GEOLOGICAL AND BIOLOGICAL SETTINGS OF

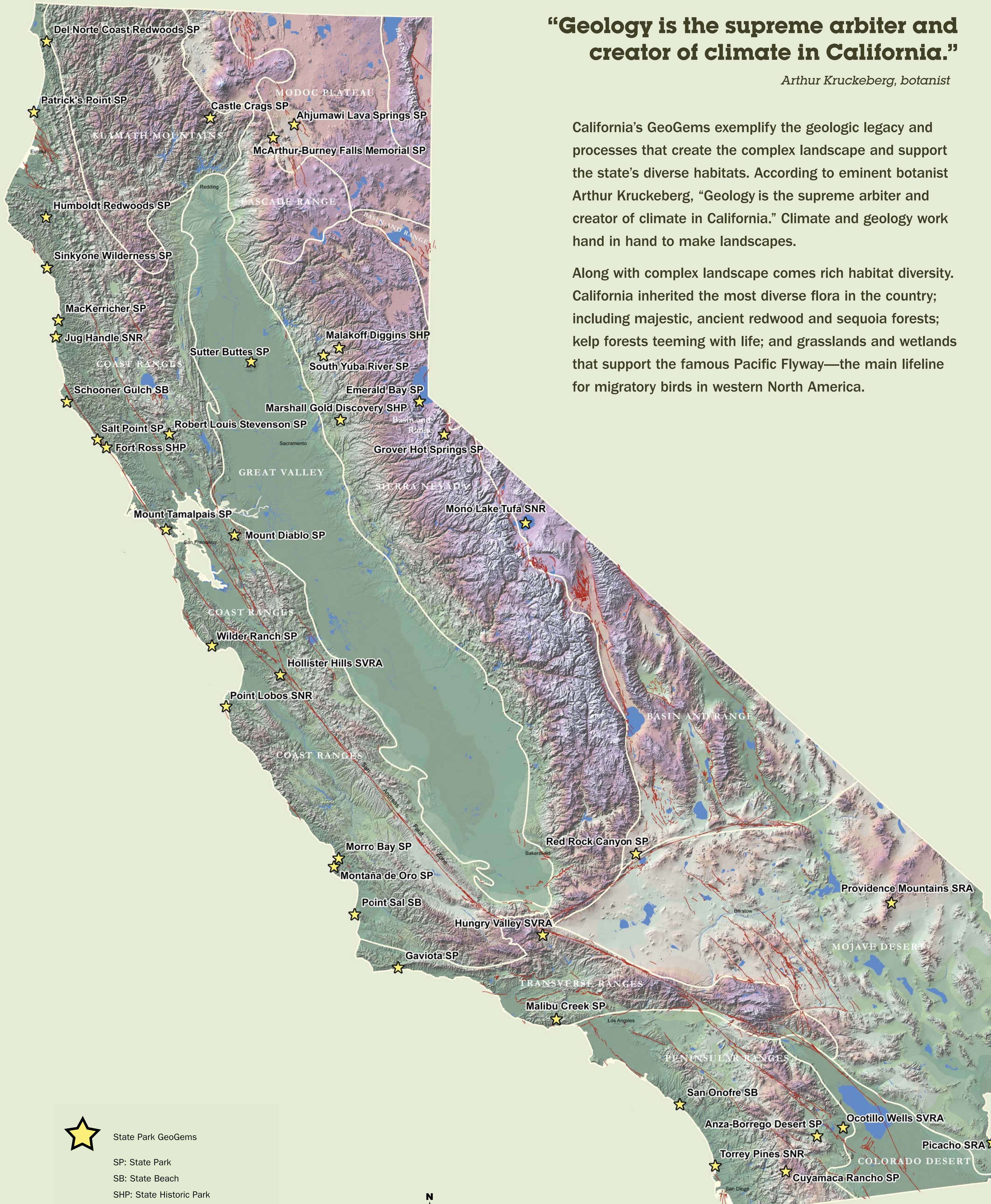
Geologic Gems of California's State Parks

"Geology is the supreme arbiter and creator of climate in California."

Arthur Kruckeberg, botanist

California's GeoGems exemplify the geologic legacy and processes that create the complex landscape and support the state's diverse habitats. According to eminent botanist Arthur Kruckeberg, "Geology is the supreme arbiter and creator of climate in California." Climate and geology work hand in hand to make landscapes.

Along with complex landscape comes rich habitat diversity. California inherited the most diverse flora in the country; including majestic, ancient redwood and sequoia forests; kelp forests teeming with life; and grasslands and wetlands that support the famous Pacific Flyway—the main lifeline for migratory birds in western North America.



State Park GeoGems

SP: State Park
SB: State Beach
SHP: State Historic Park
SRA: State Recreation Area
SNR: State Natural Reserve
SVRA: State Vehicular Recreation Area

Geomorphic Provinces

Holocene Faults Active Within Last 11,000 Years

GIS Development: Mike Fuller, C.E.G.,and Jim Thompson

N E S W

Scale 1:1,250,000

0 15 30 60 Miles

0 37.5 75 150 Kilometers

California's Biological Regions

Klamath/North Coast Bioregion

Climate and Geography

Much of the Klamath/North Coast Bioregion is covered by forest—the Klamath, Shasta-Trinity, Six Rivers, and Mendocino National Forests, Jackson Demonstration State Forest, and private forests, including the Headwaters ancient redwood forest in Humboldt County. This mountainous bioregion includes the North Coast Range and the Klamath, Siskiyou, Marble, Salmon, Trinity, and Cascade mountains. The Klamath/North Coast is the state's wettest climate, with rainfall distribution varying widely from an average annual 38 inches at Fort Bragg to 80 or more inches in the King Range National Conservation Area. The coastal climate is cool, moist, and often foggy, with rainy winters at lower elevations and snow in the higher mountains. Inland the climate is drier with low rainfall in winter and hot, dry summers.

Major rivers include the Eel, Trinity, Klamath, Russian, Smith, Salmon, Scott, Mad, and Mattole, which flows into the Pacific Ocean near seismically active Cape Mendocino. Clear Lake, Whiskeytown Lake, Clair Engle, and the western part of Shasta are the largest lakes in the bioregion.

Plants and Wildlife

Vegetation includes mixed conifer habitat of white fir, Douglas fir, ponderosa pine, Sierra lodgepole pine, incense cedar, sugar pine, red pine, Jeffrey pine, mountain hemlock, knobcone pine, western red cedar, red alder, redwood, tanoak, Pacific madrone, and chaparral.

Wetlands provide places for resting, nesting, feeding and breeding for native and migrating birds and waterfowl. Wildlife in the bioregion includes deer, fox, black bear, mountain lion, California clapper rail, Aleutian Canada geese, Roosevelt elk, osprey, fisher, bank swallow, Coho salmon, king salmon, otis blue butterfly, bald eagle, Point Arena mountain beaver, Swainson's hawk, willow flycatcher, western sandpiper, and Oregon silverspot butterfly.

Rare species include northern spotted owl, marbled murrelet, American peregrine falcon, Lotis blue butterfly, Trinity bristle snail, red-legged frog, Siskiyou Mountains salamander, Pacific fisher, Del Norte salamander, Karok Indian snail, wolverine, goshawk, and Chinook salmon. Photograph: Christopher Mizeur

Bay Area/Delta Bioregion

Climate and Geography

The temperatures in this Mediterranean climate don't vary much year-around. The coast experiences relatively cool, often foggy summers, mild falls, and chilly, rainy winters. Further inland, hot dry summers and warm autumns are followed by mild, wet winters. Snowfall is rare. The bioregion is mostly hilly with low coastal mountains and several peaks rising above 3,000 feet, including Mt. Diablo at 3,849 feet, in a state park. Coastal prairie provides grazing for wild and domestic animals, including dairy cattle.

The bioregion is named for its two major watersheds, San Francisco Bay and the Delta. Major rivers include the Russian, Gualala, Napa, Petaluma, and Alameda, and Putah Creeks. A network of reservoirs and canals comprise the State Water Project delivery system. Lake Berryessa in Napa County is the largest lake.

Plants and Wildlife

The habitats and vegetation of the Bay Area/Delta Bioregion are as varied as the geography. Coastal prairie scrub, mixed hardwoods and valley oaks are found among the rolling hills and mountains that descend to the ocean. Redwoods abound in Santa Cruz County. Coastal salt marsh lies around San Francisco Bay, and freshwater marshes are found in the Delta. Eucalyptus, manzanita, northern coastal scrub, California buttercups, goldfields, and Tiberon mariposa lily also are popular in the bioregion. Rare plants include Marin western flax, Baker's manzanita, Point Reyes checkerbloom, and Sonoma sunshine. Salt and freshwater marshes provide pickelweed, great bulrush, saltbush, and cattail.

Wetlands in the Bay-Delta—brackish and freshwater—furnish resting, nesting, feeding and breeding places for birds and waterfowl along the Pacific Flyway. These marshes, rich in biodiversity, are popular and necessary wintering spots for migrating birds.

Birds include canvasback, western grebe, black-crowned night heron, great egret, snowy egret, California brown pelican, white pelican, gull, acorn woodpecker, golden eagle, western bluebird, Caspian tern, American avocet, and cedar waxwing. Marine life includes Chinook salmon, harbor seal, sea lion, leopard shark, and bat ray. Other wildlife includes grey fox, mule deer, bobcat, raccoon, Pacific tree frog, and the swallowtail and painted lady butterfly.

Endangered species include the California least tern, California black rail and clapper rail, Smith's blue butterfly, salt marsh harvest mouse, California freshwater shrimp, northwestern pond turtle, and tidewater goby. Photograph: Greg Kulak

Central Coast

The Central Coast Bioregion features some of California's most beautiful coastal scenery, blessed with a mild, seasonally moist, and sometimes foggy climate that favors rich farmland and vineyards. This highly agricultural region is famous for artichokes, garlic, and an array of fruits and vegetables. Other industries include wine-making and dairy and cattle ranching. The coast supports a brisk fishing industry, and oil production along the southern end of the bioregion.

The bioregion extends some 300 miles from just north of Santa Cruz to just south of Santa Barbara, and inland to the floor of the San Joaquin Valley. It encompasses the counties of Santa Cruz, Monterey, San Benito, Santa Barbara, and portions of Los Angeles, San Luis Obispo, Fresno, Merced, Stanislaus, and Ventura. The region includes such popular tourist attractions as the Monterey Bay area and Aquarium, Big Sur, the Hearst Castle, and the beaches of Santa Barbara, plus many state parks and other recreational attractions. The region also is the home of such well-known military installations as Fort Ord, Camp Roberts, and Vandenburg Air Force Base. The geography offers coastal mountain ranges including the Santa Lucia and Santa Ynez, and coastal sand dunes. vegetation includes chaparral, mixed hardwood and redwood forests in the bioregion's northern coastal area, and oak woodlands. The Los Padres National Forest covers much of the southern portion of the bioregion. The Salinas and Cuyama rivers feed the bioregion's two major watersheds. Photograph: Jennifer Lotery

South Coast

Climate and Geography

The year-around mild climate and varied geographical features of the South Coast contribute to its great popularity. Hot dry summers with predictable wildfires are followed by wet winters with storms that can trigger mudslides on fire-denuded slopes. Smog remains a serious problem in the South Coast bioregion, particularly the Los Angeles basin, but air quality regulations have helped to control it.

The South Coast bioregion is a study in contrasts—ocean and desert, flatlands and mountains, including 11,500-foot San Gorgonio Peak in Riverside County. Major rivers and their watersheds are: the Santa Clara, Los Angeles, Santa Ana, San Gabriel, San Luis Rey, San Jacinto, Santa Margarita, and San Diego. Publicly owned or managed lands include four national forests: the Angeles, Los Padres, Cleveland, and San Bernardino; numerous parks, state beaches, historic parks; and federal wilderness, recreation and wildlife areas, including Malibu Creek and Point Mugu State Parks, Bolsa Chica Ecological Reserve, Torrey Pines State Reserve, and Sweetwater and Tijuana National Wildlife Refuges. In San Diego, Orange and Riverside counties, the state's Natural Community Conservation Planning (NCCP) pilot program involving local, state, and federal partners is helping to protect the coastal sage scrub habitat of the threatened California gnatcatcher. In the Santa Monica Mountains, the National Park Service, Santa Monica Mountains Conservancy, and state Department of Parks and Recreation are helping to preserve spectacular habitat. In Ventura County, endangered California condors are protected at the Sespe Condor Sanctuary.

Plants and Wildlife

Tremendous urbanization in the South Coast bioregion has brought about the most intense effects on natural resources of any bioregion, resulting in alteration and destruction of habitat and proliferation of exotic or non-native species. In fact, the popular palm tree is not native to the Golden State. Habitat varies widely, from chaparral, juniper-pinyon woodland, and grasslands at lower elevations to mixed hardwood forest, southern oak, southern Jeffrey pine and southern yellow pine at higher levels. Along the coast, where real estate is especially prized, salt marshes and lagoons no longer are common habitat. But efforts are underway from Ventura County to the Mexican border to preserve and restore coastal wetlands.

The bioregion is home to mountain lions, coyotes, badgers, grey foxes, kit foxes, black bears, raccoons, mule deer, hawks, herons, golden eagles, ospreys, peregrine falcons, desert iguanas, dolphins, whales, endangered brown pelicans, and California sea lions. Rare animals include the Stephen's kangaroo rat, monarch butterfly, San Diego horned lizard, Peninsula desert bighorn sheep, orange-throated whiptail, California least tern, Belding's savannah sparrow, least Bell's vireo, Santa Ana sucker, arroyo southwestern toad and Tehachapi pocket mouse. Photograph: Mike Fuller

Colorado Desert

Climate and Geography

The Colorado Desert is the western extension of the Sonoran desert that covers southern Arizona and northwestern Mexico. It is a desert of much lower elevation than the Mojave Desert to the north, and much of the land lies below 1,000 feet elevation. Mountain peaks rarely exceed 3,000 feet. Common habitat includes sandy desert, scrub, palm oasis, and desert wash. Summers are hot and dry, and winters are cool and moist.

The Colorado River flows along the entire eastern boundary of the Colorado Desert bioregion on its way to Yuma, Ariz., where the two states and Mexico come together. The only other river of significant size in this bioregion is the polluted New River, which flows from Mexico into the Salton Sea, the region's largest body of water, on the border of Imperial and Riverside counties. The Salton Sea was created in 1905 when the Colorado River broke through an irrigation project and flooded a saline lake bed, creating an inland sea, which now lies about 235 feet below sea level and is some 35 miles long and 15 miles wide.

Anza Borrego Desert State Park, located mostly in eastern San Diego County, but jutting into Imperial County, is the bioregion's largest recreation area, covering 600,000 acres. It offers more than 225 bird species and dozens of mammals, amphibians, and reptiles. Bighorn sheep can be seen there, as well as thrashers and owls.

Plants and Wildlife

Other species in the Colorado Desert are Yuma antelope ground squirrels, white-winged doves, muskrats, southern mule deer, coyotes, bobcats, and raccoons. Rare animals include desert pupfish, flat-tailed horned lizard, prairie falcon, Andrew's dune scarab beetle, Coachella Valley fringe-toed lizard, Le Conte's thrasher, black-tailed gnatcatcher, and California leaf-nosed bat. Photograph: Mike Fuller

Mojave

Climate and Geography

The Mojave bioregion is the western extension of a vast desert that covers Southern Nevada, the southwestern tip of Utah, and 25 million acres of Southern California—one quarter of the state. The climate is hot and dry in summer. Winters are cool to cold, depending on the elevation, with occasional rainstorms that can quickly turn a gulch or dry lake into a flash flood zone.

The landscape is mostly moderately high plateau with elevations averaging 2,000 to 3,000 feet and isolated peaks that exceed 6,000 and 7,000 feet. Though appearing barren and remote, the desert teems with biodiversity, and more than 90 percent is within three miles of a paved road or off-road vehicle track.

Palm oases provide water for wildlife, as do many streams and springs. In prehistoric times, the bioregion contained great desert lakes, which have long since evaporated and seeped underground. This bioregion has the lowest elevation in North America, 282 feet below sea level in Death Valley National Park. The Mojave, Amargosa, and Colorado Rivers are the largest rivers in this mostly arid bioregion.

Plants and Wildlife

Common habitats of the Mojave bioregion are: desert wash, Mojave creosote bush, scattered desert saltbush, Joshua tree scrub, alkali scrub, palm oasis, juniper-pinyon woodland, and some hardwood and conifer forests at higher elevations. Cottonwood willow riparian forest is rare habitat in this bioregion, as is alkali marsh and open sandy dunes.

Rare animals include the Mohave ground squirrel, prairie falcon, Le Conte's thrasher, Nelson's bighorn sheep, gray vireo, desert tortoise, pale big-eared bat, Amargosa vole, and Mohave tui chub, an olive-brown and silver fish, and the cottontail marsh pupfish, found only in Death Valley National Park. Parks and recreation areas that provide water are the home of snowy plovers, least sandpipers, killdeer, white pelicans, teal, and thousands of migratory wading shore birds, as well as eagles, harriers, falcons, owls, coyotes, badgers, great blue herons, least Bell's vireos, red-tailed hawks, and Canada geese. Photograph: California Geological Survey staff

Sierra Bioregion

Climate and Geography

The climate varies with the elevation, offering cold snowy winters and cool summers at higher elevations and rainy winters and mild summers in the foothills. Summers are dry. Snowy winters in the northern Sierra are crucial to California's water supply, which depends heavily upon spring snowmelt to feed the reservoirs of the State Water Project and a portion of the federal Central Valley Project. The projects supply about two-thirds of California's water for drinking, irrigation, and industrial use. Snowfall also is welcomed by the ski industry and a myriad of other businesses that serve and supply skiers. Mild dry mountain summers accommodate outdoor sports and activities, but when high pressure areas push temperatures upward and gusty winds blow, California is vulnerable to wildfires that consume thousands of acres of brush and timber every year.

National forests of the Sierra Bioregion are the Plumas, Tahoe, Sierra, Eldorado, Stanislaus, Sequoia, Inyo, and Toiyabe. Major rivers include the American, Feather, Yuba, Cosumnes, Tuolumne, Merced, San Joaquin, Kern, Owens, Kings, Carson, Truckee, Walker, and Stanislaus. Mono Lake east of Yosemite is famous for its peculiar tufa formations rising from the lake bed.

Plants and Wildlife

The Sierra Bioregion is rich in biodiversity, containing over half the plant species found in California and more than 400 of the state's terrestrial wildlife species, or about two-thirds of the birds and mammals and half the reptiles and amphibians. The variety of habitat types include annual grassland, blue oak savannah, chaparral, ponderosa pine, black oak woodland, mixed conifer, red fir, riparian, alpine meadow, Jeffrey pine, sagebrush, and bitter brush.

Animals that inhabit the Sierra Bioregion include lodgepole chipmunk, mountain beaver, California mountain king snake, black bear, wolverine, California big horn sheep, Pacific fisher, mule deer, and mountain lion. The California Golden Trout—the state fish—is native to the Southern Sierra. Birds include the northern goshawk, mountain chickadee, pine grosbeak, California spotted owl, mountain quail, willow flycatcher, bald eagle, and great grey owl. Photograph: Chris Wills

San Joaquin Valley

Climate and Geography

Well-suited for farming, the bioregion is hot and dry in summer with long, sunny days. Winters are moist and often blanketed with heavy fog. The broad, flat valley is ringed by the Diablo and Coast Ranges on the west and the Sierra Nevada foothills on the east. Habitat includes vernal pools, valley sink scrub and saltbush, freshwater marsh, grasslands, arid plains, orchards, and oak savannah. The growth of agriculture in the Central Valley has converted much of the historic native grassland, woodland, and wetland to farmland.

The major river is the San Joaquin, with tributaries of the lower Stanislaus, Tuolumne, Merced, and Fresno rivers. The California Aqueduct extends the entire length of the bioregion. The southern portion of the bioregion includes the Kings, Kaweah, and Kern rivers, which drain into closed interior basins. No significant rivers or creeks drain into the valley from the Coast Range.

Plants and Wildlife

Historically, millions of acres of wetlands flourished in the bioregion, but stream diversions for irrigation dried all but about 5 percent. Precious remnants of this vanishing habitat are protected in the San Joaquin Valley bioregion in publicly owned parks, reserves, and wildlife areas. Seasonal wetlands are found at the Kern National Wildlife Refuge west of Delano, owned by the U.S. Fish and Wildlife Service. It attracts a variety of ducks, shorebirds, and song birds, as well as peregrine falcons.

The Tule Elk State Reserve west of Bakersfield, owned by the California Department of Parks and Recreation, features the habitat of the tule elk —natural grassland with ponds and marshes. The reserve sustains four endangered species—the San Joaquin kit fox, blunt-nosed leopard lizard, San Joaquin antelope squirrel, and Tipton kangaroo rat—the threatened plant Hoover's woolystar, and other rare species, such as western pond turtles, tricolored blackbird, and northern harrier. Endangered species of the bioregion also include the California tiger salamander, Swainson's hawk, and giant and Fresno kangaroo rat. Other rare species include the western yellow-billed cuckoo and valley elderberry longhorn beetle.

About one-fifth of the state's remaining cottonwood and willow riparian forests are found along the Kern River in the South Fork Wildlife Area. Great blue herons, beavers, coyotes, black bears, mountain lions, red-shouldered hawks, and mule deer can be seen in the wildlife area. Other wildlife viewing sites are Millerton Lake State Recreation Area west of Madera, Little Panoche Wildlife Area near Los Banos, and the Valley Grasslands of Merced County, which attract 500,000 to 1 million birds each winter to lands owned by the state Departments of Fish and Game and Parks and Recreation, Fish and Wildlife Service, and privately. The San Luis Dam and Reservoir area, jointly operated by the state Department of Water Resources and U.S. Bureau of Reclamation, draws wintering bald eagles, abundant ducks, gopher snakes, San Joaquin kit foxes, and black-tailed deer. Photograph: Mike Fuller

Sacramento Valley

Climate and Geography

The changing of the seasons is more evident in the Sacramento Valley than in the coastal regions to the west. Summer hot spells that drive daytime temperatures into triple digits are relieved by cooling "Delta breezes" that carry moist air from San Francisco Bay eastward through the Delta and into the Sacramento area, pushing the mercury back into the more comfortable 80s and 90s. Leaves turn gold during the brief, mild autumn that ends rather abruptly with the coming of winter fog around Thanksgiving. The so-called tule fog blankets the valley for much of the winter season from December into February, keeping temperatures chilled. Except during droughts, rainfall is frequent in winter, but snowfall is unusual because temperatures, particularly in the daytime, normally remain well above freezing.

The Sacramento Valley is flat for the most part, but is situated within distant view of mountains, which are particularly visible on clear days. To the west, the coastal range foothills loom on the horizon, while the snow-capped peaks of the Sierra Nevada can be seen to the east.

The valley's two major rivers—the Sacramento and American—carry water that originates in the Sierra Nevada south and west into the Sacramento San Joaquin River Delta. The importance of the Delta cannot be overstated, for it supplies water to about two-thirds of California's 32 million population. Other rivers include the Cosumnes—the largest free-flowing river in the Central Valley—the lower Feather, Bear, and Yuba Rivers.

Plants and Wildlife

Oak woodlands, riparian forests, vernal pools, freshwater marshes, and grasslands provide the major natural vegetation of the Sacramento Valley Bioregion.

The Sacramento Valley is the most prominent wintering site for waterfowl, attracting more than 1.5 million ducks and 750,000 geese to its seasonal marshes along the Pacific Flyway. Species include northern pintails, snow geese, tundra swans, sandhill cranes, mallards, grebes, peregrine falcons, heron, egrets, and hawks.

Black-tailed deer, coyotes, river otters, muskrats, beavers, ospreys, bald eagles, salmon, steelhead, and swallowtail butterflies are just some of the wildlife that abounds in this bioregion. Species on the endangered species list include the winter-run Chinook salmon, delta smelt, giant garter snake, and the western yellow-billed cuckoo. Photograph: Mike Fuller

Modoc

Climate and Geography

The climate features hot dry summers and cold moist winters with snow at higher elevations. Geography is varied in the Modoc Bioregion, with volcanic areas and wetlands to the west and high desert to the east. Lassen Volcanic National Park, which is studded with lakes and crowned by 10,457-foot Lassen Peak; Tule Lake, and Clear Lake National Wildlife Refuges, Ahjumawi Lava Springs State Park, and Lava Beds National Monument are on the western side. The eastern side, which resembles its neighbor, Nevada, has desert alkali lakes, Honey Lake Valley, and Modoc National Wildlife Refuge. The last volcanic activity at Mount Lassen was in 1915.

As if to demonstrate the variation of the bioregion's landscapes, the 25-mile Bizz Johnson Trail linking Susanville and Westwood follows a railroad grade from high desert through grasslands and oak woodlands into a dense forest of pine and cedar.

The bioregion includes Modoc and Lassen National Forests and part of the Klamath National Forest. The largest lakes are Lake Almanor in Plumas County, Eagle Lake in Lassen County, Lower Klamath Lake in Siskiyou County, and Goose Lake in Modoc County. The Pit River flows southwest from the rugged Warner Mountains in eastern Modoc and Lassen counties across the Modoc Plateau and into the Sacramento River.

Plants and Wildlife

Juniper and sagebrush cover much of the eastern side of the Modoc Bioregion, while yellow and Jeffrey pine, white fir, mixed conifer, cedar, and aspen are common in the more mountainous and forested areas to the west. Wildlife include bald eagles, antelope, greater sandhill cranes, ospreys, Canada geese, black-crowned night herons, mule deer, muskrats, pronghorn, cinnamon teal, northern pintails, Swainson's hawks, sage grouse, rainbow trout, marmots, hummingbirds, great horned owls, black bears, coyotes, porcupine, Modoc sucker, goshawk, bank swallow, Shasta crayfish, sage grouse, and Lost River sucker. Photograph: Michael Wopat

Reference: www.ceres.ca.gov/geo_area/bioregions

California's Geomorphic Provinces

The **Klamath Mountains** consist of several rugged ranges and deep canyons. The mountains reach elevations of 6,000 to 8,000 feet. In the western part of the province, the irregular path of the Klamath River is incised into an uplifted plateau often referred to as the Klamath peneplain. The uplift has left a series of benches with gold-bearing gravels on the sides of the canyons. The province is considered to be a northern extension of the Sierra Nevada. Rocks include metamorphosed Paleozoic and Mesozoic oceanic rocks, abundant serpentinite, and granitic intrusions.

Tectonic Setting

The oceanic rocks and serpentinite represent accreted terranes with the latter being interpreted as an ophiolite. Several distinct terranes have been identified. The terranes have been intruded by granitic plutons and veins. Veins, which crosscut adjacent terranes, formed after accretion and help constrain the history. Studies that dated rocks in the province show the terranes are younger from east to west, ranging from Devonian to Late Jurassic Periods (416 to 190 million years ago.) Photograph: Christopher Mizeur

The **Coast Ranges** are a series of relatively low mountain ranges and associated valleys that trend northwest, subparallel to the active San Andreas Fault. Elevations of the ranges are typically 2,000 to 4,000 feet, sometimes reaching 6,000 feet above sea level. The Coast Ranges are predominantly composed of thick late Mesozoic and Cenozoic (251 million years ago to present) sedimentary rocks. The northern and southern portions of the province are separated by a depression containing the San Francisco Bay.

In some areas of the Coast Ranges, the topography is dominated by irregular, knobby outcrops of the landslide-prone rocks of the Franciscan Complex. In the Sonoma and Clear Lake regions Pliocene and younger volcanic flows, ash deposits, and cones are prominent. In the southern Coast Ranges, granitic and metamorphic rocks of the Salinian block lie to the west of the San Andreas Fault and extend from the southern extremity of the Coast Ranges, north to the Farallon Islands.

Tectonic Setting

The Coast Ranges record an ancient period of subduction and a subsequent regime of sideways deformation that persists today.

The predominant rocks of the Coast Ranges (referred to as the Franciscan Complex) formed as a massive pile of rock and sediment in an ancient subduction zone. The bulk of the formation is a sheared matrix with large blocks of various rock types (mélange). Adjacent enclosed blocks exhibit distinctively different metamorphic histories. Pieces of the former subducting oceanic plate, known as the Coast Range ophiolite, are scattered throughout the province.

The San Andreas Fault system, consisting of numerous splays, runs almost the entire length of the Coast Ranges. To some degree, the San Andreas Fault system has shaped the landscape across the whole province south of the Mendocino triple junction. For the past 20 million years, the movement along the faults has been generally strike-slip. The landscape reflects this sideways deformation with local areas of uplift or subsidence often reflected as parallel sequences of linear valleys and ridges. Photograph: Mike Fuller

The **Sierra Nevada** is a tilted fault block nearly 400 miles long. Its east face is a high, rugged fault scarp that contrasts sharply with its gentle western slope. The massive granites of the higher elevations are modified by glacial sculpting, forming such scenic features as Yosemite Valley. Many west flowing rivers cut deeply into the western slope. The high crest of the range culminates in Mt. Whitney with an elevation of 14,495 feet above sea level. The older metamorphic bedrock, in places still partly capped by much younger Tertiary volcanic rocks, contains gold-bearing veins associated with the northwest trending Mother Lode.

Tectonic Setting

The Sierra Nevada foothills, source of California's famous gold deposits, consist of ancient accreted terranes and one or more former subduction zones. The subduction zone(s) operated during the Mesozoic Era, 140 to 180 million years ago. The former Farallon oceanic tectonic plate was driven beneath the present day Sierra where it melted into large molten bodies known as batholiths and plutons. The terranes and sediments that accumulated in the subduction zone of this former plate boundary have been metamorphosed by the heat and fluids that radiated off the molten batholiths and plutons that eventually cooled to become the Sierran granitic rocks.

Over the last five million years, faults developed along the eastern margin of the Sierra Nevada along which the range has risen to tower above the Basin and Range province to the east. Active faults and hot springs (characteristic of the Basin and Range) penetrate the Sierran monolith and demonstrate that the boundary zone is still evolving.

The uplift of the Sierra Nevada changed the climate in California and Nevada. The mountains became a barrier to storms originating in the Pacific Ocean that moved eastward over the land. In effect, California became wetter at the expense of Nevada. This increased precipitation allowed glaciers to cover the high Sierra during the Ice Ages of the past 100,000 years. The high Sierra parks (Emerald Bay State Park and Grover Hot Springs State Park) owe some of their majestic beauty to the effects of long gone glaciers. Photograph: Mike Fuller

The **Colorado Desert** geomorphic province, between the Mojave Desert and the Peninsular Ranges geomorphic provinces, occupies a major boundary zone, the plate boundary. The province is mostly below sea level and is the on-land extension of the Gulf of California. The low-lying arid basin is occupied by the Salton Sea (surface elevation about 245 feet below sea level). Surrounding the Salton Sea are the ancient beach lines and silt deposits of extinct Lake Cahuilla. As a testament to the near-surface tectonic activity, there are several developed geothermal areas in the southern section.

The province hasn't always been so dry. The Colorado River that runs from Colorado and through the Grand Canyon has long delivered its heavy sediment load to the Gulf of California. The precise areas of sediment deposition shifted back and forth over time. Eventually the river delta became large enough to plug the Gulf and exclude the seawater from California. The seawater trapped in this province evaporated. On several occasions the lower Colorado River shifted course and sent water and sediment north of the plug instead of south. This resulted in a series of large freshwater lakes that eventually evaporated.

Tectonic Setting

The mid-oceanic ridge runs the length of the Gulf of California and is a major rift zone between oceanic plates. Based on seismic activity, the rift appears to be advancing northward into the Colorado Desert geomorphic province. The San Andreas Fault system joins into the growing rift in very complex and confounding ways. This is one of the most seismically active places in the state. The crust is so thin that geothermal energy is abundant in this very hot, parched place. Photograph: Cheryl Hayhurst

The **Peninsular Ranges** geomorphic province consists of a series of granitic mountain ranges separated by long valleys, formed from faults branching from the San Andreas Fault. The topographic trend is similar to the Coast Ranges, but the geology is more like the Sierra Nevada, with granitic rocks intruding the older metamorphic rocks. The Los Angeles Basin and the Channel Islands of Santa Catalina, Santa Barbara, San Clemente and San Nicolas are included in this province. Also included is the surrounding continental shelf (cut by deep submarine fault troughs). At the northern end of the province Mount San Jacinto forms the dramatic backdrop to the Coachella Valley more than 10,000 feet below. The Peninsular Ranges extend south across the international border into Baja California, forming the spine of Baja California.

Tectonic Setting

The Peninsular Ranges and the very similar Sierra Nevada probably formed in similar tectonic environments during the same period of time. However, they currently lie on opposite sides of the tectonic plate boundary represented by the San Andreas Fault system. The Peninsular Ranges are slowly moving northward along the coast headed toward Alaska. Photograph: Mike Fuller

The **Cascade Range**, a chain of volcanic cones, extends from southern British Columbia through Washington and Oregon into northern California. Cascade volcanoes are large cone-shaped mountains built by very explosive eruptions that produced extreme volumes of ash deposits. In California, Mount Shasta, a glacier mantled volcanic cone, rises 14,162 feet above sea level and is one of the world's largest composite volcanoes. At the southern end of the Cascade Range is Lassen Peak, a very large plug dome, which last erupted during the period of 1914 to 1921. Between these two volcanic centers, the Cascade Range is transected by the deep canyon of the Pit River, which eventually joins with the Sacramento River. Prehistoric eruptions within this mountain range left several enormous calderas, such as Crater Lake and the area partially occupied by Mount Lassen.

Just 30 miles east of Mount Shasta lies Medicine Lake volcano, a large shield volcano—so named for its broad and rounded, low profile. Despite its low profile, it is believed to be the largest of the Cascade volcanoes. Medicine Lake occupies a large caldera. Its different shape relates to the less viscous (more fluid) magma that feeds it.

Tectonic Setting

The Cascade volcanic rocks result from the subduction and partial melting of the Gorda tectonic plate in the active Cascadia subduction zone. The Mendocino triple junction marks the southern limit of the subduction zone. Many of the Cascade volcanoes are either active or potentially active.

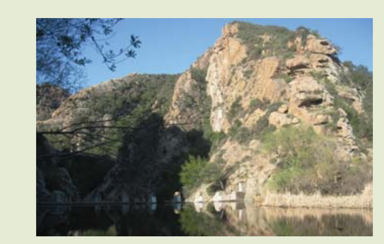
At Medicine Lake, the magma and style of volcanism is more characteristic in regions undergoing crustal thinning and extension such as in the Modoc Plateau and the Basin and Range provinces. But it also shows characteristics of the Cascades. This is an excellent example of overlap in geomorphic boundary zones. Photograph: Shannon Utley

The **Coastline** (not illustrated in main map) qualifies as a distinct geomorphic subprovince evenly divided between north and south. Because the coastline is 1,100 miles long, the climate and water temperatures in the south are more mild than in the north. The flora and fauna vary accordingly. The California coastline is a dynamic boundary zone, of varying width, where geologic forces collide. Coastal landforms include beaches, dunes, tide pools, estuaries, lagoons, steep cliffs, marine terraces, and sea stacks.

The coastline can be subdivided into two sections. The northern section runs the length of the Coast Ranges province; the southern runs along the western edge of the provinces of the Transverse Ranges and the Peninsular Ranges. Along the northern section, the coastal geomorphology is superimposed on the landforms of the Coast Ranges province. Along the southern section, the coastal geomorphology is superimposed on the landforms of the Transverse Ranges and Peninsular Ranges geomorphic provinces. The northern section runs north-by-northwest from Point Conception north to Oregon. Due to the orientation, the winter storms and waves tend to attack the northern shores head-on without the buffering effect of a broad continental shelf. Beaches are often cobbly or gravelly with scattered sandy beaches.

From San Diego to Point Conception, the coastline trends northwestwardly. Due to the orientation, the southern shores are somewhat sheltered from storms that arrive from the west and northwest. A broad continental shelf lies along the southern section. The shallow offshore shelf helps absorb wave energy by causing waves to break further from shore. Sand deposition in the form of beaches started roughly 10,000 years ago and is relatively widespread along the southern coast.

The position of the shoreline is directly related to sea level and land elevation both of which are variable through time. Sea level was as much as 400 feet lower during the last Ice Age because so much water was trapped as ice on the glaciers that covered northern and southern latitudes. During this time the shoreline position was as much as several miles west (near the Farallon Islands) of its current location. During the Ice Ages, major rivers cut deep canyons into the continental shelf creating submarine canyons such as the Monterey submarine canyon, which is twice as deep as the Grand Canyon. During the last interglacial, sea level was approximately 15-20 feet higher and coastal wetlands and estuaries were correspondingly much more extensive than today. Photograph: Jennifer Lotery



The **Transverse Ranges** are a complex series of east-west trending mountain ranges and valleys that strongly contrast with the northwest trend of the adjacent Coast Ranges and Peninsular Ranges. The section of Cenozoic sedimentary rocks within this province is one of the thickest in the world and regional structural trends are significant in the formation of important oil field structures.

The western limit of the province contains the islands of San Miguel, Santa Rosa, and Santa Cruz. The eastern limit, extends into the Mojave Desert, and includes the San Bernardino Mountains to the east of the San Andreas Fault. Within the Transverse Ranges, the San Bernardino and San Gabriel Mountains contain some of the highest peaks in southern California, ranging from 10,000 to over 11,500 feet above sea level.

Tectonic Setting

The Transverse Ranges are caught in a geological vise that has been squeezing them for the past 20 million years, from south to north producing high amplitude compressed folds and faults. The troughs of the folds became deep marine basins and the peaks are expressed as the ranges. The thick sediments were at first rapidly deposited into the deep marine basins; then with continued compression were pressed up into the ranges. Tectonic models suggest that the Ranges rotated nearly 100 degrees clockwise due to plate tectonic movements.

The ranges are bisected by the San Andreas Fault system representing a complex section of the tectonic plate boundary. This compression is thought to result from what is called the "Big Bend" in the San Andreas Fault. Overall, the trend of the San Andreas is north by northwest but in this section it bends counterclockwise, that is more northwest. In simple terms, the lands northeast of the boundary are riding on the North American plate with its northwest heading. The lands southwest of the boundary are riding on the more northerly drifting Pacific plate which is pushing into the North American plate. Photograph: Pam Irvine

The **Modoc Plateau** is a volcanic tableland with elevations ranging between 4,000 and 6,000 feet above sea level. Most of the volcanic rocks erupted as extensive fluid lava flows during the Tertiary period, between 10 and 2 million years ago. The Modoc plateau eruptive centers consists of fissures and many small cones. Eruptions were nowhere near as explosive as the Cascade volcanoes. Instead, the volcanic products consist of a thick accumulation of lava flows and tuff/ash beds that have built the plateau. Many northerly trending faults cut across the plateau, breaking it up into tilt-block mountains.

Tectonic Setting

This style of volcanism occurs in regions experiencing crustal thinning and extension such as in the Basin and Range geomorphic province to the east. The region consists of 1) Tertiary and Pleistocene basalt lava flows with more recent flows at the edge of the Cascade Range geomorphic province and 2) closely spaced, northerly-trending faults characteristic of the Basin and Range province. The Modoc Plateau geomorphic province can be thought of as a broad boundary zone between the Cascade and Basin and Range provinces. Photograph: Michael Wopat

The **Great Valley** is an alluvial plain, about 50 miles wide and 400 miles long, located between the Coast Ranges and the Sierra Nevada. The plain is drained by the Sacramento and San Joaquin Rivers, which join and enter San Francisco Bay. To the north, the Sacramento Valley floodplain is interrupted by the Sutter (Marysville) Buttes, an isolated Plio-Pleistocene volcanic plug about 2,000 feet high. The valley is filled with nearly flat-lying sediments as much as 20,000 to 40,000 feet thick. Beneath the valley, Cretaceous and Cenozoic strata form a broad U-shaped cross-sectional profile (trough) that is steeper on the west than the east. The edges of the tilted layers of Great Valley sedimentary rock can be seen along the western margin of the trough adjacent to the Coast Ranges. In the southern part of the Great Valley, the San Joaquin Valley oil fields follow uplifts and fault warps that formed "traps" for petroleum, such as those found in the Kettleman Hills.

The Great Valley has become one of the leading agricultural regions in the world due to a mild climate and extensive, fertile soils. These soils formed in wetlands as floodplain deposits replenished by sediment carried in the Sierran rivers during periodic, large floods. The floods and vast wetlands delayed the development of the Great Valley. To a large extent the floods and the sediment are now cut off by flood control and water storage dams.

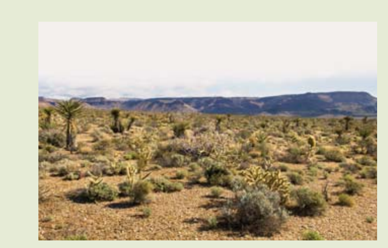
Tectonic Setting

The trough is often interpreted as a fore-arc basin between the Sierra Nevada Mountains on the east and the accretionary wedge of the Coast Ranges on the west. Sediments eroded from the Sierra Nevada and the Coast Ranges were washed into the trough, at that time occupied by the sea. The shoreline ran along the eastern edge of the modern Great Valley where sediments were deposited in deltas at the mouths of Sierran rivers. These rivers carried the abundant outwash of the glacial erosion (as exemplified at Emerald Bay State Park) into the trough. The trough eventually filled with sediment and the seas retreated. Photograph: Mike Fuller

The **Basin and Range** geomorphic province is characterized by subparallel, fault-bounded mountain ranges separated by down-dropped basins. Death Valley, the lowest area in the United States, is one of these down dropped basins. Badwater, the lowest point in Death Valley, lies at 280 feet below sea level. In general, most of the valleys in the Basin and Range are actually elevated, with valley floors lying at more than 3,000 feet above sea level. The northernmost portion of this geomorphic province in California includes the Honey Lake Basin. The Basin and Range province is the westernmost part of the much larger Great Basin that extends across several states. The region is characterized by interior drainage with lakes and playas.

Tectonic Setting

The basin and range landscape forms in response to crustal thinning and extension (stretching and pulling apart from deep dynamic forces). California lies along the western edge of the province. For the last 40 million years, the Basin and Range has been stretching from east to west, resulting in tilt block mountains and intervening down-dropped basins. The State of Nevada is actually growing in area as a result of these extensional processes. Photograph: Mike Fuller



The **Mojave Desert** is a broad interior region of isolated mountain ranges separated by expanses of desert plains. Sometimes referred to as the high desert, elevations in the Mojave Desert generally range between 3,000 to 6,000 feet. Because of the enclosed interior drainage, rainwater either seeps into the ground or is evaporated, resulting in many playas. Within the province, there are two important fault trends that control topography, a prominent northwest trend and a secondary east-west trend (an apparent alignment with the Transverse Ranges).

Tectonic Setting

The rocks in the Mojave Desert are progressively older from the west toward the east. Some of the oldest rocks (about 1.7 billion years old) in California are exposed in the eastern Mojave Desert. Here also are remnants of what was the western continental shelf during the formation of the Appalachian Mountains and the Pangaea supercontinent.

The Mojave Desert geomorphic province's wedge-shaped appearance is due to the Garlock Fault along its northern boundary (the southern boundary of the Sierra Nevada) and the San Andreas Fault along the southern boundary. Like the Basin and Range geomorphic province, this region has been growing from east to west. It is also being sliced north to south along a set of faults (the eastern California shear zone) that operate similar to and parallel with the San Andreas Fault. Photograph: California State Parks

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