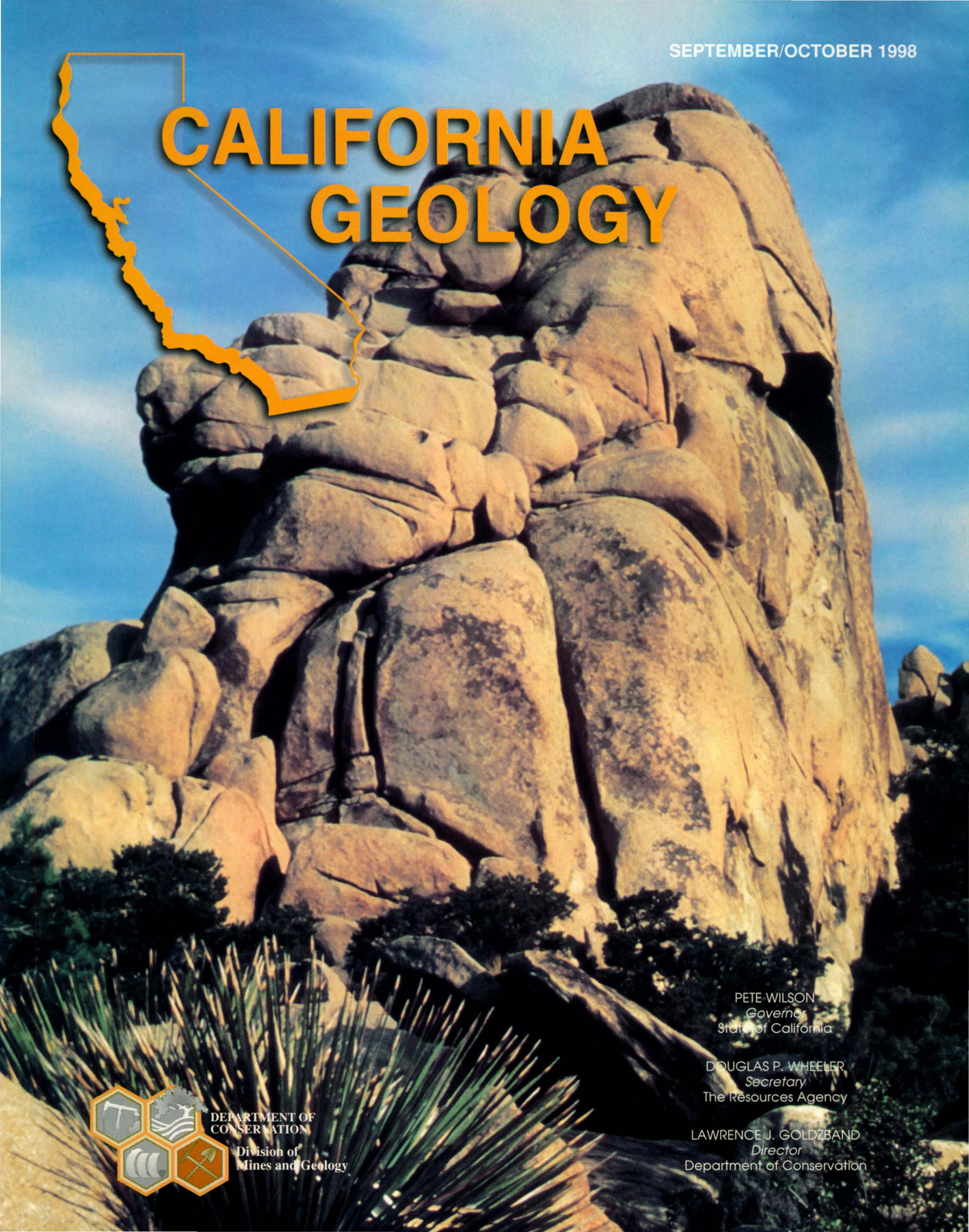
SEPTEMBER/OCTOBER 1998

CALIFORNIA GEOLOGY



PETE WILSON
Governor
State of California

DOUGLAS P. WHEELER
Secretary
The Resources Agency

LAWRENCE J. GOLDZBAND
Director
Department of Conservation

DEPARTMENT OF CONSERVATION
Division of Mines and Geology

CALIFORNIA GEOLOGY

A PUBLICATION OF THE DEPARTMENT OF CONSERVATION DIVISION OF MINES AND GEOLOGY

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The Resources Agency	DOUGLAS P. WHEELER *Secretary for Resources*
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CALIFORNIA GEOLOGY

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CALIFORNIA GEOLOGY (ISSN 0026 4555) is published bimonthly by the Department of Conservation, Division of Mines and Geology. The Records Office is at 1059 Vine Street, Suite 103, Sacramento, CA 95814. Periodicals postage is paid at Sacramento, CA.

Reports concerning Department of Conservation, Division of Mines and Geology projects, and articles and news items related to the earth sciences in California, are included in the magazine. Contributed articles, photographs, news items, and geological meeting announcements are welcome.

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Subscriptions: $12.00/1yr. (6 issues); $24.00/2 yrs. (12 issues); $36.00/3 yrs. (18 issues). Send subscription orders and change of address information to CALIFORNIA GEOLOGY, P.O. BOX 2980, Sacramento, CA 95812-2980. Subscription inquiries: (916) 445-6199.

WORLD WIDE WEB SITE: http://www.consrv.ca.gov/

SEPTEMBER/OCTOBER 1998
Volume 51/Number 5
CGEOA 51 (5) 1-28 (1998)

— In This Issue —

Cover Photo: Cretaceous White Tank monzogranite exposed in Joshua Tree National Park in the Wonderland of Rocks area of the park. These masses of rock have been sculpted through a combination of rock jointing, and chemical and physical weathering. ©1998, John Karachewski, Walnut Creek, California.

THE GEOLOGICAL SOCIETY OF AMERICA (GSA) HOLDS ANNUAL MEETING

October 26-29, 1998

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Geology of Joshua Tree National Park

San Bernardino and Riverside Counties

D.D. TRENT, Professor Emeritus, Citrus College, Glendora, California

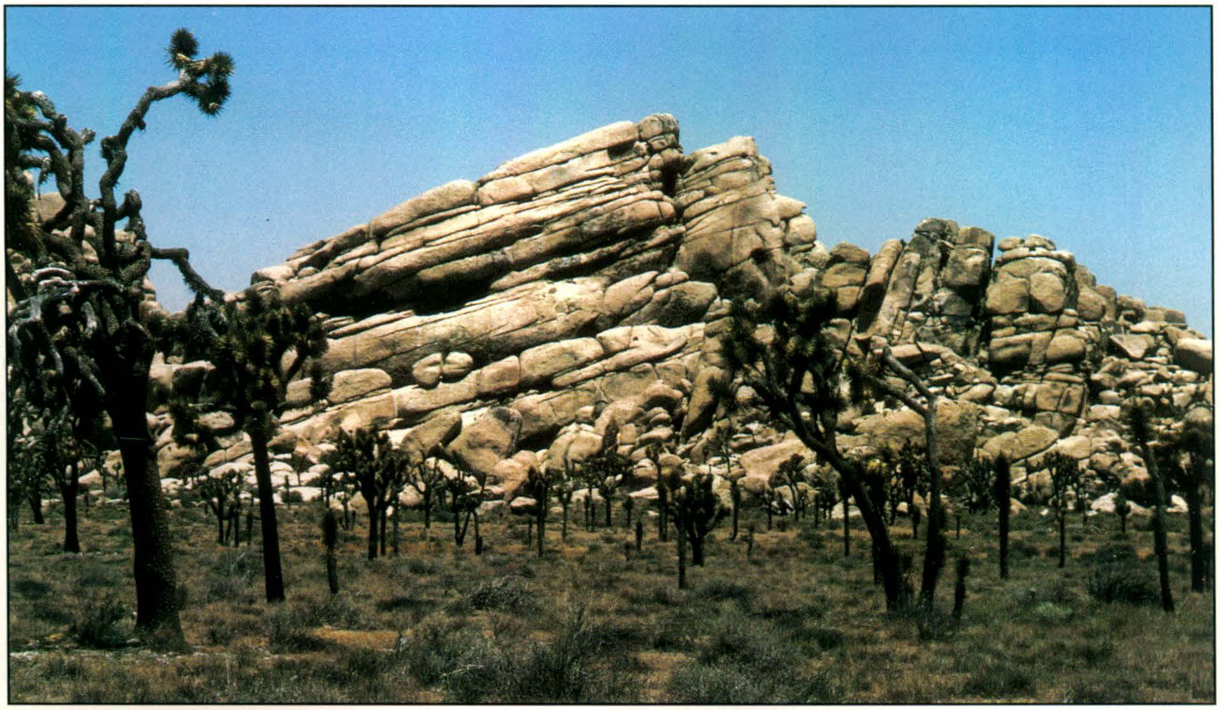

Photo 1. Inselbergs at Hidden Valley Campground display the rectangular joint system that is prevalent in the White Tank monzogranite. *Photo by D.D. Trent.*

With the passage of the Desert Protection Act in 1994, Joshua Tree National Park gained the southern portion of the Little San Bernardino Mountains, the Eagle and Coxcomb mountains and part of the Pinto Mountains. These areas add to what the park is widely known for—outstanding examples of relict erosional features, recent tectonic activity and desert landforms (Photo 1). Recent studies have revised earlier interpretations of the geology of this region. This article, updated from the original published in the April 1984 issue of CALIFORNIA GEOLOGY, reflects these studies. It is reproduced with special permission from *Geology of National Parks*, 5th Edition by Harris and others, copyright 1997 by Kendall/Hunt Publishing Company*...*editor*

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INTRODUCTION

Joshua Tree National Park, one of the nation's newest national parks, preserves a typical area of California desert landscape that includes parts of two deserts; the lower elevation Colorado Desert and the higher elevation Mojave Desert. The first-known inhabitants were the Pinto Basin people, an early culture whose artifacts have been found along the shorelines of an ancient lake that once occupied the Pinto Basin in the Park's eastern Wilderness Area. The dating of these artifacts suggests that the Pinto Basin people lived here from about 7,000 to 5,000 years ago. More recent Native American populations included the hunters and gatherers who are the ancestors of the modern Cahuilla, Chemehuevi, and Serano people. The Oasis of Mara, at the site of the Oasis Visitor Center and Park Headquarters at Twentynine Palms, was the home of Chemehuevis until the early 1900s.

In the late nineteenth century, the Oasis of Mara was a popular watering stop for miners on their way to and from the gold mines in the surrounding region. Today, within the park boundaries, are the remains of more than 2,000 abandoned mines and mining prospects. Among the more productive mines were the Lost Horse, Silver Bell, El Dorado, and Desert Queen. Estimates of the total gold production from

Area: 794,300 acres; 1,241 square miles

Proclaimed Joshua Tree National Monument: 1936

Established as a National Park: October 31, 1994

Designated a biosphere reserve: 1984

Headquarters Address:

74485 National Park Drive
Twentynine Palms, California 92277
(760) 367-5500

these mines range from $40,000 to $40,000,000.

Cattle raising went on at about the same time as the mining activity as cattlemen found the grasses in the high desert suitable for their stock. Grazing continued within what is now the park until 1945.

Beginning in the early 1920s, homesteaders began taking up land in the Twentynine Palms area. The reasons for this were the availability of water at the Oasis of Mara and the desert climate. Disabled veterans of World War I were encouraged to settle in the area in hope that the dry air would help cure their ailments. Many of the health-seekers found that an out-of-door desert lifestyle did indeed have therapeutic value. Gradually the area became more popular, bringing new housing, more roads, an influx of land developers, and cactus poachers.

A dedicated lady from Pasadena, Mrs. Minerva H. Hoyt, who had a passion for the desert, agonized over the removal of cacti and other desert plants from the Joshua Tree area to the backyard rock gardens of Los Angeles. Her efforts to protect the desert environment culminated in the creation of Joshua Tree National Monument proclaimed by President Franklin D. Roosevelt in 1936.

LOCATION AND GEOGRAPHY

Joshua Tree National Park is on the eastern end of the broad mountainous belt called the Transverse Ranges, that stretch from Point Arguello, 50 miles west of Santa Barbara, eastward for nearly 300 miles to the Eagle Mountains in the Mojave Desert (Figure 1).

The park region includes several distinct mountain ranges, the Little San Bernardino, Cottonwood, Hexie, Pinto, Eagle, and Coxcomb mountains (Figure 2). Both the southern and the northern margins of the park are marked by steep escarpments that rise abruptly from the lower desert areas. Elevations within the park range from 1,000 feet in Pinto Basin to 5,814 feet at the summit of Quail Mountain. Valleys lying between the mountain ranges are of two types: 1) structural basins formed by the down-dropping of a block between two faults and 2) erosional valleys. Pleasant Valley, between the Little San Bernardino and Hexie mountains, is an example of the structural type; Queen Valley, in the central part of the park, is an example of the eroded type.

CLIMATE

The climate of the high desert of the Joshua Tree region is that of a mid-latitude desert with relatively moderate temperatures. For example, the average temperature at Twentynine Palms, elevation 1960 feet, is only 67.3 degrees Fahrenheit (F) and at Hidden Valley Campground, 4,200 feet, the average temperature is about 7 to 12 degrees F cooler. Two factors cause eastern California to be a desert: 1) the rain shadow effect produced by the high mountains on the west, and 2) the existence during summer months of a semi-permanent high-pressure air mass, the Hawaiian High, which builds up over the northeastern Pacific Ocean and blocks the passage of frontal storm systems over California. Occasionally, during the summer and fall, the Hawaiian High weakens and moist air from the Gulf of Mexico slips into the region across Arizona, bringing thunderstorms. For this reason, August has the highest rainfall (Table 1) which, curiously enough, is usually the driest month for the more humid regions of the state.

The Hawaiian High usually dissipates during the winter months and southern California is subjected to an average of four or five frontal storms that originate in the northeastern Pacific. Consequently, it is in December and January that the desert's second rainy season occurs (Table 1). The average rainfall at Twentynine Palms is only a little over 4 inches but at higher elevations the average rainfall is greater.

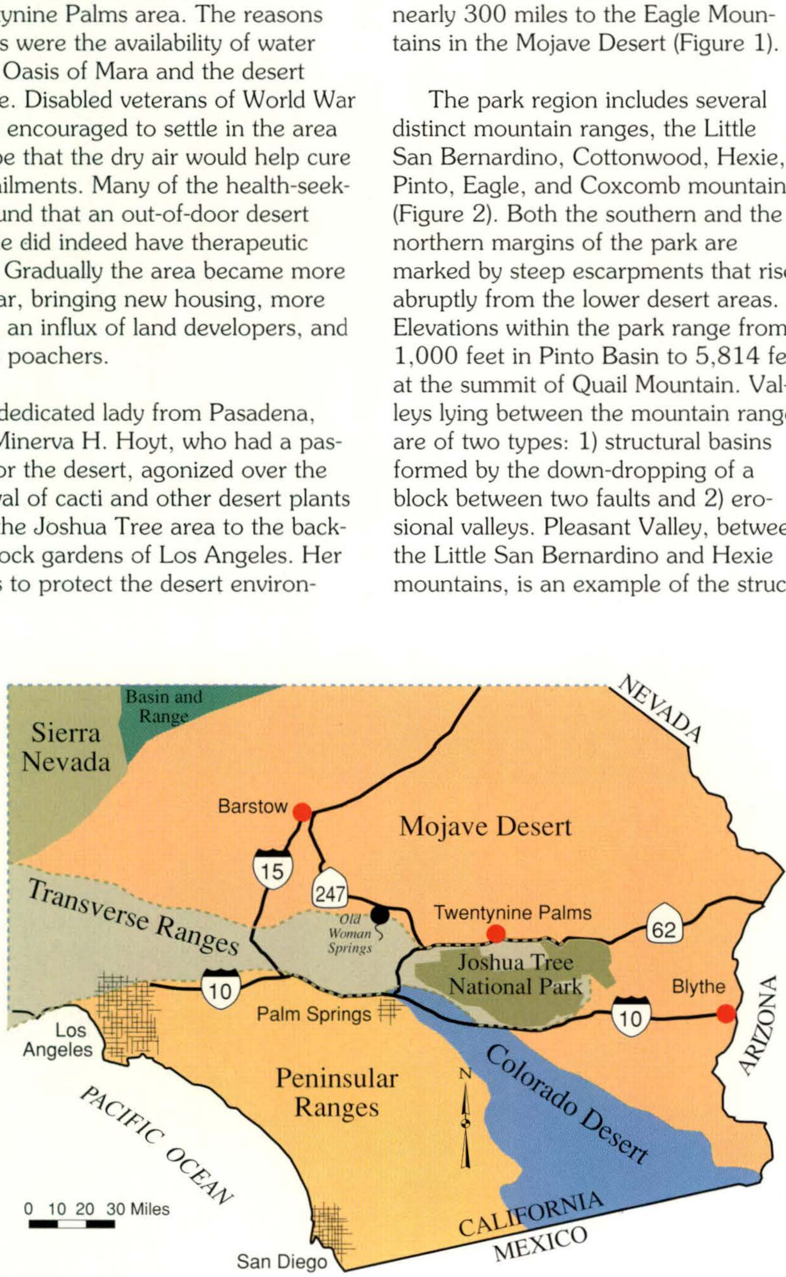


Figure 1. Regional map of southern California showing location of Joshua Tree National Park. Geomorphic provinces are also shown.

TYPES OF ROCK EXPOSED IN THE JOSHUA TREE REGION

Metamorphic Rocks

The earliest events in the geologic history of Joshua Tree National Park are recorded in rocks of early and middle Proterozoic (Precambrian) age that were formed by the metamorphism of preexisting sedimentary and igneous rocks. These rocks, formerly named the Pinto gneiss, are now recognized as fragments of a widespread metamorphic complex that was caught up in the

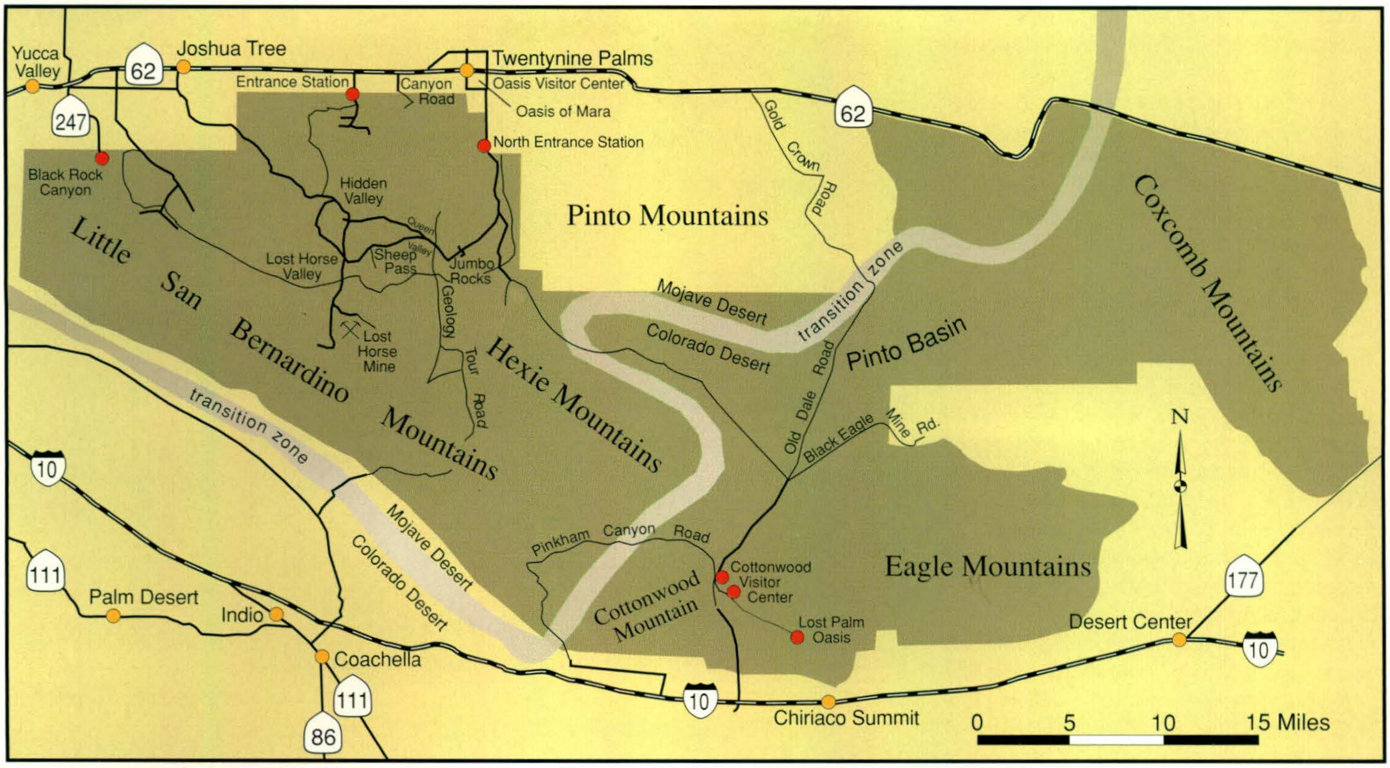


Figure 2. Map of Joshua Tree National Park. *Modified from Trent (1997).*

Table 1. Joshua Tree National Park weather records taken at the Oasis Visitor Center at Twentynine Palms at an elevation 1,960 feet. The averages were compiled from data collected from 1936 through 1991. Temperatures average approximately 7 to 10 degrees F cooler at higher elevations in the park. Higher elevations also average about 3.5 inches more precipitation annually. Courtesy of National Park Service, 1992. From Trent (1997).

Month	Average Maximum Temperature*	Average Minimum Temperature*	Average Precipitation (inches)	Average Humidity (percent)
January	62.8	31.5	0.38	28.2
February	67.7	38.2	0.35	24.1
March	74.8	42.9	0.30	19.2
April	83.1	50.1	0.10	16.5
May	90.3	55.9	0.06	14.0
June	100.6	64.8	0.02	12.3
July	105.2	70.6	0.62	17.0
August	103.0	69.5	0.68	20.8
September	96.4	62.4	0.31	16.4
October	85.7	52.6	0.32	19.5
November	71.5	41.4	0.27	25.7
December	62.3	31.6	0.46	28.4

* degrees Fahrenheit

Mesozoic tectonic arc along the Pacific margin of North America, became fragmented, and was widely distributed throughout the Transverse Ranges and vicinity. Four subunits of this complex are recognized within Joshua Tree National Park: the Joshua Tree augen gneiss, a granitic augen gneiss that crops out in the Chuckwalla, central Eagle, and south-central Pinto Mountains; the metasedimentary suite of Placer Canyon, composed of quartzite and dolomite, which uncomformably overlies the Joshua Tree augen gneiss; the distinctive augen gneiss of Monument Mountain, a dark colored porphyritic granodiorite-monzogranite,* in the Hexie Mountains; and the metasedimentary suite of Pinkham Canyon in the Chuckwalla, Eagle, Hexie, and Pinto mountains (Table 2). The Pinkham Canyon rocks include quartzite, schist, very fine-grained granofels, and dolomite, a suite identical to strata in the northeastern-most Mojave Desert near Baker that offers a tentative link between the Proterozoic rocks of the North American craton and the Transverse Ranges of California. Radiometric age dating of these Proterozoic rocks yields ages of 1.65 to 1.70 billion years before present (ybp) for the augen gneiss of Joshua Tree and 1.65 to 1.68 billion ybp for the augen gneiss of Monument Mountain, making these some of the oldest rocks known in California.

Photo 2. Proterozoic gneiss on the trail to the Lost Horse Mine. *Photo by D.D. Trent.*

Igneous Rocks

At least five different major plutons, ranging in age from middle Proterozoic to Cretaceous, have intruded the metamorphic complex described above (Photo 2). The oldest are a succession of intrusions of the igneous protoliths (parent rocks) of foliated metamorphosed hornblende gabbro, diorite and amphibolite, laminated granodioritic to monzogranitic orthogneiss, and various leucocratic granite orthogneiss (commonly garnetiferous) that intruded the metasedimentary rocks of Pinkham Canyon. The amphibolite and the leucocratic granitic orthogneiss have yielded isotopic ages of 1.71 billion ybp and 1.68 billion ybp respectively. A younger Proterozoic suite of plutonic rocks is an anorthosite-syenite intrusive complex in the southeastern section of the park, which yields a radiometric age of about 1.2 billion ybp.

The Triassic and Cretaceous plutons in Joshua Tree National Park, in common with the granitic rocks of the Sierra Nevada, the Peninsular Ranges, the Klamath Mountains, and the White-Inyo Mountains, are believed to have been generated in an oceanic-continental convergence zone. Examples of the intrusive contacts of these rocks with the Proterozoic gneiss country rocks are well exposed along the trail to Fortynine Palms Oasis and along the east side of Lost Horse Valley (Photo 3).

The oldest Mesozoic intrusion, the Twentynine Palms porphyritic quartz monzonite, consists of a matrix of small mineral grains that enclose large phenocrysts of potassium feldspar that attain lengths up to 2 inches. The pluton is of Triassic age, yielding a preliminary radiometric age of 245 million ybp. It is part of a widespread belt of Permo-Triassic plutonic rocks exposed in southern California. This belt of rocks is significant because its intrusion signals the onset of an ocean-continent tectonic convergence and subduction plutonism along the continental margin. The Twentynine Palms pluton crops out along the trail to Fortynine Palms Oasis and along the arroyo on the east side of Indian Cove campground.

The principal plutons of Cretaceous age include the Queen Mountain monzogranite, the Gold Park diorite, the White Tank monzogranite, and the Oasis monzogranite (Table 2). These rocks appear to be part of the late Cretaceous intrusive events recognized in the eastern Mojave Desert, Peninsular Ranges, and the Sierra Nevada.

The oldest of the Cretaceous plutons in Joshua Tree National Park is the Queen Mountain monzogranite. It is coarse-grained, consisting of plagioclase, potassium feldspar, quartz, and either biotite or hornblende. The Queen Mountain has yielded a radiometric age date of 104 million ybp.

The light-colored Cretaceous White Tank monzogranite predominates in the more accessible parts of the park. The White Tank pluton resembles the Queen Mountain monzogranite but differs by being finer-grained, and by containing small amounts of biotite and/

* The igneous rock terminology used here follows the modified Streckeisen (1973) classification.

Table 2. Geologic column showing major geologic events and rock units of Joshua Tree National Park. From Trent (1997).

TIME UNITS			ROCK UNITS	GEOLOGIC EVENTS
Era	Period	Epoch		
Cenozoic	Quaternary	Holocene	Alluvium, talus, playa lake sediments, dune sands	Weathering, erosion, mass wasting
		Pleistocene	Basaltic flows	Volcanism, faulting, uplift, weathering, erosion, mass wasting
	Tertiary		Basaltic flows	Volcanism, faulting, uplift, weathering, erosion, mass wasting
Mesozoic	Cretaceous		Gold Park diorite Oasis monzogranite White Tank monzogranite Queen Mountain monzogranite	Intrusions and orogeny
	Jurassic		(no record)	Orogeny?
	Triassic		Twentynine Palms porphyritic quartz monzonite	Intrusion
Paleozoic			(no record)	
Proterozoic	Z		(no record)	
	Y		Anorthosite-syenite complex (1.2 billion ybp)	
	X	Eagle Mountains Assemblage Includes the metasedimentary suite of Placer Canyon and granitic augen gneiss of Joshua Tree (1.65-1.70 billion ybp); complex suites of metasedimentary and metaigneous rocks.	Hexie Mountains Assemblage Augen gneiss of Monument Mountain (1.65-1.68 billion ybp); metamorphosed gabbro, diorite, and amphibolite (1.4-1.71 billion ybp); metasedimentary suite of Pinkham Canyon; suite of metasedimentary and metamorphic rocks.	Tectonic episodes involving metamorphism and plutonism, probably resulting from plate interactions along the western edge of the North American landmass.

or muscovite but no hornblende. What are perhaps the most scenic areas of the park underlain by the White Tank monzo-granite are Indian Cove, the Wonderland of rocks, Jumbo Rocks, White Tank, and Lost Horse Valley (Photo 4).

The youngest of the Cretaceous plutons, the Oasis monzogranite, is a garnet-muscovite-bearing pluton exposed in the area around Fortynine Palms Oasis. The garnets are blood-red and small, but large enough, nevertheless, to be visible without magnification. The muscovite grains impart a distinct glitter to the rock on sunny days.

In addition to the large monzogranite and quartz monzonite plutons already described, there are smaller masses of a similar rock, granodiorite, and small dark plutons named the Gold Park diorite. Cutting across all of these rock masses, and thus being younger in age, are dikes of felsite, aplite, pegmatite, andesite, and diorite. Pegmatite dikes in the park consist mainly of quartz and potassium feldspar with a composition close to that of granite. Making them distinctive is the very large size attained by the mineral grains, often 3 to 4 inches long.

Even younger than these dikes are veins of milky quartz that, over the years, have been prospected for gold. The quartz is sometimes stained reddish brown from the weathering of pyrite (fool's gold). Pyrite is a common mineral in quartz veins and is sometimes associated with gold or other valuable minerals. Chemical alteration of the pyrite

Photo 3. The contact between the White Tank monzogranite and Proterozoic Gneiss along the east side of Lost Horse Valley. *Photo by D.D. Trent.*

produces reddish iron oxides that stain the rocks and serve prospectors as clues that gold, silver, copper, lead, or other important ores may be present.

Basalt occurs at three places within the easily accessible parts of the park: 1) near Pinto Basin, where the basalt probably originated as extrusive flows, 2) at Malapai Hill on the Geology Tour Road (Photos 5 and 6), and in the Lost Horse Mountains. These exposures show much in common with other basalt bodies in the eastern San Bernardino Mountains and the Mojave Desert that have been age-dated at between 8 to 10 million ybp. In addition to basalt, another mafic rock, lherzolite, occurs as inclusions within the basalt at Malapai Hill and in the Lost Horse Mountains. Lherzolite is an olivine-rich peridotite that is derived from the mantle; thus, the basalt has risen some 30 to 50 miles in order to carry the inclusions to the surface.

STRUCTURAL GEOLOGY

Faults

Joshua Tree National Park is surrounded by active or recently active faults. The Pinto Mountain Fault, trending nearly east-west along the north side of the Pinto Mountains, is one of the most prominent. The fault zone is followed closely by Twentynine Palms Highway (State Highway 62) between Morongo Valley and Twentynine Palms.

Between Morongo Valley and Yucca Valley, the fault is marked by side hill benches, triangular faceted spurs, and a probable left-lateral stream offset. Quaternary basin-fill buries much of the geomorphic evidence of the fault from Yucca Valley to Copper Mountain, but just west of Copper Mountain the fault is marked by a line of vegetation. A prominent escarpment is formed by the main trace of the fault along a 1.2 mile-long shutter ridge at Copper Mountain. (A shutter ridge is formed by displacement on a fault traversing ridge-and-valley topography. The displaced part of a ridge "shuts in" an adjacent canyon.) In Twentynine Palms, the fault at the Oasis of Mara, immediately west of the Oasis Visitor Center, is marked by a line of vegetation about 1.5 miles long and by a scarp about a half-mile long and 3 to 6 feet high.

The Blue Cut Fault extends east-west through the Little San Bernardino Mountains, about a half-mile south of Keys View, under Pleasant Valley and into the Pinto Basin. The Blue Cut Fault branches from the Dillon Fault, which is even farther south and trends southeastward through the Little San Bernardino Mountains. The Blue Cut and Pinto Mountain faults are both left-lateral faults. They appear to belong to a system of faults, all about the same age,

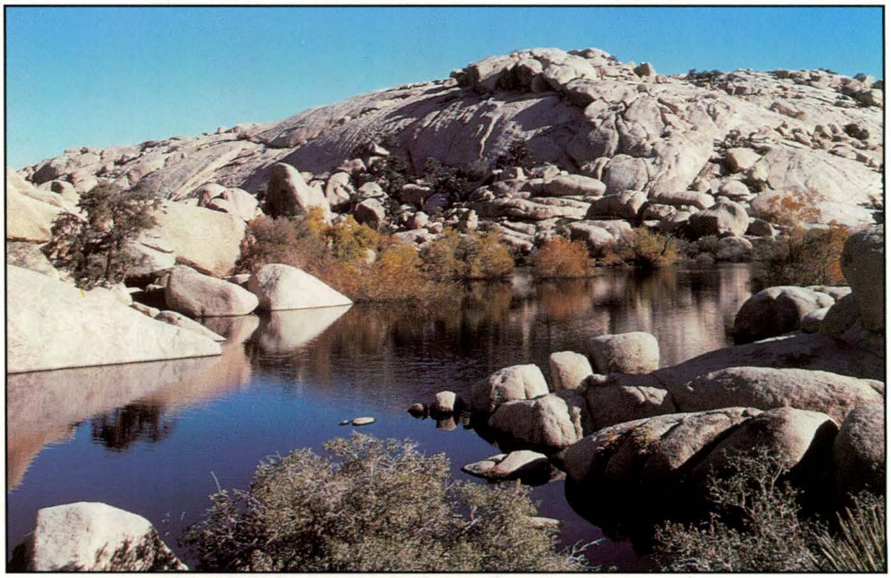


Photo 4. Rock sheeting in the White Tank monzogranite forms domelike landforms at Barker Dam in the Wonderland of Rocks. *Photo by Walter Stephens.*

Photo 5. Malapai Hill, an eroded endogenous volcanic dome, rises above the pediment of southern Queen Valley. The Hexie Mountains, behind Malapai Hill, exposed the contact between Proterozoic gneiss (dark rocks) and the White Tank monzogranite. *Photo by D.D. Trent.*

Joints

These small fissures cutting rocks may occur in sets of parallel joints and in systems of two or more intersecting sets. The White Tank monzogranite has a system of rectangular joints that is primarily responsible for the spectacular landforms in the park. One set, oriented roughly horizontally, results from the erosional removal of the overburden stress of many miles of rock that once overlay the monzogranite. These joints, sometimes called lift joints, cause exfoliation. Lift joints (or pressure release joints) are due to expansion from the release of overburden stress, somewhat analogous to that of a seat cushion resuming its shape after a person sitting on it arises. Where vertical joints are lacking or widely spaced, lift joints form domelike landforms (Photo 4).

that include the many north-northwest-trending right-lateral faults of the Mojave Desert. Included in this fault system are the Johnson Valley, Camp Rock, and Emerson northwest-trending right-lateral faults that ruptured in the 1992 Landers earthquake (M=7.3), the epicenter of which was about 22 miles northwest of Twentynine Palms. This right-lateral fault set appears to extend southeastward from the central Mojave Desert into the western part of Joshua Tree National Park in the region of Black Rock Canyon campground.

South of the Dillon and Blue Cut faults lies the San Andreas Fault Zone. The trace of the San Andreas Fault is clearly visible from Keys View (Photo 7). Along this portion of the San Andreas, the fault divides into two main branches, the Banning and Mission Creek faults. The traces of these faults are marked by the Indio Hills, an uplifted block wedged between the faults, and by a number of palm oases that are aligned along the faults.

In addition to the major faults are many minor faults throughout the region of the park. Such fault zones are often important in localizing springs. Movement by faults causes impervious zones composed of pulverized rock fragments that form subsurface barriers and may force ground water to rise. The oasis at Cottonwood Spring, for example, appears to be localized by a fault zone that has provided the fissures along which ground water reaches the surface. The Oasis of Mara at the Twentynine Palms Visitor Center has been formed in a similar manner along the Pinto Mountain Fault.

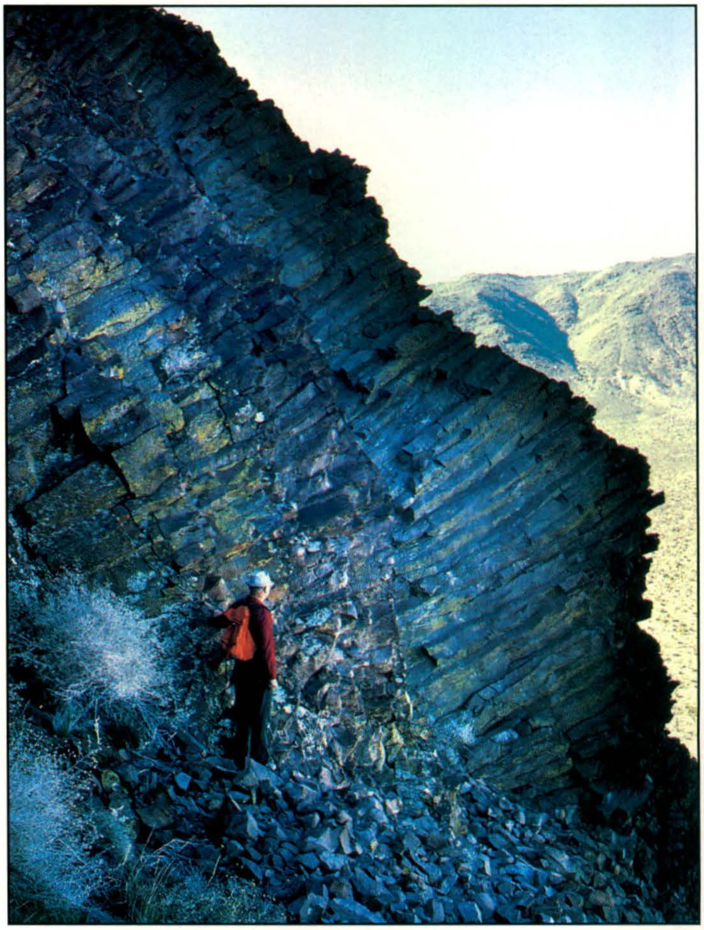


Photo 6. Columnar jointing in the basalt of Malapai Hill. *Photo by D.D. Trent.*

Photo 7. The northern end of the Salton Trough as seen from Keys View in Joshua Tree National Park. The high peak in the distance is Mount San Jacinto, 10,786 feet in elevation. Palm Springs and Cathedral City are at the base of the mountains. The Indio Hills, running from left to right in the middle distance, mark an uplifted block wedged between two branches of the San Andreas Fault. *Photo by D.D. Trent.*

Another set of joints is oriented vertically, roughly paralleling the contact of the White Tank monzogranite with its surrounding rocks. The third set is also vertical but cuts the second set at high angles. The resulting system of joints tends to develop rectangular blocks. Especially good examples of the joint system may be seen at Jumbo Rocks, Wonderland of Rocks, and Split Rock (Photo 1).

SCULPTURING THE LANDSCAPE

Weathering

Perhaps the most impressive aspect of the landforms at Joshua Tree National Park are the strange and picturesque shapes assumed by the bold granitic rock masses at the Jumbo Rocks, Wonderland of Rocks, Split Rock, and elsewhere (Photos 1 and 8). The sculpturing of these rock masses is the result of the combined action of rock jointing, and chemical and physical (mechanical) weathering. The combination of these processes results in spheroidal weathering, the peeling-off of thin concentric shells of rock that form spherical rock masses. Spheroidal weathering results from slight pressures that have been built up in the outer portions of the rock from chemical decomposition of the aluminum silicate minerals into clay minerals. For example, when potassium feldspar comes into contact with hydrogen ions and water, the following chemical reaction, called hydrolysis, takes place:

potassium feldspar + hydrogen ions + water → kaolinite + potassium ions + silica

$$2KAlSi_3O_8 + 2H^+ + H_2O \rightarrow Al_2Si_2O_5(OH)_4 + 2K^+ + 4SiO_2$$

Kaolinite, a clay mineral formed by hydrolysis in an arid environment, occupies a greater volume than the original

Photo 8. View of Lost Horse Valley from the Lost Horse Mountains. The flat surface is a pediment and the rocky knobs are inselbergs, remains of the corestones that were isolated in ages past by deep chemical weathering of the White Tank monzogranite. The foreground hills are underlain by Proterozoic gneiss. *Photo by D.D. Trent.*

feldspar. The expansion is especially great at the edges and corners of the jointed granitic rocks, resulting in the jointed blocks of rock losing their sharp edges and corners to eventually assume rounded or spheroidal shapes.

The stresses, in addition to popping off thin shells of rock, cause the mineral grains of the rock to disintegrate physically and form a loose mineral soil called grus. Furthermore, frost-wedging and root-wedging also contribute to the breakdown of rocks by physical action.

Subsoil Weathering

The concave hollows or pits that pockmark granitic rock surfaces in Joshua Tree National Park are called tafoni. Although a rather common phenomenon, the process explaining the formation of tafoni is not clearly understood. The most common explanations included hydrolysis and hydration, thermal differences due to freezing and thawing or insolation, recrystallization of salts on exposed rock faces, and wind erosion.

In many areas of tafoni, nearly all of the declivities are aligned parallel to the outcrop-soil contact. This implies that the tafoni may have originated several centimeters beneath the surface of the soil by a two-step process of chemical and mechanical weathering. The first step involves the episodic wetting and drying that caused local chemical weathering of bedrock beneath the soil surface. In the second step, climate change and soil erosion forced removal of the soil cover, exposing the chemically altered sites that became pits when exposed to the atmosphere. Because of lower evaporation rates in the declivities, they weathered more rapidly than the surrounding rock, enlarging and sometimes merging into larger pits, with Skull Rock being an especially good example (Photo 9).

Nearly vertical surfaces, commonly on the shady sides of rock outcroppings throughout the park, have been formed by subsoil weathering. The action of moisture trapped in the soil at the base of the vertical surface causes undercutting and accounts for many of the steep cliff faces because the process of wearing back and rounding off higher on the cliff cannot keep up with the undercutting at the base.

Erosion

Of the dynamic processes that carry away surficial rock material, running water, even in arid environments, is by far the most important erosional agent. Wind action is important in the desert, but the long-range effects of the wind are small when compared to the action of water.

Photo 9. Skull Rock at Jumbo Rocks campground illustrates cavernous weathering and undercutting by subsoil notching. *Photo by D.D. Trent.*

Erosional and weathering processes presently operating in the arid climate conditions in the region of Joshua Tree National Park, however, are not entirely responsible for the spectacular sculpturing of the rocks. The present Joshua Tree landscape, and that of much of the Mojave Desert, is essentially a collection of relict features inherited from earlier times of higher rainfall and lower temperatures. Thus, the desert landscape we see now is a "fossil" landscape. For example, Fortynine Palms Canyon could not have formed in the present rainfall regime. Such deep canyons must be attributed to former pluvial conditions during an epoch when the area of the southwestern United States received much greater precipitation than at present, when evaporation was considerably less, and the mean annual temperature was several degrees cooler.

LANDFORMS OF THE DESERT

The landforms encountered in Joshua Tree National Park are typical of those found in the arid portions of the southwestern United States:

1. arroyos, or dry washes—deep, flat-floored stream courses that contain water only a few hours or perhaps a few days each year;
2. playas—lakes that may contain water a few weeks a year during the rainy season;
3. alluvial fans—fan-shaped deposits of sediment formed at the base of mountains in arid regions;
4. bajadas—broad sloping aprons of rock debris that form by the coalescing of several alluvial fans;
5. pediments—gently sloping bedrock surfaces that are erosional surfaces carved along the base of desert mountains.

Pediments are a curious desert landform typical of the southwestern United States and many other desert regions. Superficially, pediments look like bajadas (depositional features) rather than products of the bedrock erosion. The slopes of pediments are slight, from 1/2 to about 6 degrees, and they are usually carved on homogeneous crystalline rock, such as granite. Pediments may be covered with a thin mantle of gravel, but if overlain by more than 10 feet of gravel cover, the resulting landform is considered depositional and is called a bajada. In order to determine whether a gently sloping desert surface is a pediment or a bajada, the observer must look at thickness of the gravel veneer, exposed along the drainage channels.

Apparently a pediment is formed by the retreat of a mountain front leaving an extensive planed bedrock surface that records the path of the retreating front. Rill wash, sheetfloods, winds, and lateral planation by streams tend to sweep the pediment clean of debris except for local accumulations of alluvium or gravel.

A pediment may be seen at Malapai Hill (Stop 7 on the Geology Tour Road).* Large expanses of bare granite pavement and bold dikes weathered out of the granite are exposed on the surface of the pediment (Photo 10).

Some investigators regard pediments as the only true desert landforms that can be attributed solely to arid conditions operating at present. Others regard pediments as features that have evolved in a sequential manner over a period of years. At issue are the relative roles of past and present processes in explaining the development of these arid region landforms.

* Road guide available at Park Visitor Center.

The origin of pediments may be closely linked to the origin of another characteristic desert landform, inselbergs, prominent, steep-sided residual hills and mountains rising abruptly from erosional plains (Figures 3 and 4). Studies in Uganda conclude that inselbergs are residuals of deep chemical weathering during the more humid environments of the late Tertiary and Quaternary periods (Figure 3A). Inasmuch as subsurface weathering is more intense

How arid region landforms differ from landforms in humid regions.

1. The internal drainage basins in deserts provide base levels of erosion that may lie well above, or even below, sea level. In humid regions, however, the ocean surface provides the base level of erosion.
2. Base levels of erosion in most deserts, and clearly in the Mojave Desert, are constantly rising as the products of erosion accumulate within the internal basins; in humid regions, the ocean provides a relatively constant base level.
3. Products of erosion in humid regions are carried great distances, eventually to the ocean. But erosion products in the desert are carried only short distances resulting in the conspicuous accumulation of loose debris in the form of sand dunes, talus, alluvial fans, and bajadas.

Photo 10. Pediment (eroded on the White Tank monzogranite) on the Geology Tour Road. Malapai Hill is to the left. *Photo by Don Dupras.*

in areas of closely spaced joints, but less so in areas of widely spaced joints, pediments form by the removal of the deeply weathered rock materials, leaving behind the sparsely jointed rock residuals as inselbergs.

The origin of inselbergs in Uganda is not totally applicable to the deserts of the southwestern United States where, unlike Uganda, tectonism has been active for millions of years and continues up to the present. Tectonism has created fault-block mountain ranges and down-dropped basins. The internal drainage of the basins results in the gradual filling of the basins with rock debris derived from the adjacent uplands, which cause a slow rise of local base levels. Stream erosion, accompanied by rising base levels, is important in forming pediments in the Mojave Desert (Figure 3B).

Climatic conditions during the late Tertiary and the Quaternary periods surely were significant in the development of pediments and inselbergs. The present climate of this region is relatively new, having been established during the Quaternary Period, which began only about 2 million years ago. Botanical evidence indicates that progressive deterioration of vegetative cover took place throughout the Mojave Desert during the Miocene and Pliocene epochs (from about 25 million to about 2 million ybp). The change in climate and the corresponding change in plant cover left increasing areas of surface unprotected by vegetation, which promoted accelerated denudation of the soil. Furthermore, the renewal of soil during the Quaternary was slowed by decreased rainfall causing the rate of soil erosion to exceed the rate of soil formation.

Eight million years ago, the landscape of the Mojave Desert was one of rolling hills covered with a soil mantle that had developed in a hot, semi-arid to humid climate. At that time, the rates of soil formation and soil erosion were closely balanced. The climate and the vegetative cover then were similar to that existing today along Interstate Highway 15 between Temecula and Escondido, California. Increased erosion removed the residual soils from the steeper hillsides leaving behind the subangular and spheroidal boulders that formerly had been the subsurface corestones that had been isolated by chemical decomposition along joint planes. Good examples of these corestone features, called "boulder-mantled slopes," may be seen along the road between the northwest entrance to Joshua Tree National Park and Hidden Valley campground (Photo 11).

Eventually, the boulder mantles crumble into grus leaving only the inselbergs that form the spectacular prominences at Hidden Valley, Cap

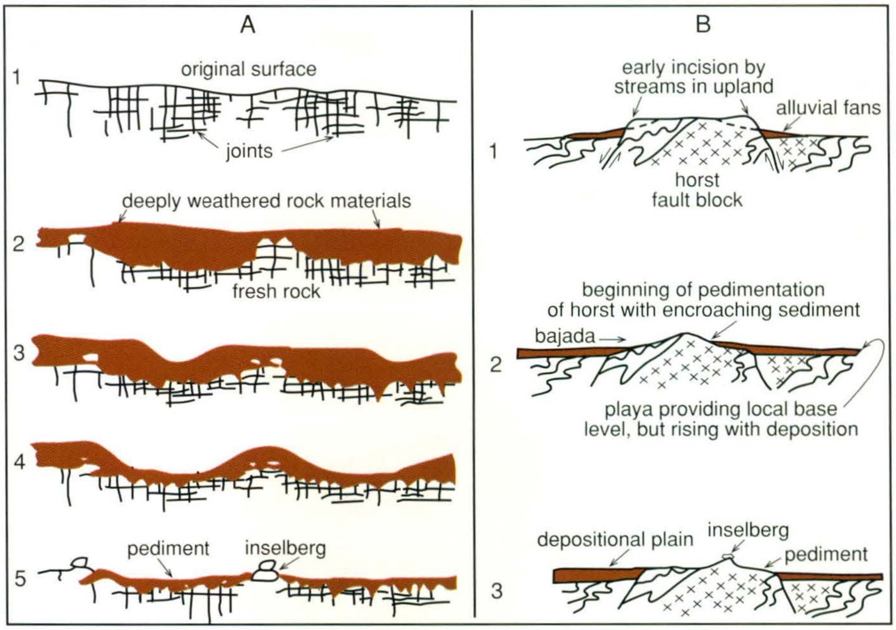
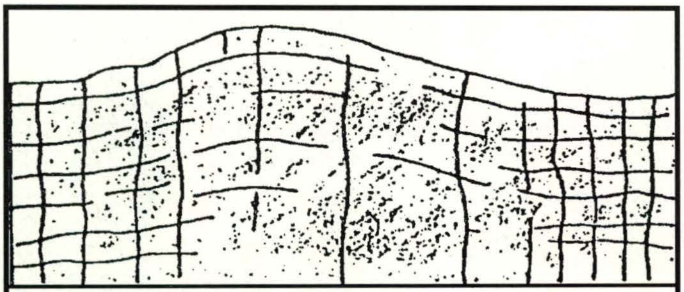
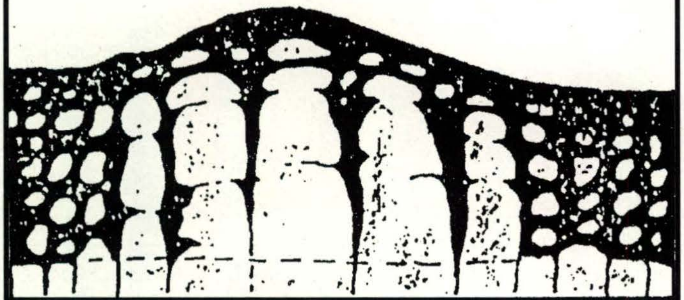


Figure 3. Two hypotheses of pediment and inselberg development. A. Pediment and inselberg development in Uganda (after Ollier, 1975): 1) Subsurface jointing in the original substrate. (2-4) Deep and complete weathering of the rock with closely spaced joints, but unconsumed rectanglar blocks in regions of widely spaced joints. 5) Removal of weathered rock leaves pediments and inselberg remnants. B. Pediment and inselberg development in the southwestern United States resulting from a combination of deep weathering of horst upland, stream erosion, and rising base levels in the adjacent down-faulted basins. *After Garner, 1974; Bradshaw and others, 1978).*

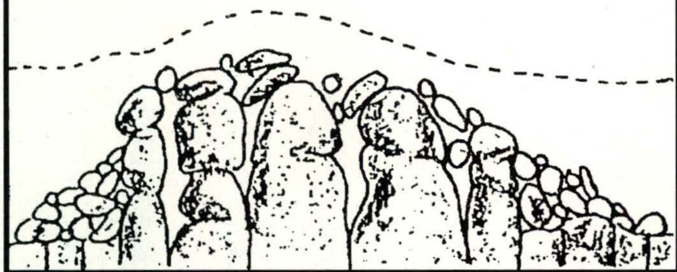
Photo 11. Boulder mantled slopes along the road between the town of Joshua Tree and Hidden Valley. *Photo by D.D. Trent.*



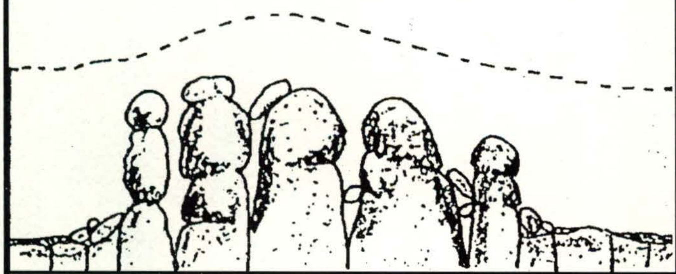
Vertical section through granitic rocks with a varied spacing of joints some 20 million years ago.



During the Pliocene, after a period of sub-humid climate and decomposition of the rock by ground water that percolated downward along joints to the water table. Decomposed rock is shown in black.



Boulder-mantled slopes developed in the past few tens of thousands of years of the Pleistocene Epoch by the removal of the decomposed rock under arid conditions. Present-day examples: along the Fortynine Palms Oasis trail and along the highway between the town of Joshua Tree and Hidden Valley campground.



The present. In higher elevations with longer exposure to conditions of arid weathering, the boulder mantle has been largely decomposed leaving steep-sided bold outcrops rising abruptly above the surrounding surface. A thin veneer of grus covers the horizontal surface. Examples are at Hidden Valley, Caprock, Ryan campground and Jumbo Rocks.

Figure 4. Diagram illustrating the formation of inselbergs at Joshua Tree National Park. *From Trent, 1984.*

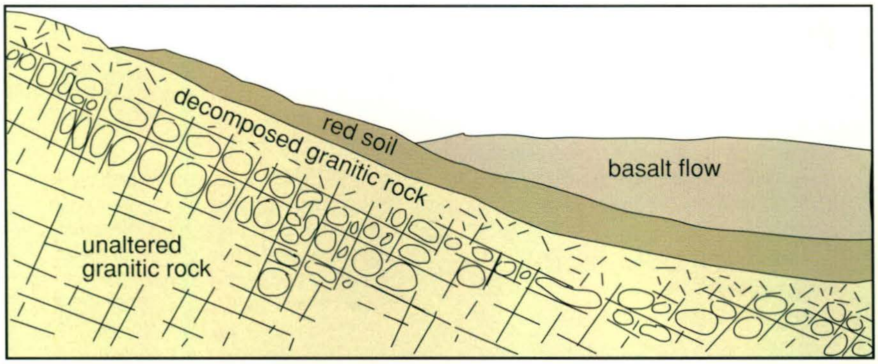
Rock, Jumbo Rocks, and along Geology Tour Road (Photo 8). The presence of these masses of undecomposed rock is evidence that the renewal of boulder mantles by present-day weathering processes is not taking place. Thus, the granitic landscape of Joshua Tree National Park, and elsewhere in the Mojave Desert, may be thought of as a fossil (relict) landscape that has evolved over a time span of several million years.

Evidence for this interpretation comes from sites in the Mojave Desert such as at Old Woman Springs, about 43 miles northwest of Twentynine Palms, where reddish iron oxide and calcite-rich soils, and corestones in a grus matrix have been preserved beneath remnants of a basalt lava flow. The lava flow at Old Woman Springs yields a radiometric age of 8 million years. Similar soils are forming today but in warm regions under the cover of heavy brush where the average rainfall exceeds 10 inches annually. Continuity between these relict soils, corestones, and grus beneath the basalt remnants, and the present-day boulder-mantled slopes in the park, establishes the boulder mantles as features inherited from a time of deep subsurface chemical weathering in the late Tertiary Period (Figure 5).

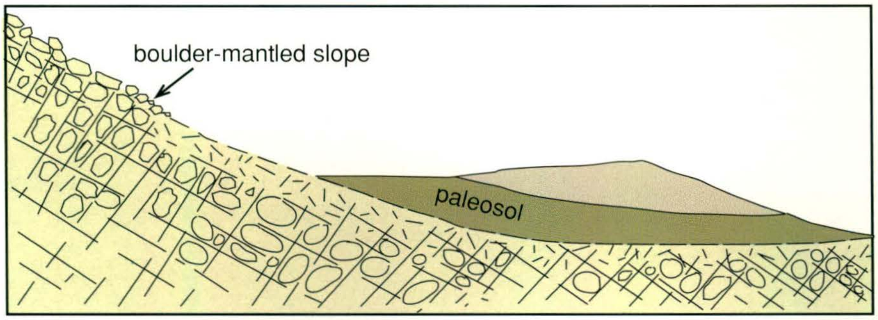
The Final Polish

Nearly all of the rock surfaces in the region of the park show some degree of desert varnish, a thin patina of insoluble clay, plus iron and manganese oxides. In some cases the surface impregnation of varnish is deep enough into the partially decomposed rock that it binds the material together and produces a dark-brown, metallic-looking rind called "case hardening." The Proterozoic gneiss and the monzogranite cropping out at Indian Cove and along the Fortynine Palms Oasis Trail reveal especially good examples of desert varnish.

Varnish is not unique to the desert, but it is best revealed there. Varnish forms today wherever water seeps into rock surfaces. In humid regions, it forms in tunnels and along railroad cuts; in the southwest, it forms where there are seeps along canyon walls. Apparently water is needed to transport the iron and manganese onto rock surfaces. The principal hypotheses for the origin of desert varnish are 1) a microbial origin in which bacteria concentrate iron and manganese oxides, and 2) an inorganic origin in which clay and iron and manganese oxides that are derived from airborne dust and other sources form thin layers on rock surfaces. Regardless of the mechanism of formation, the varnish formed long ago when the climate was different from that of today. Abundant archeological evidence from the Old World and the southwestern United States (Photo 12) indicates that varnish on today's dry surfaces must have been deposited more than 2,000 years ago. Examination of the pyramids and other stone mountains in Egypt indicates that there has been essentially no deposition of desert varnish for the last 2,000 years, some deposition in the last 5,000 years, but considerable deposition on even older stoneworks.



A. Immediately after the Pliocene episode of volcanism about 8 million years ago.



B. Present conditions showing the paleosol (ancient soil) protected from erosion by the remnant of the 8 million-year-old basalt flow and the boulder-mantled slope of corestones that formed beneath the ancient soil.

Figure 5. Diagrammatic sketch of geologic relationships at Old Woman Springs. *After Oberlander, 1972.*

Photo 12. Petroglyphs in desert varnish. *Photo courtesy of National Park Services.*

D.D. "Dee" Trent

Now semi-retired, Dee taught geology for 28 years at Citrus Community College in Glendora, California. Along the way he worked with the National Park Service, earned a Ph.D. at the University of Arizona, did field research on glaciers in Alaska and California, and mapped in the deserts of California and Arizona. He is co-author of *Geology and the Environment*, a college textbook; writes a regular column "Have You Read...?" in the *Journal of Geoscience Education*; and appears in the PBS telecourse, *The Earth Revealed.*

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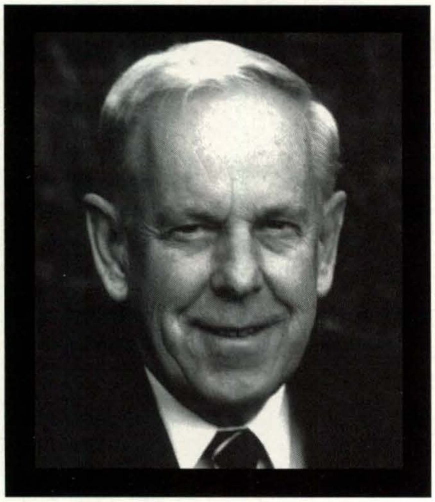
CLARENCE A. HALL IS AWARDED 1998 DIBBLEE MEDAL



Clarence A. Hall

Clarence A. Hall, professor and dean emeritus at the University of California, Los Angeles, has received the 1998 Dibblee Medal for 1998.

Hall produced more than a dozen quadrangle maps in the west central Coast Ranges and the White-Inyo Mountains of California. He also mapped along the North Pyrenean Fault in southern France. Hall's careful mapping and synthesis of complex country in coastal California from the Monterey Bay region to the Transverse Ranges resulted in landmark papers supporting large-scale strike slip on some of California's major faults and enabled identification of the southern California allochthon.

The Dibblee Medal honors the extraordinary geologic mapping achievements of Tom Dibblee, and underscores the importance of geologic mapping to help solve complex geological problems.

For more information about the Thomas W. Dibblee Geologic Foundation, visit the web site at http://dibblee.geol.ucsb.edu/

Dorothy L. Stout
Publicist, Dibblee Foundation

Mines in Joshua Tree National Park

D.D. TRENT, Professor Emeritus, Citrus College, Glendora, California

The remains of the Lost Horse Mine and the restored ore bin and 10-stamp mill. *Photo by D.D. Trent.*

Gold and silver mines are an integral part of the history of Joshua Tree National Park. The most recent count of abandoned mining sites within the park boundaries is 288, this includes 747 mine openings (Chris Holbeck, written communication, 1998, NPS). These are mainly in the Hexie and Pinto Mountains. In the Hexie Mountains immediately outside the Park, are two additional mining districts with numerous abandoned mines. Mining activity began in the region in the 1870s, and peaked in the 1920s and 1930s. The ore produced by the many mines came mainly from gold-bearing quartz veins that had intruded the granitic rocks and Proterozoic gneiss (Tucker and Sampson, 1945).

Of all the gold mining ventures in the region, the Lost Horse Mine was the most successful. Minimum production from the mine is estimated at 10,500 ounces of gold and 16,000 ounces of silver (Fife and Fife, 1982); in 1998 the value would be about $3 million. Remains of the Lost Horse Mine and its restored 10-stamp mill are accessible by an easy 2-mile hike from a trail head beginning in the south end of Lost Horse Valley. In 1966 the National Park Service acquired the mine and rebuilt much of the stamp mill and associated works (Photo).

The Lost Horse Mine was discovered in 1893 by four men, George Lang, John Lang, Ed Holland and James Fife. Development began early in 1894 when rich ore was hand cobbed from rich ore-shoots on the Lost Horse vein. Rich outcroppings and float of this gold ore were also found, some of this rich ore was sold as "jewelry gold" or specimen gold (Fife and Fife, 1982). The high-grade milling ore was sent to the small mill at Pinyon Wells, southwest of Pleasant Valley in Joshua Tree National Park. The richest known specimen of float found near the mine was picked up by Jim Fife. It was a mass of gold the size of a man's fist; the grade was estimated to be 4,000 ounces per ton (Fife and Fife, 1982). Pieces of this gold-quartz nugget are still in the family. Some of the purest portions of this nugget were carved out and made into a wedding band for Jim Fife's wife (Fife and Fife, 1982).

Sites of other mining activity in the park may be observed by hiking the Winona Mill trail that starts at loop A in the campground at Cottonwood Spring. One half mile along the trail are the remains of the Winona (or Cottonwood Spring) Mill. The concrete foundations that remain supported the mill's jaw crusher, ball mill, classifier, concentrator, and flotation tanks. The mill was here because of an assured supply of water, this being one of only two springs between Mecca and Dale; water is a critical element in milling ore. The concentrate from this mill was produced from the ore of the Mastodon Mine and from some of the smaller mines in the Hexie Mountains (Moore, date unknown).

Along the trail for another mile is the site of the Mastodon Mine. The mine was active from 1919 to 1932. Little of the mine remains today, but the reddish-brown, iron oxide-stained quartz vein, the inclined shaft, a few timbers and fragments of mining machinery clearly mark the site.

About one-half mile south of Cottonwood Spring, along Cottonwood Canyon, a trail leads to the site of Moorton's Mill. A five-stamp mill was built at this site by "Cactus" Slim Moorton, a prospector who frequented the area in the 1930s. His operation was abandoned in 1939 and little remains of his cabin and mill (Moore, date unknown).

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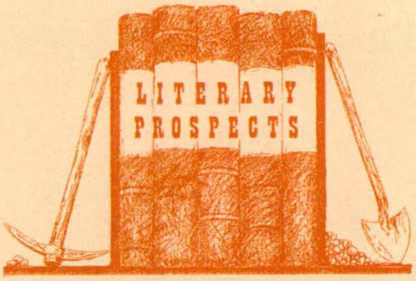


Death Valley and Owens Valley

GEOLOGY UNDERFOOT IN DEATH VALLEY AND OWENS VALLEY. By Robert P. Sharp and Allen F. Glazner. 1997. Mountain Press Publishing Company, P.O. Box 2399, Missoula, MT 59806. (800) 234-5308. 319 p. $16.00. Paper cover. ISBN 0-87842-362-1

The arid, windblown climate of Death Valley and Owens Valley has left the landscape nearly barren. The rocks that would normally be hidden beneath soil and vegetation have been exposed on a grand scale, revealing the results of nearly every type of geologic and geomorphic process. To study these earth's processes, geologists, students, and organizations come to the area from around the world.

This book describes 30 geologic features, processes, or events that have been revealed in the rock record of Death Valley and Owens Valley. A map and a narrative description of how to get to each selected location is provided at the beginning of each chapter. In addition, black and white photographs provide a preview of some of the more interesting features to look for. Also, a bibliography is provided at the back of the book that lists additional readings for each of the topics covered.

Exciting stories of California's geologic history are told through the depiction of catastrophic events such as the creation of gigantic volcanic craters, as well as the great Lone Pine earthquake of 1872, and the climactic eruption of the Long Valley Caldera. All of these events give insight into the sometime violent nature of earth's processes.

In addition to the many and varied geologic features including fault scarps, alluvial fans, welded tuff beds, and columnar jointing, the authors cover other areas of interest such as the geomorphology of the Mojave River and the Sailing Stones that move across Racetrack Playa.

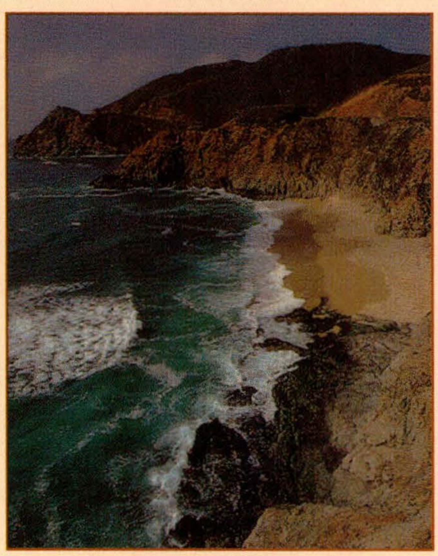
As well as being an interesting and well written description of the geology of Death Valley and Owens Valley, this book could serve as an introduction to geology for the non-geologist. Nontechnical language is used to describe geologic terms. A glossary is also included. *Review by Mike Morgan.*

Trail Guides

PENINSULA TRAILS, OUTDOOR ADVENTURES ON THE SAN FRANCISCO PENINSULA. Third edition. By Jean Rusmore, Frances Spangle and Betsy Crowder. 1997. Wilderness Press, 2440 Bancroft Way, Berkeley, CA 94704. (800) 443-7227. 374 p. Black and white photos. $14.95. Paper cover. ISBN 0-89997-197-0.

The hiking trails in this book were made possible by the efforts of civic-minded residents of the San Francisco peninsula, along with governmental and private agencies. The goal was to have interconnected parklands permanently protected in their natural state and available to the public for outdoor recreation.

Imagine yourself as a member of Gaspar de Portolá's expedition in 1769. Coming over a ridge you find "a great estuary...extending many leagues inland." This discovery site where Portolá's group first saw the body of water that is San Francisco Bay is now part of Sweeney Ridge Trail, one of San Mateo County's hiking routes. Or perhaps you might want to wander, like the Ohlone Indians, through a sunny meadow fringed with bay trees. If this appeals to you, try the Sawyer Camp Trail.



Gray Whale Cove, San Mateo County.

Over a 60,000 acre area, 151 hikes will keep you enthralled with the flora, fauna, scenic views of the Pacific Ocean, ridges and mountains of the Bay Area and birdseye glimpses of cities and communities. Every hiking trail seems to have something intriguing to offer. Look through this guidebook, select your kind of special place, and take off. *Review by Mary C. Woods.*

MARBLE MOUNTAIN WILDERNESS. By David Green and Greg Ingold. Second edition. 1996. Wilderness Press, 2440 Bancroft Way, Berkeley, CA 94704. (800) 443-7227. 176 p. $15.95. Paper cover. ISBN 0-89997-183-0.

The Marble Mountain Wilderness, set aside in 1953, grew from the Marble Mountain Primitive Area established in April 1931. The *Marbles* is the fourth largest federal wilderness in California. This area is one of the ranges of the Klamath Mountains, along with the Trinity Alps and Siskiyou Mountains.

After many millions of years in the making, the mountains were glaciated during Pleistocene time and the cirques, tarns and moraines that remain as indicators are numerous and can be seen along many of the trails. The natural history section of the trail guide includes geological, botanical and zoological summaries.

Twenty-eight trail hikes are sketched in the book, but the authors leave room for you to explore and discover on your own. The topographic map included with the guide is a definite plus because it covers the area of sixteen 7.5' U.S. Geological Survey quadrangles. The U.S. Forest Service map of the Wilderness area was also used to update information. *Review by Mary C. Woods.*

POINT REYES, A GUIDE TO THE TRAILS, ROADS, BEACHES, CAMPGROUNDS, AND LAKES OF POINT REYES NATIONAL SEASHORE. Third edition. By Dorothy L. Whitnah. 1997. Wilderness Press, 2440 Bancroft Way, Berkeley, CA 94704. (800) 443-7227. 108 p. $11.95. Paper cover. ISBN 0-89997-173-3.

This Point Reyes guidebook is for hikers, backpackers, bicyclists, equestrians, picnickers and other outdoor enthusiasts. Point Reyes National Seashore offers outdoor explorers countless opportunities, from short easy strolls to strenuous all-day hikes. If you want to stay even longer, there are four backpacking camps on the peninsula. Every public trail on the peninsula is described, giving accurate information on how to get to the trailhead, available facilities, regulations, and what you will see along the way. In addition, the author introduces you to the area's background in very entertaining and readable sections on history, geology, topography, climate, birds and animals.

The guidebook introduces you to the incredible variety of wildlife, both native and imported, that lives on this peninsula. Deer from Europe and Asia, tule elk resettled from southern California, and elephant seals, once almost extinct, are included. This area is one of the best places to watch whales during their yearly migration along the California coast. It is also a living laboratory where you can see ecosystem regeneration in progress since the 1995 fires, which devastated parts of the peninsula.

HOT SHOWERS, SOFT BEDS, AND DAYHIKES IN THE SIERRA, Walks and Strolls near Lodgings. By Kathy Morey. 1996. Wilderness Press, 2440 Bancroft Way, Berkeley, CA 94704. (800) 443-7227. 360 p. $16.95. Paper cover. ISBN 0-89997-163-6.

This hiking guide will have special appeal to those who love mountain trail hikes, but groan over carrying a backpack uphill for miles, dread sleeping on a pine needle mattress and dislike freeze-dried food. The author lists towns, villages, and resorts where lodging can be found from the north end of Lake Tahoe to the south of Mt. Whitney. She provides the address, phone number, location, elevation, and rate and policy concerning pets for accommodations in the hiking areas. You can use this information about the 120 day hike routes to plan your segment of hiking in the 430-mile long Sierra Nevada.

Trail descriptions include the granitic basins/terranes, waterfalls, glacial lakes, volcanic mudflows, basalt columns, and rockfalls—all products of geologic processes. One of five appendices lists "best" hikes for scenic views, wildflowers, lakes, meadows and forests.

Directions to trailheads, trails, roads and lodging information are thorough. This guide book provides useful information for the hiking traveler.
Review by Mary C. Woods.

Volcanoes

VOLCANOES: CRUCIBLES OF CHANGE. By Richard V. Fisher, Grant Heiken and Jeffrey B. Hulen. 1997. California/Princeton Fulfillment Services, 1445 Lower Ferry Road, Ewing, NJ 08618. (800) 777-4726. 317 p. Black and white photos. $35.00, Hard cover. ISBN 0-691-01213-X

This is a well-written book about volcanoes, related phenomena and issues for students or anyone with an interest in volcanoes—even professionals. The text is illuminated by well-chosen photographs from many sources and by many fine illustrations. The chapters end with a short list of references.

Fisher and Heiken start with an account of the eruptions of Mount Pelée on May 8, 1902 and Mount St. Helens on May 18, 1980. They discuss how people reacted and coped with the eruptions. They also comment on the actions of authorities in charge of managing both situations. The authors continue with an introduction to the fundamentals of volcanology, defining terms and concepts in clear, descriptive words and pictures. They discuss how and why volcanoes erupt, the types of volcanoes and their eruptions, and the eruptive reactions of water at or near the earth's surface with the ascending magma (molten rock charged with vapors by the confining pressure of the overlying and surrounding rocks). In the second part, Fisher and Heiken list, define, and describe the various volcanic hazards associated with eruptions. In the third part the authors tell several of the myths, ancient and modern, about volcanoes. Then as an uplifting counterpoint to the negative aspects of volcanic eruptions, they discuss the numerous advantages of volcanic activity. In the fourth part, the volcanologists discuss living with volcanoes, their hazards, and how these hazards may be lessened. There is also a short list of recent volcanologists who gave their lives to learn more about volcanoes and volcanic eruptions. As a bonus, the appendix describes locations of volcanoes one can visit and the precautions to heed when visiting active volcanoes.

Fisher is a professor emeritus of geology at the University of California, Santa Cruz. Heiken is a volcanologist at the Los Alamos National Laboratory and teaches volcanology at the University of New Mexico.
Review by Dale Stickney.

A herd of elk crosses forest devastated by the May 18, 1980 eruption of Mount St. Helens.

Teacher Feature

GEOSCIENCE CAREERS

WHAT DO GEOSCIENTISTS DO?

Geoscientists gather and interpret data about the earth and other planets. They use their knowledge to increase our understanding of earth processes and resources to improve the quality of human life. Their work and career paths vary widely because the geosciences are broad and diverse. The National Science Foundation recognizes geology, geophysics, hydrology, oceanography, marine science, atmospheric science, planetary science, meteorology, environmental science, and soil science as the major geoscience disciplines. The following list gives a glimpse of what geoscientists do in these disciplines and a variety of subdisciplines.

WHERE DO GEOSCIENTISTS WORK?

Geoscientists may be found sampling the deep ocean floor or examining rock specimens from the Moon or Mars. But the work of most geoscientists is more "down to Earth." They work as explorers for new mineral and hydrocarbon resources, consultants on engineering and environmental problems, researchers, teachers, writers, editors, and museum curators, as well as other challenging positions. They often divide their time among work in the field, the laboratory, and the office.

Field work usually consists of making observations, exploring the subsurface by drilling or using geophysical tools, collecting samples, and making measurements that will be analyzed in the laboratory. For example, rock samples may be x-rayed, studied under an electron microscope, and analyzed to determine physical and chemical properties. Geoscientists may also conduct experiments or design computer models to test theories about geologic phenomena and processes.

In the office, they integrate field and laboratory data and prepare reports and presentations that include maps and diagrams that illustrate the results of their studies. Such maps may pinpoint the possible occurrence of ores, coal, oil, natural gas, and water resources, or indicate subsurface conditions or hazards that might affect construction sites or land use.

The employment outlook in the geosciences—as in any profession—varies with the economic climate of the country. The long-range outlook is good at this time. Dwindling energy, mineral and water resources along with increasing concerns about the environment and natural hazards present new challenges to geoscientists.

INTERESTED???

A strong interest in science and a good education are the most important elements in becoming a geoscientist. The geosciences draw on biology, chemistry, mathematics, physics, and engineering. High school courses related to these subjects plus a geology earth science course, or an integrated science curriculum, will help prepare you for college. Also, get a solid grounding in English, because geoscientists need to be able to write and speak clearly. In choosing a college or university, look at the course listings for departments of geology, geoscience, earth-systems science, or environmental science to identify the geoscience programs that best match your interests. As in any profession, the applicants with the best qualifications get the best jobs. Most professional positions in the geosciences require a master's degree. A Ph.D. is needed for advancement in college teaching and in most high-level research positions.

Atmospheric scientists study weather processes; the global dynamics of climate; solar radiation and its effects; and the role of atmospheric chemistry in ozone depletion, climate change and pollution.

Economic geologists explore for and develop metallic and nonmetallic resources; they study mineral deposits and find environmentally safe ways to dispose of waste materials from mining activities.

Engineering geologists apply geological data, techniques, and principles to the study of rock and soil surficial materials and ground water; they investigate geologic factors that affect structures such as bridges, buildings, airports and dams.

Environmental geologists study the interaction between the geosphere, hydrosphere, atmosphere, biosphere, and human activities. They work to solve problems associated with pollution, waste management, urbanization, and natural hazards, such as flooding and erosion.

Geochemists use physical and inorganic chemistry to investigate the nature and distribution of major and trace elements in ground water and earth materials; they use organic chemistry to study the composition of fossil fuel (coal, oil, and gas) deposits.

Geochronologists use the rates of decay of certain radioactive elements in rocks to determine their age and the time sequence of events in the history of the earth.

Geologists study the materials, processes, products, physical nature and history of the earth.

Geomorphologists study earth's landforms and landscapes in relation to the geologic and climatic processes and human activities that form them.

Geophysicists apply the principles of physics to studies of the earth's interior and investigate earth's magnetic, electric and gravitational fields.

Glacial geologists study the physical properties and movement of glaciers and ice sheets.

Hydrogeologists study the occurrence, movement, abundance, distribution and quality of subsurface waters and related geologic aspects of surface waters.

Hydrologists are concerned with water from the moment of precipitation until it evaporates into the atmosphere or is discharged into the ocean; for example, they study river systems to predict the impacts of flooding.

Marine geologists investigate the ocean-floor and ocean-continent boundaries; they study ocean basins, continental shelves, and the coastal environments on continental borders.

Meteorologists study earth's atmosphere, including its movements and other phenomena, especially as they relate to weather forecasting.

Mineralogists study mineral formation, composition, and properties.

Oceanographers investigate the physical, chemical, biological, and geologic dynamics of oceans.

Paleoecologists study the function and distribution of ancient organisms and their relationships to the environment.

Paleontologists study fossils to understand past life forms and their changes through time and to reconstruct past environments.

Petroleum geologists are involved in exploration for and production of oil and natural-gas resources.

Petrologists determine the origin and natural history of rocks by analyzing mineral composition and grain relationships.

Planetary geologists study planets and their moons in order to understand the evolution of the solar system.

Sedimentologists study the nature, origin, distribution, and alteration of sediments, such as sand, silt, and mud. Oil, gas, coal, and many mineral deposits occur in such sediments.

Seismologists study earthquakes and analyze the behavior of earthquake waves to interpret the structure of the Earth.

Soil scientists study the role of soils in plant growth, their impact on construction and waste disposal, and ways to restore and use land resources.

Stratigraphers investigate the time and space relationships of rocks, on a local, regional, and global scale throughout geologic time—especially the fossils and mineral content of layered rocks.

Structural geologists analyze rocks by studying deformation, fracturing, and folding of the Earth's crust.

Volcanologists investigate volcanoes and volcanic phenomena to understand these natural hazards and predict eruptions.

Teacher Feature continued...

For more information about geoscience careers, visit these web sites:

American Institute of Professional Geologists
http://www.nbmg.unr.edu/aipg/

Association for Women Geoscientists
http://www.awg.org/

Association of American State Geologists
http://www.kgs.ukans.edu/AASG/AASG.html

Association of Earth Science Editors
http:www-odp.tamu.edu/publications/AESE/index.html

Association of Engineering Geologists
http://aegweb.org/

Geological Society of America
http://www.geosociety.org/

Geoscience Information Society
http://www.lib.berkeley.edu/GIS

Mineralogical Society of America
http://geology.smith.edu/msa/msa.html

National Association of Geoscience Teachers
http://oldsci.eiu.edu/geology/nagt/nagt.html

Paleontological Society
http://www.uic.edu/orgs/paleo/homepage.html

Seismological Society of America
http://www.seismosoc.org/ssa/

Society of Economic Geologists
http://www.mines.utah.edu/~wmgg/SEG.html

Society of Exploration Geophysicists
http://www.seg.org/

Society of Independent Professional Earth Scientists
http://www.sipes.org/

Society of Vertebrate Paleontology
http://eteweb.lscf.ucsb.edu/svp/

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FIRST ANNUAL EARTH SCIENCE WEEK

October 11-17

The American Geological Institute (AGI) has established Earth Science Week to raise public awareness and understanding of the earth sciences and their importance to our daily lives.

"The goal for Earth Science Week," says AGI President Susan Landon, "is to have every geoscientist in the country do something in their community to promote the earth sciences."

The celebration, which will be held annually during the second full week in October, will give geoscientists and organizations the opportunity to:

- Help students discover earth sciences
- Highlight how the study of earth sciences contributes to society
- Encourage stewardship of the earth
- Develop a mechanism for geoscientists to share their knowledge and enthusiasm about the earth.

If you'd like more information about Earth Science Week, contact Julie Jackson, Earth Science Week Coordinator, at (703) 379-2480 or jjackson@agiweb.org

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Join us in celebrating California's Gold Discovery to Statehood Sesquicentennial by visiting the DMG Library during our Open House on September 23. We will exhibit minerals, rare books and historical photographs on gold mining. Our newly released CD-ROM *California Gold Mines: A Sesquicentennial Photograph Collection* will be demonstrated. Also, complimentary copies of DMG Note 12, *Gold*, Note 24, *Tips for Gold Hunters*, and the U.S. Geological Survey's brochure *Gold* will be given to Open House guests. Hope to see you there!

801 K Street, 14th floor
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For more information about the DMG Library Open House, call (916) 327-1850.

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October 17 and 18. Whittier. Whittier Gem & Mineral Society. "Treasures of Rock-hounding." Whittier Masonic Temple, 7604 Greenleaf Avenue. Contact Marcia Grady, 365 E. College Street, Covina, CA 91723-2202.

The San Diego Association of Geologists (SDAG) Annual Field Trip: Geothermal Resources and Geological Features of the Imperial and Mexicali Valleys.

Time: October 9-12, 1998.

Place: Imperial Valley, California and Mexicali Valley, Mexico.

Agenda: Tour the Cerro Prieto geothermal plant and field in Mexico, observe bubbling mudpots, the Cerro Prieto and Imperial Valley fault traces, a recently erupted geyser, Volcano Lake and Cerro Prieto Volcano. For more information call Lowell Lindsay at (619) 258-4905 extension 208. Fax (619) 258-4916 or e-mail: sunbeltinc@usa.net

Or visit the SDAG website: http://www.znet.com/~sdag

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_____ **JULY/AUGUST 1997:** Assessing Earthquake Ground Shaking Hazard in California; California's Non-Fuel Mineral Production—1996; California's Mother Lode Highway—Mokelumne Hill to Placerville; Mountain Building.

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_____ **NOVEMBER/DECEMBER 1997:** Radon Mapping—Santa Barbara and Ventura Counties; California's Mother Lode Highway—North San Juan to Sattley; Teacher Feature—Geology of Donner Lake; 1997 California Mineral Education Conference; *The Elephant As They Saw It*; Release of New Preliminary Seismic Hazard Zone Maps; Index to Volume 50—1997.

_____ **JANUARY/FEBRUARY 1998:** The Discovery of Gold in California; gold GOLD GOLD!; Gold in the California Desert—Past, Present, and Future; Teacher Feature—Gold Dust Memories; The Varied Uses of Gold; Dibblee Medal Citation; Sesquicentennial Edition of the Map of California Historic Gold Mines.

_____ **MARCH/APRIL:** New Geologic Maps Lend Support to Better Building Design in California earthquake Country; Reducing Future Earthquake Losses in California; Teacher Feature—April is Earthquake Preparedness Month; A Slice of Earth—Anatomy of an Earthquake; Release of New Official Seismic Hazard Zone Maps.

_____ **MAY/JUNE 1998:** Geology and Slope Stability Along Highway 50; Real-Time Monitoring of Active Landslides Along Highway 50, El Dorado County; 1997 California Mining Review; Teacher Feature—Geologic Time.

_____ **JULY/AUGUST 1998:** Short History of Man and Gold; Scenes from the California Gold Rush; Division of Mines and Geology—Open House; Division of Mines and Geology Library, Past, Present and Future; California Gold Mines Photograph Collection; Teacher Feature—Landforms; Release of New Official Seismic Hazard Zone Maps.

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DMG Releases New and Revised Official Maps of Earthquake Fault Zones of May 1, 1998

SUPPLEMENT NO. 1 TO SPECIAL PUBLICATION 42—1997 EDITION

Official Maps of new and revised Earthquake Fault Zones (see map) are issued pursuant to the Alquist-Priolo Earthquake Fault Zoning Act. Revised maps supersede earlier Official Maps.

The maps may be reviewed at the offices of the affected city and counties, and the DMG offices listed below. They are not available for purchase from DMG. They may be purchased from:

BPS Reprographic Services
149 Second Street
San Francisco, CA 94105
(415) 512-6550.

Official Maps issued on May 1, 1998. (Numbers keyed to index map.)

- *1. Shelter Cove
- 2. Santa Paula
- 3. Camarillo

* Revised zone map.

City and counties affected by new or revised Earthquake Fault Zones shown on Official Maps of May 1, 1998.

City	County
Camarillo	Humboldt Ventura

For information on Official Maps of Earthquake Fault Zones previously issued, and for provisions of the Alquist-Priolo Earthquake Fault Zoning Act, see the 1997 edition of Special Publication 42 *Fault-rupture Hazard Zones in California*. SP42 is $5.00; order from the DMG offices listed below or use the order form on page 23.

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