ECONOMIC MINERAL DEPOSITS IN THE COAST RANGES

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Mercury mining in the Coast Ranges is the counterpart of gold mining in the Sierra Nevada. The histories of exploration for the two metals run parallel courses in the early mining development of the State, partly because the possession and use of mercury was essential for the recovery of gold by amalgamation. Actually the mining of mercury began in the Coast Ranges in 1845, prior to the discovery of gold in the Sierra Nevada, when "Indian Paint Rock" at New Almaden was identified as cinnabar, the chief ore of mercury. Subsequent successful developments encouraged prospecting both to the north and south and many more mercury deposits were discovered, as were also deposits of other metallic minerals, principally chromite, manganese oxide, and copper sulfides.

Later, as the population increased, demands for nonmetallic commodities, such as clay for brick, cement rock, lime, limestone, pumice, building stone, sand, and gravel, and other materials of construction developed, leading to the opening of pits and quarries in suitable formations close to the population centers. Also, as industry moved westward nonmetallic minerals to meet the needs for industrial products and chemical processes were found. This led to the exploitation of asbestos, barite, bromine, carbon dioxide, diatomite, dolomite, feldspar, gypsite, limestone, magnesite, perlite, pyrite, salt, and sulfur. Source areas of fuel and power were explored and developed, first resulting in the production of bituminous rock and coal in the late 1800's, and more recently in the production of petroleum, natural gas, and natural steam. The search for deposits of minerals of value is still in progress, and new discoveries are still being made.

The economic deposits of the Coast Ranges provided at least 43 separate mineral commodities to industry during the period 1850–1965, and the cumulative value of all these mineral commodities is estimated at $2,500,000,000. This figure includes not only the better known products but also many minor products, notably antimony ore, black sand, borax, gemstones, gold, graphite, silver, and uranium minerals. Additional commodities which occur in the province and have some potential for future production are nickel, olivine, and phosphate rock. The relative value of the individual mineral products is shown in Table 1.

Table 1. *Estimated value of minerals produced from California Coast Ranges, 1850–1965* [1]

Largest production (over $1,000,000,000)	Large production (over $100,000,000)	Moderate production ($1,000,000 to $100,000,000)	Small production ($100,000 to $1,000,000)	Little or no production (under $100,000)
Petroleum	Cement	Magnesia (sea water)	Perlite	Barite
	Sand and gravel	Limestone	Pumice	Antimony
	Mercury	Lime	Gypsite	Platinum
	Natural gas	Brick	Carbon dioxide gas	Graphite
	Rock products	Clay and shale	Natural steam	Black sand
	Salt	Coal	Gemstones	Uranium
		Chromite	Sulfur	Zinc
		Dolomite	Borax	Nickel
		Bromine		Tungsten
		Sand		Phosphate
		Feldspar		Sodium sulfate
		Mineral water		
		Magnesite		
		Manganese ore		
		Asbestos		
		Bituminous rock		
		Pyrites		
		Diatomite		
		Copper		
		Silver-gold		
		Sandstone (dimension)		

[1] Annual State production reports group commodity values where necessary to conceal confidential data of individual producers; hence, only approximate cumulative values are available.

Table 2. *Geologic environment of economic mineral deposits in the Coast Ranges.*

Age of host rock	Geologic Occurrence and host formation	Mineral deposit
Quaternary (Recent)	Sea water of San Francisco, San Pablo, and Monterey Bays.	*Salt* (sodium chloride) produced by solar evaporation of ponded sea water.
		Bromine recovered as a byproduct from salt-works bittern (only on San Francisco Bay).
		Magnesium compounds produced from sea water and bitterns by treatment with calcined dolomite. Principal plants at Newark and South San Francisco on San Francisco Bay and at Moss Landing on Monterey Bay.
	Mud and oyster shells in lenses on floor of San Francisco Bay.	*Cement* produced at tidewater near Redwood City from mud and shells recovered by floating suction dredges.
	Mud and waters of Borax playa lake southeast of Clear Lake.	*Borax and soda*, borax crystals recovered from water by pan evaporation; some soda potential.
	Surficial deposits from hot calcareous springs in Contra Costa and Solano Counties.	*Travertine* supplied cement plants for many years.
	Quartz veins in volcanic rocks.	*Silver and gold.* Production from two mines near Calistoga totaled over $1,000,000.
	Basalt, at Sulphur Bank hydrothermal area bordering Clear Lake.	*Sulfur and mercury.* In thermal area basalt above water table leached of all but silica and sulfur deposited; below water table clay alteration and formation of major mercury deposit.
	Surficial deposit in arid eastern foothills of province in Fresno County.	*Marl.* A "caliche" formed by evaporation of carbonate-bearing ground water.
Quaternary (Pleistocene to Recent)	Stream beds and terraces; river bars and banks; alluvial cones and fans.	*Sand and gravel* in the unconsolidated sediments close to metropolitan centers and major construction projects. Principal deposits in Livermore Valley, Niles Cone, Russian River, Salinas River, Sisquoc River, and Santa Maria River.
	Beaches and adjoining upland in Del Norte, Humboldt, and Santa Cruz Counties.	*Black sand* containing gold, platinum, and magnetite.
	Beaches and adjoining upland.	*Sand* in beaches and dunes north of Del Monte in Monterey County and at Oceano Beach in San Luis Obispo County.
	Dunes overlying and adjacent to granite basement at Pacific Grove, Monterey County.	*Feldspar and silica*, sand products separated by flotation or magnetic separation.
	Volcanic flows and pyroclastic rocks at the southern end of Clear Lake.	*Crushed stone* and decorative rock. *Pumice and obsidian.*
	Fractures in volcanic rocks in Lake and Napa Counties	*Mineral water*, bottled and sold since 1856.
Quaternary-Tertiary (Plio-Pleistocene)	Irregular, discontinuous lenses of massive sulfide in intrusive-extrusive Leona rhyolite.	*Pyrites*, mined on west flank of Berkeley Hills and used in manufacture of sulfuric acid.
Tertiary (Pliocene)	Large bodies in flows of Sonoma volcanics	*Perlite* in St. Helena area, Napa County, and Santa Rosa, Sonoma County.
	Layers of massive pyroclastic rocks in Sonoma volcanics.	*Pumice* and obsidian in Napa area of Napa County.
	Fresh water deposit interbedded with Sonoma volcanics near Napa.	*Diatomite*, used for pozzolanic properties.
(Lower Pliocene)	Calcareous "reefs" between diatomaceous shale and sandstone in Pancho Rico Formation in Monterey and San Luis Obispo Counties.	*Phosphate rock*, thin but extensive beds recently investigated.
(Miocene)	Fracture filling and replacement of quartz veins and breccia in volcanic rocks.	*Antimony and mercury.* Some mercury production; small antimony production.
(Late Miocene to late Eocene)	Sisquoc, Santa Margarita, upper Monterey and Kreyenhagen Formations.	*Diatomite* deposits are extensive in the southern Coast Ranges; occur in northern Coast Ranges as far north as Point Arena.
(Upper Miocene)	Light-colored friable marine sandstone of the Santa Margarita Formation.	*Sand*, large deposits and plants near Felton, Santa Cruz County.
	Multicolored, fine-grained, limy, siliceous sedimentary rocks of the Monterey Formation.	*Stone*, building stone and flagging.
	Overlying siliceous Monterey shale	*Phosphate rock*, pellets in sand layers over wide area.
(Middle to Lower Miocene)	Steep dipping bed in Temblor Formation	*Coal*, sub-bituminous mined in Stone Canyon, Monterey County.
(Lower Miocene)	Shell deposit in Vaqueros Formation	*Limestone*, mined for sugar refining at Lime Mountain; San Luis Obispo County.
(Upper Eocene)	Zone in Kreyenhagen Formation crops out along flank of Vallecitos syncline, San Benito County.	*Bentonite*, swelling and non-swelling.
	Surficial edges of up-turned gypsiferous beds cropping out in the arid foothills along the eastern border of the province from Merced to Kern Counties.	"*Cap*" *gypsum* or gypsite with thin overburden on the hilltops.
(Middle Eocene)	Steep-dipping beds in Domengine and Tesla Formations.	*Coal*, sub-bituminous mined near Mount Diablo and Corral Hollow.
		Clay and sand, interbedded with coal.

Table 2. *Geologic environment of economic mineral deposits in the Coast Ranges—Continued*

Age of host rock	Geologic Occurrence and host formation	Mineral deposit
Tertiary (some Quaternary and Late Cretaceous)	Many formations of Tertiary age; greatest production, by far, from Miocene and Pliocene rocks. Minor amounts from other Tertiary formations, Pleistocene, and Cretaceous rocks. Traces from late Jurassic formations. Most of the reservoir rock is sandstone but some significant production from fractured shale. Type of structures involved are anticlines, faulted anticlines, and stratigraphic traps.	*Petroleum*, natural gas, greatest cumulative value of all Coast Ranges mineral commodities. Major fields are in the Tertiary marine basins, including Santa Maria, Cuyama, Salinas Valleys. Almost all petroleum of the Coast Ranges province has come from the southern ranges—Salinas Valley and south. Some of the great fields are San Ardo in Monterey County, Santa Maria Valley, and Cuyama and Russell Ranch fields in Santa Barbara County and the Coalinga anticline in Fresno County. A dry gas field near Eureka, Humboldt County.
Late Cretaceous (to Pliocene)	Marine shale and claystone. Numerous large deposits in the Coast Ranges.	Brick, clay products, expansible shale.
Late Cretaceous	Cretaceous sandstone.	*Stone*, dimension sandstone used extensively in construction of buildings at Stanford University, San Jose, and San Francisco during early 1900's.
	Fracture fillings and replacement in fractured Panoche shale and sandstone (and Franciscan sandstone) under New Idria thrust fault.	*Mercury*, the high degree of fracturing in the rocks has favored ore deposition. About 30 percent of California deposits occur in these rocks.
Late Cretaceous to Late Jurassic (Deposits associated with peridotite and serpentine, and serpentine hydrothermally altered to silica-carbonate rock).	Epithermal veins, fracture fillings, and replacement deposits in silica-carbonate rock (a hydrothermal alteration product of serpentine). About 50 percent of California deposits occur in fractured silica-carbonate rocks.	*Mercury*, Coast Ranges have supplied about 85 percent of United States production. Principal districts are New Almaden in Santa Clara County, New Idria in San Benito County, and Mayacmas in Sonoma, Lake, and Napa Counties.
	Recrystallization of fractured, massive serpentine by short-fiber chrysotile.	*Asbestos*, chrysotile, widely distributed throughout Coast Ranges, extensive new deposits being mined (1965) in southeastern San Benito County and adjacent Fresno County.
	Magmatic segregations of chromite in peridotite and peridotite altered to serpentine.	*Chromite*, widely distributed throughout the length of the Coast Ranges. No mining in 1965; greatest production has come from San Luis Obispo, Glenn, Del Norte Counties and Fresno County.
	Fracture fillings and replacement bodies in serpentine.	*Magnesite* formerly mined near common border of Santa Clara and Stanislaus Counties and elsewhere.
	Lateritic remnants of early Tertiary erosion surfaces developed on serpentine and peridotite in Mendocino County.	*Nickel* sulfide minerals of primary origin occur widely in the peridotites and serpentines. During laterization part of the nickel is dissolved and redeposited as garnierite in underlying silica boxwork. Some commercial potential.
	Fault zones in Franciscan rocks and serpentine; source of heat probably Quaternary volcanic rocks.	*Natural steam* produced for power at The Geysers, Sonoma County. *Carbon dioxide gas*, near Hopland. *Mineral Springs*, resorts popular in pre-motoring days.
(Deposits associated with sedimentary or metasedimentary rocks).	Massive lenticular sulfide body in rocks of the Franciscan Formation.	*Copper* from sulfide ores at Island Mountain, southern Trinity County.
	Veins of natrolite in fractured metamorphics included in serpentine.	Gemstone, benitoite, with neptunite and joaquinite.
	Lenses, pods, or veins within or near bodies of serpentine.	Nephrite, jadeite, orbicular jasper.
	Quartz veins in Francisan sandstone.	*Gold*, a number of small mines in Los Burros district of Monterey County.
	Calera Limestone member of Franciscan Formation. Highly fractured fault sliver in San Andreas Fault zone.	*Limestone and cement*. Permanente Cement Co. plant, Santa Clara County, is the largest producer of cement in California.
	Chert members of Franciscan Formation enclose lenses of sedimentary manganese materials later oxidized.	*Manganese* deposits throughout the Coast Ranges. Large percentage of Coast Range production from Ladd-Buckeye mines at junction Alameda, Santa Clara, San Joaquin, and Stanislaus Counties. Belt extends northwestward into Humboldt County.
Pre-Cretaceous rocks of Salinian block.	Roof pendants of highly deformed, metamorphosed marine sedimentary rocks in granite. "Gabilan crystalline Limestone" in Sur Series in Santa Cruz, Gabilan, and Santa Lucia Mountains.	*Limestone and cement*, major cement quarries and plants at Davenport in Santa Cruz County and San Juan Bautista in San Benito County. Limestone quarries near Santa Cruz.
	Replacement deposits of dolomite, cutting across limestone belts in Monterey and San Benito Counties.	*Dolomite* mined from major quarries at Natividad in Monterey County and south of Hollister in San Benito County.
	Replacement deposits in limestone.	*Barite* deposits near Fremont Peak supplied small production. Now in State park.

Table 2. *Geologic environment of economic mineral deposits in the Coast Ranges—Continued*

Age of host rock	Geologic Occurrence and host formation	Mineral deposit
Quaternary to Pre-Cretaceous	In various attitudes from flatlying to steepdipping. Quaternary to Miocene volcanic rocks; Miocene siliceous shale; Franciscan sandstone, limestone, chert, and greenstone; granitic rocks; Sur Series metamorphic rocks.	*Stone*, crushed and broken for use in metropolitan areas of San Francisco Bay and other centers of population.

ENVIRONMENT OF MINERAL DEPOSITS

The geologist exploring for mineral deposits in the Coast Ranges should understand the environment in which they have formed. Some deposits, called syngenetic, formed as part of the rock formation in which they occur, as for example, chromite deposits in ultramafic rock. Other deposits, called epigenetic, formed subsequent to their host rock, as did the quicksilver deposits. Mineral deposits are complex, however, and for the formation of many deposits more than one process is involved. Nevertheless, broad generalizations are warranted, and observations recorded at well-exposed deposits can often be extended successfully to nearby unexplored areas. Armed with a knowledge of origin and environment, the geologist concentrates his search in areas where suitable rock units exist, and thereby enhances his chance of discovery of the desired deposit. Some typical occurrences of mineral deposits in the Coast Ranges province are described below, and these and others are summarized in Table 2.

MAGMATIC SEGREGATIONS OF CHROMITE

Deposits of chromite occur in ultramafic rocks like peridotite, which consists of magnesium-iron silicates, chiefly of olivine and pyroxene. However, because these two minerals are easily altered to serpentine, while chromite remains unaltered, deposits of chromite are generally found in serpentine formed from peridotite or other ultramafic rock. The deposits may consist of compact, high-grade masses of chromite with little or no foreign material, or of low-grade deposits of chromite grains, nodules, stringers, or layers disseminated through the serpentine body.

Most of the deposits originated as erratically distributed magmatic segregations in peridotite, and no zones of altered chromite are available to guide the prospector. However, since chromite deposits often occur in clusters, bodies of serpentine known to contain chromite are likely places to prospect for additional deposits. Chromite released from its host rock is resistant to weathering and persists in stream canyons far below the outcrop, thus acting as a guide to the primary deposit. Occasionally, the detrital chromite may be sufficiently concentrated to form a workable secondary placer deposit.

As serpentine and peridotite host rocks are widely distributed throughout the Coast Ranges of California, chromite deposits are also widespread. Practically all counties have yielded some chromite, but the principal production in recent years has come from San Luis Obispo, Fresno, and Glenn Counties. California is the second largest producer of chromite of all the States. Most of the production, however, has been made during wartime emergency periods when premium prices were offered. Cumulative production from mines in the Coast Ranges is about 185,000 long tons valued at approximately $10,000,000.

EPITHERMAL DEPOSITS OF MERCURY

Mercury deposits in California, like those in most other parts of the world, are found in regions of Tertiary and Quaternary volcanic activity. The presence of cinnabar at Coso Hot Springs in Inyo County, at The Geysers in Sonoma County, at the Sulphur Bank mine in Lake County, and at Amedee Hot Springs in Lassen County demonstrates this association. In most districts, however, the cinnabar was deposited during an earlier period and only the roots of the spring systems remain.

The deposits were formed by the deposition of ore minerals from alkaline sulfide solutions at relatively low temperature and shallow depths. The mercury minerals fill fractures and pores or replace the host rock. Impervious rock overlying porous host rocks have proven to be especially effective traps. Some large and rich deposits have resulted from cinnabar replacing silica-carbonate rock—a hard, brittle rock formed by the hydrothermal alteration of serpentine to a mixture of quartz, opal, and a carbonate, usually magnesite. Over half of the larger mercury deposits occur in this rock with the cinnabar either replacing the rock or filling fractures. The New Almaden mine near San Jose provides an excellent example of ores in silica-carbonate rock. This mine produced over a million flasks of mercury sold for $50,000,000, but at 1965 prices worth ten times this amount. Although its workings reach a depth of 2,450 feet below the surface, the deepest of any mercury mine in the world, about half of its ore was mined above the 800 level.

Many mercury deposits occur in the extremely deformed sedimentary rocks of the Franciscan Formation with which the serpentine and silica-carbonate rocks are associated. Deposits also occur in the less-deformed rocks of the Knoxville, Paskenta, Chico, and Panoche sequences. The New Idria mine, in the heart of the Diablo Range, is an example of a major producer with ore bodies chiefly in overturned, altered, indurated, and fractured Panoche shale beneath a steep reverse fault. This mine has produced over 500,000

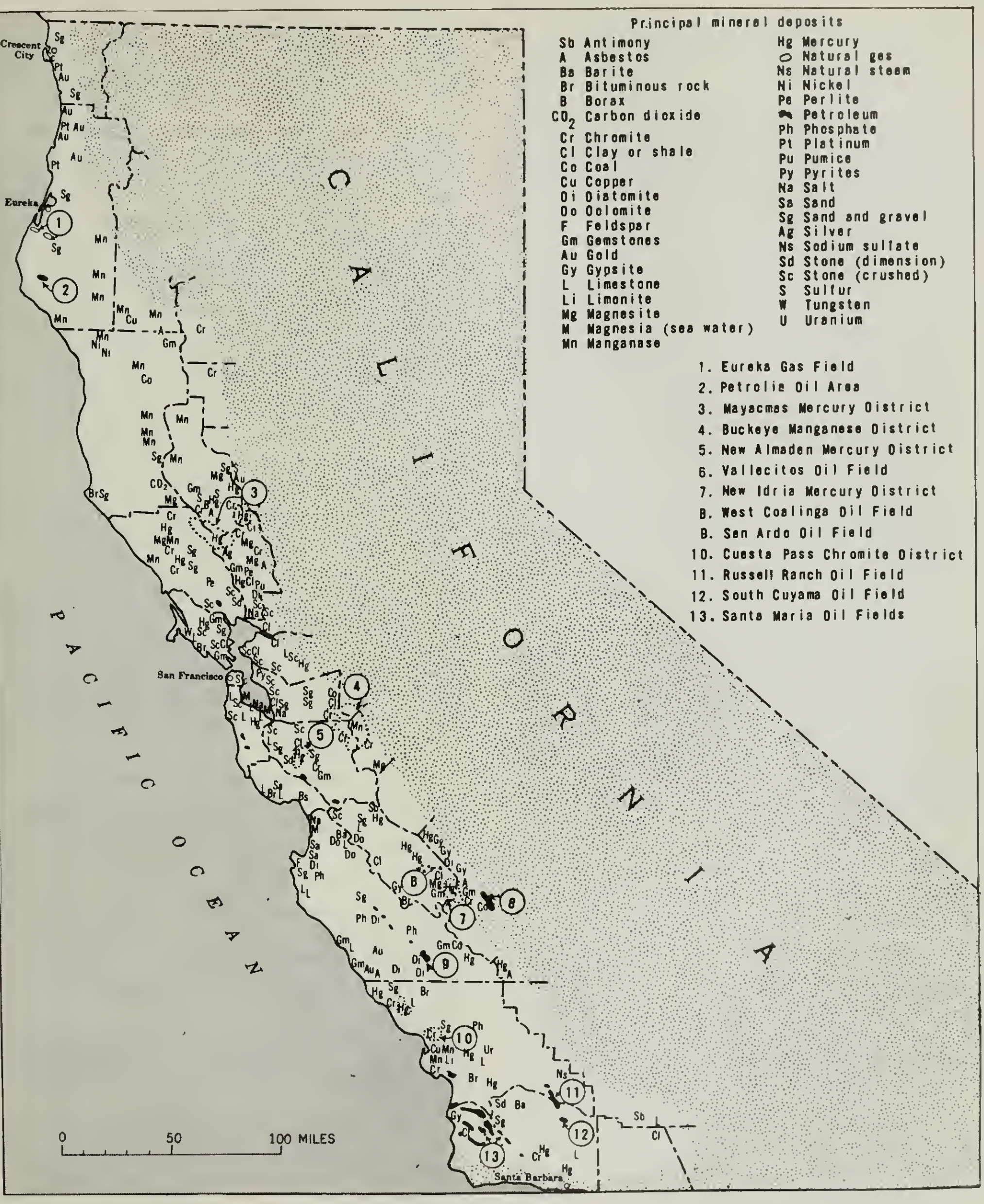

Figure 1. Map of northern California, showing the location of the principal mineral deposits, mining districts, and oil and gas fields in the Coast Ranges.

flasks and in 1965 was the largest producer in the United States. Elsewhere Tertiary sedimentary and volcanic rocks and Quaternary volcanic rocks contain major deposits. Recent small placer deposits also have been producers.

California quicksilver mines have produced about 85 percent of the mercury in the United States, and the great bulk of this production came from deposits in the Coast Ranges. The cumulative production of mercury in this province is about 2¾ million flasks valued at about $198,000,000.

HYDROTHERMAL DEPOSITS OF COPPER

Many occurrences of copper mineralization occur throughout the Coast Ranges, but only one deposit has yielded appreciable production. This is the massive sulfide body, consisting of pyrite, chalcopyrite, and pyrrhotite, located at the Island Mountain mine in southwestern Trinity County. The ore body occurs as a lenticular mass along a shear zone in slightly metamorphosed rocks of the Franciscan Formation. Replacement of the host rock was the dominant process in the formation of this deposit, although minor fracture filling is evident. The Island Mountain mine was active from 1915–30 when 9,000,000 pounds of copper, 144,000 ounces of silver, and 8,600 ounces of gold were produced. A geophysical survey suggests that some small unexposed ore bodies remain unmined.

METAMORPHIC DEPOSITS OF CHRYSOTILE ASBESTOS

Recently, a major asbestos industry has been developed in the Coast Ranges in western Fresno County. Here, a mass of serpentine, so intensely sheared that much of the rock has little coherence, yields smooth, flaky surfaces, similar to "mountain leather," bounded by polished chips of serpentine. On examination, the flexible leathery flakes were identified as matted, short-fiber chrysotile recrystallized from serpentine during the shearing process. Although the chrysotile fibre in this deposit is short, its ease of access to West Coast manufacturing makes it very valuable. Since 1960, four plants have located in the area to process the short-fiber asbestos for industrial usage.

CHEMICAL SEDIMENTARY DEPOSITS OF MANGANESE

Manganese deposits are associated with rocks of the Franciscan Formation, principally with the chert lenses which are widely distributed throughout the Coast Ranges. Franciscan chert ordinarily is thinly layered with shaly partings, but locally it forms large massive lenses which enclose concentrations of manganese minerals. The primary materials were manganese carbonates and silicates deposited in relatively flat lying positions in marine basins of restricted circulation. These materials and the enclosing rocks were folded, faulted, eroded, and oxidized to ores of the pyrolusite and psilomelane type. It is believed that the silica, manganese, and associated iron are of marine origin and were precipitated simultaneously.

Most of the manganese ore production has been made during wartime, and the Coast Ranges province has been the source of about half of the State's manganese ore. The principal production has come from the Ladd-Buckeye area south of Tracy.

SEDIMENTARY DEPOSITS OF LIMESTONE AND DOLOMITE

Large roof pendants of coarsely crystalline limestone and dolomite are found in the pre-Cretaceous rocks of the Santa Cruz Mountains, in the Gabilan Range and the Sierra de Salinas bounding the Salinas Valley, and in the Santa Lucia Range farther southeast in San Luis Obispo County. Included are bodies of high-grade limestone, dolomite, and mixed carbonate rocks in masses aggregating millions of tons. Practically all the dolomite consumed in northern California originates in quarries in the Gabilan Range.

The Calera limestone member of the Franciscan Formation provides a dense limestone used in the San Francisco area for making cement and for aggregate. The principal limestone quarries are on the San Francisco peninsula, and are located in the largest of many small discontinuous segments of the Calera member that are found extending along the San Andreas fault zone for a distance of about 30 miles. The limestone is thickest, about 400 feet, at the Permanente Cement Co. quarry about 40 miles south of San Francisco.

Large unmetamorphosed limestone deposits of Tertiary age are found in the southern Coast Ranges. The sugar refineries of the Salinas Valley currently use bedded shell limestone from the Vaqueros Formation, which is quarried at Lime Mountain northwest of Paso Robles. Lenses of oyster shells and mud are dredged from the floor of San Francisco Bay to manufacture cement at Redwood City.

SEDIMENTARY DEPOSITS OF CLAY AND SHALE

Conditions during Eocene time favored the deposition of high-grade sedimentary clays in lagoons bordering inland seas. Small deposits of fire-clay are found in the Tesla Formation in a narrow belt in southeastern Alameda County. The clay occurs in a synclinal structure with a sequence of white sand, subbituminous coal, shale, and anauxite clay. The structural conditions of the clay beds require expensive underground mining, and this factor has retarded their large-scale development.

Ceramic plants in the San Francisco area fill their requirements with shale quarried from the deposits of Jurassic and Cretaceous age which are widely distributed throughout the Coast Ranges province.

SEDIMENTARY DEPOSITS OF DIATOMITE

Extensive deposits of diatomaceous shale are found in the southern and central Coast Ranges where they are associated with volcanic ash and clastic sedimentary rocks. Deposits of commercial importance, which formed in a marine environment during Miocene and Pliocene time, crop out extensively from central

Monterey to southern Santa Barbara Counties and were formerly mined near Bradley. Additional marine beds occur in San Mateo and Santa Cruz Counties. Older marine diatomaceous beds of Eocene age crop out in western Fresno, Merced, and Stanislaus Counties. Fresh water deposits of Tertiary age occur in Napa County, where they are currently mined for use as a pozzolan. The chief uses of diatomite are for filters, insulation, and fillers.

SEDIMENTARY DEPOSITS OF SAND AND GRAVEL

Alluvial deposits of Quaternary age obtained from stream channels, terraces, flood plains, fans, and cones supply most of the sand and gravel required for concrete aggregate. Some of the principal source areas from north to south in the province are along the Eel, Mad, and Russian Rivers, Cache Creek, Alameda Creek, Arroyo Mocho, Corral Hollow, Coyote, and Los Gatos Creeks, and the Salinas, Santa Maria, and Sisquoc Rivers.

OTHER SEDIMENTARY DEPOSITS

Other economically important sedimentary deposits in the Coast Ranges contain bentonitic clay, bituminous rock, coal, and phosphate rock.

PETROLEUM

The natural habitat of petroleum is also in the sedimentary rocks. It is generally accepted that oil and gas are derived by natural distillation from organic remains buried in the sediments of marine basins. The principal basins of accumulation in the Coast Ranges are in, and adjoining, the Salinas, Santa Maria, and Cuyama Valleys.

At the San Ardo oil field in the Salinas Valley, beds of the Monterey Formation lie on a basement of eroded granite. Lower shale source beds of the Monterey Formation grade eastward into sandy reservoir beds, which are overlain by diatomaceous shale and by the Santa Margarita Formation of late Miocene age. Cumulative production from discovery in 1947 to 1963 inclusive was 135,000,000 barrels of 10-12 gravity oil from depths of 2,100 to 2,500 feet.

The Santa Maria Valley oil field occurs in a faulted stratigraphic trap, formed by an overlap of the Pliocene Sisquoc beds on the truncated reservoir sands of the Monterey Formation. Cumulative production from discovery in 1934 to 1963 inclusive was 136,000,000 barrels of 12-17 gravity oil from depths of 2,500-5,700 feet. Other fields in the Santa Maria basin are Arroyo Grande, Casmalia, Cat Canyon, Guadalupe, Lompoc, Orcutt, and Zaca, whose aggregate production to the end of 1963 was 353,000,000 barrels of oil.

In the Cuyama Valley the Russell Ranch field is in a homocline with closure against a normal fault. The principal production is from a thick body of sands in the Vaqueros Formation. Cumulative production from discovery in 1948 to 1963 inclusive was 58,000,000 barrels of 21–40 gravity oil from depths of 2,500–3,500 feet.

The South Cuyama field is an asymmetric faulted anticline with its principal production from the lower Miocene sand of the Vaqueros Formation. Cumulative production is 168,000,000 barrels of 26–35 gravity oil from depths of 3,600–4,300 feet.

Smaller oil fields are found in the Vallecitos syncline and in the Ciervo anticline, San Benito County; the Sargent anticline, and the Moody Gulch monoclinal fold in Santa Clara County; and the La Honda and Half Moon Bay fields in San Mateo County. Considerable quantities of natural gas have been produced from the various oil fields and also from the Eureka gas field in Humboldt County near the Pacific coast.

The total production of petroleum products in the Coast Ranges through 1965 is estimated at 920,000,000 barrels of oil and 700,000,000,000 cubic feet of gas.

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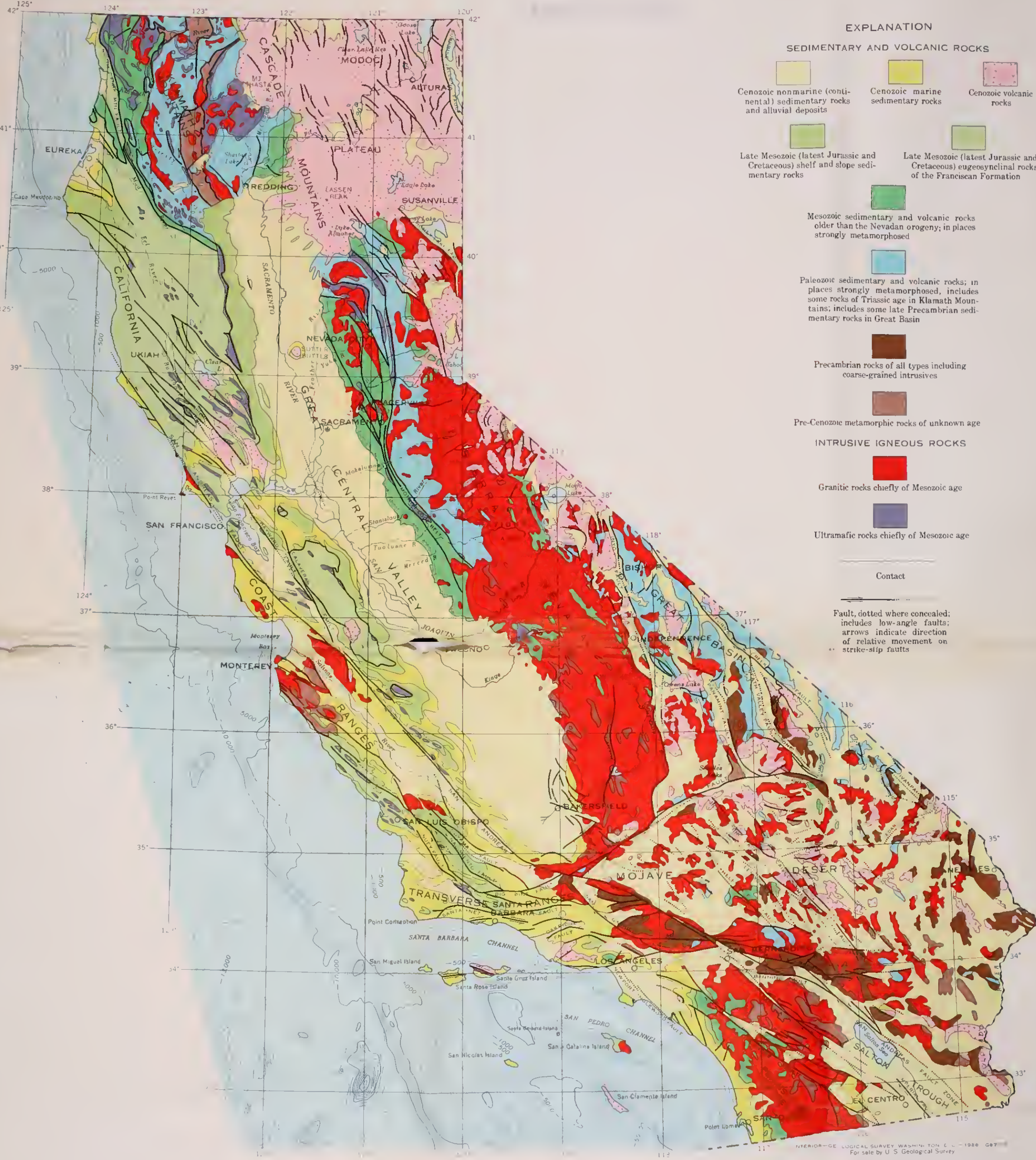
MISCELLANEOUS GEOLOGICAL INVESTIGATIONS
MAP I-512



EXPLANATION

SEDIMENTARY AND VOLCANIC ROCKS

Cenozoic nonmarine (continental) sedimentary rocks and alluvial deposits

Cenozoic marine sedimentary rocks

Cenozoic volcanic rocks

Late Mesozoic (latest Jurassic and Cretaceous) shelf and slope sedimentary rocks

Late Mesozoic (latest Jurassic and Cretaceous) eugeosynclinal rocks of the Franciscan Formation

Mesozoic sedimentary and volcanic rocks older than the Nevadan orogeny; in places strongly metamorphosed

Paleozoic sedimentary and volcanic rocks; in places strongly metamorphosed, includes some rocks of Triassic age in Klamath Mountains; includes some late Precambrian sedimentary rocks in Great Basin

Precambrian rocks of all types including coarse-grained intrusives

Pre-Cenozoic metamorphic rocks of unknown age

INTRUSIVE IGNEOUS ROCKS

Granitic rocks chiefly of Mesozoic age

Ultramafic rocks chiefly of Mesozoic age

Contact

Fault, dotted where concealed; includes low-angle faults; arrows indicate direction of relative movement on strike-slip faults

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1966
For sale by U. S. Geological Survey

GEOLOGIC MAP OF CALIFORNIA

COMPILED BY U.S. GEOLOGICAL SURVEY
AND CALIFORNIA DIVISION OF MINES AND GEOLOGY

SCALE 1:2 500 000

0 50 100 MILES

SUBMARINE CONTOUR INTERVALS 500 AND 1000 FEET DATUM IS SEA LEVEL

1966