in the winter but leafless during the hot dry summer months, and vernal pools, full of showy annual flowers in the spring but completely dried up in the summer.

Coast redwood (*Sequoia sempervirens*) forest, North Coast
Photo © Marc Hoshovsky



Vegetation
Generalized Vegetation Cover
Conifer Forest
Woodland
Grassland
Marsh
Desert
Sagebrush Shrubland
Chaparral Shrubland
Sparsely Vegetated or Barren
Urban or Agriculture
Source:
National Land Cover Database (NLCD)
U.S. Geological Survey (2016)
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
114°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
33°0'0"N
OREGON
OREGON
IDAHO
NEVADA
NEVADA
UTAH
ARIZONA
ARIZONA
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SANTA ROSA ISLAND
SAN NICOLAS ISLAND
SANTA CATALINA ISLAND
SAN CLEMENTE ISLAND
Salton Sea
Colorado River
Miles
25 12.5 0 25 50
Kilometers
40 20 0 40 80