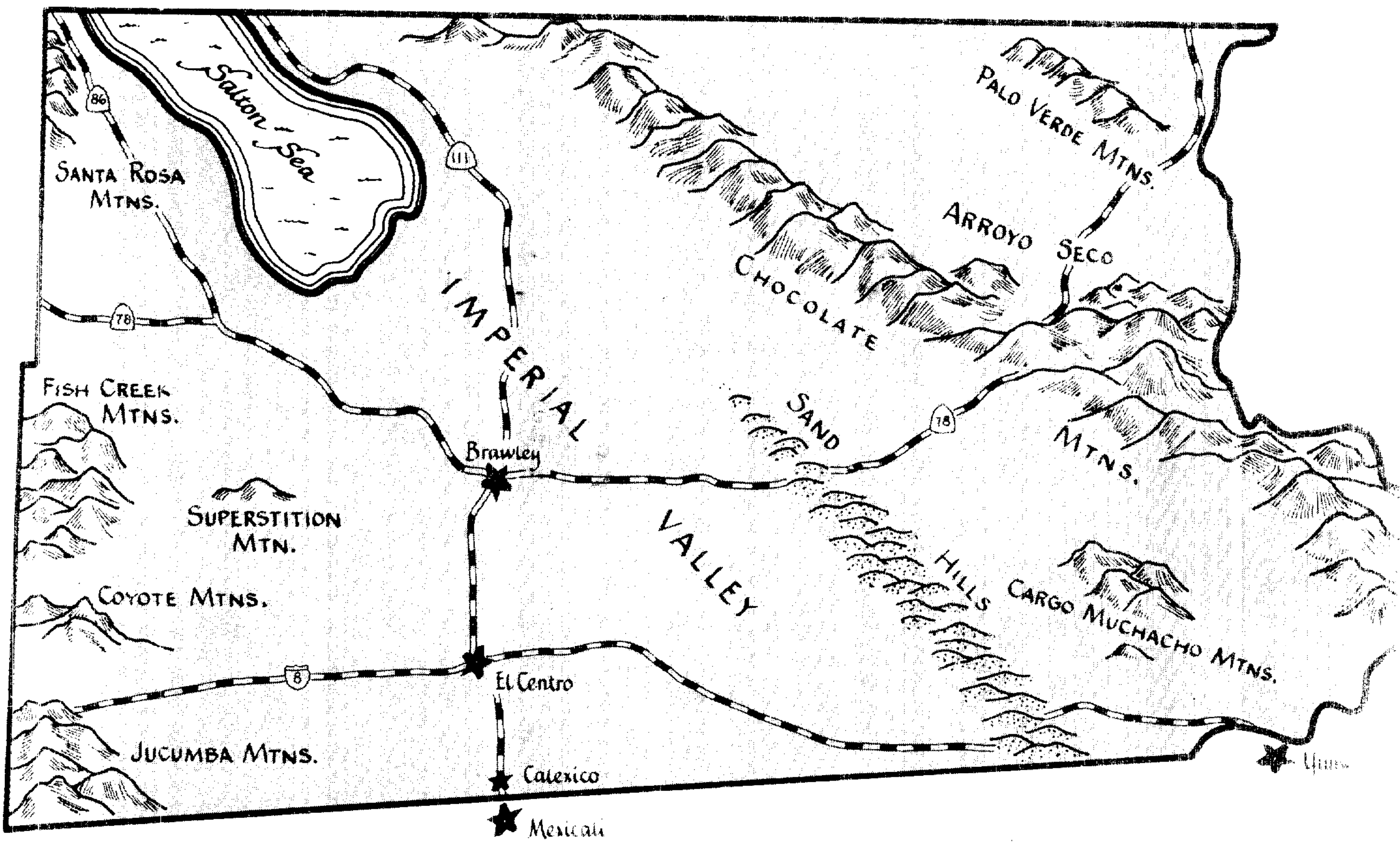
COUNTY REPORT 7

GEOLOGY AND MINERAL RESOURCES OF IMPERIAL COUNTY, CALIFORNIA



CALIFORNIA DIVISION OF MINES AND GEOLOGY

Geology and Mineral Resources of

IMPERIAL COUNTY

California

By Paul K. Morton
Geologist

COUNTY REPORT 7

California Division of Mines and Geology
1416 Ninth Street, Room 1341
Sacramento, CA 95814

1977

With Data on Geothermal Resources by
C. Forrest Bacon and James B. Koenig (1971)

Photo 1. Frontispiece. The Sand Hills, as viewed toward the northwest from County Park. The prevailing wind direction, as indicated by the alignment of the sandfall faces in the background and ripples in the foreground, is toward the observer and slightly to the right.

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PREFACE

This report represents data collection and geologic interpretations that were made during the period 1961 through 1965. Between that period and 1975, publication of the manuscript was delayed for lack of funding. It was impractical to continually update the report during that long delay; consequently, when the report was finally published, it was already more than 10 years old. The reader should be aware of these facts and consider that the effective date of this report is 1966.

The author believes that most of the data contained in the report are still valid and useful. Two of the more important developments of knowledge between 1966 and the present are (1) the great bulk of new subsurface data collected during investigation of the geothermal power potential in Imperial Valley and (2) new geologic age dates and faulting concepts in the Chocolate Mountains, particularly with regard to analogies drawn with the Vincent thrust fault of the San Gabriel Mountains. Many of the important contributions to this knowledge were made by the faculty and graduate students at the University of California, Riverside; University of California, Santa Barbara; California State University, Los Angeles; and California Institute of Technology.

Paul K. Morton

April 24, 1975

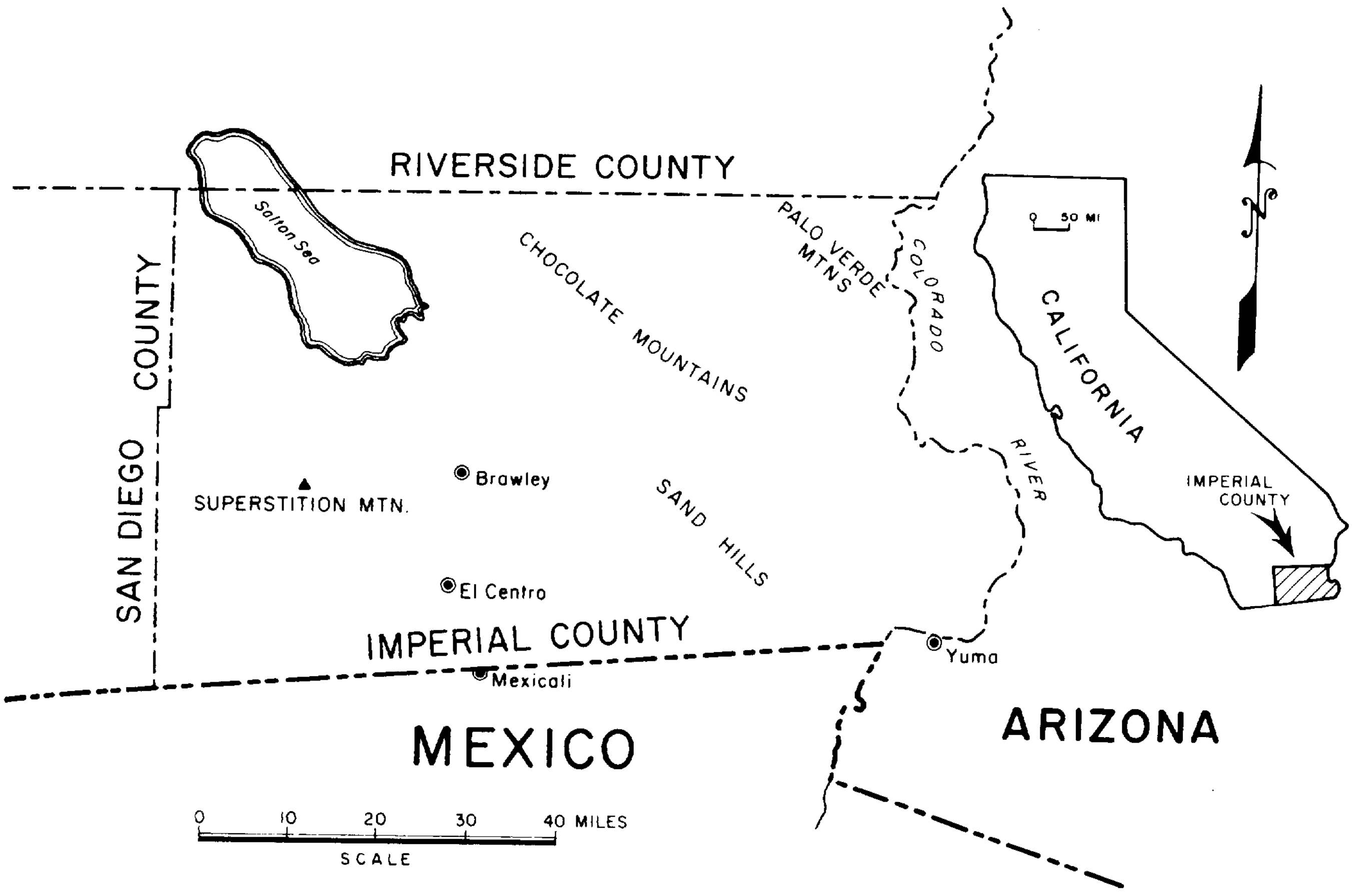

Figure 1. Index Map of Imperial County.

ABSTRACT

Imperial County comprises 4284 square miles of southeasternmost California. Within its boundaries lie three provinces, each distinct in its geological and physiographic characteristics.

The northeastern half of the county is part of the Mojave Desert province, which is underlain mainly by pre-Cretaceous metamorphic rocks of the Chuckwalla Complex and Orocopia Schist, complexly intruded by plutonic rocks of Mesozoic age. These rocks are overlain and intruded by Tertiary volcanic and pyroclastic units, which in turn are covered by non-marine clastic rocks of Tertiary and Quaternary ages. Imperial Valley, in the Salton Trough (formerly called Colorado Desert) province, is a large northwest-trending, almost featureless plain, which occupies much of the central part of the county. The Salton Sea, which lies at its northwestern extremity, separates it from Coachella Valley, farther northwest.

Imperial Valley is covered predominantly by Quaternary lakebeds, sand dunes, and alluvium which overlie Tertiary non-marine and marine sedimentary and volcanic rocks. These Tertiary units are well exposed in the low-lying hills bordering the west side of the valley. The Salton Trough province merges with the Peninsular Ranges province along this western edge of the county. The latter province is comprised predominantly of Paleozoic(?) metasedimentary rocks and gneiss, which have been intruded by plutonic igneous rocks of Cretaceous age.

A largely northwest-trending structural fabric has developed in most of the county; this is especially reflected by the San Andreas, Elsinore, San Jacinto, and related fault systems, which traverse the central and western parts of the county.

The total estimated value of mineral production in the county from 1880 through 1968 exceeds $74 million. Gypsum, sand and gravel, gold, manganese, carbon dioxide, pumice, and crushed stone account for the bulk of the production. Of possible future importance is the drilling of geothermal wells for the generation of electric power and the recovery of minerals and fresh water from superheated brines.

Introduction

Although Imperial County ranked only twenty-ninth among California's fifty-eight counties in 1968 mineral production, it is endowed with a wide variety of minerals, which amplifies its importance in relation to actual production. Among its varied mineral occurrences, gypsum, sand and gravel, gold, manganese, natural carbon dioxide, pumice, and crushed stone have accounted for most of the production (figure 2).

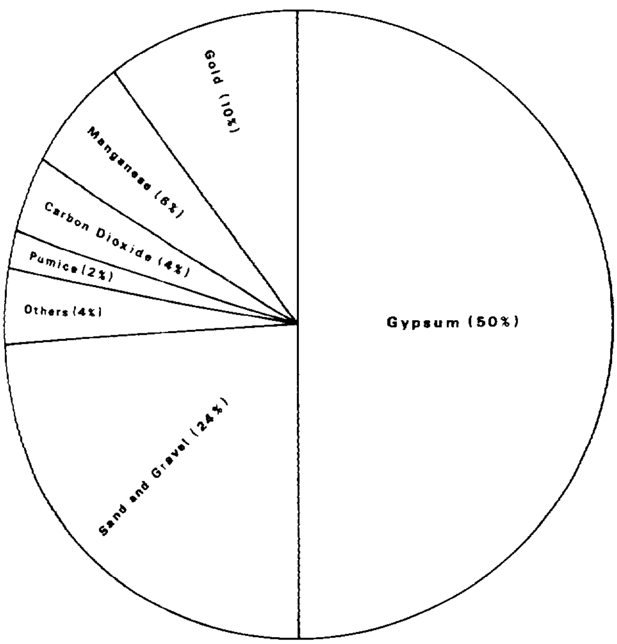

Figure 2. Rank of Principal Mineral Commodities in 1907–08.

Other deposits in approximate order of over-all dollar value of production are: sericite mica, silver, tungsten, strontium, kyanite, optical calcite, copper, limestone, barite, clay, salt, sodium sulphate, silica, uranium, gemstones, and nickel. Another resource of great potential value is natural steam from geothermal fluids. Pilot plant investigations of this unusual resource have been conducted periodically since 1965.

The total estimated value of all mineral resources of the county produced from 1880 through 1968 exceeds $74 million.* About half of this total is attributed to the value of gypsum produced (table 1).

*Imperial County was created from San Diego County in 1907; estimate for prior years is based upon individual mine statistics compiled for San Diego County.

Summary of County Mineral Trends and Needs

Because Imperial is a growing county, much of its natural mineral wealth may eventually be developed. Opportunities and needs for mineral raw materials are found in the county's expanding economy. The more obvious needs are related to the inevitable construction demands. Additional sources of sand and gravel are needed even now. Utilization of limestone, for cement, from local sources will probably become economically feasible. Gypsum, already developed, is likely to find expanding markets. Available sources of pumice and claystone for expanded lightweight aggregate lie ready for exploitation when the need arises.

Industrial materials such as kyanite, mineral fillers (clay, limestone, sericite mica, tuff), salt, potash and calcium chloride (geothermal sources), and sand (Sand Hills) are readily available.

The county has large probable reserves of geothermal fluids. Certain of these are brines rich in potash, which offer additional incentive for mineral development. Several potential products of these fluids —electric power, fresh water and mineral salts—may provide Imperial Valley with a new industry. Low cost power sources can provide added incentive for industrial development, enhancing the value of the county's mineral resources.

Gold and manganese deposits of the county contain sizable reserves, although present-day economics are largely unfavorable for their development. Current trends in the development of more efficient mining and processing methods indicate the probability that these resources will eventually be exploited.

Principal Geographic and Cultural Features

Imperial County, comprising 4284 square miles, is in southeasternmost California. It is bounded on the north by Riverside County, on the west by San Diego County, on the south by the state of Baja California, Mexico, and on the east by Yuma County, Arizona.

The county is divisible into three geographic units— a western mountainous area, Imperial Valley, and an eastern mountain and basin area (see figure 3).

The western mountainous area constitutes about 5 percent of the county and is included in the eastern extremities of the Peninsular Ranges province. Those parts of the province that lie in Imperial County are, from north to south: the eastern edge of the Santa

Table 1. Mineral production in Imperial County, 1880–1968.

Year	*Gold*	*Silver*	*Miscellaneous stone*	*Unapportioned*	*Includes*	*Others*	*Total*
1942	$6,090	$120	$62,470	$438,450	Calcium chloride, carbon dioxide, copper, lead, optical calcite, gypsum, magnesium chloride, manganese, salt, kyanite, saltcake, strontium	----------	$507,130
1943	----------	----------	99,452	585,751	Carbon dioxide, gypsum, manganese, optical calcite, kyanite, strontium	----------	685,203
1944	----------	----------	89,690	474,573	Calcium chloride, carbon dioxide, gypsum, manganese, mica, salt, kyanite, strontium	----------	564,263
1945	----------	----------	68,429	315,002	Carbon dioxide, optical calcite, gypsum, manganese, mica, kyanite, strontium	----------	383,431
1946	7,105	50	136,300	582,589	Carbon dioxide, gypsum, kyanite, mica, salt, strontium	----------	726,044
			Sand and gravel				
1947	----------	----------	$232,704	907,843	Carbon dioxide, kyanite, mica, gypsum	----------	1,140,547
1948	5,985	84	U	2,086,439	Gypsum, sand, gravel, stone	----------	2,092,508
1949	1,120	8	306,988	1,384,814	Carbon dioxide, gypsum, pumice, stone	----------	1,692,930
1950	61,565	388	492,682	1,693,295	Clay, carbon dioxide, gypsum, pumice, stone	----------	2,247,930
1951	27,790	185	----------	1,609,637	Carbon dioxide, gypsum, pumice, sand, gravel	----------	1,637,612
1952	14,420	165	104,987	1,474,374	Carbon dioxide, gypsum, manganese, pumice, stone	Lead— $48	1,593,994
1953	175	1	370,049	1,885,516	Gypsum, manganese, carbon dioxide, pumice, strontium	Crushed stone— 35,481	2,291,222
1954	1,260	10	749,286	2,181,718	Carbon dioxide, gypsum, manganese, pumice, stone, strontium, tungsten	----------	2,932,274
1955	U	U	331,739	1,843,040	Clay, gemstone, gold, gypsum, mica, pumice, silver, stone	Manganese— 49,238 Manganiferous ore— 497,758	2,721,775
1956	U	U	517,616	1,845,799	Gemstone, gold, gypsum, mica, pumice, silver	Manganese— 32,330 Stone— 50,965	2,446,710
1957	35	181	438,654	1,895,990	Gemstone, gypsum, manganese, mica, pumice	Copper— 422 Lead— 472 Stone— 43,258 Zinc— 162	2,379,174
1958	U	U	318,239	2,482,450	Gemstone, gold, gypsum, lead, manganese, mica, pumice, silver, stone, zinc	----------	2,800,689
1959	----------	----------	479,147	2,844,534	Gemstone, gypsum, manganese, mica, pumice	Stone— 24,759	3,348,440
1960	----------	----------	493,986	1,766,950	Gypsum, gemstone, mica, pumice	Stone— 41,737	2,302,673
1961	----------	----------	1,161,742	2,018,187	Gypsum, lime, mica, pumice, stone	Gemstones— 927	3,180,856
1962	----------	----------	967,978	2,121,942	Gypsum, lime, manganese, mica	Clay— 3,067 Pumice— 1,064 Stone— 62,825 Gemstone— 410	3,157,286
1963	455	9	955,033	2,288,423	Clay, gypsum, lime	Mica— 9,800 Pumice— 10,600 Gemstone— 60 Stone— 31,721	3,296,101
1964	105	1	940,000	2,296,573	Clay, gypsum, lime, mica	Stone— 24,422	3,261,101
1965	----------	----------	699,000	2,070,601	Barite, clay, gypsum, lime, mica	Stone— 87,238	2,856,839

Table 1. Mineral production in Imperial County, 1880–1968—Continued.

Year	Gold	Silver	Sand and gravel	Unapportioned	Includes	Others	Total
1966			959,000	1,771,371	Barite, $CaCl_2$, clay, copper, gold, gypsum, lime, mica, silver	Stone— 85,593	2,815,964
1967			4,090,000	1,834,961	$CaCl_2$, clay, gold, gypsum, lime, mica	Stone— 6,545	5,931,506
1968			1,569,000	2,483,097	$CaCl_2$, clay, gold, gypsum, lime, silver	Stone— 6,202	4,058,299
Totals	$126,105	$1,202	$16,177,830	$45,183,919		Total 1942–1968	63,052,501
						Total 1907–1941*	9,075,690
						Estimated minimum prior to 1907**	3,559,009
						Grand total	$75,687,200

* See Sampson and Tucker, 1942, p. 110–111, for yearly breakdown prior to 1942.
** Pre-1907 estimate is based upon production of principal mines; Imperial County was not created until 1907.
U = See Unapportioned column.

Rosa Mountains, the Fish Creek Mountains, the Coyote Mountains, and the southeastern edge of the Jacumba Mountains (see figure 3).

Imperial Valley, the southeastern half of a broad northwest-trending basin, lies athwart the central part of the county. It is about 50 miles across from southwest to northeast and extends 70 miles from the north to the south boundaries of the county. At the north end of the valley and extending northwestward out of the county lies the Salton Sea, a saline lake fed by waste water from the Imperial Irrigation District. Northwest of the Salton Sea in Riverside County, the narrow extension of the Salton Sea depression is termed the Coachella Valley; the two valleys together with the Salton Sea comprise the Salton Trough. Formerly this was called the Colorado Desert. Imperial Valley is an almost featureless plain. It is interrupted on the west and southwest by the low lying San Felipe Hills, the Superstition Hills, Superstition Mountain and Yuha Buttes. The eastern edge of the valley is marked by the Sand Hills, a belt of sand dunes 5 miles wide that stretches 45 miles from the Mexican border northwestward towards the Salton Sea.

The western limits of the eastern mountain and basin area, a part of the great Mojave Desert, is marked by the Chocolate Mountains. They extend from the Colorado River on the east side of the county, northwestward to the north boundary and beyond. A smaller group of mountains, the Cargo Muchacho Mountains, lies between the Chocolate Mountains and the Sand Hills. Interrupting the desert floor northeast of the Chocolate Mountains are three relatively smaller groups: the Little Mule Mountains, the Black Hills, and the Palo Verde Mountains.

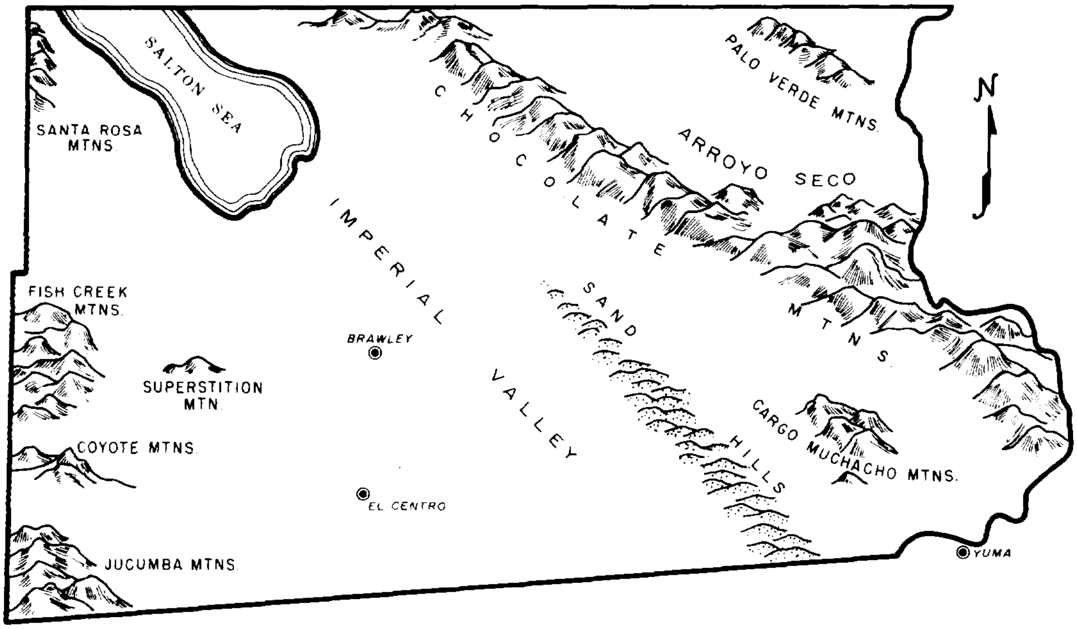

Figure 3. Map of Principal Geographic Features.

Elevations in the county range from 231 feet below sea level at the surface of the Salton Sea (1963) to 4548 feet at an unnamed peak in the Jacumba Mountains near the juncture of the Mexican border and the San Diego county line at the extreme southwest corner of the county. On the average, however, elevations in the mountainous areas range between 1000 and 2000 feet.

The climate of the region is extremely arid. The mean annual rainfall at the weather station in Imperial is 3.01 inches, and the mean annual temperature is 73°F. During the six hottest months of the year, May through October, the average maximum temperature exceeds 100°F. The lowest average monthly minimum temperature occurs during January when it is 29°F (Imperial Irrigation District, 1963).

Climatic conditions in general appear to be nearly the same throughout Imperial County. Rainfall generally ranges between 3 and 4 inches per year. Maximum temperatures vary in a given day by as much as 15° between areas below sea level and those over 3000 feet elevation; but in most areas maximum temperatures are within 5° or 10° of valley temperatures. Minimum temperatures generally are within a range of 10° (Dale, 1959).

Imperial County has a population of 74,492 (1970), nearly all of whom live in the Imperial Valley. The Winterhaven area, with several hundred people, is the only community of significant size outside the valley. Agriculture is the principal industry of the county, with an annual gross yield of $246,731,000 in 1969 (Imperial Valley Development Agency).

Accessibility, although excellent in Imperial Valley, is only fair in the remaining lowland areas and poor in most mountainous areas. U.S. Highway 80 and State Highways 79, 86, 98, 111, and 115 traverse the county. The main Los Angeles to New Orleans line of the Southern Pacific Railroad follows a course northwestward from Winterhaven along the east side of the Salton Sea. Branch lines service the Imperial Valley agricultural areas. The San Diego and Arizona Eastern rail line runs from San Diego to Yuma via Ocotillo, El Centro, and Holtville. Air West and Imperial Airlines operate scheduled flights from the El Centro Airport.

Land and Land Use

Of the 2,741,760 acres of land within Imperial County, approximately 1,499,402 acres or 54.7 percent are under Federal control. These lands include unreserved public land, military reservations and withdrawals, reclamation withdrawals, wildlife refuges, Indian reservations, and the like (see table 2). About 33 percent of the Federal land is held by the U.S. Department of Defense, and most of the remainder by various agencies of the U.S. Department of the Interior. The Imperial Irrigation District owns about 1½ percent, and State lands account for about 3½ percent of the county. Much of the Federal and State land is closed to prospecting and mineral entry.

Persons desiring to prospect or locate mineral claims in Imperial County may obtain information regarding the status of land and other information relative to

*Table 2. Summary of lands owned by public agencies in Imperial County.**

Agency	*Acres*
FEDERAL	
Agricultural Research Service	80
Bureau of Land Management	391,782
Bureau of Reclamation	570,515
Fish and Wildlife Service	11,075
Bureau of Indian Affairs	18,526.94
Immigration and Naturalization Service	7.6
Post Office Department	2.0
Bureau of Customs	0.7
General Services Administration	3.2
Department of Defense	
Army	36,350
Navy	461,279
Atomic Energy Commission	9,741
Federal Aviation Agency	40
Total Federal ownership	1,499,402.44
STATE	
Department of Agriculture	6.07
University of California	250
California State Colleges	22
Department of Employment	2.12
Military Department	6.10
Department of Fish and Game	8,315.09
Department of Parks and Recreation	30,072.41
Department of General Services	2.06
Department of Finance	45,332.78
Tax Deeded Lands	17,598
Department of Public Works	4,426
Department of Motor Vehicles	1.53
Total State ownership	106,034.16
COUNTY	
Total County ownership	15,579.65
CITIES	
Brawley	725.11
Calexico	521.44
El Centro	710.80
Holtville	?
Imperial	?
Westmorland	86.11
Total City ownership	2,043.46
SCHOOL DISTRICTS	
Elementary and high	609.40
Junior colleges	160
Total school district ownership	769.40
SPECIAL PURPOSE DISTRICTS	
Cemetery	102.07
Community services	680
Fire protection	0.58
Hospital	19.32
Sanitary	5.82
Imperial Irrigation District (County only)	42,424.69†
Public utility	8.0
County water	5.0
Total special district ownership	43,245.48
Total government ownership	1,667,074.59 acres
Total acres in county	2,741,760
Percentage of government ownership	60.80 percent

* Compiled from Senate Permanent Fact Finding Committee on Natural Resources, 1965, Public land ownership and use in California: Senate of the State of California, 326 p.

† Owns 60,612.92 acres in Imperial and Riverside Counties.

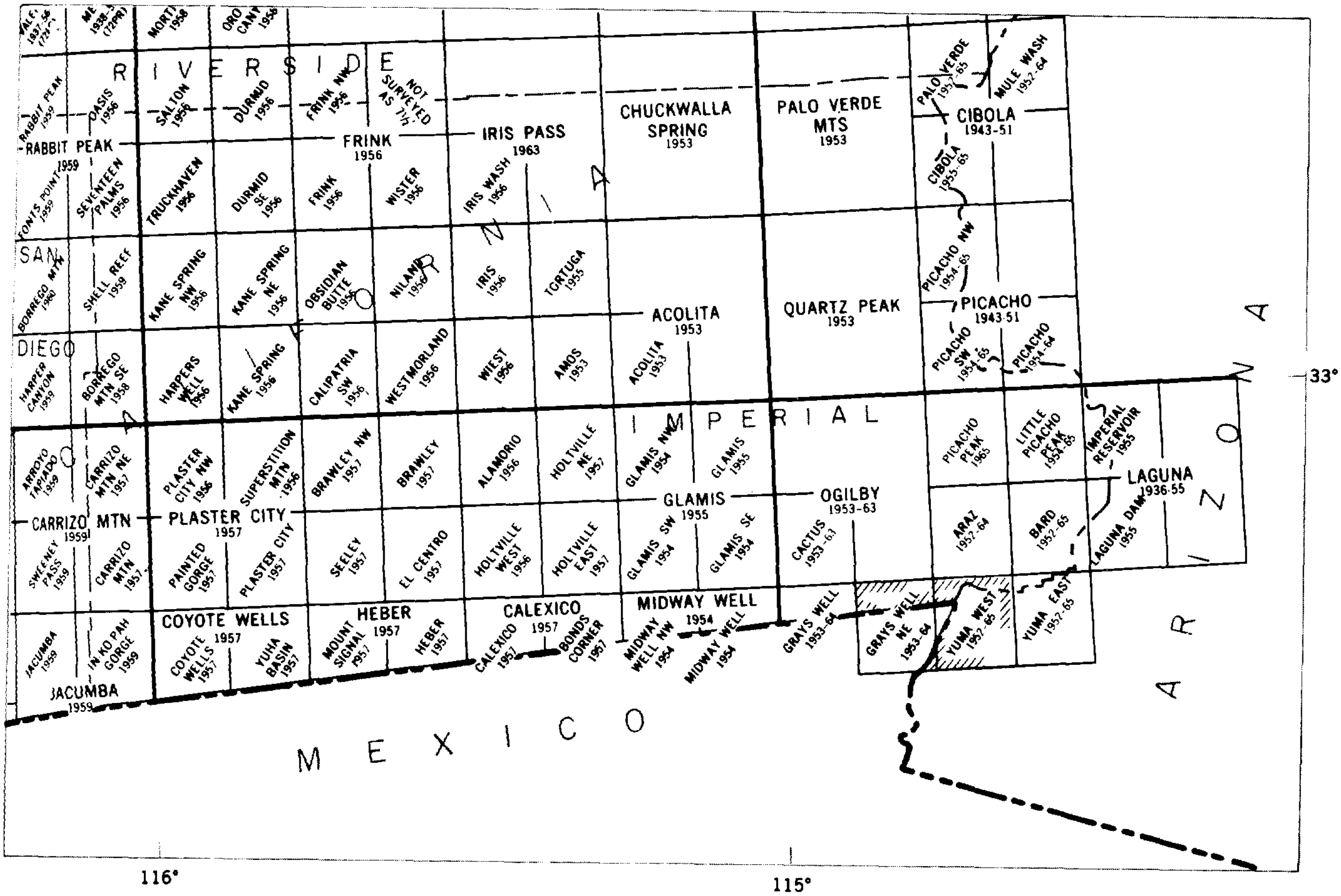

Figure 4. Index to Topographic Map Coverage (published by U.S. Geological Survey).

mining from the several agencies listed in table 3. Some references containing information useful in determining the manner of locating claims, leasing mineral land, and mineral rights are listed below.

Topographic maps made by the U.S. Geological Survey at scale of 1:62,500 (15′ sheets) are available for all parts of the county (see figure 4). Coverage at 1:24,000 is available for the western half of the county and those areas bordering the Colorado River. Topographic maps at a scale of 1:250,000 (1° sheets) are published by the U.S. Army Map Service. Aerial photographic coverage of the county is available through several agencies as noted in table 3.

History

Imperial County is steeped in the early history of the western United States. Since 1540, when Pedro de Alarcon was sent by Francisco Vasquez Coronado to explore the head of the Gulf of California, this region has contributed many scenes to the drama of history. It was on that voyage in 1540 that Castillo, Alarcon's pilot, made the first chart of the gulf. The chart, which was eventually published, was the only map of the region for many years and, evidently, provided the base from which many subsequent maps were made (Sykes, 1914, p. 14).

No new knowledge of the region was contributed until the year 1700 when Father Eusebius Francis Kino, a Jesuit missionary, determined that California was not an island as was popularly believed. Kino explored the region of the lower Gila River (east of Yuma) and in 1700 journeyed to its confluence with the Colorado River and southward to the gulf beyond. The following year, at the same place, Father Kino learned from Indians that it was an 8- to 10-day journey west to the Pacific Ocean.

Father Kino's carefully drawn maps and those of his near contemporary Father Consag provide an interesting insight into the configuration of the Colorado Delta area during that period, as do those of John Rocque (1762?) and Father Pedro Font (1776). The latter two are cited by Sykes (1914, p. 14) as providing stimulus for speculation on the early formation of a lake in the Salton Basin. Rocque's map shows the Colorado and the Gila Rivers flowing into a lake that is separated from the gulf, although the lake is shown trending northeast; Salton Basin trends northwest.

Sykes states (1914, p. 15) that a diversion of the Colorado River into the Salton Trough probably occurred sometime between 1706 and 1760; but, if so, no mention is made of it by the Franciscan Friar Francisco Garces or Father Pedro Font, who each crossed

Table 3. Sources of information about mining in Imperial County. (Compiled 1966)

Agency	*Address*	*Type of information or services available or for reference use*
California, State of:		
Parks and Recreation, Department of	Room 1416, 1416 Ninth Street, Sacramento 95814	Mineral leasing information and prospecting permits for Anza-Borrego Park; right of way
Colorado River Basin Regional Water Quality Control Board	82-380 Miles Avenue, Indio 92201	Regulate water pollution
Fish and Game, Department of	Room 903, 217 West First Street, Los Angeles 90012	Water pollution regulation in wildlife areas
Industrial Safety, Division of	3460 Wilshire Boulevard, Room 906, Los Angeles 90005	Mine safety orders, mine inspection
Labor Law Enforcement, Division of	1107 Ninth Street, Room 600, Sacramento 95814	Laws pertaining to employment
Mines and Geology, Division of	Room 1065, 107 South Broadway, Los Angeles 90012	Geology, geologic hazards, mineral resources, mines, mineral production statistics, state mining laws
Oil and Gas, Division of, District No. 1	830 North La Brea, Inglewood 90302	Regulations pertaining to conservation of oil and gas, descriptions of oil fields, yearly summary of operations in California oil fields (including geothermal steam).
State Lands Division	217 West First Street, Room 305, Los Angeles 90012	Mineral leasing and prospecting of state land
Water Resources, Department of	909 South Broadway, Los Angeles 90015	Reports on water resources, water rights, water table and well data, dam supervision, state water projects, etc.
Imperial County:		
Assessor-Collectors Office	939 Main, El Centro 92243	Land ownership data
Imperial Irrigation District	Public Information Office, 582 State, El Centro 92243	Mineral leasing, water and power acquisition
Imperial Valley Development Agency	P.O. Drawer IV, Imperial 92251	General information concerning business, industry, and recreation
Recorder	939 Main, El Centro 92243	Records of claims (alphabetical by claim name or locator) recording of claims, etc.
United States:		
Agriculture, Department of, Commodity Stabilization Service, Performance and Aerial Photo Division Western Laboratory	2505 Parleys Way, Salt Lake City, Utah 84109	Aerial photos of most of Imperial County
Army Corps of Engineers	751 South Figueroa Street, Los Angeles 90017	Boundaries of military reservations and certain other federal lands
Commerce, Department of, Atomic Energy Commission	222 Southwest Temple, Salt Lake City, Utah 84101	Regulations, purchase contracts and geologic information regarding uranium deposits
Geological Survey, Oil and Gas Leasing Division	300 North Los Angeles Street, Los Angeles 90012	Oil leasing regulation and supervision on public land
Geological Survey, Office of Mineral Exploration	345 Middlefield Road, Menlo Park 94025	Loans for exploration of certain minerals
Geological Survey, Public Inquiries Office	Room 7638, 300 North Los Angeles Street, Los Angeles 90012	Topographic maps and publication sales
Geological Survey, Pacific Region Engineers	345 Middlefield Road, Menlo Park 94025	Sales copies of aerial photos of parts of Imperial County and advance topographic maps
Indian Affairs, Bureau of	Real Property Management Officer, 2800 Cottage Way, Sacramento 95821	Leasing of tribal lands for mineral development
Land Management, Bureau of	1414 Eighth Street, P.O. Box 723, Riverside 92507	Claim and patent information, homesteads, federal mining laws, land withdrawal, mineral leases
Mines, Bureau of	450 Golden Gate Avenue, San Francisco 94102	Mineral statistics, mining methods, mineral processing, cost analyses, marketing data
Reclamation, Bureau of	Regional Office, 2800 Cottage Way, Sacramento 95821	Applications for reopening land withdrawn from mineral entry

the Salton Trough at least twice (1774 and 1776)—once each with Captain Juan Bautista de Anza on separate expeditions (Bryan, 1925, p. 15). William Blake, a geologist, learned from the Cahuilla Indians in 1853 of a legend that indicated the presence of a large lake in the Salton Trough. The lake extended "from mountain to mountain" and disappeared "little by little" (see photo 2). The legend also relates that the water once returned without warning, overwhelming the Indians and driving them back to the mountains.

In 1779 Father Garces established, near the present site of Winterhaven, the Mission de la Purísima Concepción, which at the time was welcomed and indeed sought by the Yuma Indians. What the Yumas did not anticipate, however, was the establishment also of a Spanish colony of some 53 families, who expropriated some of the best farm lands. This led to an Indian uprising on July 17, 1781, in which nearly all of the Spanish male population was killed, including Father Garces. The women and children were taken captive, and the settlement was abandoned (Darton, 1933, p.

Photo 2. Ravines in the Bed of Ancient Lake Cahuilla. The lithograph is from a sketch by Charles Koppel in W. P. Blake's "Report of a geological reconnaissance in California."

237). During the short tenure of the settlers at Winterhaven, placer gold was mined in the vicinity of the Potholes, 10 miles northeast of the colony (Henshaw, 1942, p. 152). This, probably, was the earliest recorded mining activity in what is now Imperial County and, indeed, possibly in the state.

The next recorded mining in the area was shortly after the establishment of the Republic of Mexico in 1823. During that period until the Mexican-American War, the Mexicans mined gold in the Cargo Muchacho Mountains.

American exploration of this region began about 1828 with the appearance of Sylvester Pattie, his son James, and their party of trappers. Another trapper, R. W. H. Hardy, entered the area about the same time. These men contributed little to the knowledge of the region, however; and it wasn't until 1846 that a geographic record was made by an American, Lieutenant W. H. Emory. Emory accompanied General S. W. Kearney, with Kit Carson as guide, and 200 dragoons on a military reconnaissance from the Rio Grande in New Mexico to San Diego.

In 1847, Lieutenant Colonel Cooke and his Mormon battalion established a wagon road along the same route followed by Kearney. This route was essentially the same one established by the Indians and used later by the missionaries and de Anza. The route was to play a prominent role in the early development of California. It was used as an important road to the Pacific coast for several decades and became the route of semi-weekly Butterfield stages, beginning in 1858.

With the establishment of Fort Yuma in 1851, the Yuma-Winterhaven area became a permanent settlement and the center of activity in the region. Undoubtedly, the early development by Americans of the mines at the Cargo Muchacho Mountains and in the Picacho district was materially aided by the protective presence of the U.S. Army and the growing American population at Yuma.

Mining development was aided also by the advent of steamboat traffic on the Colorado River, which began in 1852 and continued through 1895. Heavy mining and milling equipment could be shipped to within wagon-hauling distance of the Paymaster, Picacho, and Cargo Muchacho districts. Of even greater significance, however, was the completion of the Southern Pacific railway in 1879, providing, for the first time, coast-to-coast service and a safe means of transporting gold and silver concentrates or bullion.

Development in the Imperial Valley area began about the turn of the century when the California Development Company built the first canal system to the valley. The first Colorado River water from the system entered the valley in June 1901, and rapid development ensued. With this development came the consequent supporting mining industry to supply brick, sand, and gravel.

By 1905 the population of the valley had reached 12,000. During that year, too, the water that had transformed the desert into a rich farming region threatened to further transform it into an inland sea. A breach excavated in the canal for a connection to the river, to increase flow during a period of low water, became so enlarged during a subsequent period of high run-off that the canal was receiving the full flow of the river. The Salton Basin filled and became a lake as in ancient times. Repeated attempts to fill the breach failed, but finally in 1907, through efforts of the Southern Pacific Company, the breach was closed. In the meantime, 350,000 acres had been inundated.

The water level reached an elevation of 195 feet below sea level or a maximum depth of 83 feet. Water subsidence was rapid, however; and by 1920 the lake level stood at 250 feet below sea level. Since the early 1930s, the level has risen steadily because of waste runoff from increased irrigation and a lower percolation rate through the lake bottom sediments. The level in 1965 was 232.5 feet below sea level and has been almost static thereafter.

With the construction of the All American Canal and the many dams on the Colorado River from 1934 to 1942, Imperial County has experienced continued growth based upon a guaranteed and controlled water source and continued development of its other natural resources. (See District summaries, commodity discussions, and mine descriptions for additional historical data.)

Water Resources

Mining and milling activities normally require substantial amounts of water of good quality. With the relatively few active mining operations in the county, however, the mining industry consumes only a small proportion of the available water. Most mines in the county are remote and have little water available to them. They must rely upon imported water or solve the problem by hauling ore to be milled where water is available.

Precautions to avoid stream or ground water pollution do not constitute major problems in the county, except in areas adjacent to the Colorado River and the Salton Sea. These areas are subject to stringent control by the California Regional Water Quality Control Board, Colorado River Basin Region.

The Colorado River is the largest source of water available to the county, and most of the water consumed comes from this source. Approximately 3,000,000 acre-feet of water are utilized each year. The water is diverted from the Colorado River through the All American Canal 35 canal miles westward to Imperial Valley, where it is used for irrigation and domestic needs. Waste water from irrigation drains into and maintains the level of the Salton Sea.

The Salton Sea, a brine lake, holds about 6,000,000 acre-feet of water containing about 37,500 ppm dissolved solids (1970); sea water contains about 35,000 ppm (see table 4). Because the Salton Sea supports game fish and waterfowl and is a recreation center, its pollution is a major concern. A group of Federal and State agencies have studied the problems of increased salinity in Salton Sea, and have proposed several schemes to stabilize salinity and lake level (Federal-State Technical Group, 1969). Severe restrictions involving the use of the lake, and particularly waste discharge into it, are enforced by the California Regional Water Quality Control Board, Colorado River Basin Region (No. 7), and the California Department of Fish and Game. Analyses of Colorado River and Salton Sea water are given in table 4.

The California Department of Water Resources has divided the ground water basins in Imperial County into 13 hydrologic units. These are noted on the map in figure 5, and data describing the features are tabulated in tables 5–7. (For detailed information, see California Division of Water Resources, 1954, Ground water occurrence and quality, Colorado River Basin region: Division of Water Resources Water Quality Investigations Report 4.)

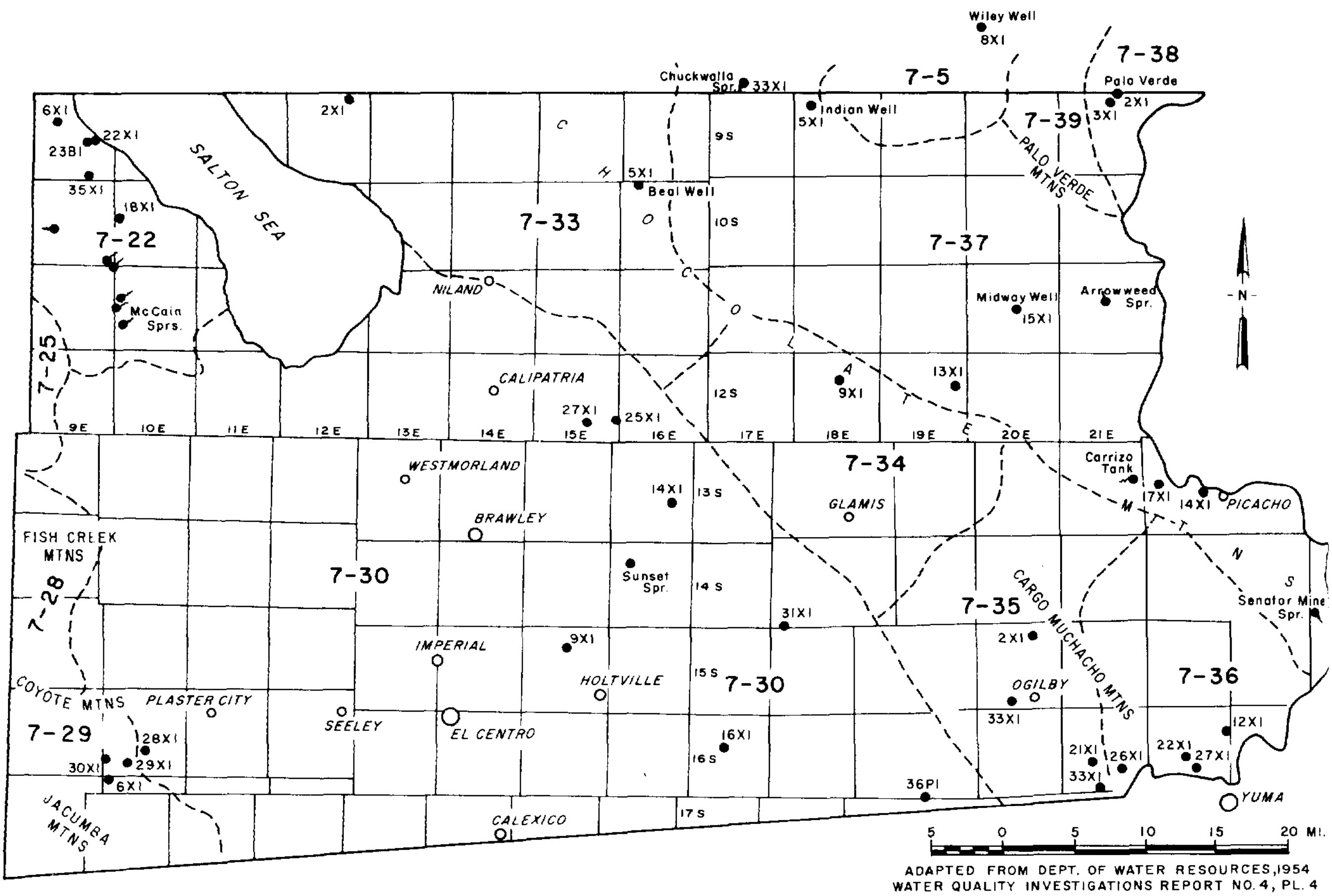

Figure 5. Map of Hydrologic Units and Water Wells. ***Adapted from California Division Water Resources, 1954, plate 4.***

Table 4. Comparative analyses of various Imperial County water sources. With Searles Lake and sea water in percentage of dissolved solids (from Ver Planck, 1958, p. 123).

	Sea water	Searles Lake	Salton Sea June 3, 1907	Salton Sea June 10, 1916	Salton Sea March 21, 1929	Salton Sea Nov. 23, 1953	Colorado River at Yuma	Geothermal steam well*	Salton Sea May 18, 1964†
	%	%	%	%	%	%	%	%	p.p.m.
Na	30.593	28.72	31.29	} 33.0	} 31.2	30.0	19.75	20.9	} 9,700
K	1.106	7.73	0.65	} 0.4	}		2.17	7.2	}
Ca	1.197	--	2.80	1.9	1.6	2.7	10.35	10.3	905
Mg	3.725	--	1.81	1.7	4.5	2.7	3.14	Trace	1,010
Fe_2O_3	--	--	0.002	Trace	--	--	--	1.2 (Fe)	--
Al_2O_3	--	--	0.016	--	--	--	--	--	--
SiO_2	--	--	0.26	0.1	--	--	3.04	Trace	--
Cl	55.292	38.51	47.83	49.2	50.9	43.8	19.92	60.2	13,900
Br	0.188	0.25	Trace	--	--	--	--	--	--
SO_4	7.692	--	13.41	13.0	11.0	20.0	28.61	--	7,410
B_4O_7	--	3.66	--	--	--	--	--	0.16	--
CO_3	0.207	--	1.85	} 0.7	} 0.8	} 0.6	13.02	--	} 175
HCO_3	--	--	--	}	}	}	--	--	}
Dissolved solids, p.p.m.	35,000±	344,431	3,648	16,472	31,050	35,545	702	335,674	33,000

* From McNitt, 1963, p. 33.
† From Hely, Hughes, and Irelan, 1966, p. 22.

*Table 5. Range in mineral constituents and physical properties of ground water in Imperial County.**

Source†	Temperature °C.	EC × 10⁶ at 25°C.	pH	Range in mineral constituents in parts per million											Total solids p.p.m.	Percent sodium	Total hardness as $CaCO_3$ p.p.m.
				Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B			
Chuckawalla Valley (7-5)																	
Wells	24	6,320	8.3	568	16.2	1,025	----	0.8	283	1,487	1,960	100	35.0	1.2	4,372	94	1,628
	21	677	7.1	7.2	0.0	42.4	----	0.0	41.5	54.7	77.5	0.0	1.7	0.0	420	26	22
West Salton Sea Basin (7-22)																	
Wells	------	10,000	------	492	169	3,013	----	----	1,682	289	5,006	-------	------	22.3	10,400	77	1,923
	------	3,650	------	275	23	498	----	----	167	40	1,012	-------	------	1.4	2,260	58	781
Artesian Wells	------	9,110	------	297	89	1,887	----	----	600	1,399	2,663	-------	------	4.6	5,450	95	1,107
	------	6,550	------	40	33	1,537	----	----	85	92	2,041	-------	------	2.2	5,310	75	235
Coyote Wells Valley (7-29)																	
Wells	------	1,800	------	86	41	3,137	----	288	1,061	1,522	2,508	-------	------	1.9	8,660	99	383
	------	520	------	3	1.6	80	----	0.0	152	53	71	-------	------	0.14	442	56	24
Imperial Valley (7-30)																	
Wells	------	4,300	------	345	86	820	----	192	647	595	1,508	-------	1.31	5.0	2,590	79	1,113
	------	740	------	12	8	62	----	0	0	22	89	-------	0.18	0.0	440	41	96
Wells	------	45,400	------	1,046	918	8,578	----	540	1,061	1,522	17,383	-------	1.18	7.0	37,900	94	6,379
	------	4,740	------	63	38	516	----	0	12	25	1,030	-------	0.84	0.27	3,330	75	313
Artesian Wells	------	8,490	------	182	106	1,646	----	72	1,000	1,530	1,907	27	3.23	10.1	5,570	88	889
	------	1,130	------	7	3	222	----	0	97	55	124	Tr	0.30	0.22	691	41	38
Springs	------	10,010	------	393	191	1,842	----	Tr	1,324	2,582	2,059	-------	------	1.18	7,540	88	1,767
	------	2,820	------	37	40	430	----	0	219	128	550	0.0	------	0.0	1,720	64	256
East Salton Sea Basin (7-33)																	
Wells	35.5	22,350	8.3	1,110	800	5,000	----	360	603	10,100	3,260	11.2	60	410	24,548	97	6,058
	21.5	581	8	17.6	0.5	42	----	0	290	8.4	71	0.0	0.4	0.08	356	27	46
Artesian Wells	------	6,650	------	200	63	1,141	----	----	506	281	1,800	-------	------	4.1	3,850	------	758
	------	4,190	------	90	52	708	----	----	207	190	1,143	-------	------	1.6	2,390	------	438
Ogilby Valley (7-35)																	
Wells	------	2,740	8.3	149	149	384	3.9	----	354	265	667	5.0	0.8	0.72	1,600	64	458
	------	680	7.9	17	7	11	0.4	0	104	13	65	2.5	0.0	0.0	368	7	71
Yuma Valley (7-36)																	
Wells	------	18,660	7.9	403	186	4,432	----	----	1,647	3,686	4,331	14.9	1.8	0.3	14,680	75	1,655
	------	892	7.7	45.2	0.5	147	----	0	49	65.8	72.0	6.2	0.8	0.1	538	42	142

*Table 5. Range in mineral constituents and physical properties of ground water in Imperial County—Continued.**

Source†	Tem-perature °C.	EC × 10⁶ at 25°C.	pH	Range in mineral constituents in parts per million											Total solids p.p.m.	Per-cent sodi-um	Total hardness as CaCO₃ p.p.m.
				Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B			
Arroyo Seco Valley (7-37)																	
Wells	------	4,270	7.8	598	60	808	----	----	732	1,385	860	126	6.0	1.62	2,970	87	1,73[illegible]
	------	548	6.9	20	0.0	4	----	0	24	12	21.3	5.0	0.0	0.0	330	14	54
Springs	------	3,310	------	84	6	776	----	----	244	733	744	------	------	0.23	2,450	88	23[illegible]
	------	610	------	21	5	1.4	----	0	79	63	43	------	------	0.0	493	4	77
Palo Verde Valley (7-38)																	
Wells	------	16,760	7.9	257	89.6	3,805	----	----	431	1,745	5,006	5.7	------	3.1	11,000	92	1,01[illegible]
	------	1,287	7.3	80	29	178	----	0	180	134	163	0.99	------	0.18	856	43	31[illegible]

*** Extracted from California Division of Water Resources, 1954, p. 48, 49.**
† See figure 5 for locations.

*Table 6. Typical water levels at wells in Imperial County.**

Well number†	Depth of well, in feet	Casing diameter, in inches	Date	Depth to water, in feet	Ground surface elevation above sea level
Chuckawalla Valley (7-5)					
8S/20E-8X1			5/22/52	25	----------
West Salton Sea Basin (7-22)					
9S/9E-22X1			9/ 4/50		—200
10S/10E-18X1			9/ 4/50		—60
Coyote Wells Valley (7-29)					
16S/10E-28X1	53	8	12/16/48	22.8	260
16S/10E-29X1	68		12/16/48	29.0	275
16S/10E-30X1	156	4	12/16/48	125.0	400
Imperial Valley (7-30)					
13S/16E-14X1	39.5	2	5/19/47	33.5	41.1
14S/18E-31X1		10	5/19/47	49.7	116.1
16S/17E-16X1	59	1.5	5/19/47	56.1	84.2
12S/15E-25X1	1,100	4	9/15/48	+7.22	—55
12S/15E-27X1	430	2.5	9/15/48	+25.38	—85
15S/15E-9X1	399	2	9/ 2/48	+9.75	—77
East Salton Sea Basin (7-33)					
8S/12E-1X1	15		5/27/52	14	941
10S/16E-5X1	42		6/11/52	38	1,280
8S/12E-7X1		4	3/20/50	+29.9	—150
9S/12E-2X1	325	10	9/ 6/48		—50
Tributary to Amos Valley (7-34)					
12S/18E-9X1			5/10/50	5.0	1,100
Ogilby Valley (7-35)					
15S/20E-2X1	521		1/19/49	380	550
15S/20E-33X1	210	4	1/27/49	185	300
16S/21E-21X1	293	10	1/19/49	160.5	275
Yuma Valley (7-36)					
16S/21E-26X1	110		6/ 1/50	105.2	250
16S/22E-12X1	Shallow	2	6/ 1/50	6.6	150
16S/22E-22X1	Shallow	2	6/ 1/50	4.2	140
16S/22E-27X1	225	6	12/27/45	13.0	120
Arroyo Seco Valley (7-37)					
9S/18E-5X1	22+		6/11/52	22	----------
Palo Verde Valley (7-38)					

* Extracted from California Division of Water Resources, 1954, p. 59.
† See figure 5 for locations.

Table 7. Mineral analyses of typical ground waters in Imperial County.*

*Table 7. Mineral analyses of typical ground waters in Imperial County *.*

Source†	Location	Depth of well, in feet	Date collected	Temperature °C.	EC $\times 10^{6}$ at 25°C.	pH	Mineral constituents in parts per million / equivalents per million: Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F p.p.m.	B p.p.m.	Total solids p.p.m.	Per-cent sodium	Total hardness as $CaCO_3$ p.p.m.	Suitable use
Chuckawalla Valley (7-5) Wiley (Riverside Co.)																					
Well	8S/20E-8X1	------	5/22/52	21	3,770	7.1	568	50.5	343	------	0	283	1,487	366	100	1.7	1.2	3,282	31	1,628	
							28.40	4.17	14.92			4.63	30.95	10.30	1.62						
West Salton Sea Basin (7-22), (5 complete and 15 partial analyses available)																					
Well	9S/9E-8X1	------	9/18/50	------	3,650	------	275	23	498	------	------	167	289	1,012	------	------	1.4	2,260	58	781	
Well	9S/9E-35X1	------	9/18/50	------	10,000	------	492	169	3,013	------	------	1,682	40	5,006	------	------	22.3	10,400	77	1,923	
Artesian Well	9S/9E-22X1	------	9/ 4/50	------	9,110	------	297	89	1,537	------	------	85	1,399	2,041	------	------	2.2	5,450	75	1,107	
Artesian Well	10S/10E-18X1	------	9/ 4/50	------	6,550	------	40	33	1,887	------	------	600	92	2,663	------	------	4.6	5,310	95	235	
Palm Wash Spring	10S/9E-20	------	1/10/49	------	4,070	------	73	26	775	------	0	222	41	2,141	0	------	3.8	2,260	85	290	
Coyote Wells Valley (7-29), (6 complete analyses available)																					
Well	16S/10E-28X1	53.0	12/16/48	------	------	------	3	14	3,137	------	288	1,061	1,522	2,508	------	------	1.9	8,660	99	65	
Well	16S/10E-29X1	68	12/16/48	------	1,800	------	86	41	225	------	0	165	112	441	------	------	0.14	1,095	56	383	
Well	16S/10E-30X1	156	12/16/48	------	520	------	10	20	80	------	0	152	53	71	------	------	0.15	442	62	107	Domestic
Well	16½S/10E-6X1	------	5/ 8/52	------	876	8.25	7.0	1.6	183	------	3.0	264	55.2	95.0	4.3	12.0	0.4	502	94	24	
							0.35	0.13	7.95		0.10	4.33	1.15	2.68	0.07						
Imperial Valley (7-30), (103 complete and 1 partial analyses available)																					
Well	13S/16E-14X1	39.5	5/19/47	------	6,100	------	120	94	1,200	------	0	189	372	1,951	------	0.91	5.20	3,560	79	686	
Well	14S/18E-31X1	------	5/19/47	------	2,370	------	167	86	337	------	0	220	431	620	------	1.31	0.50	1,550	49	770	
Well	16S/17E-16X1	59.0	5/19/47	------	3,410	------	60	32	671	------	0	24	478	869	------	0.80	4.90	2,220	84	281	
Well	16S/19E-36P1	228	3/31/52	21	876	8.3	84	29	105	0.4	0	176	265	103	2.5	0.6	0.04	694	41	329	Irrigation
							4.19	2.38	4.56	0.01		2.88	5.53	2.90	0.040						
Artesian Well	12S/15E-25X1	1,100	3/10/36	31.5	3,940	------	64	40	770	------	------	339	682	706	2	1.90	3.30	------	84	324	
Artesian Well	12S/15E-27X1	430	9/15/48	34.8	2,670	------	42	14	560	------	------	280	325	575	------	0.95	2.3	1,800	88	163	
Artesian Well	15S/15E-9X1	399	9/ 2/48	32	3,200	------	42	32	667	------	51	582	242	621	------	0.50	2.4	1,868	86	244	
Sunset Spring	14S/16E-8	------	1/16/51	------	4,100	------	37	40	897	------	0	1,324	128	703	------	------	1.8[n]	3,130	87	256	
East Salton Sea Basin (7-33), (7 complete analyses available)																					
Well	8S/12E-1X1	15	5/27/52	21.5	3,555	7.9	17.6	0.5	832	------	0	566	507	557	8.1	60.0	4.7	2,372	97	46	
							0.88	0.04	36.18			9.28	10.57	15.70	0.13						
Beal Well	10S/16E-5X1	42	6/11/52	23.8	581	7.8	71.6	15.3	42	7.4	0	290	8.40	71	0	0.40	0.08	356	27	242	Domestic; irrigation
							3.57	1.26	1.83	0.19		4.76	0.175	2.00							
Artesian Well	8S/12E-7X1	------	3/20/50	31	4,190	------	90	52	708	------	------	207	190	1,143	------	------	1.6	2,390	78	439	
Artesian Well	9S/12E-2X1	325	9/ 6/48	70.8	6,650	------	200	63	1,141	------	------	506	281	1,800	------	0.56	4.1	3,850	77	758	
Tributary to Amos Valley (7-34), (1 complete analysis available)																					
Well	12S/18E-9X1	------	5/10/50	------	1,590	------	195	40	105	------	0	262	515	92	------	------	0	1,210	26	652	

*Table 7. Mineral analyses of typical ground waters in Imperial County—Continued *.*

Source†	Location	Depth of well, in feet	Date collected	Temperature °C.	EC × 10⁶ at 25°C.	pH	Mineral constituents in parts per million / equivalents per million: Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F p.p.m.	B p.p.m.	Total solids p.p.m.	Per-cent sodium	Total hardness as $CaCO_3$ p.p.m.	Suitable use
Ogilby Valley (7-35), (8 complete analyses available)																					
Well	15S/20E/2X1	521	1/19/49	------	2,740	------	149	21	384	------	0	104	242	667	------	------	0.72	1,600	64	458	
Well	15S/20E-33X1	210	1/27/49	------	1,530	------	17	7	316	------	0	317	41	344	------	------	0.22	830	91	71	Domestic
Well	16S/21E-21X1	293	1/19/49	------	680	------	64	35	11	------	Tr	122	13	160	------	------	0.18	370	7	304	Domestic; irrigation
Well	16S/21E-33X1	200	3/31/52	21	1,019	7.9	60	14	175	3.9	0	251	116	181	5.0	0.8	0	668	64	207	Domestic
							2.99	1.15	7.60	0.1		4.12	2.42	5.10	0.080						
Yuma Valley (7-36), (6 complete analyses available)																					
Well	16S/21E-26X1	110	6/ 1/50	------	1,380	------	59	19	212	------	0	268	174	202	------	------	------	935	68	225	Domestic
Well	16S/22E-12X1	------	6/ 1/50	------	2,380	------	98	25	434	------	------	49	524	502	------	------	------	1,630	73	347	
Well	16S/22E-22X1	------	6/ 1/50	------	18,660	------	403	158	4,432	------	------	1,647	3,686	4,331	------	------	------	14,680	85	1,655	
Well	16S/22E-27X1	225	12/27/45	------	------	------	327	186	516	------	------	260	421	349	------	------	------	2,060	42	1,580	
Senator Mine Spring	15S/24E-6	------	5/ 9/50	------	2,500	------	73	21	452	------	0	458	232	451	------	------	0.14	1,680	79	268	
Arroyo Seco Valley (7-37), (18 complete analyses available)																					
Well	8S/17E-33X1	------	6/ 5/52	22	2,370	6.9	57.0	0	456	------	0	102	277	512	5.0	5.2	1.0	1,386	87	142	
							2.85		19.80			1.67	5.77	14.40	0.08						
Well	9S/18E-5X1	------	6/11/52	------	1,527	7.8	31.5	6.16	340	9.0	0	732	7.3	221	126	0.45	0.84	915	86	104	
							1.57	0.506	14.8	0.23		12.0	0.154	6.23	2.04						
Well	11S/20E-15X1	------	5/22/52	22	548	7.6	94.2	5.3	19.0	------	0	302	16.3	21.3	9.9	0	<0.1	330	14	257	Domestic; irrigation
							4.71	0.44	0.83			4.96	0.34	0.60	0.16						
Well	12S/19E-13X1	------	5/15/52	------	2,960	7.8	106	1.1	520	------	0	81.7	251	740	5.6	6.0	0.8	1,692	81	270	
							5.32	0.09	22.60			1.34	5.22	20.80	0.09						
Well	13S/22E-14X1	18	5/13/52	29	1,405	7.9	45.2	15.1	247	------	0	416	127	177	6.2	1.8	0.3	888	75	175	
							2.26	1.24	10.74			6.82	2.65	5.00	0.10						
Well	13S/22E-17X1	------	5/13/52	29	892	7.7	55.8	0.5	147	------	0	242	65.8	72.0	14.9	0.8	0.1	538	69	142	Domestic
							2.79	0.04	6.40			5.61	1.37	2.03	0.24						
Chuckawalla Spring	8S/17E-33	------	5/11/50	------	3,310	------	84	5	776	------	0	79	733	744	------	------	0.70	2,450	88	231	
Carrizo Tank	13S/21E-13	------	5/10/50	------	610	------	21	6	1.4	------	0	244	63	43	------	------	0	493	4	77	Domestic; irrigation
Palo Verde Valley (7-38), (5 complete analyses available)																					
Well	6S/23E-31G2	150	9/13/51	------	2,145	7.3	170	49	245	------	0	431	559	192	1.9	------	0.27	1,479	43	626	
							9.88	4.03	10.68			7.07	10.75	5.41	0.032						
Well	6S/23E-36N1	------	2/14/52	------	------	7.6	257	89.6	810	------	0	306	866	1,130	------	0.4	------	3,532	63	1,010	
Well	7S/22E-34X1	------	3/24/51	21	1,287	7.9	80	29	178	4.75	0	258	134	250	0.99	------	0.18	856	54	319	Domestic; irrigation
							3.99	2.38	7.74	0.122		4.24	2.80	7.05	0.016						
Well	9S/21E-2X1	------	5/11/50	------	1,540	------	99	29	221	------	0	305	355	163	------	------	0.69	1,170	57	366	
Well	9S/21E-3X1	280	5/11/50	------	16,760	------	178	73	3,805	------	0	180	1,745	5,006	------	------	3.1	11,000	92	744	

* Extracted from California Division of Water Resources, 1954, p. 40–47.
† See figure 5 for locations.

Geology

The geology of Imperial County has been studied by many investigators although most of their work has been concentrated in the western parts of the county. William P. Blake's *Report of a geologic reconnaissance of California* (1858) is the earliest known work, and Brown's *The Salton Sea region* (1923) is the only work which covers the entire county. Neither, however, is complete. In 1965 a report on the geology of lower Colorado River area was in preparation by the Water Branch of the U.S. Geological Survey. This report promises to be an important contribution to the geology of eastern Imperial County [subsequently published as Professional Paper 486]. Geologic work is in progress by researchers of the University of California, Riverside, and the Bureau of Reclamation in Imperial Valley and the sand hills to the east, in connection with development of geothermal resources.

Some of the principal works dealing with the geology of Imperial County are listed in the references at the end of this report.

General Features

Imperial County lies in parts of three natural geomorphic provinces: the Peninsular Ranges province, the Salton Trough province, and the Mojave Desert province (figure 6). Each of these provinces is a distinct physiographic unit and reflects a distinct geologic history.

Only a small part of the eastern Peninsular Ranges province lies in Imperial County: the eastern tip of the Santa Rosa Mountains, the Fish Creek Mountains, the Coyote Mountains, and the southeastern tip of the Jacumba Mountains. The province is characterized in its broader physiographic features by northwest-trending mountains of moderate to sharp relief.

The oldest rocks in the province are Paleozoic(?) metasedimentary rocks and gneiss which are intruded by acid igneous rocks of Mesozoic age. These crystalline rocks are overlain or flanked by Tertiary marine and non-marine sedimentary and volcanic rocks which mark the western edges of the Salton Trough province.

The northwest-trending valleys within the Peninsular Ranges reflect right-lateral faults of similar trend and probable large displacement. These are, from north to south: the San Felipe Hills, San Jacinto, San Felipe, and Elsinore faults. The Tertiary and older rocks adjacent to these faults are highly deformed and owe their present structural configuration to the same tectonic forces which produced these faults and related folding.

The Salton Trough province extends from its western boundary with the Peninsular Ranges province eastward 30 to 60 miles to the edges of the Chocolate and Cargo Muchacho Mountains and includes the

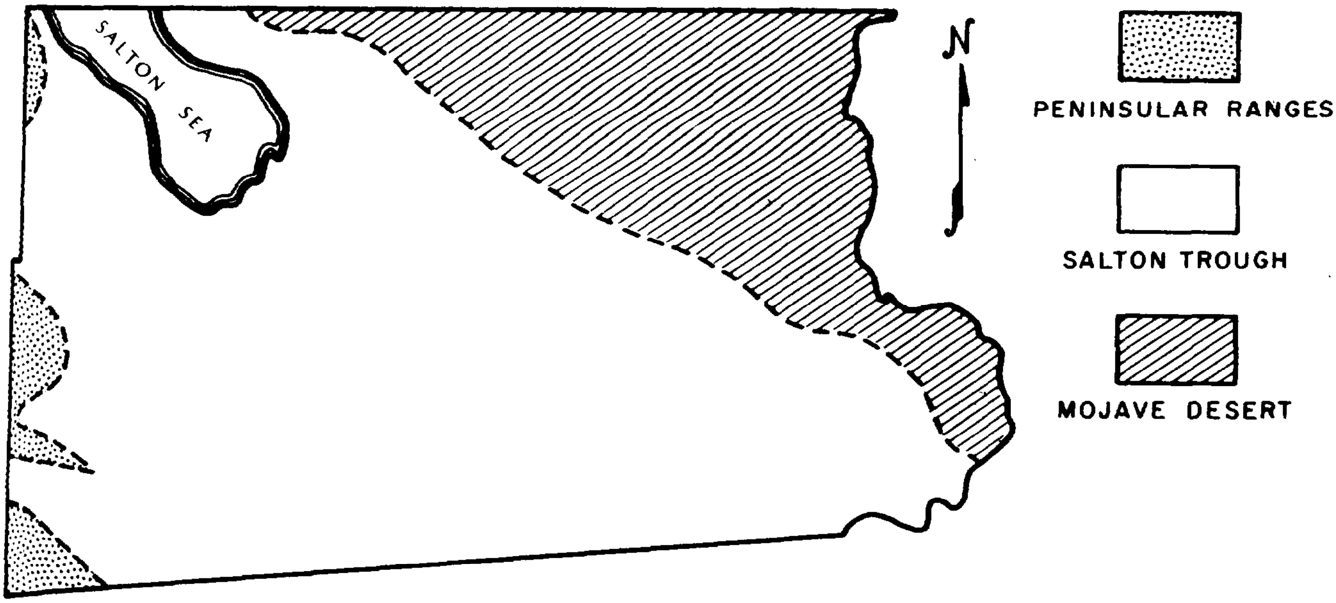

Figure 6. Map of Geomorphic Provinces.

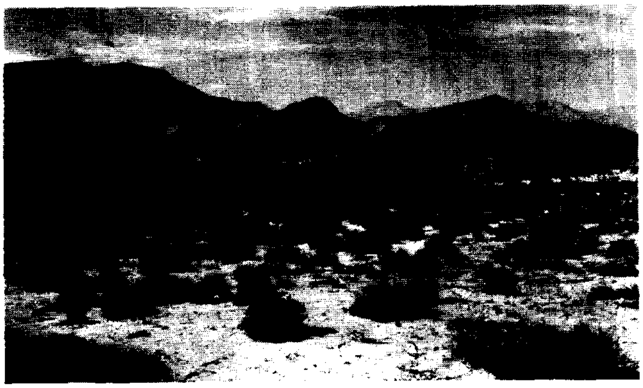

Photo 3. Travertine Deposit Along the Shore of Lake Cahuilla. The deposit appears on the west shoreline of the ancient lake, on the east front of the Santa Rosa Mountains. The view is west.

structural trough of the Imperial and Coachella Valleys and the Salton Sea.

Imperial Valley is essentially a flat featureless alluvium-filled northwest-trending basin except along its western and eastern boundaries. The western fringes of the basin are interrupted by the low-lying San Felipe Hills, just south of the Salton Sea; the Superstition Hills and Superstition Mountain, which are west of Brawley; and Yuha Buttes near the Mexican border. These gently elevated areas are underlain predominantly by deformed Tertiary non-marine and marine sediments.

A small body of Mesozoic granitic rock is exposed adjacent to the southeasternmost extension of the San Jacinto fault at Superstition Mountain. The San Andreas-Mission Creek fault zone is exposed near Durmid and Pope on the northeast shore of the Salton Sea, but its trace farther southeast is not apparent. The linear nature of the Sand Hills, especially their southwestern front, and geophysical evidence (Kovach *et al.*, 1962, p. 2869; and Biehler, 1964) strongly suggest the presence of a fault in that area. Other known and potentially active faults underlie Imperial Valley, including the Imperial fault, locus of the disastrous 1940 earthquake.

Below the alluvial cover of Imperial Valley lies an unexposed succession of Tertiary and Quaternary sedimentary rocks at least 20,000 feet thick (Rex, 1970). Fragmentary drill hole logs from exploratory holes drilled for oil and for geothermal steam indicate that the sedimentary rocks are composed predominantly of nonmarine sandstones and clays and of lacustrine deposits, but these have not been generally assigned formational names. Most of the wells were reported to have encountered entirely nonmarine rocks.

Basement depths generally are greater at the south end of the valley (figure 9). The depths to basement in the Imperial Valley range from at least 15,400 to 11,000 feet at the east and west margins to over 20,000 feet within a large area in the central portion of the valley. Certain abrupt changes in the central part of the trough are interpreted as fault-controlled.

The Salton Trough is believed to be the northern extension of a zone of crustal separation or rifting known as the East Pacific Rise. The opening of the trough and the adjacent Gulf of California to the south probably was initiated in Pliocene time. The rifting mechanism is believed still to be operating. The *en echelon* faults cutting the Salton Trough are believed to be transform faults offsetting the rift center progressively northwest.

The remainder or eastern part of the county comprises the Mojave Desert province. In it lie the Cargo Muchacho, Palo Verde, Little Mule, and Chocolate Mountains, and the Black Hills. The Cargo Muchacho and Chocolate Mountains are characterized by sharp relief and general northwest alignment. Both ranges contain gneiss, schist, and granitic rocks of the Precambrian(?) Chuckwalla Complex and Orocopia Schist; but in the Chocolate Mountains these rocks are intruded or overlain by Mesozoic metavolcanic and metasedimentary rocks (McCoy Mountains Formation(?)), Mesozoic plutonic rocks, and by Tertiary volcanic and pyroclastic rocks. These in turn are overlain by Tertiary non-marine conglomerate, Pliocene(?) basalt flows, Pleistocene gravel, and Holocene alluvium.

Only the Pliocene(?) basalt and alluvium overlie Mesozoic rocks in the Cargo Muchacho Mountains. The Little Mule and Palo Verde Mountains and the Black Hills are comprised of a wide variety of Tertiary volcanic and pyroclastic rock although small masses of underlying Chuckwalla Complex rocks crop out at scattered localities (see plate 1).

Rock Units

Precambrian(?) Rocks

Rocks ascribed to Precambrian(?) age in Imperial County are divided mainly into two groups, the Chuckwalla Complex and Orocopia Schist, both named by Miller in 1944. The Chuckwalla Complex, named for excellent exposures in the Chuckwalla Mountains, was first described in the Cottonwood and Little San Bernardino Mountains in southeastern Riverside County. The Orocopia Schist was named for the Orocopia Mountains, the type area, which is just northwest of the Chocolate Mountains in Riverside County.

Chuckwalla Complex

The most abundant exposures of the Chuckwalla Complex in Imperial County occur in the high central parts of the northwestern end of the Chocolate Mountains. The complex also underlies several square miles southeast of Midway Well in the central Chocolate Mountains and occurs in several smaller areas throughout the eastern half of the county, notably near the Picacho mine, Pilot Nob, and the Paymaster mine.

The Chuckwalla Complex in Imperial County has a typically mottled or patchy gray appearance when viewed from a distance—a function of its complex multiple intrusive nature. Smaller more homogeneous bodies within the complex commonly appear a dull dark gray. In general, topographic expression of the unit is characterized by moderately steep rugged terrain.

The rocks are composed of quartz biotite gneiss and various foliated hybrid granitic rocks and granophyres which range in composition from gabbro to granite, but acid and intermediate rocks are more common than basic ones. Of these rocks, gneiss is the most common and is shown separately where feasible on the geologic map (plate 1). The average gneiss is composed of quartz, albite or other soda-lime feldspars, and biotite with minor magnetite and chlorite. Calcite-rich bands parallel to the schistosity and well-rounded quartz grains were noted in some gneiss and suggest that it may be in part of sedimentary origin. Cataclastic textures are common. All stages of assimilation of the gneiss in granitic rocks are evident with hybrid varieties common. A sample of foliated granite collected 3 miles northeast of Beal Well is composed principally of quartz, orthoclase, and microcline. Subordinate amounts of sericite, magnetite, chlorite, and an unidentified ferromagnesium mineral are present.

Many of the gold-silver deposits outside of the Cargo Muchacho Mountains occur in gneissic rocks of the Chuckwalla Complex. The paucity of deposits in younger rocks suggests that the deposits may be Precambrian in age.

Miller (1944, p. 20) assigned a Precambrian age to the Chuckwalla Complex. It is clearly older than all other units observed in contact with it, but an absolute age date has not been determined [1966].

Orocopia Schist

The Orocopia Schist crops out principally in the central and southeastern Chocolate Mountains. The largest bodies occur at Mammoth Wash, Blue Mountain, northeast of Glamis, east of Indian Pass, and along the south bank of the Colorado River upstream from Imperial Reservoir.

Exposures of Orocopia Schist are generally dark, almost black, boldly resistant tilted strata. The rock weathers into flaggy plates whose flat, mica-covered surfaces commonly glisten in bright light.

The unit is composed mostly of sericite-albite schist, quartz sericite schist, biotite schist, phyllite, and quartzite, although a distinctive actinolite schist facies is exposed in at least one area, about 7 miles northeast of Acolita. Marble occurs in the schist in the Orocopia Mountains, although none has been noted in the Chocolate Mountains. A sample of sericite-albite schist collected about 9 miles northeast of Acolita is composed principally of sericite and albite with minor biotite and quartz, bedding was apparent parallel to the schistosity in thin section. No estimate of the thickness of the unit has been made in the Chocolate Mountains.

The age of the Orocopia Schist has not been satisfactorily demonstrated. Miller (1944) stated that it is probably of late Precambrian age because of its lithologic similarity with Pelona Schist of the San Gabriel Mountains, but even the age of that rock unit has not been clearly demonstrated in the literature.

Only a few mineral deposits occur in Orocopia Schist in the county. The Vitrefrax Formation which contains kyanite and sericite deposits in the Cargo Muchacho Mountains might possibly be correlated with the Orocopia Schist, although the metamorphic rank of rocks in the former unit is higher.

Vitrefrax Formation

The Vitrefrax Formation was first described by Henshaw (1942) at its only known locality in the Cargo Muchacho Mountains. The unit underlies an area of less than 1 square mile at the western front of the range.

It consists of quartzite, sericite schist, kyanite-quartz granulite, and kyanite-pyrophyllite sericite pelitic schist (U.S. Bureau of Mines, personal communication). Both amphibolite and granulite assemblages are present.

The quartzite is a gray, medium-grained rock composed of granoblastic grains of quartz with interstitial fine-grained magnetite and hematite. The rock grades into kyanite-rich granulite zones composed of large porphyroblasts of kyanite in radiating aggregates in a matrix of granoblastic quartz. Hematite, magnetite and rutile are common; and pyrophyllite, tourmaline, and pyrite are present locally.

Pure sericite schist occurs in discontinuous masses as much as 100 feet thick and a few hundred feet long. It contains variable amounts of disseminated quartz.

Henshaw dated the Vitrefrax Formation simply as pre-Mesozoic. Miller (1946, p. 490) gives the age as probably early Precambrian but does not state his evidence for this. The unit may be a facies of the Orocopia Schist that has undergone a higher grade of metamorphism.

Tumco Formation

The Tumco Formation, described by Henshaw in 1942, crops out over much of the northern half of the Cargo Muchacho Mountains. It is named for its type area in Tumco Valley in the northwestern part of the range where it underlies a four-square-mile area.

The Tumco Formation consists of more than 6000 feet of metasedimentary rocks ranging in composition from fine- to medium-grained hornblende schist to gray to pinkish-gray, highly indurated arkosite (Henshaw, 1942, p. 155). According to Henshaw, the arkosite is composed of 25 percent microcline, 25 percent orthoclase, 45 percent quartz, with biotite, hornblende, magnetite, apatite, and zircon making up the remaining 5 percent. The hornblende schist is characterized by its thinly bedded nature and its large hornblende porphyroblasts. It is intercalated throughout the arkosite at wide stratigraphic intervals in unjointed beds a few inches to a foot in thickness. It is composed of 20 to 40 percent microcline and orthoclase, 45 percent quartz, 2 to 18 percent biotite, 8 percent epidote, and 5 percent hornblende. The schistosity is defined by large scattered crystals of biotite and hornblende (Henshaw, 1942, p. 158).

According to Henshaw, well-rounded quartz and feldspar grains in the arkosite attest to its sedimentary origin. He suggests a tuffaceous origin for the schist. However, Henshaw's description of arkosite and hornblende schist fits contemporary descriptions of quartzo-feldspathic schist of the albite-epidote amphibolite facies (Williams, Turner, and Gilbert, 1954, p. 210; Turner and Verhoogan, 1951, p. 465).

Henshaw (1942, p. 148) has indicated the age of this unit simply as pre-Mesozoic. Miller (1946, p. 490) states that it is probably early Precambrian, but because of the lack of evidence given for this, it is probably best to regard the age as pre-Mesozoic.

The only mineral deposits known to occur in the Tumco Formation are the Tumco lode gold deposits in the Cargo Muchacho district. However, the deposits of the district are not limited solely to this formation.

Paleozoic(?) or Triassic(?) Rocks

Rocks described as Paleozoic(?) or Triassic(?) in age have been described briefly by Dibblee (1954, p. 21). These unnamed rocks comprise perhaps 20,000 feet or more of biotite schist and interbedded limestone, which in some areas are further metamorphosed to gneiss and marble.

The thickest exposed section of these schists and limestones crops out in the Santa Rosa Mountains just outside Imperial County in San Diego and Riverside Counties. Some 10,000 feet of gray mica schist and gray-to-white limestone crop out in the eastern parts of the Coyote Mountains. These grade westward and southward into gneissic and granitic rocks at the steep western and southwestern fronts of the range (Dibblee, 1954, p. 21). Rocks of this more advanced stage of metamorphism also are exposed in the foothills of the Jacumba Mountains and in the higher north and eastern parts of the Fish Creek Mountains.

Probably the most significant economic potential of these rocks lies in the fairly large bodies of cement-grade limestone that they contain (see Coyote Mountains and Fish Creek Mountains deposits). Several metal occurrences, including gold, copper, and tungsten, are associated with these rocks, but none has yielded significant amounts of ore.

Mesozoic Rocks

McCoy Mountains Formation(?)

Metasedimentary and metavolcanic rocks tentatively correlated with the McCoy Mountains Formation of Miller (1944, p. 32) have been recognized at several localities in Imperial County. The largest exposure is a west-trending elongate mass 7 miles long and ½ mile wide centered about ½ mile north of Indian Pass in the southern Chocolate Mountains. Another ½ square mile area is about 3 miles south of Picacho. Two of the remaining areas are also in the Picacho area—1½ miles east, and 2 miles southwest of Picacho. A fifth occurrence is an exposure of metaconglomerate in the area about the Senator mine, west of Imperial Dam.

The rocks of this unit in Imperial County are composed of metasandstone, metaconglomerate, phyllite, meta-andesite, other metavolcanic rocks, and minor limestone; phyllite is the most common of these. Areas underlain by this formation are characteristically dark gray or gray-green and tend to have rounded, subdued topography. Correlation of these rocks with those of the McCoy Mountains Formation in Riverside County is based on their similarity in lithology, degree of metamorphism, and their similar contact relationships with Precambrian(?) and Tertiary rocks. A probable late Paleozoic or Triassic age was assigned to the McCoy Formation by Miller (1944, p. 52).

Mineral deposits that have been found in this unit in Imperial County include the copper prospects south of Picacho and near Quartz Peak and the Trio and Senator gold mines at the Colorado River. The genesis of these deposits does not appear to be related to the occurrence of the formation.

Cretaceous Igneous Rocks

Igneous rocks related to the southern California batholith of probable Cretaceous age are widespread in Imperial County as they are elsewhere in the inland provinces of California.

In the Peninsular Ranges province part of the county, west of Imperial Valley, the dominant plutonic rocks are granodiorite with lesser amounts of granite, quartz monzonite, and quartz diorite (Dibblee, 1954, p. 21). The separate mountainous areas of the western Imperial Valley such as Signal Mountain, Superstition Mountain, Fish Creek, Vallecito, and Santa Rosa Mountains are underlain by bodies of diorite. quartz diorite, and gabbro. Plutonic rocks in the Chocolate Mountains are predominantly granite and quartz monzonite. The various granitic intrusive masses have not been closely studied in the Chocolate Mountains. In the Cargo Muchacho Mountains, Henshaw (1942) identified biotite granite, leucogranite, quartz diorite, and quartz monzonite. He demonstrated that biotite granite and leucogranite were later than quartz diorite and quartz monzonite in the Cargo Muchacho area but dated all as Mesozoic. Miller (1946), however, assigned a Paleozoic date to both granite types and a late Mesozoic age to the quartz diorite and quartz monzonite. Quartz diorite from Superstition Mountain has been determined by lead alpha methods to be 155 million years ± 10 percent, or Jurassic to Late Triassic in age (Bushee *et al.*, 1963, p. 805).

Widely scattered throughout the county are deposits of gold, silver, copper, tungsten, and uranium associated with various Mesozoic intrusive rocks. The Mesozoic era probably was one of the more important metallogenetic epochs during the geologic history of the region. The fact that metallic mineral deposits are genetically related to the emplacement of Mesozoic plutonic rocks has been amply demonstrated throughout the western United States and Mexico (Lindgren, 1928, p. 1002); Imperial County is no exception. More study is needed, however, to determine which type or types of intrusive rock in the county are most likely to be associated with metal deposits, and which particular sets of conditions were necessary for ore deposition.

Cenozoic Rocks

A great variety and thickness of Tertiary and Quaternary sedimentary and volcanic rocks occur in Imperial County. In the Imperial Valley and the Peninsular Ranges the Cenozoic section comprises more than 20,000 feet of nonmarine, marine and volcanic rocks representing accumulation since Miocene time in a very broad basin that corresponds generally to the present drainage basin of Imperial-Coachella Valley (Rex, 1970, figure 3; Dibblee, 1954, p. 22). In the eastern or Mojave Desert province the Cenozoic section consists of abundant Tertiary and Quaternary volcanic rocks which are intercalated with an almost equally abundant variety of nonmarine sediments and pyroclastic rocks (see plate 1).

Hypabyssal Rocks

A peculiar rock unit characterized by its well-layered appearance crops out in a 6-square-mile area at the west-facing northern tip of the Chocolate Mountains. Its stratified appearance is due to the presence of numerous parallel dike-like bodies of quartz latite porphyry within the main body of porphyritic quartz monzonite rock. Individual dike-like bodies are 10 to 40 feet wide and can be traced 2000 feet or more. They trend N 35 degrees to 50 degrees W and dip steeply southwest and northeast parallel to the regional structure, including at least two large fault zones within the unit itself. The parallelism of these features and some textural relations as well suggest that these rocks lie in a zone that has long been undergoing deformation.

Field relations indicate that the dike-like bodies intrude the coarser grained material, and thin sections thought to be representative of the unit indicate a hypabyssal origin; however, some sections show characteristics, such as spherulitic texture and corroded dipyrimidal quartz phenocrysts, that are common in extrusive rocks as well as shallow intrusive rocks.

The age of this rock unit has not been satisfactorily determined. The dike-like bodies within it may be correlative with the Tertiary volcanic rocks exposed elsewhere in the Chocolate Mountains. It is not clear what the genetic relationships are between these dikes and the coarser grained quartz monzonite that contains them. If it can be shown that the two rocks are similar in their bulk chemistry, a strong possibility exists that they are related closely in time. Upon these admittedly tenuous presumptions, the unit is here considered to be at least as old as Tertiary in age, although a much older age is equally tenable.

Imperial Valley and the Peninsular Ranges

SPLIT MOUNTAIN FORMATION

The oldest exposed Cenozoic rocks on the west side of Imperial Valley are the non-marine conglomerate and sandstone of the Split Mountain Formation (Tarbet, 1944). The formation is well exposed at its type area at Split Mountain Gorge in the northwest Fish Creek Mountains, where it consists of 2700 feet of red and gray granite-rich fanglomerate, sandstone, and diorite breccia. Another large area of exposures is in the southeast foothills of the Jacumba Mountains east of Davies Valley. The unit apparently thins towards Imperial Valley; it is present only at two localities in the Coyote Mountains (Dibblee, 1954, p. 22). The Split Mountain Formation rests on an erosional surface cut into the Paleozoic and Cretaceous rocks. It has been dated as middle Miocene (Durham, 1954, p. 27).

ALVERSON ANDESITE

Alverson Andesite is a sequence consisting mostly of andesite flows of varied color and interbedded tuff, breccia, and non-marine sandstone and conglomerate which crops out in southwestern Imperial County. The largest exposures cover 2 to 3 square miles and all of the known exposures fall in a north-south belt 20 miles long and 12 miles wide. The most abundant of these are in the eastern Coyote Mountains, where about 700 feet of strata are exposed. The rock is 400 feet thick at the type area in Alverson Canyon of the Coyote Mountains. Other large exposures are in the southern Fish Creek Mountains and the eastern foothills of the Jacumba Mountains.

Alverson Andesite overlies middle Miocene Split Mountain Formation and underlies Pliocene Imperial Formation. It is dated by Dibblee (1954, p. 22) as probable late Miocene.

Alverson Andesite has been mined and crushed for use as roofing granules and decorative stone.

FISH CREEK GYPSUM

Fish Creek Gypsum crops out only in a 16-square-mile area in the northwestern Fish Creek Mountains. The deposit consists of pure gypsum and anhydrite as much as 200 feet thick. A 5-foot thickness of celestite occurs at its northwesternmost occurrence about 60 feet above the base of the formation, but it has not been noted elsewhere in the gypsum. The gypsum is described by Dibblee (1954) as post-Alverson Andesite but is included as part of the Split Mountain Formation of Miocene age by Woodard (1961) and Ver Planck (1952).

Both gypsum and the celestite have been mined from this formation, which currently yields a significant part of the nation's total yearly output of gypsum (see U.S. Gypsum mine).

IMPERIAL FORMATION

The Imperial Formation, named by Woodring (1931), is the only dominantly marine formation known to occur in Imperial County. It crops out in one almost continuous northwest-trending belt extending 22 miles from its northwestern tip in the Vallecito Mountains of San Diego County, through the Fish Creek Mountains, to the southeastern flanks of the Coyote Mountains (photo 4). The belt is 3 to 11 miles wide from southwest to northeast. Smaller exposures crop out in the San Felipe Hills and in the foothills east-southeast of Coyote Wells. The Imperial Formation has been reported but not confirmed in numerous exploratory oil wells and steam wells throughout Imperial Valley but does not crop out on the east side of the valley.

It is composed predominantly of yellow and gray claystone with interbedded sandstone, and oyster-shell reefs. The basal 5 to 200 feet consists of sandstone and conglomerate. Thickness of the formation is as much as 3700 feet on the north side and 2700 feet on the south side of Carrizo Creek in the Fish Creek Mountains (Dibblee, 1954, p. 22) and 2800 feet thick in drill holes near Obsidian Butte at the east side of Imperial Valley.

The age of the Imperial Formation has been variously determined to be late Miocene to middle Pliocene (Christensen, 1957, p. 100; Durham, 1954, p. 27). Woodard (1961, p. 73), however, states that the Imperial Formation grades laterally and upward into the Palm Spring Formation, which he dates as middle Pleistocene.

Petroleum exploration activities in the Imperial Valley have been directed towards possible oil accumulations in the Imperial Formation, but through 1963 none had been commercially extracted. A small amount of claystone from the unit has been utilized as a cattle feed extender. Other applications for the abundant, large masses of homogeneous clays found in the formation may be found in the future.

Photo 4. Terrain Underlain by Imperial Formation. The view of the Pliocene formation is to the east; Carrizo Mountain is on the left skyline.

PALM SPRING FORMATION

The Palm Spring Formation conformably overlies the Imperial Formation, which grades upward into it. Named by Woodring (1931), the Palm Spring Formation is composed of a thick sequence of interbedded light-gray non-marine arkosic sandstone and reddish clay. It crops out in a discontinuous belt along the lower flanks of the Jacumba Mountains, northwestward through the Coyote and Fish Creek Mountains, and northward from San Felipe Creek to the east flanks of the Santa Rosa Mountains. Another belt, outside the county, trends northwestward from the west edge of the Orocopia Mountains on the northeast side of the San Andreas fault. A brackish water delta(?) facies of the Palm Spring Formation has been reported underlying the Borrego Formation in steam wells at the southeast end of the Salton Sea.

According to Dibblee the Palm Spring Formation is 6500 feet thick north of Carrizo Creek and 4800 feet thick south of Carrizo Creek. It thins to the west where it grades into Canebrake Conglomerate. It has been dated variously as middle Pliocene (Dibblee, 1954, p. 22), Plio-Pleistocene (Smith, 1961, unpub.), and middle Pleistocene (Woodard, 1961, p. 73).

CANEBRAKE CONGLOMERATE

The Canebrake Conglomerate, named by Dibblee (1954, p. 23), is the coarse marginal facies of both the Imperial and Palm Spring Formations. In Imperial County it crops out only at the extreme northwest tip of the county west of Travertine Point. In its thickest exposures, which occur outside the county, it is 7,000 feet thick. It is composed of conglomerate containing mostly granitic and metamorphic debris. As Canebrake Conglomerate transcends the Imperial and Palm Spring Formations, it is mostly of Pliocene age, but the upper parts may be as young as Pleistocene.

Northwest of Truckhaven, Canebrake Conglomerate contains a 100-foot-thick varicolored rhyolite flow, which has been termed Truckhaven Rhyolite by Dibblee (1954, p. 24). As this flow is contained in the Canebrake Conglomerate, it is considered here to be a member of that unit.

BORREGO FORMATION

The Borrego Formation, named by Tarbet (1944), is the lacustrine facies of the Palm Spring Formation (Dibblee, 1954, p. 23). It crops out abundantly west of the south end of the Salton Sea and is exposed along the east shore of the Salton Sea between Pope and Durmid, west of the San Andreas fault. It is composed of gray clay with interbedded sandstone and contains a lacustrine fauna of minute mollusks, ostracods, and Foraminifera. Near Bertram the clay contains lenses of sodium sulphate as much as 6 feet thick; these have been mined (see Bertram deposit under Salines). A maximum thickness of about 6000 feet of Borrego Formation is attained west of the county boundary and east of Borrego Sink (Dibblee, 1954, p. 24).

Dibblee (1954) dates the Borrego Formation as probably late Pliocene, but Downs and Woodard (1961) date underlying Palm Spring Formation as middle Pleistocene on the basis of a vertebrate fauna. If the latter is correct, the Borrego Formation is correspondingly younger.

OCOTILLO CONGLOMERATE

The Ocotillo Conglomerate was first described by Dibblee (1954, p. 24) and apparently is named for exposures near Ocotillo Wells. However, the type area is northeast of Borrego in the northern part of the Borrego Badlands, San Diego County. It consists of as much as 1000 feet of gray granitic pebble conglomerate. The formation is dated by Dibblee as Pleistocene or possibly late Pliocene, but the latter age may be ruled out by Downs and Woodard's work on the Borrego Formation (above). The formation lies unconformably upon the Borrego and Palm Spring Formations and grades eastward into the Brawley Formation. In Imperial County it crops out just north of State Highway 78, at the eastern end of Superstition Mountain, and in the valley east of the Coyote Mountains.

BRAWLEY FORMATION

The Brawley Formation, named and described by Dibblee (1954, p. 24), represents the lacustrine facies of the Ocotillo Conglomerate. The formation, which consists of about 2000 feet of light gray clays, sandstone, and pebble gravels, is very similar to the Borrego Formation but is younger, according to Dibblee. Brawley beds are exposed on the basinward side of the Ocotillo Conglomerate in the Superstition Hills, Superstition Mountain, and in the area north and west of the junction of State Highways 86 and 78. The Brawley Formation is dated as Pleistocene or late Pliocene (Dibblee, p. 24), but if determinations by Downs and Woodard (1961, p. 21) are valid then it is at least as young as middle Pleistocene and probably younger.

QUATERNARY ACIDIC VOLCANIC ROCKS

Five volcanic domes composed of rhyolitic pumice and obsidian intrude and overlie lake beds of the Brawley Formation at the southeastern shore of the Salton Sea. The domes are aligned in a north-northeast-trending arc about 4 miles long. Each underlies an area of less than ½ square mile.

These rocks are clearly younger than Brawley lake beds and have been subjected to the wave-cutting action of at least one stage of ancient Lake Cahuilla (see photo 5). In addition, the high geothermal gradient (U.S. Bureau of Reclamation, 1971, map, following p. 22) and presence of carbon dioxide and steam wells, as well as weak discharge of gases from joints and fractures in the domes, suggest that these intrusions are still cooling. The age of these domes, as determined by R. W. Kistler and John Obradovich in one sample of obsidian from Obsidian Butte, was about 16,000 years (Muffler and White, 1969, p. 162).

Pumice mined from two of these domes has been utilized in the manufacture of concrete blocks in Calipatria and has been marketed as an abrasive material.

Photo 5. Wave Cut Terraces of Lake Cahuilla. The view of the north cone of Obsidian Butte is to the north.

QUATERNARY LAKE BEDS

Most of the central parts of the Imperial Valley more than 40 feet below sea level are underlain by clay and silt deposits of ancient Lake Cahuilla. Shoreline deposits a few hundred feet wide circumscribe the Salton Basin and consist predominantly of unconsolidated sand and fine gravel. Basinward these grade into silt and clay. The western shoreline in some areas is marked by a thin coating of travertine on the older rocks (see photo 3). In general, Lake Cahuilla beds are believed to be less than 100 feet thick.

Lake Cahuilla originated by periodic overflow and diversions of the Colorado River into the Salton Basin. The lake was in existence as recently as several hundred years ago, according to Indian legend (Blake, 1857, p. 228), zoological evidence (Hubbs, 1948, p. 107), and radiometric data (Radiocarbon, 1963, p. 261). Hubbs states that the main stage of its existence however is probably much older—possibly Wisconsin or early postglacial.

The coarse shoreline facies of these beds are an important source of sand and gravel for aggregate, well-packing, and drain-tile gravel. Clay from beds near El Centro has been mined for making common brick and drain tile.

Eastern and Northeastern Imperial County

SEDIMENTARY BRECCIA

Moderately deformed sedimentary breccia of questionable age crops out at several localities in the southeastern Chocolate Mountains. It is exposed near the Colorado River at Laguna Dam and at various places near the southwest front of the range. Its erosional characteristics and pale grayish-yellow color from a distance cause the breccia to resemble that of the Pliocene(?) non-marine clastic rocks discussed below. Good exposures are rare, as the breccia is generally mantled with colluvial material. Road and stream cuts show the unit to be composed of poorly sorted highly angular clasts of metavolcanic and metasedimentary rocks, with minor gneissic plutonic rocks in a matrix of poorly to moderately well-cemented siltstone and sandstone.

The sedimentary breccia lies with great unconformity upon the metavolcanic-metasedimentary rock unit here correlated questionably with the McCoy Mountains Formation and upon older rocks as well. Because of the absence in it of Tertiary volcanic rocks, which crop out near some exposures, the sedimentary breccia is assigned tentatively an early Tertiary age, although it may be older. The only volcanic rock in known contact with the breccia is Pliocene(?) vesicular basalt, which overlies it.

ANDESITE

Both intrusive and extrusive andesite are moderately abundant in the Palo Verde Mountains and adjacent parts of the Chocolate Mountains to the south. Generally the intrusive andesite is very dense, tough, and poorly jointed and forms resistant masses, which weather to prominent black rounded knobs. The andesite flows, on the other hand, occur in deeply weathered, poorly resistant, subdued forms. Andesite flow breccia and agglomerate are common.

Andesite units intrude and overlie the metamorphic and plutonic rocks and are in turn overlain by later Tertiary red beds and acidic flows. They appear to be earlier than acid and intermediate hypabyssal rocks discussed below, because a non-marine conglomerate overlying andesite does not contain acidic or intermediate rock clasts.

An apparent relationship exists between these andesites and the occurrence of manganese deposits. Many manganese deposits occur in andesite and their distribution coincides with that of the general distribution of the andesite (see pl. 1).

POST-ANDESITE RED BEDS

A red, well-bedded conglomerate and interbedded red sandstone unit, composed of well-rounded to subangular cobble-sized clasts of gneiss, granitic rock, quartzite, and andesite, is well exposed in the western Palo Verde Mountains and the northern part of the southeastern Chocolate Mountains. This unnamed formation underlies an area of 3 square miles in the Chocolate Mountains, where it attains a thickness of at least 1000 feet. It lies directly on an irregular andesite breccia surface (Hadley, 1942, p. 463). The conglomerate is very well indurated with a coarse, sandy-to-pebbly matrix. In the Palo Verde Mountains the cobbles are less coarse and more angular and the proportion of sand to cobbles is correspondingly greater than in the Chocolate Mountains. The unit is moderately folded with dips as great as 40 degrees.

Little has been done in the way of correlating the age of this formation, but examination of the cobbles contained in it suggests that it is intermediate in age between Tertiary andesite described above and later Tertiary acid volcanic and pyroclastic rocks described below.

This conglomerate is an important host rock for manganese deposits in the Paymaster district and for barite in the Palo Verde district.

TERTIARY ACID AND INTERMEDIATE HYPABYSSAL ROCKS

Hypabyssal rocks composed mainly of dacite or latite porphyry plugs and rhyolitic to dacitic dikes in granitic and metamorphic rocks crop out in widely scattered areas in the Chocolate (see photo 6), Palo Verde, and the Little Mule Mountains. From a distance these rocks appear reddish and present a patchy appearance against the predominant dark gray colors of the rocks they intrude. The dikes are generally small but locally abundant.

Photo 6. Tertiary Intrusive Rocks Flanked by Chuckwalla Gneiss. The Chuckwalla Complex gneiss is of probable Precambrian age. The view of Buzzards Peak, near Midway Well, is to the north.

The exact age of these rocks is uncertain. They are probably Tertiary, however, because they intrude Cretaceous igneous rocks and are overlain by late Tertiary nonmarine and brackish water sediments.

ACID AND INTERMEDIATE VOLCANIC FLOWS

Overlying(?) the acid and intermediate hypabyssal rocks is an unmeasured but great thickness of deformed flows and interbedded pyroclastic rocks of acid and intermediate composition. These rocks crop out along the northeast flanks of the north half of the Chocolate Mountains and underlie the greater part of the southern Chocolate Mountains. The general terrain is characterized by badlands interrupted by jagged volcanic necks, cuestas, and buttes. A patchwork-like appearance in tints of red, yellow, brown, to white is characteristic of this unit.

These areas commonly coincide with areas underlain by the acid and intermediate hypabyssal rocks. This fact suggests that the flows may have been the result of a contemporaneous extrusive phase of the emplacement of the hypabyssal rocks; however, more detailed study is necessary to determine the exact relationship between these rocks. It also seems apparent that the rocks can be divided into two or more units, but at this writing the data do not make this possible.

At present, these rocks have no economic applications and are not associated with any known metallic mineral deposits. However, because of their diverse nature the possibility exists that these rocks may provide a source of pumice, perlite, volcanic cinders, roofing granules, and other volcanic rock products.

INTER-VOLCANIC LAKE BEDS

A distinctive unit characterized by well-bedded flaggy tuffs and freshwater limestone crops out at scattered localities in the middle and southeastern part of the Chocolate Mountains. This moderately deformed unit crops out as far west as Mount Barrow and eastward nearly to the Colorado River near Julian Wash. Apparently it was deposited in a basin that coincides generally with the Arroyo Seco Valley. The unit appears to be not more than a few hundred feet thick. This fact, compared with the unit's relatively wide distribution and near-absence of clastic material, suggests that the formation originated in a rather large short-lived, quiet lake surrounded by low-lying terrain. The creation of the lake may have been due to the damming of drainage by volcanic flows, followed by a period of relative quiesence during which the water-laid fine tuffs and limestone were deposited.

The age relationships of this unit are not entirely clear; it overlies Tertiary intrusive andesite near the Paymaster mine and is moderately deformed.

Small quantities of flaggy tuff from this unit have been marketed for facing stone.

PLIOCENE(?) VESICULAR BASALT

Fine-grained vesicular basalt flows overlie Tertiary sedimentary and volcanic rocks in the extreme southeastern Chocolate Mountains. The basalt has been faulted and uplifted and is moderately to gently tilted. Characteristically this sequence of flows forms prominent black mesas, the lower margins of which are strewn with large sub-rounded boulders. The flows contain minor intercalated conglomerate beds in some areas and at Black Mountain, northeast of Glamis, Pliocene(?) non-marine clastic rocks both overlie and underlie the basalt. Thickness of the basalt ranges from a few feet near Glamis to at least 200 feet on Black Mountain. The unit overlies Tertiary(?) sedimentary breccia near Laguna Dam and is overlain by Plio-Pleistocene(?) gravel in the Picacho area. It is considered here, therefore, to be possibly Pliocene in age although direct evidence is lacking [in 1966].

PLIOCENE(?) NONMARINE CLASTIC ROCKS

Moderately deformed sediments of possibly Pliocene age crop out in several areas in northeastern Imperial County. The principal areas extend from about 10 miles east of Glamis northeastward to Vinagre Wash (photo 7) and the Arroyo Seco-Cibola area at the Colorado River and southeastward to large areas in the Carrizo Wash-Picacho Peak area.

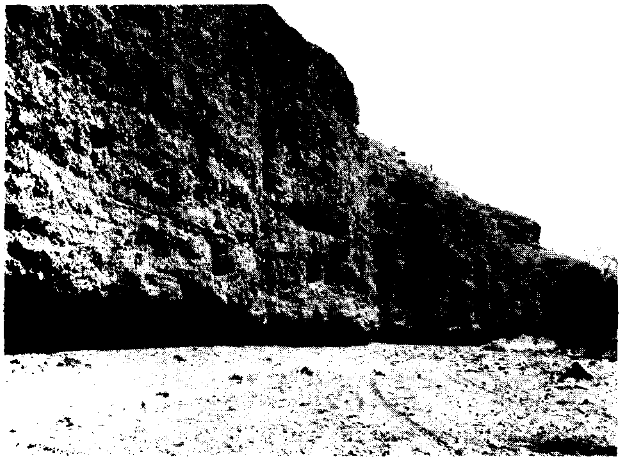

Photo 7. Pliocene(?) Non-Marine Clastic Rocks. The rocks are exposed near Vinagre Wash, in the central Chocolate Mountains.

This unit is characterized by grayish-yellow, low-lying, rounded and dissected hills, which lie between mountainous areas of sharper relief. The beds are composed of interbedded moderately cemented, pebbly siltstone, poorly sorted sandstone, and conglomerate. Clasts in the conglomerate are poorly sorted, angular to subangular and consist mostly of metamorphic and granitic rocks with lesser amounts of volcanic debris locally, whereas elsewhere volcanic debris is predominant.

Inconsistent relationships between these rocks and the Pliocene basalt described above indicate that this unit represents a period of deposition congenerous with at least part of the volcanism of Tertiary time. The beds unconformably overlie the post-andesite red beds of Tertiary age and are overlain by Pliocene(?) estuarine deposits; they are both overlain and underlain by Pliocene(?) vesicular basalt at Black Mountain.

BOUSE FORMATION

Brackish water to marine deposits comprised of a basal limestone member, an interbedded clay, silt, and sand member, and tufa crop out in an area straddling the Colorado River in the Cibola Valley-Arroyo Seco vicinity. This formation has been reported to underlie areas as far north as Parker, Arizona, and has been logged in U.S. Geological Survey drill holes from Laguna Dam southward to the Mexican border (Metzger, 1968, p. 127).

Studies of the Parker-Blythe-Cibola area have indicated that this newly described formation consists of a basal limestone member as much as 100 feet thick composed of thin-bedded, white marly limestone and cross-bedded, light tan barnacle-coquina. The basal member is overlain by several hundred feet of thinly interbedded clay, silt, and sand. The tufa member is only about 1 foot thick, but it effectively masks older rocks along the lower margins of the mountainous areas because of its occurrence as a coating on its irregular depositional surface (Metzger, 1968, p. 130–133).

Bouse Formation overlies Pliocene(?) non-marine clastic rocks and is overlain by Colorado River gravels. Fossil evidence, though not completely definitive, indicates a Pliocene age for the formation and a possible correlation with the Imperial Formation at the Salton Trough.

PLIO-PLEISTOCENE(?) VOLCANIC CONGLOMERATE

Deformed conglomerate of possibly Plio-Pleistocene age crops out at scattered localities, mostly along the low frontal parts of the ranges. The gravel occurs in low-lying hills of grayish-buff color on the basinward flanks of the mountains or is exposed underlying older alluvium terraces in the walls of the deeper arroyos.

The rocks dip as much as 15 degrees basinward near the mountains but flatten away from the mountain fronts (photo 8).

Photo 8. Plio-Pleistocene Volcanic Conglomerate. The conglomerate, dipping moderately to the southwest, is unconformably overlain by older alluvium near Unnamed Wash, in the Picacho Peak quadrangle.

In general the beds are only partly consolidated and therefore offer little resistance to erosion. The clasts are poorly sorted and angular to sub-angular and consist largely of volcanic debris. They contain clasts of gneiss, schist, and plutonic rocks as well. Clasts derived from the upper Colorado River region are characteristically absent even adjacent to the present course of the river. In areas adjacent to Yuma Valley this unit interfingers with a gray sandstone unit on the valleyward limits of the gravels.

The exact age of the conglomerate is not known, and no significant fossils have been found in it. It overlies the Pliocene(?) basalt described above and is overlain by undeformed gravel of probable Pleistocene age. These facts suggest a questionable Plio-Pleistocene or Pliocene age for the unit.

OLDER ALLUVIUM

Dissected flat-lying alluvium is present in most of the larger canyons and along the upper margins of the valleys of the county. These poorly consolidated silts, sands, and gravels typically form desert pavement terraces coated with desert varnish between dry washes.

This alluvium is, for the most part, locally derived, poorly sorted, angular material and reflects the lithology of the mountainous areas flanking the deposits.

In the mesa-like areas bordering the present Colorado River flood-plain, this alluvium interfingers and grades into ancient Colorado River deposits. These are made up predominantly of poorly consolidated yellow-gray silt containing well-rounded pebbles and cobbles of quartzite, which are characteristic of the upper Colorado River drainage areas.

What has been described as Chemehuevis Formation by Lee (1908, p. 18), Longwell (1954, p. 55) and others is included with the older alluvium here, but no attempt to describe its field relations is made.

PLEISTOCENE DUNE SAND

An extensive, thick accumulation of dune sand comprising the Sand Hills occupies a northwest-trending area of approximately 160 square miles at the southeast margin of Imperial Valley. These dunes attain a thickness of at least 200 feet in the central parts of the hills (see frontispiece).

According to Norris and Norris (1961, p. 610–612), the sand is composed of 60 to 70 percent quartz and 30 to 40 percent feldspar with generally less than one percent biotite, magnetite, garnet and epidote. A ferric oxide coating is present on 25 to 60 percent of the grains and imparts a pale orange cast to the sand. Sixty percent of the grains are sub-rounded to subangular; the remainder are equally divided between angular and rounded and nearly all grains are frosted or pitted.

An age older than Holocene is suggested for the dunes by the presence of shoreline features higher than the last prominent stage of ancient Lake Cahuilla (Robison, J. H., 1965, personal communication). Radiocarbon age dates obtained from the inner parts of tufa deposits at Travertine Point, on the west side of the valley, indicate that a lake occupied the Salton Basin as long ago as 13,000 plus or minus 200 years. Outer parts of the tufa crust yielded a date of 1890 plus or minus 500 years, which may represent the last high stage (elevation 40 feet) of the lake (Radiocarbon, 1963, p. 260, 261). In view of these data, a Pleistocene age for the formation of the dunes seems likely.

HOLOCENE ALLUVIUM

The broadest expanses of Holocene alluvium are in the Imperial Valley, on Pilot Knob Mesa and at the head of the Colorado River delta. It occurs also in the numerous dry washes emanating from the mountainous areas. The alluvium consists mostly of clay and silt grading to sandy gravel near the mountains.

HOLOCENE SAND DUNES

Dune sands of Holocene age are common on the East and West Mesa areas of Imperial Valley. These range from thin veneers to broad dunes at least 20 feet thick.

Structural Features

Peninsular Ranges and Salton Trough Provinces

The Salton Trough, a northwesterly extension of the Gulf of California, is a rift valley that owes its existence to the same tectonic forces that created the Gulf. A wealth of new geological and geophysical evidence indicates that the Gulf is a product of sea-floor spreading; that the East Pacific Rise, which extends directly to the mouth of the Gulf, is a spreading center; and that segments of this spreading center extend up the Gulf and are offset *en echelon* by a series of northwest-trending transform faults, the most northerly being the San Andreas.

The net result is that the Baja California peninsula has been rifted away from mainland Mexico in a northwesterly direction and has probably been shortened lengthwise due to strike-slip movement along the faults. The Salton Trough is a tensional feature with attendant ductile thinning and break up of the crust near spreading centers. The thick sequence of sediments that covers the valley floor acts as an insulator and thermostat to partially mask the high temperature anomalies associated with the spreading centers. In substantiation, thermal anomalies have been observed in the area south of the Salton Sea with trends perpendicular to the fault pattern. This is the pattern that would be expected for offset spread centers. The sedimentary rocks in the thermal areas show progressive metamorphism with depth reaching greenschist facies at depths as shallow as 4000 feet near Niland. Youthful volcanic rocks are known to be associated with only one such anomaly, indicating that shallow volcanism is not the principal factor in the metamorphism and thermal anomalies. These factors, combined, strongly suggest the presence of spreading centers beneath the alluvial blanket.

Magnetic anomalies associated with reversals of the Earth's magnetic field, as recorded in cooling extruded rocks elsewhere at spreading centers, have been interpreted to indicate a total average spreading rate of 6 cm a year near the northern end of the East Pacific Rise. The magnetic data indicate that the mouth of the Gulf of California opened within the last 4 million years; however, paleontologic evidence shows that portions of the upper Gulf may have been in existence as long ago as Miocene time (Larson, Menard, and Smith, 1968). Complementary with this is the concept of progressive development through time, from south to north, of the succession of transform faults, which in Imperial County include the Elsinore, San Jacinto, and San Andreas fault systems. Although this infers that the Elsinore and San Jacinto faults, for example, are older than the San Andreas, at least locally, it does not mean that activity on them has ceased or even that it is less than that on the younger San Andreas. Spreading rates may vary along a spreading center, thus controlling the relative motion on opposite sides of a transform fault.

The southwestern half of Imperial County, including Imperial Valley and the mountains to the west, is characterized by numerous northwest-trending faults and attendant strong folding. The faults, as has been stated, are divided into three major fault systems, which are designated from northeast to southwest, the San Andreas, San Jacinto, and Elsinore faults. Most of the faults in these three systems exhibit right-lateral as well as vertical movement with the northeastern block sometimes appearing to be structurally higher than the southwest block. Folding resulting from the same stresses is readily observed in the extensively exposed Tertiary rocks along these fault systems.

The San Andreas fault, which trends northwestward through two-thirds of California, has existed, in some form, since before the end of Cretaceous time. The southern part of the fault is apparently much younger than its central and northern parts, as is suggested by the concept that the mouth of the Gulf of California opened only 4 million years ago. The evidence indicates that the southeastern segment formed and joined the much older northern parts of the fault within the last few million years (Elders, Rex, Meidav, and Robinson, 1970; Anderson, 1971).

The fault can be projected southeastward from the northeast shore of the Salton Sea into Mexico, either along the southwest edge of the Sand Hills or farther southwest, through the Calipatria area. Although the fault trace is conspicuous where it enters the county east of the Salton Sea, only geophysical evidence points to its existence in the southern part of the county.

In exposures near Bertram, the lake deposits of the Borrego Formation are contorted into tight N 75° W-trending folds adjacent to the fault on its southwest side. On the northeast side, the Palm Spring Formation is comparatively less disturbed although it lies topographically higher, as at Bat Cave Buttes in Riverside County. To the southeast, the fault is not evident at the surface. A seismic profile (Kovach *et al.*, 1962, p. 2869) has shown fixed basement depths of 2200 feet on the east side of the Sand Hills and 9372 feet on the west side, but precise location of a fault was not attempted. Electrical resistivity and gravimetric studies by Meidav (1969 and 1970) have further indicated the presence of the San Andreas fault to the southeast and that it bifurcates into two main branches designated the Sand Hills and Calipatria faults (see plate 1).

The San Jacinto fault consists of a complex system of faults that traverses the county from near San Felipe Creek in a 10-mile-wide zone extending southeastward through the Superstition Hills and Superstition Mountain and crosses into Mexico about where the Alamo River crosses the border. Included in this system are the San Jacinto, Santa Rosa, San Felipe Hills, San Felipe, Superstition Hills, Superstition Mountain, and Imperial faults. According to Dibblee (1954, p. 26), the Santa Rosa and San Felipe Hills were elevated by this fault system; but principal movement in the system is right lateral. The 1968 Superstition Mountain earthquake resulted in offset along a portion of the system. Perhaps, too, the Imperial fault, which has been active in historic time, should be included in the San Jacinto system.

The third major fault system is the Elsinore fault system, which borders the southwest face of the Coyote Mountains. A southeastern projection of the Elsinore fault aligns with the northwestern projection of the Laguna Salada fault, which borders Yuha Buttes near Mexico. The two faults have been shown to be connected by evidence of steep gravity gradients across their extensions (Kovach *et al.*, 1962, p. 2862). Dibblee (1954, p. 27) states that the Coyote Mountains were elevated along the Elsinore fault and tilted northward and that tight east-trending drag folds adjacent to the fault indicate great lateral movement.

The major topographic lows, or re-entrants, found at the west side of Imperial Valley along the southwestern sides of the San Jacinto and Elsinore fault systems have been interpreted as evidence of downthrow to the south on these systems. An alternate, newer interpretation is that incipient rifting is occurring along the spreading centers offset on these transform faults and that the Salton Trough, instead of opening headward to the north, is being in part offset and is opening to the west.

Mojave Desert Province

The structural features of northeastern Imperial County are not as clearly understood as those in the southwestern part, where they have been studied in greater detail. In general the structural grain appears

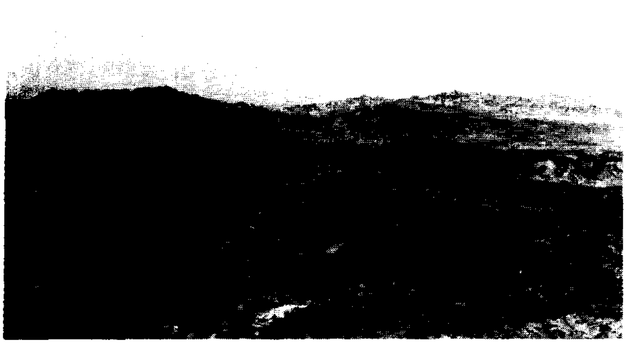

Photo 9. Mammoth Wash Fault Zone. This is a westward view of the fault zone in the Acolita quadrangle, Chocolate Mountains.

to be northwest, as is common elsewhere in California. The faults in the Mojave Desert province most commonly are not regional through-going faults. The most extensive faults in this part of the county are, at most, 5 to 10 miles long. They are variable in strike and, with most, the dip-slip component is apparently greater than the strike-slip component. Faulting, although extensive, is not nearly as conspicuous as in the southwestern part of the county. This is because there are fewer regionally distributed layered rocks to demonstrate deformation clearly and because the individual faults are smaller.

The broad structural pattern, though poorly understood, seems to indicate that the Chocolate Mountains have been uplifted and tilted towards the northeast with the northwestern end of the range structurally higher than the southeast. This hypothesis is supported by the distribution of the exposed rock units. The northwestern end of the range is underlain by generally older rocks of the Chuckwalla Complex. Farther southeast, in the central parts of the range, Mesozoic granitic rocks predominate, and still farther southeast the terrain is underlain mostly by Tertiary rocks. Topography of the north and central parts is generally higher and more pronounced. Likewise, relief at the southwestern front of the range is more pronounced than along the northeastern side. Correspondingly, older Quaternary rocks are more in evidence in the southeastern areas than northwestern and more along the northeastern than on the southwestern side, suggesting that these areas have been subjected to relatively less erosion as a result of having been uplifted to a lesser degree.

This broad pattern is complicated at the southeastern end of the range by a series of *en echelon* northwest-striking dip-slip faults, which have resulted in southwest-tilted sections of homoclinal layered Tertiary volcanic rocks and several large east-trending faults of undetermined significance. The Cargo Muchacho Mountains probably represent an upfaulted block related in some undetermined way to the Chocolate Mountains. Strong northwest faulting is evident there and may be a part of a strong frontal system of faults extending southeastward from the Chocolate Mountains.

Little is known about the structure in the Black Hills, Little Mule, and Palo Verde Mountains, but it appears to consist predominantly of a gently to moderately east-tilted series of volcanic and pyroclastic strata.

Mineral Resources

District Summaries *

Coyote Mountains District

The Coyote Mountains district lies in southwestern Imperial County centered about 28 miles west of El Centro in Townships 15 and 16 South and Range 9 East, an area comprising about 50 square miles of the Coyote Mountains that lie in Imperial County. The remaining west portion of the district lies in San Diego County (see Weber, 1963). The mountains trend northwest and have a bold, straight southwest-facing front. Sharp relief, with elevations ranging from 400 to 2400 feet, is characteristic in the southeastern parts, but low-lying badland-type terrain prevails in the northwestern areas.

A remarkable variety of mineral deposits have been found in the Coyote Mountains, although none of these has yielded significant tonnages of commercial material. Occurrences of beryllium, clay, limestone, marble, nickel, quartz, roof granules, sand and gravel, and silica sand are known to exist there. Of these, however, only clay, marble, quartz, roof granules, and sand and gravel have been sold. It is, nonetheless, an area of considerable interest in that it does contain deposits of potential economic significance. Large reserves of cement-grade limestone are present in the Carrizo Mountain area in addition to numerous smaller deposits (see Coyote Mountains limestone deposit). Several areas are underlain by deposits of clay that heretofore have been utilized only as a cattle feed supplement. Nickel prospects near Fossil Canyon have aroused considerable attention in recent years, although none has proved to be of economic grade. Beryl occurrences in pegmatite dikes of the western part of the district are of undetermined grade and extent.

The core of the Coyote Mountains consists of several thousand feet of Paleozoic(?) or Triassic(?) schist, limestone, dolomite, quartzite, and gneiss. Mica schist, quartzite, and limestone beds crop out in the Carrizo Mountain area of the eastern part of the district. Gneiss and minor lenticular bodies of limestone crop out to the south and west along the higher parts of the southwestern front of the range. Minor bodies of pre-Tertiary peridotite and quartz diorite intrude the metamorphic sequence, along with pegmatite dikes which are common in the western end of the district.

An essentially conformable sequence, 7500 feet thick, of Cenozoic non-marine and marine sediments rests with profound unconformity on the metamorphic rocks. The oldest of these is the Split Mountain Formation of early to middle Miocene age (Durham, 1954, p. 27). The Split Mountain Formation, which consists mostly of coarse non-marine clastic sediments, crops out only in one major locality in the Coyote Mountains—along the southwestern front, west of Fossil Canyon.

Alverson Andesite, including andesite breccia flows and tuff of probable late Miocene age, rests disconformably on the Split Mountain Formation and, locally, directly upon the pre-Tertiary rocks. These volcanic rocks crop out as isolated bodies in the eastern and southeastern sections of the district.

The Imperial Formation, comprised of marine clays, conglomerates, sandstones, and calcareous shell-reef deposits of early and middle Pliocene age (Christensen, 1957, p. 100), is extensively exposed throughout the district. It overlies the Alverson Andesite unconformably in some areas but elsewhere lies directly on the metamorphic rocks. The Imperial Formation is overlain conformably by the late Pliocene Palm Spring Formation, which is made up of light-gray sandstones and reddish clays of terrestrial origin. These rocks flank most of the areas along the lower margins of the range. The formation is about 2500 feet thick at its type locality at the north side of the range, south of Carrizo Wash.

The Pliocene Canebrake Conglomerate, which elsewhere in the region interfingers with the Imperial and Palm Spring Formations, overlies the Palm Spring Formation along the southwestern front of the range west of Fossil Canyon. It is as much as 2000 feet thick on the south side of the range. Overlying the Canebrake Conglomerate, in areas where elevations exceed 1500 feet, is a maximum thickness of 150 feet of fanglomerate of probable Pleistocene age (Christensen, 1957, p. 129).

The dominant structural features of the Coyote Mountains district are the Elsinore and numerous other northwest-trending right lateral normal faults and the partly related complex folding in the Cenozoic sediments. Secondary northeast-trending normal faults are common in the central parts. The Coyote Mountains represent a fault block uplifted and tilted northeastward from the range-forming Elsinore fault. Attendant right lateral movement is indicated by the drag fold features in the sediments adjacent to the fault (Dibblee, 1954, p. 27). A major synclinal structure is

* The term "district" as used in this report does not necessarily conform with formal mining district names, but is used rather in its geographic sense.

apparent in the northwest-central part of the district with a fold axis trending generally parallel to the Elsinore fault. The recency of uplift of the Coyote Mountains is attested to by the presence of Quaternary alluvium perched high in the range south of Carrizo Mountain and recent fault features along the Elsinore fault zone.

The mineral deposits of the Coyote Mountain district, as would be expected from the wide variety of commodities represented, are of widely different origins. The limestone and marble are of sedimentary origin and are to be found predominantly in the metamorphic sequence. A very pure detrital limestone (coquina) in the Imperial Formation unconformably overlies the older limestone near Carrizo Mountain, and may enhance the value of the underlying deposits (see Coyote Mountains limestone).

The nickel occurrences near Fossil Canyon (Roark prospect) are associated with a pyroxenite body which has been intruded into gneiss. The garnierite-morenosite occurrences noted thus far have been adjacent to the southern intrusive contact of the pyroxenite with quartz diorite. Another nickel occurrence (Edwards prospect), 2 miles eastward, however, lies within foliated granitic rocks. Pegmatite dikes, intruded into the metamorphic rocks, are the host rock of the beryl occurrences and also for the quartz mined for silica. Alverson volcanics have provided the source material for a roofing granule operation (Weaver deposit). Clay and silica sand occur in the Imperial Formation. Sand and gravel from Holocene fanglomerate at the mouth of Fossil Canyon is utilized for asphalt concrete.

Probably the best potentially economic mineral resource of the Coyote Mountain district lies in the development of the limestone deposits near and on Carrizo Mountain and elsewhere in the metamorphic series (see figure 7 under Limestone). Population growth in the Imperial Valley and San Diego areas may some day provide a market of sufficient size to support a cement plant utilizing these sources of limestone. Also of potential value are the extensive clay beds in the Imperial Formation which are well exposed south of Carrizo Wash. These are composed of low-grade clays or clay-size material that may be found useful in the future.

Fish Creek Mountains District

The Fish Creek Mountains district is in the extreme western part of Imperial County about 25 miles due west of Brawley. It comprises about 70 square miles in Townships 13 and 14 South and Ranges 9 and 10 East. The Fish Creek Mountains are roughly oval-shaped in plan with precipitous eastern and northern fronts and gentle slopes along the south and west boundaries. Elevations at the eastern front rise from 50 feet near the base to more than 2,000 feet at the crest, over a distance of 1 mile.

The Fish Creek Mountains are most noted for their deposits of gypsum, which constitute the largest reserves in the state. A commercial deposit of celestite (strontium carbonate) occurs locally within the gypsum and has been mined from one area at the north boundary of the district. Gold, copper, tungsten, limestone, and silica have also been noted, but little or no production is known from these prospects.

Earliest known production from the Fish Creek Mountains gypsum deposits was in 1922, 2 years after the completion of the San Diego and Arizona Eastern Railroad. Total gypsum production from the deposit exceeds 8 million tons through 1960 (see U.S. Gypsum Company mine for more complete historical detail). The U.S. Gypsum Company deposit (Fish Creek Mountains mine) was active in 1975.

The oldest rocks exposed in the Fish Creek Mountains are a series of Paleozoic or possibly Triassic(?) metasedimentary rocks, which include biotite schist, quartzite, limestone, and gneiss. These rocks underlie areas of bold relief along parts of the north, east, and southeast fronts of the range. The foliation and bedding in the rocks trend mainly northwest. Within the same terrain are plutonic rocks of probable Cretaceous age. These rocks vary in composition but are mainly quartz diorite and quartz monzonite. Varying degrees of foliation are also present in these rocks. Pegmatite dikes of more acid composition are abundant in the plutonic and metamorphic rocks.

A thick sequence of Cenozoic marine and nonmarine sedimentary rocks lies on an erosional surface cut into the pre-Tertiary plutonic and metamorphic rocks. The oldest of these are the coarse clastic nonmarine rocks belonging to the Split Mountain Formation of early Miocene age. The Split Mountain Formation is exposed in three northwest-trending belts in the northwest sector of the district. Conformable with and resting upon, Split Mountain Formation is a nearly pure section of gypsum (Fish Creek Gypsum). This body is as much as 200 feet thick and contains minor lenses of anhydrite and celestite. It crops out on both sides of a large northwest-trending valley that drains into Fish Creek at the extreme northwestern end of the range.

The southeasternmost exposures of the Split Mountain Formation are overlain by Alverson Andesite, a dark brown basic flow of probable late Miocene age. Both Alverson Andesite and the Fish Creek Gypsum are overlain by marine sediments of the Imperial Formation. The Imperial Formation is early or middle Pliocene in age and is composed of yellow and gray claystone, sandstone, and calcareous shell reefs. It crops out in a wide northwest-trending belt in the far southwestern area of the range. Farther southwest the Palm Spring Formation, consisting of terrestrial sandstones and red clays of Pliocene or Pleistocene age, overlies the Imperial sediments.

Future mineral potentialities in the Fish Creek Mountains district lie in the development of the known exposures of gypsum. The reserves of these bodies are great; and, unless unforeseen new demands for such material develop, outside of normal population increase requirements, little need exists for exploration of unexposed bodies. Should such a need arise, however, the most favorable areas to explore are the valley area between the two major gypsum bodies and the area underlain by Imperial Formation along the lower flanks of the valley to the southwest. Limited possibilities also exist beneath the large areas underlain by the Imperial Formation west and southwest of the westernmost exposures of gypsum. Additional lenticular masses of celestite may exist within the gypsum beds, and these possibly could be detected by careful geochemical sampling.

A large body of limestone (Waters' deposit) at the head of Red Rock Canyon may be of economic value in the future. Its value is dependent in part upon population growth in the Imperial Valley and San Diego areas and upon the development of larger, more accessible deposits in the Coyote Mountains to the south.

Southeastern Chocolate Mountains District

The Southeastern Chocolate Mountains district comprises about 110 square miles centered about 16 miles north of Yuma in the extreme southeastern end of the Chocolate Mountains. It contains the Picacho and Potholes districts and is bounded by the limits of the range on the south, by the Colorado River on the east and north, and by Carrizo Wash on the west. The area consists of low-lying dissected terraces interrupted by ragged, variably resistant highlands and resistant volcanic pinnacle-like masses. Elevations range from 200 to 2000 feet above sea level.

From this district came the earliest mineral production in California. Placer gold deposits in the Potholes area, some 10 miles northeast of Yuma, were worked by the Spaniards in 1779–81. This activity met a tragic end when on July 17, 1781, the Spanish community at Yuma, including that at the Potholes, was eradicated by the Yuma Indians (Bryan, 1925, p. 16). No further mining was attempted in the district until after the establishment of the Republic of Mexico in 1823. Shortly thereafter the Potholes deposits were worked by the Mexicans.

American interests became significant after 1849 when an army post was established at Yuma. Mining activity for the period 1850 to 1880 is poorly documented, but placer mining was known to have been pursued in the Picacho district after 1857. Mining activity probably existed also at the Potholes. In 1880 the Picacho lode gold deposit was discovered, which provided impetus for the discovery before the turn of the century of most of the remaining known deposits. These include the Senator, Duncan (Three C's), Trio, Mendeville placer, Golden Dream, and other mines. Productivity was greatest in 1890–1910. The next period of any consequence was during the 1930s.

The Southeastern Chocolate Mountains district has been mined for lode and placer gold, silver, lead, and copper although most of the activity was limited to the search for gold. Total output from the district is difficult to determine because few permanent records were kept prior to 1880. Statistics prior to 1907 are included in San Diego County figures; however, the author estimates that from $2,000,000 to $3,000,000 worth of minerals has been extracted.

The oldest rock unit exposed in the district is quartz biotite gneiss, which is tentatively correlated with the Precambrian(?) Chuckwalla Complex of Miller (1944, p. 16–21). This rock crops out mainly in three relatively small areas in the district. One area lies just southeast of Picacho Peak along the road to Picacho. It comprises about 1 square mile and contains several lode gold properties, the most important of which is the Picacho mine (photo 10). A second mass underlies ⅔ of a square mile centered 2 miles southwest of Little Picacho Peak. The third body underlies a small area adjacent to Imperial Reservoir.

The next younger rock unit is sericite schist, which crops out in a several-square-mile area bordering the Colorado River from Picacho to Ferguson Lake. These rocks are overlain by a series of metasedimentary and metavolcanic rocks, which probably correlate with the McCoy Mountains Formation of late Paleozoic age. They consist mostly of interbedded metaconglomerate, quartzite, phyllite, and meta-andesite. The rocks crop out in relatively small bodies, the largest two of which underlie about 1 square mile about 3 miles east of Picacho Peak and 1½ miles east of Picacho. Smaller bodies crop out near the Senator mine, half a mile west of Imperial Dam, and at the Three C's mine, 1 mile north of Laguna Dam.

A small body of metamorphic rock of granitic composition crops out adjacent to the Colorado River in the vicinity of the Laguna Dam. The age of the rock has not been determined, but it is probably pre-Cretaceous because it is intruded by Mesozoic igneous rocks in Yuma County, Arizona (Wilson, 1960).

Overlying the pre-Tertiary crystalline rocks is a Tertiary(?) sedimentary breccia composed of angular clasts of metavolcanic and igneous rocks. This unit crops out in the yellowish-gray rounded hills west of Laguna Dam.

By far the most abundant rocks in the district are Tertiary volcanic rocks of widely variant composition and types. Probably the oldest of these are intrusive and extrusive bodies of andesite. These are overlain by welded tuff, tuff, lapilli tuff, and other volcanic rocks of acidic composition. Overlying(?) the acidic rocks are extensive Pliocene(?) basalt flows, which cap most of the mountains between Senator Wash and the southwestern limit of the range.

Most of the volcanic and pyroclastic rocks crop out in a wide west-northwest-trending belt extending from the Colorado River between Ferguson and Senator Washes and extending to the western limit of the district beyond Picacho Peak. Prominent northwest-trending ridges, underlain by moderately tilted southwest-dipping multicolored beds and separated by wide alluviated valleys, are common in this area. The lithologic sequence commonly appears to be repeated by faulting from ridge to ridge.

Adjacent to the Colorado River along most of its shoreline and underlying the wide flat valleys within the range is a thick sequence of Pleistocene(?) fanglomerates and siltstone. These have been greatly warped and deeply dissected by stream erosion. Older alluvium and interfingering primordial Colorado River gravels occupy the broad areas of low relief within and flanking the range.

The lode gold deposits of the district apparently are pre-Tertiary in age, as are all the deposits in the older rocks; none of the volcanic rocks appear to be

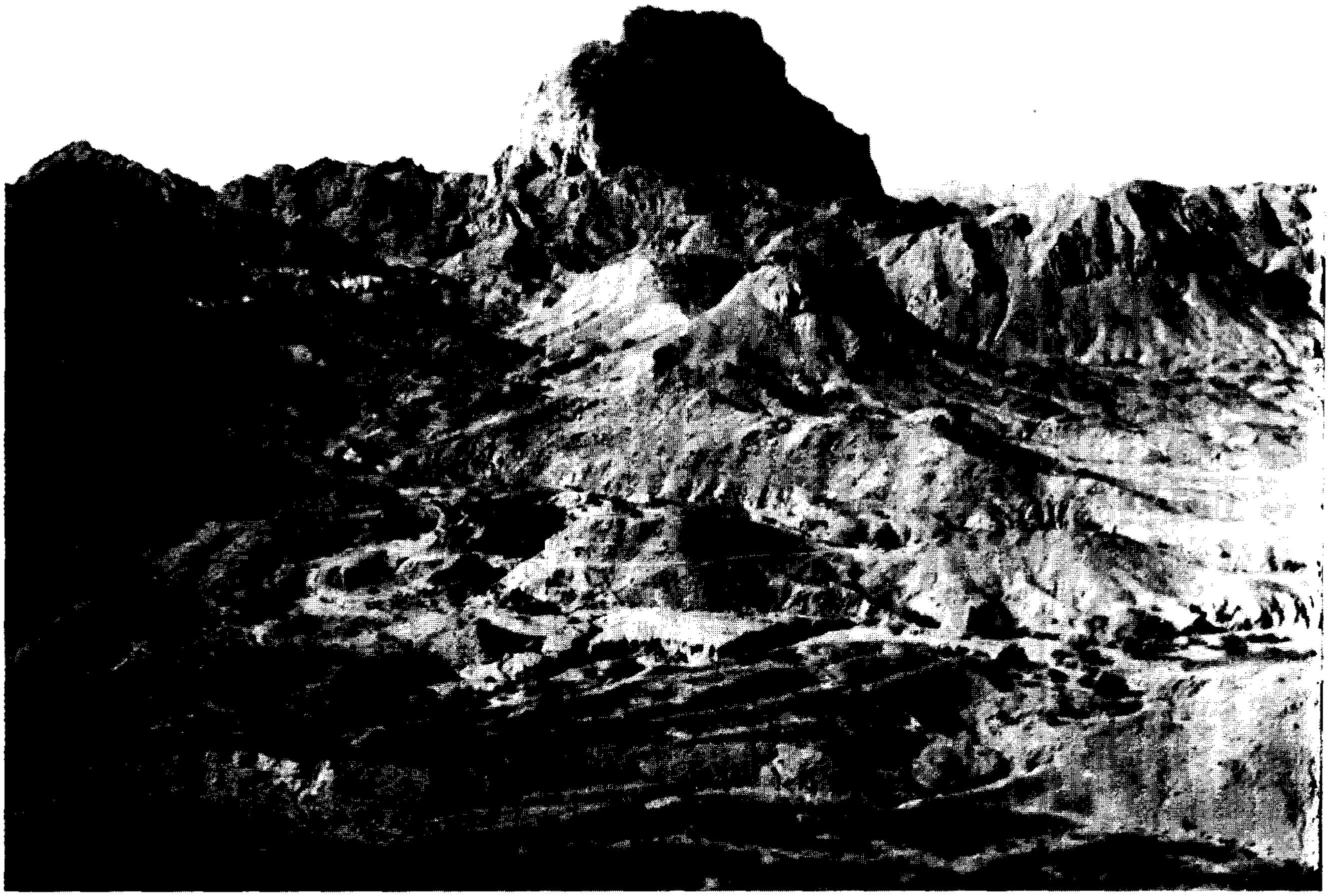

Photo 10. Picacho Basin Area. The Picacho mine and Picacho Peak appear in this westward view.

associated with the mineral deposits as they are in some other southern California areas. The most recent age for gold mineralization appears to be postdeposition of the metaconglomerate, as the veins at the Senator and Three C's mines are partly contained in these rocks.

The controls and origin of the deposits are not altogether clear. Most of the veins are deposited along distinct fault planes; but, at the Rainbow mine, mineralization occurs along minor fractures and planes of schistosity in gneiss. Source of the gold-bearing solutions is not known, but it may be related to emplacement of Mesozoic granitic rock, relatively little of which is exposed in the southeastern Chocolate Mountains. Wilson (1933, p. 46) has suggested a late Mesozoic age for similar gold deposits in southern Yuma County, Arizona.

Prospecting for lode gold in the district should be focused in pre-Tertiary rocks. Gneiss appears to be the more favorable host of the older rocks as indicated by the large number of deposits it hosts. None of the known gold deposits is contained wholly within schist or metaconglomerate. At the Three C's and Senator mines, metaconglomerate forms only the hanging wall of the vein. Especially favorable areas for lode gold are those containing masses of gneiss that lie within the watershed areas above known placer gold deposits. The converse is true for placer deposits. The famous Potholes deposits are contained in Pleistocene gravel of local derivation.

Too little is known of the copper deposits in the district to suggest guides to prospecting. The only occurrences of copper appear to be confined to the metavolcanic rocks 3 miles south of Picacho (see Picacho copper). Prospects near Black Mountain also are contained in metavolcanic rocks (see Franco prospect).

Cargo Muchacho District

The Cargo Muchacho district comprises the Cargo Muchacho Mountains, in the southeast corner of Imperial County. The area totals some 50 square miles in Townships 14 and 15 South and Ranges 20 and 21 East, centered about 14 miles northwest of Yuma, Arizona. The mountains form a northwest-trending oval-shaped area, which is about 5 miles wide and 11 miles long. The topography is steep and elevations range from about 600 to 2200 feet above sea level.

Mining activity in the district dates as far back as a brief period from 1780 to 1781 when the placer grounds in Jackson Gulch were exploited (Henshaw, 1942, p. 152). The next known activity was carried on by Mexican interests shortly after the establishment of the Republic of Mexico in 1823. It may have been from an incident during this period that the name of the mountains was drawn. According to the legend two boys were playing prospector, imitating their fathers, and returned to camp one evening with their shirts loaded with rich gold ore. Hence the name "loaded boy" or in Spanish "cargo muchacho".

With the installation of Fort Yuma, American miners began to take an interest in the area. Probably the most important single stimulus to mining in the area was the establishment of the Southern Pacific Railroad line between Yuma and the Pacific coast in 1877. Between that date and 1900, most of the now known deposits were discovered and developed. The bulk of the estimated $5,100,000 worth of gold produced in the district was mined during that era. The most productive properties in the order of their importance were the Tumco, American Girl, Cargo Muchacho, and Padre y Madre mines.

Aside from gold, deposits of copper, kyanite, sericite mica, and wollastonite occur in the district. Of these, only the kyanite and sericite deposits have yielded any significant commercial production. These deposits, Bluebird Kyanite and Western Non-Metallic, have been productive mainly since 1930.

The Cargo Muchacho district lies in a terrane predominantly of crystalline rocks of pre-Mesozoic and Mesozoic age (see plate 1). The oldest of these, the Vitrefrax Formation, consists of quartzite, sericite schist and quartz sericite schist, and kyanite-quartz granulite. The formation crops out along the central part of the southwest-facing front and along the extreme eastern flanks of the range.

Overlying the Vitrefrax Formation is the Tumco Formation, also of pre-Mesozoic age. It consists of what Henshaw (1942, p. 155) describes as arkosite interbedded with somewhat less abundant thin beds of hornblende schist, which are as much as a foot thick. The arkosite contains numerous dikes of granitic composition. These are more abundant near bodies of a light-colored granite (leucogranite), and the contact with the granite is gradational. The granite, according to Henshaw (1942, p. 156, 159), probably represents granitized metasedimentary rocks of the Tumco Formation. The Tumco Formation crops out along the west front of the north half of the range and extends eastward into its central and eastern parts.

The remainder of the district is underlain almost entirely by a complex of various Mesozoic granitic intrusive rocks including biotite granite, quartz monzonite, quartz diorite, and the aforementioned leucogranite. Minor andesite dikes dated by Henshaw as probably Tertiary crop out in the west-central areas. Relatively small, low, isolated hills on the northeast and southwest fringes of the range are capped by flat-lying olivine basalt flows of probable Quaternary age (Henshaw, 1942, p. 183).

The known ore deposits of the Cargo Muchacho district are confined to the southwestern slopes of the range in a zone which trends N 35° W, parallel to the range. This zone is about 2 miles wide and 8 miles long. The structures that contain the veins, according to Henshaw (1942, p. 183), are generally east-striking faults, which dip from 20 to 40 degrees southward. A possible reason that no mineral deposits of any consequence are known on the northeast side of the range is that most of the faults, which appear to have controlled the loci of mineralization, are limited to the southwest side of the range. However, this does not preclude the possibility of deposits on the northeast side.

The greatest number of deposits and the most productive ones are in the Tumco Formation. Both the Tumco group of mines and the American Girl mine are in this formation. Next in significance is quartz diorite, which is host rock in the Cargo Muchacho, Padre y Madre, and Pasadena mines among others. Least important host rocks are the leucogranite, quartz monzonite, and biotite granite; these contain only minor deposits. Tertiary andesite and basalt contain no known ore deposits.

Prospecting possibilities would seem to be somewhat limited in the district, in view of the small area and the degree to which it has already been explored. Areas underlain by Tumco arkosite, especially where exposures are poor, offer perhaps the best, though limited, opportunities of success. Such areas have been explored, but the chances of deposits having been overlooked there are greater. Furthermore, application of new geologic, geochemical, and geophysical methods offer new potential to old districts; and technological advancements in the fields of benificiation, extractive metallurgy, and mining methods could someday elevate the district to new productivity.

Palo Verde District

The Palo Verde district comprises the Palo Verde Mountains in the northeast corner of Imperial County about 20 miles southwest of Blythe. It includes an area of about 45 square miles lying mostly in Townships 9 and 10 South and Ranges 20 and 21 East, S.B.M. (see plate 1).

The Palo Verde district is most noteworthy for its manganese deposits, although several barite prospects and one mercury prospect have been explored. Mines from the district have yielded about 25,000 tons or 47 percent of the total manganese production for the county. Earliest recorded production was in 1917 from the Chocolate Drop group and in 1918 at the Lugo (Black Beauty) mine. Other periods of notable activity were 1945–1948 and 1952–1959. Activity in the latter period, the most productive, was achieved under impetus of the U.S. General Service Administration stockpile purchasing programs of July 1951 and July 1952. These programs were terminated when the quota was reached in 1960. The most important mines have been the Chocolate Drop group in the northwestern part of the district and the Lugo mine in the central part, which have accounted for most of the production for the district.

The Palo Verde Mountains are comprised predominantly of Tertiary volcanic rocks of diverse composition and type which overlie and intrude Precambrian (?) crystalline rocks of the Chuckwalla Complex. The only exposures of the latter rocks, mostly gneiss, are in a 1- to 2-square-mile area on the southwestern slope of the central part of the range.

The volcanic rocks include an early intrusive series and a later series of flows and pyroclastic material. The larger, more highly resistant peaks and knobs of the range are composed predominantly of intrusive bodies of andesite, dacite, or latite porphyry. These are overlain by gently to moderately dipping, mostly north-trending pyroclastic rocks and flows of acidic to intermediate composition. In the northwestern part of the range near the Chocolate Drop group, a moderately deformed Tertiary conglomerate unit overlies the andesite. It forms a northeast-trending homoclinal sequence which dips 30°–40° southeastward. The conglomerate is overlain by flat-lying pyroclastic rocks and amygdaloidal flows of acidic to intermediate composition. Flanking the east side of the range and overlying the pyroclastic rocks are broad areas of deeply dissected Pliocene(?) nonmarine clastic rocks. These in turn are overlain by limited exposures of Bouse Formation and much more extensive older alluvium, which covers most of the flat-lying areas surrounding the range and extends up broad deeply eroded canyons well into the range itself.

Manganese mineralization has occurred mostly in the Tertiary intrusive andesite and in the older alluvium fanglomerate, although known deposits do occur in all rock units in the district except the pre-Tertiary rocks and the latite porphyry. A strong controlling factor for deposition commonly appears to be adequate channels through which the mineralizing solutions could move. The principal channels are narrow, well-defined shear zones. The fanglomerate has proved to be a favorable host rock probably because of the numerous natural open spaces caused by brecciation of rock of such heterogeneous nature.

The reasons for the andesite being a favorable host rock are not clear, for it is a dense tough material, and shearing in andesite provides narrower less brecciated zones. Perhaps the answer lies in some undetermined genetic relationship of the mineralizing solutions to the andesite. This hypothesis is enhanced by the fact that occurrences of manganese coincide with the distribution of andesite. Also of note is that bodies of latite porphyry, which is an equally tough, dense material and is sheared and fractured to about the same degree, are not known to contain deposits.

Mine workings show that the deposits decrease sharply in grade and size below 50 to 100 feet from the surface, thus suggesting supergene enrichment by surface water. Whether or not the source of manganese was primary or secondary requires more careful study, but the following observations may bear on the problem.

1. Little or no wall rock alteration is apparent.
2. Barium is present in abundance in the form of psilomelane, but barite is rare. Barite does occur separately, however, in veins near the Chocolate Drop deposit.
3. In general, the ore minerals consist of psilomelane, pyrolusite, braunite, ramsdellite, and manganite in a gangue of calcite, chalcedony, quartz, and hydrous iron oxides.
4. No clearly hypogene mineral assemblages were noted although small amounts of barite do occur, as noted above. Barite is considered by some to be hypogene (Hewett, 1954, p. 1431).
5. The ages of host rocks range from perhaps mid-Tertiary to Quaternary.
6. The source of manganese was widespread within the district as the deposits do not appear to be confined to any particular zone, area, or belt.

Hewett and Fleischer (1960, p. 23–24) state th most of the manganese oxides recovered from 20 min in southeastern California are of hypogene origin a though the 20 mines were not named. In a later pap (Hewett *et al.*, 1963, p. 13), they postulated a hyp gene origin for the Tolbard (Pioneer) deposit (Pa master district), but the basis for this was not clear.

The great majority of the veins are no more th 10 feet wide and a few hundred feet long. They a confined to relatively minor fault zones; and, althou large faults are not abundant in the range, the ma ones (those that are a mile or more in length) do n appear to be mineralized.

The possibility of additional deposits in the distr appears favorable, especially in areas underlain Quaternary fanglomerate, as these are favorable ho rocks and are by nature poorly exposed. Henc concealed deposits may exist. As the upper surfa of the fanglomerate are likely to be covered with loo debris, stream channels offer the best possibilities f prospecting. The possibility of finding new sour in andesite is not as likely as for fanglomerate beca these rocks are typically well exposed in this area a may have been explored more fully in the past.

Paymaster District

The Paymaster district comprises an area of appro mately 200 square miles centered about 14 miles nort east of Glamis. It is bounded on the north and sou by the limits of the Chocolate Mountains and includ a strip 4–6 miles wide on either side of the Glam Blythe road. Midway Well lies near the northern ed of the district.

Within the district are deposits of copper, lode a placer gold, manganese, silver, clay, pyrophyllite, a roofing granules. Mines in the district were product as early as 1867, when the Paymaster mine was d covered. Most of the yield for the district is attribu to silver and manganese production.

The oldest rock exposed in the district is quar biotite gneiss and schist, which is tentatively correla with the Precambrian(?) Chuckwalla Complex. T rock forms the core of a small group of mountains east and southeast of Midway Well. It also crops in isolated areas near the Paymaster, Caveman, a Mesquite mines in the northwest, east, and southw parts of the district. The gneiss is overlain by a hig foliated muscovite chlorite schist, tentatively c related with later Precambrian(?) Orocopia Schist. crops out mainly in a large body which lies along western boundary of the district south and southw of Imperial Gables. Schist also underlies the north west slopes of Mount Barrow, and underlies phyl and coarse metasedimentary rocks of the McC

Mountains Formation(?) where they crop out at the southeast base of Black Mountain. A small stock of quartz monzonite is intruded into the Chuckwalla Complex, 1 mile northwest of Quartz Peak. Another small body of quartz monzonite underlies an area 2 miles southwest of Midway Well, near the Paymaster mine.

A wide range of Tertiary volcanic rocks crops out over much of the district. Undivided Tertiary intrusive, extrusive, and pyroclastic volcanic rocks, ranging from rhyolite to andesite, underlie much of the southwest flanks of the Chocolate Mountains in the southwestern part of the district and the mountains east of the Blythe-Ogilby road in the north part of the district. An inter-volcanic unit of lakebeds characterized by well-bedded flaggy tuffs and fresh water limestone crops out near the Paymaster mine. It is of uncertain age, but it overlies intrusive andesite of Tertiary age. Moderately deformed conglomeratic red beds, which apparently pre-date all but the andesitic volcanic rocks, crop out near the Pioneer mine. A gently tilted Pliocene(?) basalt flow rock underlies the area that comprises Black Mountain. It overlies and underlies slightly deformed Pliocene(?) nonmarine beds which crop out southwest of Black Mountain, thus indicating contemporaneity with them. The same non-marine beds crop out northward in the vicinity of Vinagre Wash and Arroyo Seco where they underlie Pliocene Bouse Formation deposits of siltstone, fine sandstone, marl, and sandy calcarenite. Undeformed older gravels underlie much of the low lying areas. Holocene alluvium, which is much less abundant than the older gravels, is confined mostly to washes.

With the exception of manganese, the metal deposits of the district appear to be limited to the Precambrian(?) rocks. The silver-lead deposits of the Paymaster mine area, the silver-gold deposits at the True Friend and Silver Moon mines, and the gold mines in the Gold Basin area are in gneissic rocks which are intruded by rhyolite dikes. The Caveman Group and Crown uranium mines are in schistose rocks.

Even the placer gold deposits in the extreme south end of the district appear to be derived from gneiss immediately underlying the pedimented surfaces on which they lie. Such a relationship to the older rocks is noticeable, not only in the Paymaster district, but in the Cargo Muchacho and Picacho districts and other mines as well. This observation suggests that prospecting is likely to be more fruitful in areas underlain by rocks of the Chuckwalla Complex and, to a lesser extent, in areas underlain by Orocopia Schist(?) and McCoy Mountains Formation(?). The relationship of rhyolite dikes to ore deposition, which has been noted near several deposits, has not been determined but may prove to be of significance.

The manganese deposits of the Pioneer and adjacent mines are probably related in age and origin to the manganese deposits of the Palo Verde district to the north and to the numerous deposits in eastern Riverside County. Even though some of these deposits occur in host rocks as young as Quaternary age, their origin is not clear. Where observed, the deposits appear to be supergene (see discussion of Palo Verde district).

The source of the manganese is not fully understood, but most of the deposits in Imperial County occur in the Tertiary intrusive andesite of the Palo Verde Mountains or in rocks associated with the andesite. Furthermore it seems apparent that the known deposits of manganese in Imperial County are notably lacking in rocks older than Tertiary. It is equally apparent that most of the deposits in the Paymaster district are centered in the northeast part of the district where andesitic volcanic rocks related to those in the Palo Verde Mountains are present (see Palo Verde district and Pioneer mine.)

Commodity Discussions

Property descriptions of all the known mineral localities are listed alphabetically according to commodity in the following section. Under each commodity heading is a general discussion followed by a tabulated, cross-referenced list of all known property names and synonyms. Descriptions are provided only under what is considered by the author to be the principal name at the property. Synonym entries are listed after the principal name in parentheses and are found cross-referenced to the principal name in the alphabetical tabulated list.

Locations are given according to the California township and range land net and also in reference to well-known geographic points where possible. The appropriate available quadrangle map is noted and may be purchased from the U.S. Geological Survey (see table 3). No exhaustive effort was made to obtain ownership data; where this information could be obtained without undue time expenditure, it is listed with the date of its determination in parentheses.

Geology where possible was obtained first-hand, but limited time and poor accessibility of many deposits necessitated the use of previously published information in many instances. References are listed chronologically in abbreviated form. The author's last name and the last two digits of the year of publication precede the page citation. The letter "t", where used, designates a tabulated list only. To obtain the full bibliographic citation the reader must refer to the list of references at the end of this report.

Barite

Known occurrences of barite in Imperial County are limited to T. 9 S., R. 19–20 E., S.B.M. (projected), in the Palo Verde district in the northeastern part of the county. Total production from these deposits through 1964 amounted to less than 100 tons, but the deposits have been known only since 1957.

The barite occurs in veins associated with manganese deposits in volcanic rocks and nonmarine conglomerate of Tertiary age (see Palo Verde district).

Name, location, owner	Geology	Remarks and references
Palo Verde barite deposit E½ sec. 12, W½ sec. 13, T9S, R20E, SBM (projected), Palo Verde Mountains quadrangle (15 minutes), about 23 miles southwest of Blythe, in the northwestern Palo Verde Mountains 3 miles due west of Thumb Peak. Imperial Mining Company, Baldwin Park (1964)	Barite occurs in a vein that strikes due north and dips very steeply eastward in Tertiary andesite. The vein is about 6 feet wide where it is exposed at the north end and is exposed discontinuously southward about ½ mile along a narrow fault zone. The northernmost exposure is less than 200 feet long, and the remaining outcrops are erratic, narrow, and poorly exposed. The vein, where it is excavated, consists of breccia composed of an estimated 70–80 percent barite, 20–30 percent wall rock, and minor calcite. The barite occurs in a coarsely crystalline, bladed, and coarsely lamellar habit. A second narrower vein, which is vertical and strikes N 30 degrees E, occurs about 600 feet to the west. It is only about 1 foot wide and can be traced 200 feet along its strike.	This deposit was mentioned in "Gem Trail Journal" in 1952 (Henry 52:76) but apparently was not staked until 1963. In April 1964, the principal vein was being explored by an open cut which was then 50 feet long by 10 feet wide and 8 feet high at the face. Southward projections were exposed by shallow bulldozer trenches.
White Swan (Hyduke-Robinson Development Co.) barite mine NE¼, SE¼ sec. 24, T9S, R19E, and the SW¼ sec. 19, T9S, R20E, SBM, Palo Verde Mountains quadrangle (15 minutes), Palo Verde Mountains, about 24 miles southwest of Blythe, 8 miles S 15 degrees W of Wiley Well, and 3.6 miles S 63 degrees W of Thumb Peak. Grover Kiherny, 416 Laurel Avenue, Glendora (1963)	Fissure-filling barite veins in Tertiary nonmarine conglomerate. The conglomerate is a part of an essentially monoclinal sequence striking N 10–30 degrees E and dipping at moderate angles to the southeast, underlying an area of about 2 square miles. Locally in the mine area, however, the beds strike N 60 degrees W and dip 25 degrees NE. The unit is a distinct rust-red color, well bedded, cobble conglomerate with thin interbedded medium-grained sandstone of similar color. Clasts range from pebble to small boulder size but average about 5 inches in diameter. They are well rounded and consist of gneiss, granitic rock, quartzite, and andesite. The veins, apparently fault controlled, lie discontinuously along two separate zones. The eastern zone is arcuate and trends N 35 degrees W at its north end and about N 15 degrees W at the southern extremity; the dip is nearly vertical. Individual veins, which cannot be traced continuously throughout the zone, are from a few tens of feet to 200 feet long and range in thickness from a few inches to as much as 4 feet. The most prominent vein crops out at the northernmost end of the zone. It appears to lie along a shear zone, at least 10 feet wide, that strikes N 35 degrees W and is apparently vertical. The barite is itself sheared and broken into fragments ranging from large boulders 3 feet in diameter to chips less than an inch in diameter. Mixed in with the barite are mud from the surface and conglomeratic debris. The original vein appears to have been at least 4 feet wide. The barite occurs as white, very coarsely crystalline, dense material in divergent groups of tabular crystals. Commonly manganese dioxide and reddish-brown chalcedony has been deposited between crystal boundaries or parallel to the vein walls, resulting in striking striped, chevron, and imbricating patterns. The west zone has an overall N 20 degrees W trend but individual veins strike from N 10 degrees W to N 20 degrees E with a dip ranging from 45–60 degrees westward. The veins are as much as 5 feet wide but generally are narrower. The veins appear to be fault controlled but the faults are of little structural significance.	These claims were first located in 1957 by Walter Scott and relocated in 1961 by Ned Hyduke, who initially developed the property. In March 1962, the property was acquired by F. A. Matthews; and, in May, 90 tons were shipped. In 1963 development consisted of two open cuts and extensive trenching along both veins. The larger cut was 8 feet wide, 8 feet deep, and 200 feet long. The second cut, about 1200 feet to the southeast, was about 8 feet wide, 8 feet deep, and 60 feet long.

Carbon Dioxide

Naturally occurring carbon dioxide entrapped in Quaternary sedimentary rocks underlying the southeast end of the Salton Sea is one of the most interesting mineral resources in Imperial County. At one time this resource had great economic significance for Imperial County.

The presence of the gas has been known for over a century, emanating as bubbles from the so-called "mud pots," which are prevalent at the southeast corner of Salton Sea (see photo 11). These mudpots, or mud volcanos, are thermal springs which emit a slow flow of warm brine, steam, and carbon dioxide into clayey soil. As a result of this process, ponds of mud form, from which large bubbles of carbon dioxide and steam evolve. Accumulations of mud and salts around the most active springs form small cones which resemble miniature volcanos.

In 1927, The Pioneer Development Company drilled the first three exploratory holes in the area to test the geothermal steam potential (see Geothermal Resources). Steam was encountered in a hole on Mullet Island, but the low pressures and flow volume discouraged further attempts; however, the presence of large volumes of carbon dioxide with the steam drew more interest. The first hole was drilled expressly for carbon dioxide in September, 1932, by the Salton Sea Chemical Products Corporation, through the efforts of Carl Einhart. It was the first such well drilled in California. The hole was discontinued at 1054 feet when difficulties developed in handling the hot drill pipe; carbon dioxide was encountered at a depth of 310 feet.

Unidentified flammable gases were also noted in the hole, but no depth was indicated in the well logs (Rook and Williams, 1942, p. 19). This well was in sec. 28, T. 11 S., R. 13 E., S.B.M., about 7 miles southwest of Niland, and is outside the present limits of the field. In October 1932, a second and more successful well was drilled in sec. 12, T. 11 S., R. 13 E., S.B.M., to a depth of 750 feet. A considerable volume of pure carbon dioxide was derived from this hole, but it yielded no commercial production. A third well nearby furnished a flow sufficient to operate a small carbon dioxide block plant, which was completed in August, 1934. The original rated capacity of the plant was 10 tons per day. The parent company was dissolved in October, 1935, and a new company, the Pacific Imperial Dri-Ice, Inc., was formed. This company operated the plant until February, 1940, at which time the properties, including six wells, were acquired by Natural Carbonic Products, Inc., which operated until 1944.

Contemporary developments led to the formation of Cardox Corporation, one of the two major producing companies during the active history of the field. From October to December 1934, the Imperial Carb-Ice Corporation drilled four holes in the SE¼ sec. 2, T. 11 S., R. 13 E., S.B.M. The gas produced was initially sold to Salton Sea Chemical Products Corporation, but in 1936 the company built its own plant in nearby Niland. Imperial Carb-Ice Corporation sold its interests including the plant to National Dry Ice Corporation in January, 1937.

National Dry-Ice subsequently became known as the Cardox Corporation, which remained active until 1954 when production from the field was discontinued. Some of the factors contributing to the shut-down were the rise of level of the Salton Sea, widespread use of modern refrigeration systems, distance to marketing centers, short well life, and competition from artificially produced gases.

The Salton Sea carbon dioxide field lies in the structural basin that is the Imperial Valley, an almost featureless plain. The valley is interrupted in the vicinity of the field by five volcanic plugs aligned in a north-northeast-trending arc. The plugs are from 1 to 2 miles apart except for two plugs that coalesce at Red Island.

The gas producing area comprises a northeast-trending area 3 miles long and 1 mile wide near the northeast terminus of the plugs. More than 160 wells have been drilled in the field, most of which produced carbon dioxide. However, because of a relatively short well life of about 2 years, generally fewer than 20 wells were producing at any given time. Production has come mostly from depths ranging from 200 to 700 feet, with normal well-head pressures of about 150-175 pounds per square inch. (Bransford, 1942, p. 199). Total production from the field has been estimated by Oesterling and Spurck (1964, p. 165) to be more than 3½ billion cubic feet of carbon dioxide; the gas was compressed to liquid and dry ice at an average conversion factor of 16,200 cubic feet of gas to 1 ton of ice or liquid.

Photo 11. "Mud Volcano" and "Mud Pots" near Niland. These volcano-like forms develop at warm springs as a result of the slow evolution of steam and carbon dioxide through thick mud. Such structures attain heights of as much as 6 feet. This one appears about 4 miles southwest of Niland.

The reservoir rock apparently is non-marine sandstone of the Pleistocene Brawley or Borrego Formations (anonymous private report) which are overlain by the Quaternary clays exposed at the surface.

The structure of the Tertiary sediments underlying the area is not clearly understood because the only information available comes from incomplete well logs. Gravity (Kovach *et al.*, 1962, p. 2850) and magnetic (Kelley and Soske, 1936) data on the area, however, indicate a positive anomaly centered just east of Red Island. These data, coupled with known thermal activity (plate 1), indicate a cooling igneous mass relatively near the surface. The volcanic domes of the area, which are Quaternary in age, probably emanated from this source (see geology section).

Knowledge of faulting in the area is equally uncertain. The San Andreas fault projects into the general area from known traces near Pope about 10 miles to the northwest; direct evidence, however, is lacking.

The carbon dioxide may have originated in one of two ways: (1) direct volcanic exhalations and (2) evolution from the calcination of calcareous sediments as a result of the heat accompanying intrusion of an igneous mass (Bransford, 1942, p. 199; Muffler and White, 1968, p. 190–193). Evidence tends to support the latter hypothesis although a minor amount of direct volcanic emanation may have been present.

Whatever the source, the gas has migrated along fractures and porous parts of the overlying sedimentary rocks until entrapped by impervious rock. The impervious rock here, in all probability, is clay or claystone. It has been suggested that the San Andreas fault, or branches thereof, provided the necessary fracturing for the migrations of the gas (Rook and Williams, 1942, p. 27). Such a hypothesis would necessitate, however, that the fault has not created sufficient fracturing in Holocene times to allow the rapid escape of the gases through the fault zone to the surface or that subsequent hydrothermal alteration has sealed fractures almost as fast as they were opened tectonically.

Name, location, owner	Geology	Remarks and references
Cardox Western, Inc., (Imperial Carb-Ice Corporation, National Dry Ice Corporation) wells Sec. 2, T11S, R13E, SBM, Niland quadrangle (7½ minutes), at the southeast edge of the Salton Sea, 4 miles due west of Niland. Imperial Irrigation District (?), El Centro	Carbon dioxide gas-impregnated Pleistocene sedimentary rocks. (see Carbon Dioxide text).	See Carbon Dioxide text for history, production and development (Huguenin 36:21, 37:18–19; 38:17–18; 39:43; 40:51; 41:44; Bransford 42:198–201; Rook and Williams 42:13–33; Sampson and Tucker 42:144–145; Musser 43:35–36; 47:42; Averill and Norman 51:326; Goldman 57:106–108).
Imperial Carb-Ice Corporation		See Cardox Western, Inc.
National Dry Ice Corporation		See Cardox Western, Inc.
Natural Carbonic Products, Inc. Secs. 1, 2, 11, 13, T11S, R13E, SBM, Niland quadrangle (7½ minutes), about 4 miles west of Niland at the southeastern shore of the Salton Sea. Imperial Irrigation District, El Centro	Carbon dioxide gas in Quaternary sedimentary rocks. (See Carbon Dioxide in text).	See Carbon Dioxide text for history, production, and development. (Huguenin 36:21; 37:18–19; 38:17–18; 39:43; 40:51; 41:44; Bransford 42:198–201; Rook and Williams 42:13–33; Sampson and Tucker 42:145; Musser 43:35–36; Goldman 57:106–108).

Clay

Relatively few clay deposits are developed in Imperial County although this commodity is potentially important. The most significant deposits have yielded common clay, which was used for making brick and tile. Poorly documented production data indicate that a total of 150 to 200 thousand tons of material was mined from the clay-rich lacustrine deposits of Holocene age near El Centro. Most of the bricks were produced during the period from 1907 through 1928, the last year of production.

The remainder of the clay mined in the county is estimated to be not more than a few thousand tons, most of which apparently has come from the McKnight deposit, T. 12 S., R. 19 E., S.B.M., northeast of Glamis (Sampson and Tucker, 1942, p. 132). The material mined there is fire clay (kaolinite) in a hydrothermally altered zone between metasedimentary rocks and rhyolite porphyry (see mine description).

Of potential but poorly assessed significance are yellowish-gray claystones of the Pliocene Imperial Formation, which underlie much of the area in and between the Coyote and Fish Creek Mountains (see photo 4). These deposits are moderately deformed, well exposed, and attain a thickness of 450 feet. The mineralogy and physical properties of these clays have not been determined. Small tonnages of material from these deposits have been mined and ground for use as cattle-feed supplement in Imperial Valley.

Other possible sources of clay lie in the hydrothermally altered Tertiary tuffs and flows in the Chocolate Mountains southeast of Midway Well.

Clay--continued

Name, location, owner	Geology	Remarks and references
American-Portland Cement Company deposit Reportedly in Carrizo Creek area north of the Coyote Mountains; not confirmed, 1962. Undetermined, 1962.		Uncorrelated old name; not visited, 1962. (Tucker 26:268).
Cal-Min-Co deposit Middle of the S½ sec. 20, T14S, R12E, SBM, Superstition Mountain quadrangle (7½ minutes), near the southeast tip of Superstition Mountain, about 16 miles west-southwest of Brawley. Harry K. Hebbard, 562 Willard, Brawley (1962)	Pale grayish-brown clay in the Pleistocene Brawley Formation. The clay bed strikes about N 30 degrees E and dips about 5 degrees NW. It is at least 20 feet thick and crops out over many acres of the surrounding area. The clay has not been identified mineralogically, but it contains a moderately high proportion of calcium carbonate and other soluble salts. Plasticity is moderate. Iron content is low enough so that it fires the same color as green-ware.	This deposit has been operated since 1951, and several thousand tons have been mined. The material is crushed and bagged on the property, and sold locally for use as a cattle feed supplement and soil conditioner. The mine is developed by an open pit a few hundred feet in diameter and a few feet in depth. No overburden is present.
Desert Gold and Aluminum Corporation deposit		See Powder Uranium and Minerals prospect (Sampson and Tucker 42:131).
Columbia Cement Company deposit Reportedly near Carrizo Creek north of the Coyote Mountains; not confirmed, 1962. Undetermined, 1962		Uncorrelated old mame;not visited, 1962. (Tucker 26:268).
Full Moon deposit Reportedly in T10S, R16E, SBM, southwest flank of the Chocolate Mountains, 8 miles north of Iris Siding; not confirmed, 1962. Undetermined, 1962; J. Thebo, La Mesa (1926).	Reported to be a white high-aluminum clay.	Uncorrelated old name; not visited, 1962. (Tucker 26:269; Sampson and Tucker 42:132).
Jumbo Clay Reportedly in secs. 6, 7, and 8, T16S, R9E, SBM, Coyote Mountains, 5 miles north-northwest of Dos Cabesos siding of the San Diego and Arizona Eastern Railroad; not confirmed, 1962. Undetermined, 1962; C. H. Lundsford and F. W. Sterns, San Diego (1942), (possibly Paul C. Estep, 1426 Broadmoor, West Covina)	Extensive deposits of high-silica, low-alumina clays underlie much of the areas in, and flanking, the range. Most of these are in the Pliocene marine Imperial Formation.	Uncorrelated old name; exact locality not visited. Little or no production. (Sampson and Tucker 42:132).
Lucky Star		See McKnight deposit.
McKnight (Lucky Star) deposit NW¼ sec. 36, T12S, R19E, SBM, Quartz Peak quadrangle (15 minutes), central Chocolate Mountains, 10 miles N 52 degrees E of Glamis, 3.7 miles S 10 degrees W of Imperial Gardens. State of California (school section); formerly leased to J. H. McKnight, Los Angeles (1942).	Unidentified fire clay in a hydrothermally altered zone along a contact between metasedimentary rocks and rhyolite porphyry. The zone strikes N 70 degrees E and dips 50 degrees SE with quartzite forming the hanging wall and the volcanic rock on the footwall side. The zone of alteration is from 25 to 30 feet wide. According to Walker et al. (1956, p. 26), abnormal radioactivity as high as 3.4 M.R./hr. occurs in the zone. It is attributed to small amounts of torbernite(?), autunite and carnotite which are associated with quartz, talc, gypsum, calcite. Torbernite occurs on the hanging wall side and autunite on the footwall.	Inactive, 1962. Development consists of an open cut 50 feet long and wide and 20 feet deep. A 40-foot adit and 100-foot open cut were reported previously, but were not verified in 1962. It was also reported that several thousand tons of material were shipped to Los Angeles for use by a pottery concern, but excavation indicates less than 2000 tons have been mined. (Sampson and Tucker 42:132; Walker, Lovering and Stephen 56:26–27).
O'Callaghan deposit Mostly in the NE¼ of SE¼ sec. 14, T16S, R9E, SBM, Carrizo Mountain quadrangle (7½ minutes), 3 miles north-northwest of Ocotillo, at the extreme southeastern base of the Coyote Mountains. Mineral Development Enterprises, Ross and Minnie O'Callaghan, Box 131, Ocotillo.	Ten to 30 feet of relatively pure yellow-gray claystone. The clay is a part of the Pliocene Imperial Formation which is extensively exposed in much of the Coyote Mountains and attains a thickness of as much as 450 feet. In the mine area the formation strikes N 60–80 degrees E and dips 10–20 degrees SW. The clay is exposed in a number of low-lying erosional remnants with alluviated areas separating the bodies. Locally the remnants are overlain by a few feet of older alluvium.	Production undetermined but small. The material is reported to be used as a livestock feed supplement. It is mined by bulldozer-type equipment in shallow open cuts, crushed, ground, and bagged on the property.

Clay—continued

Name, location, owner	Geology	Remarks and references
Powder Uranium and Minerals (Desert Gold and Aluminum) prospect SE¼ sec. 24, T12S, R19S, SBM, in the Paymaster district, Chocolate Mountains, 11½ miles N 50 degrees E of Glamis, 1½ miles south of Imperial Gables. George Burslem and Fred D. Stout, Box 341, El Centro (1962)	Kaolinization along a shear zone that strikes N 30 degrees E, dips 70 degrees NW between schist (hanging wall) and quartzite (footwall). The zone of alteration extends 30 to 40 feet into the schist and extends a few hundred feet along strike. The shear zone is parallel to the foliation in the schist. No uranium minerals were noted, although radiation detection equipment was not used.	Development consists of a 20-foot shaft at the northeast end of the zone and a 30-foot crosscut adit driven northwestward with an appended 20-foot drift driven to the northeast. Numerous test pits and trenches dot the property. (Tucker 42:131; Oesterling and Spurck 64:168).
Simons Brick Company deposit Reportedly 1 mile southeast of El Centro; not confirmed, 1962. Undetermined, 1962; W. R. Simons, 125 West Third Street, Los Angeles (1926).	Lacustrine clays of Holocene age.	Uncorrelated old name; not visited, 1962. Formerly mined for use in making common brick near El Centro. Operated periodically upon local demand during the first two decades of the century. (Tucker 26:268–269).
Undetermined Reportedly in SW¼SW¼ sec. 23, T11S, R20E, SBM, Quartz Peak quadrangle (15 minutes), northern part of the central Chocolate Mountains, 2 miles southeast of Midway Well. Southern Pacific Company (1964).	Hydrothermally altered tuff in a deformed volcanic sequence consisting of tuff, tuff breccia, rhyolite, and andesite. The beds strike N 20 degrees E, and dip moderately southeast. The tuff containing the altered zone is about 50 feet thick and crops out discontinuously to the southwest. The clay zone is 12 feet wide and lies adjacent to a north-trending(?) fault.	Not visited, 1964. Not developed other than by shallow cuts. (Anonymous report, 1964).

Copper

Most of the widely scattered copper deposits in Imperial County are prospects with little or no recorded production. Almost all of the 312,000 pounds of copper mined in the county was recovered as a by-product from the gold ores of the Cargo Muchacho Mountains. Elsewhere in the county the greatest number and concentration of prospects are in the vicinity of Peter Kane Mountain, 16 miles northeast of Glamis. The occurrences there lie in a discontinuous belt extending from Gold Basin southward to Peter Kane Mountain and Black Mountain, in the proximity of the microwave repeater station. The copper occurs mainly as chrysocolla and malachite in narrow veins which are either in or near aplite dikes. The dikes are tabular bodies generally less than 10 feet wide and 100-200 feet long. The host rocks include gneiss, schist and quartz monzonite of the Chuckwalla Complex and phyllite of the McCoy Mountains Formation.

Other copper occurrences are known in the Picacho district, parts of the northwestern Chocolate Mountains, and in the Fish Creek and Coyote Mountains of western Imperial County.

Name, location, owner	Geology	Remarks and references
Bonanza Queen prospect SE¼ of SE¼ of sec. 24, T14S, R9E, SBM, Plaster City Northwest quadrangle (7½ minutes), Anza-Borrego State Park, southeast Fish Creek Mountains, about 14 miles north-northeast of Ocotillo, near the crest of the steep southeast front of the range, east of the east fork of Barrett Canyon. State of California, Anza-Borrego State Park; Claim notice: V. McCrory, Box 175, Westmoreland, F. Schoelkopf, San Diego, and A. Williams, Riverside (1955).	Copper oxides and carbonates in a pronounced fault zone that can be traced for more than ½ mile. The fault, which strikes N 65 degrees E and is vertical, separates pre-Tertiary gneissic rocks on the northwest from Tertiary sediments on the southeast. Mineralization of the fault zone is extremely spotty and weak where exposed.	Little or no production. Developed by a 25-foot vertical shaft. Other small prospects occur along the same fault (see Hanks Lost Mine under Manganese).
Campbell prospect Uncorrelated old name; may be the prospect found in SE¼ of NE¼ sec. 26, T14S, R9E, SBM, Carrizo Mountain northeast quadrangle (7½ minutes), in a closed area of Anza-Borrego State Park, Fish Creek Mountains, about 13 miles due north of Ocotillo, near the east fork of Barrett Canyon. Undetermined, 1962; George Campbell, Seeley (1942)	Oxides and carbonates of copper in narrow, weak fractures associated with the contact between a pegmatite dike in a metasedimentary-igneous complex. The hanging wall consists of quartzite and biotite schist; the footwall is pegmatite.	This deposit not positively identified as the Campbell prospect, 1962. (Tucker 26:252; Sampson and Tucker 42:111; Ver Planck 52:121t).

Copper—continued

Name, location, owner	Geology	Remarks and references
Caveman (Scudder) group NW¼ of NE¼ sec. 26, T12S, R20E, SBM, Quartz Peak quadrangle (15 minutes), in the Paymaster district, Chocolate Mountains, about 16 miles east-northeast of Glamis, and 1¼ miles N 39 degrees W of Quartz Peak on Peter Kane Mountain. Ralph Scudder, c/o Sattlinger & McKee, 628 Main Street, El Centro. (1962)	Irregular and spotty mineralization along a contact zone between schist and a granitic intrusive rock. The schist appears to be a large inclusion in an apophysis of the granitic rock in a still larger body of schist and gneiss. The main mass of the granitic rock is prominently exposed along the canyon wall to the northwest. The mineralized zone strikes generally N 10 degrees W and dips 10 degrees SW. It is highly altered, iron stained, and contains sparsely and irregularly distributed copper oxide stains. No sulfides were noted.	The deposit is explored by an irregular open cut 40 feet long and 6–8 feet wide which extends down dip about 30 feet. Other smaller cuts lie to the southeast. Little or no production. (Tucker 26:252; Sampson and Tucker 42:111; Oesterling and Spurck 64:110).
Copper Glance prospect Reported in sec. 10, T14S, R23E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; E. E. Feeler, San Bernardino (1902)		Probably same as Picacho Copper prospect. (Aubury 02:6t).
Copper King prospect Reportedly in sec. 10, T14S, R23E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; E. E. Feeler, San Bernardino (1902)		Probably same as Picacho Copper prospect. (Aubury 02:6t).
Edwards prospect Middle north edge of NW¼ of sec. 7, T16S, R10E, SBM, Painted Gorge quadrangle (7½ minutes), southeast tip of Coyote Mountains, 4.4 miles N 11 degrees E of Ocotillo, 2.7 miles S 46 degrees E of Carrizo Mountain. George F. Edwards, 1869 Oliver Avenue, San Diego (1962).	Weakly mineralized pod of copper-stained breccia in a fault zone. The pod occurs on the footwall side of the zone and appears to be no more than 10 feet wide on a side. The fault, which here is entirely in gneiss, is 40 feet wide, strikes due east and dips steeply north. Minor amounts of nickel occur in an unidentified black copper-manganese bearing material occurring in the pod.	No recorded production. Developed by a shallow shaft.
Francho Copper prospect S½ sec. 2, secs. 11, 12, 13, T13S, R20E, SBM in the Quartz Peak quadrangle (15 minutes), central Chocolate Mountains, 25 miles northwest of Winterhaven, 2½ miles south-southeast of Quartz Peak (Principal claim in NE¼ sec. 12). V. F. Hirt, 4069 Mannes St.; J. L. C. Brown, 5934 Mission Boulevard; A. C. Cook, 9520 Bellegrave Avenue; Walter Van de Mark, 3634 Verde Street, Riverside (1962)	Irregular veins and veinlets associated with narrow dikes of acidic to intermediate composition which intrude a metamorphic unit composed of meta-andesite, phyllite, and meta-conglomerate. The metamorphic unit is thinly overlain by a gently tilted Pliocene(?) basalt flow. Debris from the flow mantles the underlying rocks so that exposures are poor. Bulldozer cuts have exposed a ten-foot mineralized zone in section 12 which apparently trends N 70 degrees E for a distance of 200 feet. The zone consists of irregular, apparently discontinuous veins of quartz, chrysocolla, malachite, and other copper oxide minerals in meta-andesite. The narrow dikes closely associated with the veins are of acidic or intermediate composition. At least one quartz vein 500 feet to the southwest of the section 12 zone contains abundant fine-grained crystals of black tourmaline as well as copper minerals indicating a relationship of the veins to the dikes. Another vein on a west-facing slope about 500 feet west of the main bulldozer cuts is contained in an 8-foot shear zone which appears to trend N 25 degrees W and dip steeply northeast. The host rock there is a gray phyllite. Evidence of other veins beneath the basalt debris is evident in float material mixed with the basalt debris. The full extent of these additional veins was not determined. Four samples cut by the U.S. Bureau of Mines in the N 70 degrees E zone averaged 2.4 percent copper.	No record of production. Developed by a 15 degree inclined cut 200 feet long by 10 feet wide by 3 feet deep; a pit 100 feet in diameter that has a maximum depth of 10 feet; and several smaller cuts.
Imperial Buttes prospect		See Marcella prospect under Silver-Lead.

Copper—continued

Name, location, owner	Geology	Remarks and references
Marcella (Imperial Buttes) prospect		See under Silver-Lead.
Picacho Copper (Copper Glance, Copper King) prospect. S½ sec. 1, T14S, R22E, SBM, Little Picacho Peak quadrangle (7½ minutes), southeastern Chocolate Mountains, 17 miles north of Yuma, Arizona, 3 miles N 80 degrees E of Picacho Peak and 3¼ miles S 10 degrees E of Picacho. Undetermined, 1962; F. M. Ferguson, H. S. Gifford and T. E. Rochester (1956), address undetermined.	Several scattered and irregular fracture fillings occur within an east-trending area of about 5000 feet long and 2000 feet wide. Individual occurrences have no apparent consistency but the gross effect of all of them is a zone 100 feet wide and 1600 feet long trending N 75 degrees E in the southern half of the area. The country rock in this southern half is a dark-gray metavolcanic rock containing numerous blastophenocrysts of sericitized orthoclase. Occurrences in the remaining prospects are contained in metasandstone and metaconglomerate. Individual bodies are generally less than 2 feet wide and extend 20 to 50 feet along the surface. They consist of veinlets, ¼ inch to 1 inch wide, composed mostly of malachite containing minute crystalline aggregates of tenorite. Azurite is present but rare. No primary ore minerals were noted, although chalcopyrite was reported by Tucker (26:252).	Facts regarding the early history of this deposit are obscure even though it was recognized as early as 1902. Although the property was churn drilled prior to 1914, the driller and results were not known. Development consists of several shallow shafts, the deepest of which are 100 and 50 feet respectively. Numerous trenches and prospect pits are scattered throughout the area. Production, if any, is unrecorded. (Aubury 02:6; Merrill 16:732; Sampson and Tucker 42:111).
Scudder prospect		See Caveman prospect.
Silver Queen		See Gold Basin mine under Gold.
Volunteer Group mine Middle of the S½ sec. 23, T12S, R20E, SBM, Quartz Peak quadrangle (15 minutes), in the Paymaster district, central Chocolate Mountains, about 20 miles east-northeast of Glamis, and 1½ miles N 34 degrees W of Quartz Peak Undetermined 1961; Peter J. Kane, Brawley (1942).	The mine lies within and near the northeastern edge of an oblong northwest-trending body of quartz monzonite which is about 1000 feet wide and 2600 feet long. Several narrow elongate aplite dikes cut the quartz monzonite in the mine area. Copper mineralization has occurred in a few short, narrow parallel shear zones that strike N 10 degrees W and dip 75–85 degrees NE. The principal shear zone is 8–10 feet wide and can be traced several tens of feet. It contains little gouge or breccia and mineralization was largely limited to veinlets in narrow fractures. The veins consist principally of chrysocolla, malachite, and azurite. Sparsely disseminated chalcopyrite is reported to occur in one of the prospect holes.	The deposit was discovered in 1917 and was developed from that date through the early 1920's. A small but undetermined tonnage of ore was processed in a leaching plant on the property during that early period. Workings consist of a 70-foot shaft (not observed, 1961); an open cut 50 feet long, 25 feet wide, and 10 feet high at the face; and several shallow shafts, pits, and cuts. No recent activity is apparent. (Tucker 26:253; Sampson and Tucker 42:112; Oesterling and Spurck, 64:110).
Undetermined Extreme western edge of the NW¼ sec. 2, T12S, R20E, SBM Quartz Peak quadrangle (15 minutes), in the Paymaster district, Central Chocolate Mountains, about 18 miles northeast of Glamis, and 4 miles S 12 degrees E of Midway Well. Undetermined, 1961.	Chrysocolla and other copper oxides occur with quartz and calcite as irregular fracture fillings in gneiss.	Very poorly exposed in a small dry wash; explored by shallow bulldozer cuts in an area less than 100 feet square.

Diatomite

Only one deposit of diatomite is known in Imperial County. It occurs about 2½ miles southwest of Ocotillo and consists of two erosional remnants of diatomite in lake beds of early Holocene(?) age. The diatomite appears to rest on older alluvium consisting of granitic debris and is overlain by unconsolidated sand. No production is known.

Diatomite--continued

Name, location, owner	Geology	Remarks and references
White Christmas (Grey Bank) deposit NE¼ sec. 11, T17S, R9E, SBM, In-ko-pah Gorge quadrangle (7½ minutes), at the eastern edge of the Jacumba Mountains, about 2⅙ miles southwest of Ocotillo, 2.0 miles S 33 degrees E of Sugarloaf Mountain Andrada Desert Enterprises, Inc., 77 Palo Alto, Ocotillo, 92259; Ray L. Miller, Pres., Laguna Beach (1965)	Two erosional remnants of diatomite in lake beds of early Holocene(?) age. The diatomite lies in a small valley flanked on the west and southwest by quartz diorite and to the east and north by Tertiary volcanic rocks and fanglomerate. The diatomite appears to rest on older alluvium consisting of granitic debris and is overlain by unconsolidated sand. The northernmost body lies near the center of the NE¼ of sec. 11 about 1100 feet N 25 degrees W of the southern body; it is roughly triangular-shaped in plan, about 150 feet long in a north-south direction, and as much as 60 feet wide east and west. The southern body is a crescent-shaped northeast-trending body about 200 feet long and as much as 50 feet wide. This body, however, appears to extend underneath the sandy alluvium to the north. Both bodies are flat lying and are 10–12 feet thick. The diatomite can be divided into a lower grayish, buff-white bed and an upper pale gray bed. Where observed in the south body, the two beds were each about 6 feet thick. They are composed principally of diatoms with lesser amounts of volcanic ash, sand grains of quartz, feldspar and mica. The lower bed is the less sandy of the two but it still contains a moderate amount of sand.	First located in 1941 by Leonard Larson and Associates; little or no production. Development is limited to a few small cuts.

Feldspar

One unconfirmed feldspar deposit has been reported in Imperial County. It reportedly occurs in the Superstition Mountains in southwestern Imperial County, but its exact location or nature has not been determined. No production of feldspar has been reported.

Name, location, owner	Geology	Remarks and references
Graham-Jackson prospect Reportedly in T15S, R11E, SBM, south slope of the Superstition Mountains; not confirmed, 1962. Not determined, 1962; W. Graham and H. L. Jackson, Brawley (1942)	A northwest-striking dike which is 6 to 18 feet wide and 2000 feet long. The dike is reported to be in gneiss and schist.	Uncorrelated old name; not visited, 1962. (Sampson and Tucker 42:134).

Gems and Minerals

Although the gem and mineral industry is largely a recreational one and even though the hobbyist is largely responsible for obtaining the materials he consumes, his enthusiasm and increasing numbers has led to the economic search for these materials by others.

The best known Imperial County localities lie in the northeastern corner of the county in areas popularly designated the "Hauser ('Howser') beds" and the "potato-patch". Other widely scattered but lesser known localities exist, almost all of which lie in the eastern half of the county.

The localities lie mainly in areas underlain by volcanic rocks because these rocks provide conditions favorable for the deposition of the various quartz family minerals which are so avidly sought.

Vast areas in Imperial County are underlain by volcanic rocks which range in age from Tertiary to Quaternary. The Chocolate Mountains, which transect the eastern parts of the county from northwest to southeast, contain thick sections of pyroclastic and volcanic rocks. These rocks are particularly abundant in the southeastern end of the range but are present also in the northwestern areas, where they lie mainly along the lower flanks of the range. The Little Mule, Black, and Palo Verde Mountains, which lie to the north of the Chocolate Mountains, are also made up mostly of volcanic rocks. Many of these areas will doubtless prove to be fruitful to the gem and mineral collector who seeks the various varieties of chalcedony, agate, and opal that are found in such rocks.

Among the more unusual minerals found in the county are blödite (see Bertram mine under Salines), claudetite, dumortierite, kyanite, and turquoise. These and many more are listed by Murdoch and Webb in "Minerals of California" (1960, p. 44). Many of the minerals listed, however, are unconfirmed localities.

The occurrence of claudetite, an arsenic oxide, was described by Kelley (1936, p. 137–138) from a sulfur prospect 6 miles north of the 4–S Ranch and 1½ miles west of the Colorado River. Crystals from this locality were described by Palache in the *American Mineralogist* (1934, p. 128). Dumortierite occurs as boulders in the older alluvium about 12 miles north of Ogilby and south of Indian Pass. The source area of these boulders has never been determined. Similar dumortierite boulders have also been noted at Clip, Arizona, (Schaller, 1905, p. 211–224) suggesting that the source area may be quite far removed.

Blue-green turquoise is reported to occur in pockets and in nodules in porphyritic rock (Sampson and Tucker, 1942, p. 134) at an unconfirmed locality 2 miles east of Midway Well. Other colorful copper minerals such as chrysocolla are abundant in that area, however, and it is possible that one of these was improperly identified as turquoise.

Name, location, owner	Geology	Remarks and references
Allen-Beal deposit Reportedly 2 miles east of Midway Well on the trail to the True Friend and Silver Moon mine, north part of central Chocolate Mountains, Paymaster district. Probably in the SE¼ of T11S, R20E, SBM; not confirmed, 1962. Undetermined, 1962; Charles Allen and Frank Beal, Brawley (1926)	Blue-green turquoise reported in pockets and nodules in porphyritic rock. Chrysocolla is abundant in the general area, and it is possible that it was mistaken for turquoise.	Uncorrelated old name; not visited, 1962 (Tucker 26:270; Murdoch and Webb 56:336)
Double Buttes		See Twin Buttes agate field.
Hauser beds E½ sec. 20, T9S, R19E, SBM, Palo Verde quadrangle (15 minutes), between the Palo Verde Mountains and the Black Hills, 9.9 miles S 37 degrees W of Wiley Well. Undetermined, 1962.	Geodes in Tertiary tuff beds which are intercalated with a series of volcanic flows of acidic composition. The series strikes north and dips moderately east. Cutting material is found in deeply weathered zones in tuff and perlite which crop out mostly in the canyons and saddles. Much of the material has come from the deeply weathered material found in Quaternary terraces consisting of a punky mixture of altered rock fragments, gypsum, and geodes.	Commercial development of this deposit was attempted during some undetermined interval with apparently little production. Most of the material has been removed by "rock hounds", for whom this deposit has become a classic collecting locality. (Henry 52:72–79; Ransom 55:18–22; Vargas and Vargas 60:32–34).
Indian Pass area Secs. 28, 29, 30, T13S, R21E, SBM (projected), Quartz Peak quadrangle (15 minutes), southwest front of the Chocolate Mountains, about 22 miles north-northwest of Yuma, Arizona. Partly by Richard L. and Arma M. Singer, Glamis (1964) (placer gold claims)	Dumortierite-quartzite Boulders and petrified palm root in Quaternary older alluvium. Subangular to subrounded desert varnish-covered cobbles and boulders moderately abundant and widely dispersed. (See Indian Pass placer gold.)	The area was being explored for placer gold in 1964; a widely known collecting locality for many years. (Ransom 55:19).
Pinto Wash area Actually along Pinto Wash in Mexico near the border; mistakenly considered by some to be in Imperial County. Undetermined (Mexico)	"Wonderstone" and petrified wood. "Wonderstone" of this locality is chalcedony which displays concentric red banding caused by rhythmic migration of iron oxides.	Not observed in place. (Included here because of Imperial County access and often mistaken location).
Potato Patch beds E½ secs. 16, 21, T9S, R19E, SBM, Palo Verde quadrangle (15 minutes), between the Palo Verde Mountains and the Black Hills; 9 miles southwest of Wiley Well. Undetermined, 1964.	Geodes in a thin tuff bed between two rhyolitic flows. The beds strike northwest and dip moderately to the northeast.	Extensive trenching by "rock hounds." (Vargas and Vargas 60:32–34).
San Felipe Hills concretion locality S½ sec. 22, T11S, R10E, SBM, Kane Spring NW quadrangle (7½ minutes), north-facing front of the eastern San Felipe Hills, 7½ miles northwest of Kane Spring. Undetermined, 1962	Yellos-gray sandstone concretions which have weathered out of Pliocene Borrego Formation. These concretions range in size from a few inches to a few feet in diameter and are 1 to 4 inches thick. The rocks have taken on a wide array of grotesque and bizarre forms. They are moderately well indurated and mildly fissile.	Although concretions cannot be considered a gemstone or mineral it is included here because this type of material is of interest to the "rock hound." (Kiessling 64:75).
Thumbs		See Twin Buttes agate field.
Twin Buttes (Double Buttes; The Thumbs) agate field Secs. 8, 9, 16, 17, T9S, R20E, SBM, Palo Verde quadrangle (15 minutes); 6 miles south of Wiley Well. Undetermined, 1962	Various forms of chalcedony in pyroclastic and other volcanic rocks. The agate forms narrow irregular veins and veinlets in fractures. Reportedly present here are yellow, black and green agate (some banded), sard, chalcedony roses with carnelian centers, and mammilary psilomelane.	Scattered localities (Henry 52:72–79; Ransom 55:18–22; Vargas and Vargas 60:39–84).

Geothermal Resources

Exploratory drilling in a newly developed geothermal steam field at the southeast end of the Salton Sea was undertaken beginning in February 1961. By the end of 1964 a total of 11 wells had been drilled in the area. No new steam wells were drilled between 1965 and the end of 1971; however, Magma Power Company expected to start drilling its "Magmamax" 1 well near Niland in January 1972.

The area explored lies in the central part of the northwest-trending structural trough that is the Imperial Valley. The nearly featureless valley is interrupted a few miles west of the steam wells by five volcanic domes. The domes are composed of rhyolite, obsidian, and pumice. They are aligned in a broad northeast-trending arc which approximates the present southeast shoreline of the Salton Sea. The alignment of the domes suggests that they may lie along a fault. Surface rock temperatures, gas discharge, high geothermal gradient, and numerous carbon dioxide and steam mud pots suggest a possible Holocene age for the volcanic rocks (see Muffler and White, 1969, p. 162).

A magnetic survey by Kelley and Soske in 1936, an aeromagnetic survey by the U. S. Geological Survey (Griscom and Muffler, 1971), and a gravity survey by Kovach, Allen, and Press in 1962 show positive anomalies in the area drilled, suggesting the presence at depth of a dense, magnetic, cooling intrusive mass. Such an intrusive mass may represent the parent magma of the volcanic domes (McNitt, 1963, p. 32.)

Griscom and Muffler (1971) have estimated that a magnetic mass, probably consisting of intrusive rocks, lies buried at least 7000 feet below the surface, is probably 12,000 feet thick, and is 18 miles long and three to five miles wide. Analyses of magnetic data further indicate that two superimposed smaller magnetic masses extend upward to within less than 1000 feet of the surface and that these, in turn, have several small masses no more than half a mile wide superimposed upon them. All five volcanic domes are associated with these small masses.

Logs obtained from wells in the area indicate that the valley fill is underlain successively by lacustrine marls and evaporites which are probably correlative with the Pleistocene Brawley or Pliocene Borrego Formations, by Pliocene marine sediments of the Imperial Formation, Alverson Andesite, and by Miocene terrestrial sediments of the Split Mountain Formation.

The San Andreas fault projects to within two miles northeast of the test wells, and what may be a parallel branch of it transverses the area less than one mile to the northeast (Kelley and Soske, 1936, p. 497).

The earliest attempt to develop geothermal steam for power from this area was in 1927. In that year the Pioneer Development Co. drilled three holes in Sec. 10, T.11S.,R.13E., SBM, about one-half mile east of Mullet Island. The deepest of the three holes was 1473 feet. Steam was encountered in all three holes, but the pressures and volume were considered insufficient for the operation of a steam generating plant. It was these exploratory wells, however, that led to the development of the carbon dioxide field which was productive from 1932–1954. Even though most of the CO_2 wells were drilled to depths of less than 700 feet, several of the holes were brought in out of control as a result of uncontained steam (Rook and Williams, 1942, p. 19).

The first well deep enough to penetrate the lower superheated zone was the No. 1 Sinclair, which was drilled as a wildcat oil venture by the Kent Imperial Oil Company in 1957 to a total depth of 4700 feet. Temperatures as high as 562°F were recorded in that hole and the total mass flow (steam and water) was 26,000 lbs. per hour. Two subsequent wells, the Sportsman No. 1, total depth 4729 feet, and the I.I.D. No. 1, total depth 5232 feet, were the first holes since 1927 that were drilled expressly to explore and develop the steam potentialities of the area. The Sportsman No. 1 hole, which had an inside diameter of five inches, flowed 65,000 lbs. of steam and 285,000 lbs. of water per hour at 390°F and about 200 p.s.i.g. well-head pressure in a sustained test. The highest recorded in-hole temperature was 643° F., the highest ever recorded in a hole drilled for steam. The I.I.D. No. 1 hole, inside diameter seven inches, flowed 125,000 lbs. of steam and 500,500 lbs. of brine per hour at 405°F and 200 p.s.i.g. well-head pressure in a 90-day test during the summer of 1962. These data were calculated by the company to represent an energy potential of 5000 KW and 10,000–15,000 KW respectively.

The maximum depth reached by a well in this group was 8100 feet and the average was about 5000 feet. Koenig (1970) has suggested that data indicate that a brine pool exists beneath this area with a maximum dimension of 12 to 20 square miles and that the volume of brine contained within the reservoir is in excess of one cubic mile. Reservoir temperatures reach 680°F. at a depth of about 7000 feet.

The high salinity of the brines from the wells presents a serious problem in disposal, but also offers further economic potentialities in recovery of contained minerals. The brine contains about 335,000 ppm. in dissolved solids, a figure which makes disposal of the effluent into the Salton Sea undesirable from the standpoint of the adverse effect it would have on the fish and wildlife of the region. Because of this fact and also because of the unique composition of the brine, the extraction of the dissolved salts from it is of paramount interest.

Table 8 shows the composition of a representative sample of the brine and table 9 the hypothetical combinations. High concentrations of sodium, calcium and potassium chlorides occur. It is interesting to note that the Searles Lake brines contain about 345,000 ppm in dissolved solids (Ver Planck, 1958, p. 123), very nearly the same concentration as this well effluent. However, the concentration and composition of the two brines are somewhat different.

The steam-well brines (pH 5–6) contain about 60.2% Cl, 20.8% Na, 10.3% Ca, and 7.1% K in the dissolved solids, as compared with 38.5% Cl, 28.72% Na, tr. Ca, and 7.73% K in Searles Lake brine.

Table 8. Comparison of geothermal well brine with Searles Lake and Salton Sea brines (p.p.m.).

Constituent	Geothermal brine[1]	Searles Lake[2]	Salton Sea[3]
Cl	201,756.7	132,640.4	15,568.7
Br	--	861.1	--
SO_4	(34.)[4]	45,499.3	7,109.0
B_4O_7	537.3	12,606.2	--
CO_3	--	} 27,210.0	213.3
HCO_3	--		
Na	70,000.0	98,920.6	} 10,663.5
K	24,000.0	26,624.5	
Ca	34,470.0	--	959.7
Mg	18.0	--	959.7
Fe_2O_3	4,200.0 (Fe)	--	--
Al_2O_3		--	
SiO_2	5.0	68.9	
Li	149.9		
B_2O_4	537.3		
Total p.p.m.	335,674.2	344,431	35,545
Sp. gr.	1.207		

[1] McNitt, 1963, p. 33 (Sportsman No. 1 Well).
[2] Recalculated from Ver Planck, 1958, p. 123.
[3] Adjusted from Ver Planck, 1958, p. 123.
[4] From a Smith-Emery Co. analysis; not included in total.

*Table 9. Hypothetical combinations of brine from Sportsman No. 1 Well *.*

Constituent	p.p.m.	Percent of solids
SiO_2	5.0	0.001
$CaCl_2$	95,466.6	28.5
$MgCl_2$	71.4	0.02
NaCl	180,747.9	53.9
KCl	45,803.5	13.7
$FeCl_3$	12,198.2	3.7
$Na_2B_4O_7$	694.4	0.2
Total	334,987.0	

* Analyst: Smith-Emery Co., Los Angeles, August 31, 1961.

It would apear that, in terms of total available salts and the favorable concentrations of calcium and potassium, the Salton Sea geothermal well brines compare most favorably with those utilized at Searles Lake.

A very intriguing fact which came to light in late 1962 was that the effluent contains a relatively high concentration of heavy metals. Semiquantative spectrographic analyses of the evaporated residue from the brine contained in parts per million of the original brine: Fe, 2,000; Mn, 1,400; Zn, 500; Sr, 400; B, 390; Ba, 750; Pb, 90; Cs, 15; As, 12; Cu, 6; Cd, 2; Ag, 15 (White, 1968, p. 313; White, 1963, p. 920).

A black substance deposited on the inside of the discharge pipe of the I.I.D. No. 1 hole was reported to assay 381 ounces of silver and 0.11 ounces of gold per ton. An estimated five to eight tons of this material was deposited in the 275-foot-long horizontal discharge pipe in a 90-day period (Oesterling and Spurck, 1964, p. 150; White, 1963, p. 921). The brine pool is believed to contain the following tonnages of various elements: Fe, 10 million; Mn, 7 million; Zn, 2.5 million; Pb, 450,000; As, 60,000; Cu, 30,000; Cd, 10,000; Ag, 5,000. Studies are continuing to determine if economic recovery of these elements can be made.

The unique composition of the effluent first led to the speculation that the wells have tapped a primary or magmatic source. Now it is believed that whereas the brine is in fact an ore-forming hydrothermal solution, the several elements have been accumulated in the water by intensive leaching of trace quantities from the Tertiary and Quaternary sediments underlying the Salton Trough (Doe *et al.*, 1966).

In January, 1965, Morton International entered into an agreement with the O'Neill group to allow Morton's subsidiary, Imperial Thermal Products, to conduct pilot operations of chemical recovery and electric power generation on the geothermal leasehold. This pilot operation (Phase 1) terminated January 3, 1967, with the announcement that Morton, with the O'Neill group as minority participants, would construct a plant for commercial recovery of specific commodities (Phase 2). Similar pilot operations set up by Earth Energy, Inc., a subsidiary of Union Oil Company, on property adjacent to the Morton-O'Neill property were inactive in 1967.

By 1968, Morton International, Incorporated, shelved its plans to construct a plant for the extraction of sodium, calcium, potassium, and lithium chlorides from the geothermal brine. Both the complexity of technical problems of recovery and waste disposal and the uncertain economic future for potash and lithia dictated this decision.

However, Chloride Products, Incorporated, of West Covina, increased its production of calcium chloride from the Niland geothermal brine in 1968. The brine was produced from well Sinclair No. 3 and was processed on a 36-acre property southwest of Niland.

A new company, General Earth Minerals, obtained an option on production of brine from wells Sinclair No. 3 and 4 in 1969. Several studies were underway into methods for utilization of the geothermal brine for electric power production, for production of various chemical salts, and possibly as a source of fresh water.

The infant geothermal industry will be greatly expanded by the developments at Niland and Cerro Prieto, Mexico, just across the border. At Niland the potential exists for a major extractive chemical industry; while at Cerro Prieto the potential for electric power generation appears great. Both fields are part of the Salton-Mexicali geothermal province and have a common origin, which is a function of thinning of the crust and of establishment of convection cells for transfer of heat through water-saturated sediments.

Evidence of metamorphism of Pliocene and Quaternary sediments is shown by core samples taken from the bottom of the I.I.D. No. 1 well, and from an oil-test (Wilson #1) drilled by Standard Oil of California, 22 miles to the south (Muffler and White, 1969). The samples, which were identified as being from the Palm Spring Formation or Borrego Formation, have undergone pyritization, chloritization, epidotization, and calcitization. At temperatures below 100° C, K-micas begin to form; chlorite and calcite begin to be present at 180° C, with attendant liberation of CO_2. Above 300° C, epidote and K-feldspar begin to form, indicating that the greenschist facies has been reached. Metamorphism is continuing at the present.

High heat flows have been noted at other areas of the Imperial Valley (see figure 7). These areas offer additional possibilities for future exploration.

In 1971 descriptions of a series of Known Geothermal Resources Areas, in California, delineated by the U.S. Geological Survey, were published in the "Federal Register", March 25, April 2, April 3, April 17, and October 5. These designations were made as a result of the federal "Geothermal Steam Act" which was signed into law on December 24, 1970. The act, in addition to providing leasing regulations for federal lands, defines "Known Geothermal Resources Area" and requires publication in the Federal Register of a determination of all lands included in any such area within one hundred and twenty days after the effective date of the Act. Determinations of additional areas will likewise be published from time to time.

A Known Geothermal Resources Area is one in which the geology and other factors would "engender a belief in men who are experienced in the subject matter that the prospects for extraction of geothermal steam or associated geothermal resources are good enough to warrant expenditures of money for the purpose." Lands within these areas will be leased by competitive bidding while those outside will be leased on a first-application basis. Final rule-making with regard to federal leasing and operating regulations, which comply with the requirements of the National Environmental Policy Act, were still pending at the end of 1971.

A description of the standards used by the U. S. Geological Survey and a copy of the Geothermal Steam Act of 1970 is contained in the Survey's Circular 647 "Classification of Public Lands Valuable for Geothermal Steam and Associated Geothermal Resources."

The State of California, with the Division of Oil and Gas as the regulatory agency, expected to delineate a series of "geothermal resource areas" early in 1972. These will be similar in nature to the Federal Known Geothermal Resources Areas but will not necessarily have similar boundaries or locations.

Six Known Geothermal Resources Areas, or KGRAs, are located in Imperial County in the area south and east of the Salton Sea. These include the Salton Sea, Heber, Dunes, Brawley, Glamis, and East Mesa (plate 1).

An active program of research study has been carried on since 1965 in these areas by the University of California at Riverside. The outlining of these "hot spots" has largely resulted from the geophysical surveys and shallow drillings conducted by the University under contract to the U. S. Bureau of Reclamation for $285,000. Data from over 100 drill holes, 17 of which reached depths of 500 ft., were analysed and used to detect steep temperature gradients (plate 1). The highest gradient found was at Heber and measured over 24°F/100 feet.

A very important fact has come to light as a result of the recent studies: there is no evidence that the highly corrosive hypersaline brine (25% dissolved solids), present in the Salton Sink, exists elsewhere in the U.S. portion of the Imperial Valley (Rex, 1970, p. 5). This means that for the five Known Geothermal

Table 10. Geothermal steam wells drilled in Imperial County through 1964.

Name	*Company*	*Location*	*Date spudded*	*Remarks*
....	Pioneer Development Co.	Sec. 10, T11S, R13E, ½ mi. E. of Mullet Island	1927	3 holes; deepest hole 1,473 ft. (see text). Discovery well.
Sinclair No. 1	Kent Oil Co.	NW¼ sec. 10, T12S, R13E, 3½ mi. S. of Red Island	1957	T.D. 4,700 ft. Perforated at 3,370 ft. in 4⅜ I.D. hole. Flowed 26,000 lbs. steam, water per hour. Max. temp. 562° F. Wildcat oil well.
Sportsman No. 1	O'Neill, Ashmun, & Hilliard, Midland, Texas	Center E½ sec. 23, T11S, R13E, 1 mi. E. of Red Island	Jan. 26, 1961	T.D. 4,729 ft. (see text).
Sinclair No. 2	Western Geothermal, San Francisco	NW¼ sec. 10, T12S, R13E, 3½ mi. E. of Red Island	1961	T.D. 2,368 ft.
I.I.D. No. 1	O'Neill, Ashmun, & Hilliard, Midland, Texas	NW¼ sec. 23, T11S, R13E, 1 mi. E. of Red Island	Jan. 1962	T.D. 5,262 ft. (see text).
Sinclair No. 3	Western Geothermal, San Francisco	NW¼ sec. 10, T12S, R13E, 3½ mi. S. of Red Island	Nov. 1, 1962	T.D. 6,920 ft.
River Ranch No. 1	Earth Energies, Inc., Santa Barbara	NW¼NW¼ sec. 24, T11S, R13E, 1.8 mi. E. of Red Island	Oct. 14, 1963	T.D. 8,100 ft.
I.I.D. No. 2	Shell Oil Co.	NE¼SE¼ sec. 22, T11S, R13E, 0.5 mi. E. of Red Island	Dec. 30, 1963	T.D. 5,836 ft.
State of California	Shell Oil Co.	SE¼SW¼ sec. 23, T11S, R13E, 1.2 mi. ESE. of Red Island	April 11, 1964	T.D. 4,859 ft.
Sinclair No. 4	Western Geothermal, San Francisco	SE¼SE¼ sec. 4, T12S, R13E, 3.2 mi. S. of Red Island	1964	----------------------------
J. J. Elmore No. 1	Earth Energies, Inc., Santa Barbara	NW¼SW¼ sec. 27, T11S, R13E, 0.5 mi. E. of Rock Hill	May 22, 1964	T.D. 7,117 ft.
Hudson No. 1	Earth Energies, Inc., Santa Barbara	NW¼SE¼ sec. 13, T11S, R13E, 2.4 mi. NE. of Red Island	July 1964	----------------------------

Resources Areas other than the Salton Sea, a relatively noncorrosive geothermal fluid, somewhat less saline than sea water, can be produced. Development of a major steam field at Cerro Prieto in Mexico, using similar fluids, is well under way, and the first of four 75 megawatt generating plants is expected to begin operation there in 1972.

The U. S. Bureau of Reclamation, in its continuing geothermal investigation in the Imperial Valley, plans an orderly program leading to the development of a producing steam field and a prototype desalting plant. Proposed expenditures of funds by the Bureau, the Office of Saline Water, and others for this work will amount to a total of $74,870,000 by job completion time in 1976.

One of the major objectives of the Bureau's program is to provide a source of good quality water to augment the Colorado River supply. This will be done by using power produced from geothermal steam to operate a modern desalination plant. It is still too early, however, to choose the best method of desalting, since the process will depend upon the mineralization, temperature, and rate of flow of the brine from the source wells.

Some of the major problems faced by the Bureau, and any others who attempt production of the geothermal resources in the Imperial Valley, are waste water disposal, subsidence, and gas emissions. Waste water, particularly that which comes as an effluent from a desalination plant, is a high-density brine and can best be handled by "reinjection" in deep drill holes near the periphery of the reservoir, where it will flow by gravity into the reservoir. The method is attractive economically, not only for disposal, but also from the standpoint of helping to maintain reservoir pressure and for reduction of the potential subsidence problem that often accompanies fluid withdrawal.

The subsidence problem can further be met by recharge with other waste waters available in the area, such as excess irrigation water, which now flows into the Salton Sea, or water from the Sea itself. A series of precise level lines were being run in the Valley, late in 1971, to serve as a base of reference for future subsidence measurements. Measurements made in the past have shown that the natural subsidence rate in the valley is slightly over one inch in ten years and that the valley is widening at about 3 inches each year as a result of crustal spreading.

Air pollution is perhaps not as serious a problem as the others mentioned here, as the technology now exists to efficiently control gas emissions. Noxious gasses such as hydrogen sulfide can be trapped and removed as in a project now being launched at The Geysers geothermal field. The process of gas removal by current methods is, at present, an expensive one.

The sequence of development of steam fields in the Imperial Valley is expected to begin at Heber, North Brawley, Glamis and East Mesa, followed by other known and as yet undelineated prospects.

Standard Oil Company of California has for some years been actively exploring for geothermal steam in the Imperial Valley. In 1963 to 1964 they drilled a series of 17 exploration holes, each 500 feet deep, at widely scattered locations throughout the valley. More recently their efforts have been concentrated in the Heber general area, where in 1971 they drilled a series of 67 exploration holes. This group included 38 holes drilled to depths of 211 feet, 28 holes drilled to 484 feet, and one hole drilled to 463 feet.

This company now has approximately 16,000 acres in the Imperial Valley, mostly in the Heber area, under geothermal steam leases. Additionally they have approximately 4,000 acres under oil and gas leases, making a total of 20,000 leased acres in the Valley.

Geothermal Exploration

Exploration tools used in the search for geothermal resources in the Imperial Valley have included heat flow, resistivity, gravity, magnetic and marine seismic surveys. Heat flow studies, using shallow drill hole temperature gradient measurements, have been conducted over much of the area south, southeast and east of the Salton Sea (plate 1).

Total heat flow is made up of the heat flow by conduction plus heat flow by convection plus heat flow by radiation. The first two are of prime importance in measurements for a geothermal area such as the Imperial Valley. Although computations are made using heat flow units, which are measured in calories per square centimeter per second, field data are most often gathered in the form of temperature gradients in degrees fahrenheit per 100 feet or degrees centigrade per 100 meters of depth. Normal gradients are often stated to be of the order of one degree F. per 100 feet or three degrees C. per 100 meters; however, these figures may vary widely with the materials involved.

Gradients measured on several of the areas considered prospective for geothermal development in Imperial Valley are 24° F/100 feet at Heber, 10.4° F/100 feet at East Mesa, 27° F/100 feet at the Dunes, 6.3° F/100 feet at Brawley and 19.8° F/100 feet at Salton Sea (Meidav and Rex, 1970, p. 4). Most of the data measured are from a large number of test holes 100 feet deep. Comparison of this information with data from 17 holes 500 feet deep, drilled by Standard Oil Co., indicated that, in most cases, no significant difference exists between the shallow and deeper hole data. It is probable that, in projected vs. measured temperature gradients below 1000 feet, differences will be significantly greater.

Resistivity has been used in conjunction with a gravity map of the area (plate 1 overlay) to delineate areas of high heat flow (Meidav and Rex, 1970). Experience has shown that areas of gravity highs in the Imperial Valley are often associated with areas of high heat flow. This may be due to a combination of factors such as the presence of an intrusive mass near the surface and the fact that consolidation and metamorphism of the sediments takes place in the areas of high heat flow.

Gravity highs were used as indicators of abnormal temperature gradients in selecting a series of traverses for electrical and heat flow soundings made across the Imperial Valley. A high current transmitter (5 amp) and high sensitivity receiver (10μv) were employed

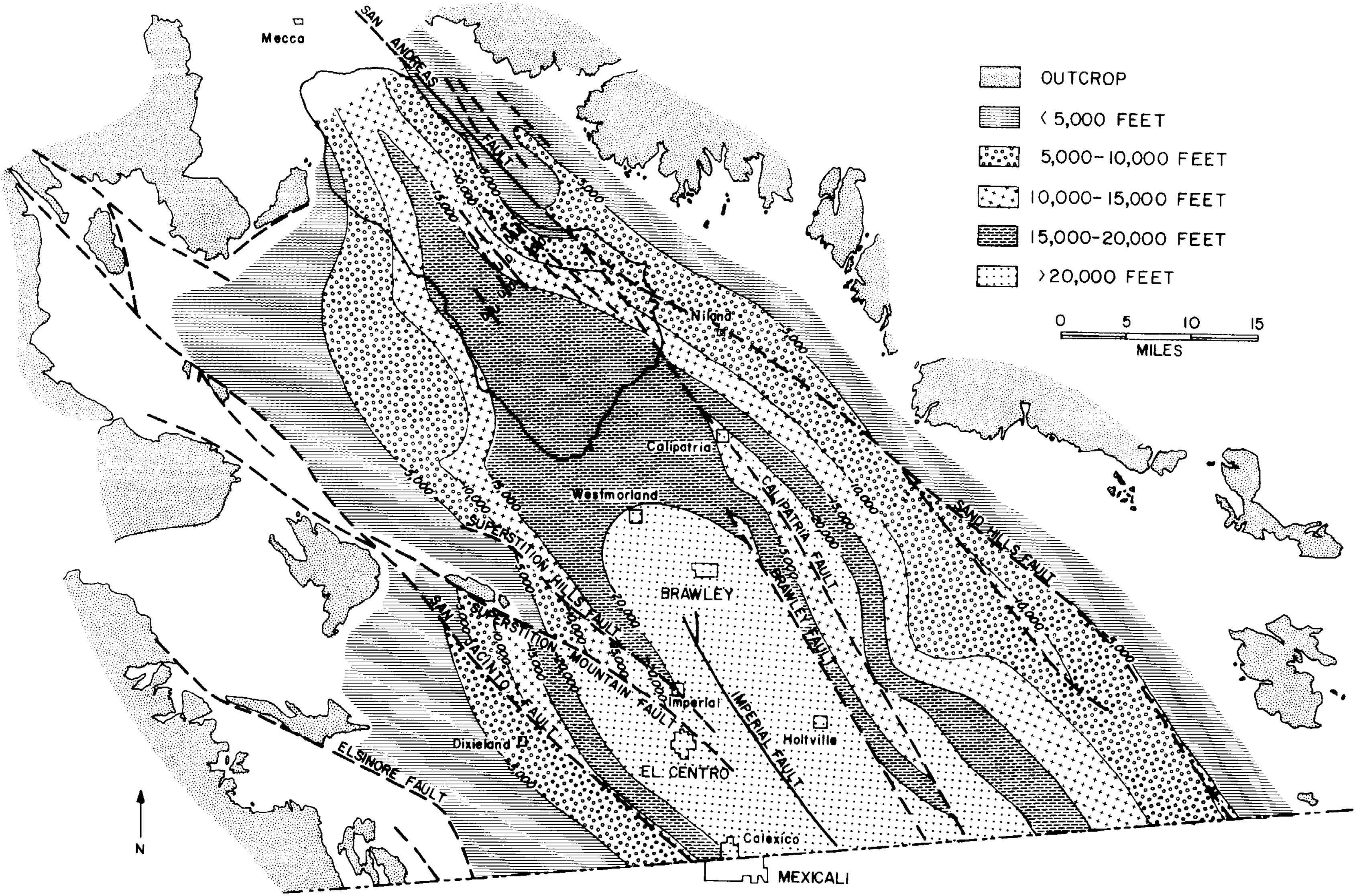

Figure 7. Depth to Basement. *From Rex and Meidav, 1970.*

in order to probe depths up to 8000 feet. The survey made use of the well-known increase in electrical conductivity with increased temperature for ionic conductors to delineate zones of high heat. Normal resistivities in some sedimentary rocks measure as high as 1,000 to 10,000 ohm meters, but effective closure over a reservoir in Imperial Valley was indicated by resistivities of the order of 5 ohm-meters or less.

Results of the resistivity surveys in the Imperial Valley have been useful in locating and suggesting vertical displacements on faults, particularly the southern extension of the San Andreas. Additionally, anomalously high resistivity values compared to temperature gradients from drill hole data suggest a possible dry steam source near Heber.

Magnetic surveys have been very useful in delineating buried intrusive masses such as those associated with the Buttes at the south end of the Salton Sea.

Marine seismic data, collected on the Salton Sea for the California Department of Water Resources, have indicated that the Salton Sea is transected by a large number of faults, many of which are probably still active. The data indicate that a down-warping movement of the order of 2-3 cm/year is taking place on the sea floor (Meidav and Rex, 1970, p. 11). Additional corroborative information was obtained on the Southern extension of the San Andreas fault, now believed to be coincident with the Calipatria fault.

Results of the geophysical investigations indicate that electrical resistivity, together with shallow drilling, is an excellent tool for exploration of geothermal prospects, not only for delineation of high heat areas, but also for basin studies and fault investigations. Gravity surveys and maps can be used in conjunction with resistivity to pinpoint areas for detailed study. Magnetic surveys are useful in the determination of location and extent of buried intrusive masses. Seismic surveys, although not as useful as in oil exploration, can be extremely helpful in determining regional structural features.

Gold

By far the greatest number of mineral deposits in Imperial County are those developed for the recovery of gold. Of approximately 220 deposits listed herein, about 75 are gold mines or prospects. In total value of mineral production in the county, gold ranks second to gypsum. Since 1907, when Imperial County was formed, the total recorded value of gold recovered in the county amounts to an estimated $2,569,000. It is difficult to estimate the value of gold produced prior to 1907 because the statistics are combined with those of San Diego County. Moreover, the U.S. Bureau of Mines did not compile county statistics prior to 1880 and gold mining was pursued in what now constitutes the county as early as 1780. An estimate based upon production of the principal mines operating in 1893–1964 falls into the range of $6,000,000 to $7,000,000.

The first mining ventures in Imperial County followed the establishment of a Spanish community at the site of Yuma in the autumn of 1780. Placer mining activities are reported for less than a year thereafter in the vicinity of the Potholes adjacent to the Colorado River about 10 miles northeast of the community (see History).

No further development of these deposits was attempted until after the establishment of the Republic of Mexico in 1823. Between that time and the end of the war with Mexico in 1848, Mexicans worked the placer deposits at the Potholes and in the Cargo Muchacho Mountains.

American influence was felt in the area during and immediately following the Mexican War. Lieutenant Colonel Cooke and his Mormon battalion established a wagon route to the coast which traversed the southern part of the county in 1847. Fort Yuma was established in 1849 in connection with the work of the U.S. Boundary Commission. These events and the final subjugation of the Yuma Indians in 1851 provided strong impetus to settlement and exploration in the area. Newberry (1862, p. 21) states that mines were developed near the present site of the Picacho mine as early as 1857. Probably the most important single event affecting mining, however, was the completion of the Southern Pacific Railroad between Yuma and the Pacific coast in 1877. This allowed convenient shipment of heavy mining equipment, supplies, personnel, and bullion. By 1890 the mining industry was firmly established with notable activity at the Picacho and Hedges (see photo 12) areas. Peak periods of production were 1890–1910 and 1937–1942.

The most productive gold-producing areas in the county, in the probable order of their importance, are the Cargo Muchacho Mountains, the Picacho district, the Paymaster district and the Potholes area. All of these areas lie within a 600-square-mile region centered in the southeastern corner of the county. The region embraces the Cargo Muchacho Mountains and the southeastern half of the Chocolate Mountains. A few mines or prospects are known in the northwestern Chocolate Mountains, and even fewer occur in western Imperial County.

Photo 12. Ghost Town, Circa 1900. This town, Hedges, was a mining camp near the Tumco mine in the Cargo Muchacho Mountains. The view is northwest. ***Photo courtesy of the Title Insurance and Trust Company, Los Angeles.***

Lode gold deposits have accounted for most of the county production, and placer deposits usually occur close to their lode sources.

According to Henshaw (1942, p. 189–190), lode gold deposits in the Cargo Muchacho Mountains may be late Mesozoic in age and hence may be related to post-intrusive hydrothermal activity of the granitic intrusions of that period. The Cargo Muchacho deposits, in addition to gold, contain a mineral assemblage, wall rock alteration, and vein structures indicative of mesothermal deposits (Henshaw, 1942, p. 190).

From what little is known about the remaining deposits in the county it appears that they are of different origin and epithermal rather than mesothermal, as evidenced by the paucity of sulfide minerals and wall rock alteration. In addition, most of the gold deposits outside of the Cargo Muchacho Mountains are contained in pre-Cretaceous metamorphic rocks, especially gneiss of the Chuckwalla Complex. Furthermore, none contains associated copper or tungsten minerals, as do the Cargo Muchacho deposits. These differences suggest the possibility of two separate ages of mineralization; the earliest possibly is pre-Cretaceous.

Name, location, owner	Geology	Remarks and references
Albert Pothamus mine		Uncorrelated old name; probably at or near Golden Dream mine. (Crawford 96:331).
Alcyon mine		Uncorrelated old name; probably at or near Golden Dream mine. (Crawford 96:331).
Alfonso mine		Uncorrelated old name; probably at or near Golden Dream mine. (Crawford 96:331).
American Boy NE¼ sec. 17, T15S, R21E, SBM (projected), Ogilby quadrangle (15 minutes), Cargo Muchacho Mountains, 4.8 miles N 52 degrees E of Ogilby, on the south side of American Girl Wash, 1 mile west of Stud Mountain. Undetermined, 1962; may be included in American Girl mine holdings.	Nearly east-striking vein along the contact between Tumco Formation arkosite, which forms the footwall, and quartz diorite. The vein dips moderately to the south. Similar in many respects to the American Girl deposit of which it is an apparent extension.	Production statistics from this property are included in those for the American Girl mine. (Henshaw 42:192, pl. II).
American Girl mine NW¼ sec. 17, NE¼ sec. 18, T15S, R21E, SBM (projected), Ogilby quadrangle (15 minutes), Cargo Muchacho district, southwest central Cargo Muchacho Mountains; 13 miles northwest of Yuma, 4 miles N 40 degrees E of Ogilby. Frank A. Morrow, 1121 Lloyd Center, Portland, Oregon (1962)	Three essentially parallel veins that strike nearly due east and dip 25–70 degrees S in Tumco Formation arkosite. The east end of the veins swing slightly to the north. Tumco arkosite is composed of fine- to medium-grained, gray, highly indurated metasediments made up of quartz and feldspar with minor hornblende and biotite. Relict bedding is apparent in minor compositional changes, banding, and interbedded thin layers of green-gray hornblende schist. Biotite granite crops out a few hundred feet south of the veins on the surface, and its contact with arkosite bears generally parallel to them, but transects them in the eastern parts of the mine. The veins are designated from north to south the Blue, White, and Brown veins; the latter is the principal one. It dips 25–35 degrees S, apparently parallel to the relict bedding in arkosite. The Brown vein ranges in width from a few feet to as much as 40 feet. It has been mined along the strike a distance of 1500 feet and to an inclined depth of 850 feet. Maps of the stoped areas indicate an apparent rake of the main orebody to the west. The veins include the following primary ore minerals: gold, native silver, chalcopyrite, covellite, chalcocite, bornite, galena, and sphalerite. Secondary ore minerals include azurite, malachite, cuprite, native copper, and chrysocolla. Gangue minerals noted were quartz, pyrite, calcite, sericite, chlorite, biotite, fluorite, magnetite, hematite, and hydrous iron oxides (Henshaw 42:184). Anomalous radioactivity amounting to five times normal background count has been noted in the mine (Walker, et al 56:27). Above the 250-foot level	The American Girl mine was located in 1892 and was mined continuously until 1900. During this period an estimated 35,000 tons of ore was mined that averaged $8.00 per ton in gold (at $20 per ounce). Little or no additional mining was done thereafter until the period 1913–1916 when 20,000 tons of ore was milled that averaged $6.50 per ton. From 1916–1936, the mine was idle but from 1936–1939 about 150,000 tons was mined valued at $900,000 ($35 per ounce). The mine has been idle through 1962. Total estimated production is 205,000 tons valued at $1,285,000. The mine was patented in 1920 (no. 726106). Development consists of two single-compartment inclined shafts 740 feet and 850 feet deep. The American Girl shaft, the original working shaft, was sunk in the footwall of the Brown vein at an incline of 35 degrees in the upper levels and 25 degrees in the lower part. The Tybo shaft, about 800 feet west of the first shaft, was sunk at a similar inclination to an 850-foot depth. Main levels were developed at 100-foot intervals to the 700 level; the lowest is the 740 level. Total main level horizontal workings exceed 8700 feet. Many of the workings were caved and inaccessible in 1962. (Crawford 96:331; Aubury 02:6t; Merrill 16:728; Tucker 26:255; Tucker 38:9; Tucker and Sampson 40:10, 16; Sampson and Tucker 42:113–114; Henshaw 42:147–196; Walker, Lovering, and Stephens 56:10t, 27).

Gold—continued

Name, location, owner	Geology	Remarks and references
	the gold occurs free but below that it occurs both free and enclosed in grains of pyrite and chalcopyrite. Most of the gold was −325 mesh. Wall rocks have undergone intense sericitization, chloritization and feldspathization for several tens of feet away from the veins. Where biotite granite is present, as in the far eastern parts of the vein, only chloritization is prevalent. The Blue vein is about 200 feet north of the Brown vein and strikes parallel to it but dips more steeply (70 degrees S). The White vein is between the Blue and Brown veins and also dips 70 degrees S but strikes more to the northeast so that it intersects both of the other two veins. The Blue and the White veins apparently were mined only in their upper levels and the records are obscure as to their exact nature. At the bedrock surface these veins are obscured by alluvium. Mineral assemblage and wall rock alteration of this deposit indicate a mesothermal origin (Henshaw 42:190).	
Apache		See Picacho mine.
Arizona mine Reportedly in sec. 17, T15S, R21E, SBM, Ogilby quadrangle (15 minutes), adjoining the *American Girl mine* on the east, Cargo Muchacho Mountains; not confirmed, 1962. Undetermined, 1962; J. Ernest, Los Angeles (1914)		Uncorrelated old name; not visited 1962. Probably never more than a prospect. (Merrill 16:729).
Banner (Overlook) Group Reportedly adjacent to the Tumco mine on the east, Ogilby quadrangle (15 minutes), Cargo Muchacho Mountains; not confirmed, 1962. Undetermined, 1962; Larry Wren, Ogilby (1914)	Reportedly it was hoped that this prospect would prove to be an extension of the Golden Queen ore body, though apparently this was not borne out.	Uncorrelated old name; not visited, 1962 (Crawford 96:331; Merrill 16:729).
Big Bear and Little Bear (Little Bear) prospect Center of N½ sec. 30, T15S, R21E, SBM, in the Ogilby quadrangle (15 minutes), at the base of the southeastern part of Cargo Muchacho Mountains, about 12½ miles northwest of Yuma, Arizona, 2.5 miles N 70 degrees E of Ogilby. Undetermined, 1961; Balch, Contares, and Bennett, El Centro (1942).	Three to 5-foot wide brecciated and altered shear zone, strikes N 60 degrees E, dips 50 degrees SE in quartz diorite gneiss.	Little if any production. Developed by a 100-foot inclined shaft sunk S 80 degrees E at 40 degrees, moderately askew to the dip. Forty feet of drift was driven on the 40-foot level. Three other 10-foot shafts have been sunk (Henshaw 42:pl. II; Sampson and Tucker 42:114).
Big Chief		See Land Group.
Blossom (Salamanca Consolidated) mine Near the center of N½ sec. 19, T15S, R21E, SBM (projected), in the Ogilby quadrangle (15 minutes), southeastern Cargo Muchacho Mountains, 13½ miles northwest of Yuma, Arizona, 3 miles N 50 degrees E of Ogilby. Robert K. Foster, Box 575, Winterhaven (1961)	(Not determined, 1961, because of inaccessible workings, poor surface exposures). Previously reported to be two veins which strike N 15–25 degrees W and dip 50 degrees SW in quartz diorite gneiss. The vein is 1 to 4 feet wide, and is exposed for several hundred feet in the workings. The veins are composed primarily of quartz with pyrite, chalcopyrite, and free gold.	Known as early as 1894. Developed by 3 shafts, the Blossom, Valencia, and Valencia No. 2. The shafts are 280, 240, and 70 feet deep respectively. The Blossom shaft (inclined) is the farthest northwest and the Valencia shaft is about 400 feet to the southeast. The Valencia No. 2 shaft was sunk about 175 feet northeast of the Valencia shaft. Several hundred feet of workings are reported to exist. (Crawford 94:238; 96:332; Aubury 02:6t; Merrill 16:729t; Tucker 26:255; 40:17; Sampson and Tucker 42:114; Henshaw 42:194).
Buena Vista mine		See Senator mine (Crawford 96:332; Aubury 02:6t).

Gold—continued

Name, location, owner	Geology	Remarks and references
Butterfly Group Reportedly in sec. 17, T15S, R21E, SBM (proj.), Ogilby quadrangle (15 minutes), Cargo Muchacho Mountains, east of the American Girl mine; not confirmed, 1962. Undetermined, 1962; S. C. Samson, Ogilby (1942)	Two to 4-foot vein that strikes northwest and dips northeast.	Uncorrelated old name; not visited, 1962; may be the same property as the Morning Star prospect although no 325-foot inclined shaft mentioned in earlier Butterfly reports was found at the Morning Star. Old reports state that levels were developed at the 100, 200, and 300 foot points of a 325-foot inclined shaft. (Tucker 26:255; Sampson and Tucker 42:115–116).
Calcite		See Land Group.
California Gold King mine		See Picacho mine.
California Picacho mine Reportedly 4 to 5 miles from the Colorado River, presumably in Little Picacho Wash, south of Picacho; not confirmed, 1962. Undetermined, 1962	Auriferous gravel in Holocene stream wash.	Uncorrelated old name; not visited 1962. An attempt to work this deposit by hydraulic methods in the early 1890's failed because of pumping problems. (Crawford 94:238; 96:333).
Cargo Muchacho (Cargo) mine S½ sec. 20, T15S, R21E, SBM, in the Ogilby quadrangle (15 minutes), Cargo Muchacho Mountains, 11½ miles northwest of Yuma, Arizona, 3.6 miles N 70 degrees E of Ogilby. Holmestake Mining Company, Mr. Kenneth Holmes, Yuma, Arizona (1961)	A vein in a shear zone parallel to foliation in quartz diorite gneiss. The vein strikes N 10 degrees W to N 10 degrees E and dips about 55 degrees E. It is 4–8 feet wide, is exposed for more than 1200 feet along strike, and has been explored more than 600 feet down dip. A post-ore fault of undetermined strike is reported to intersect the vein between the 350 and 450-foot levels. The fault dips 20 degrees eastward and displaced the vein westward (Crawford 94:239). Two narrower veins occur below and east of the fault. These have been mined in the lower levels, but do not appear to crop out at the surface. Judging from the map, the principal ore shoot of the main vein was mined between the sixth and third levels north of the shaft. The ore shoot apparently was mined as much as 300 feet along the strike between the third and fifth levels. Near the surface only a few tens of feet along strike was mined. About 1000 feet south of the main shaft the vein passes into quartz monzonite where the vein was much less prominent and productive. The north end of the vein is truncated by an east-trending vertical fault about 650 feet from the main shaft. Little exploration has been done to locate the displaced northern extension. The hanging wall of the vein is somewhat more fractured than the footwall and has undergone chloritic alteration. In addition to gold the veins contain sparse pyrite and tabular zones of scheelite. These tabular zones are as much as 100 feet in their longest dimension and 10 feet thick. The scheelite occurs erratically in veinlets, surface coatings, and less commonly disseminated in the vein quartz (Bateman and Irwin 54:39).	This is one of the first deposits mined in Imperial County. The deposit was located in 1877 by Thomas Porter Neet et al, and by 1882, 14,000 tons of ore had been mined which averaged $12 per ton. The mine was surveyed for patent in 1892. Other periods of major activity were 1890–1894 and 1936–1942, 1949–1952(?). Tailings of ore milled in the 1890's were cyanided (?) about 1940. Total production probably exceeds 25,700 ounces of gold valued at $852,000. The mine is developed by a 680-foot inclined shaft at the north end of the vein, and a 200-foot vertical shaft about 1100 feet south of the deep shaft. Most of the stopes are below the third level. The area as far north as 800 feet of the main shaft was explored on the surface by several shallow shafts. In another prospect a 125-foot adit was driven due north from a point 1000 feet N 70 degrees W of the main shaft. (Hanks 86:81; Storms 92:385–386; Crawford 94:239; 96:334; Aubury 02:6t; Merrill 16:729; Tucker 26:255; 38:9; Sampson and Tucker 42:117; Henshaw 42:194, pl. II; Averill and Norman 51:326; Bateman and Irwin 54:39).
Castle prospect NE¼ sec. 9, T13S, R19E, SBM (projected), at the southwestern base of the Chocolate Mountains, 6.8 miles N 54 degrees E of Glamis. Richard Castle, Glamis. (7 claims)	Ten-foot thickness of Quaternary older alluvium overlying deeply weathered gneiss. Gold is apparently mostly in the weathered gneiss adjacent to the contact with the gravels.	No recorded production. Explored by shallow open cuts.
Central mine Reportedly in sec. 12, T14S, R22E, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; Allen T. Smith, Picacho (1902)		Uncorrelated old name; probably long abandoned. (Aubury 02:6t).

Gold—continued

Name, location, owner	Geology	Remarks and references
Coffee Pot (Coffee) mine NE¼ sec. 1, T15S, R20E, SBM, Ogilby quadrangle (15 minutes), about 16 miles northwest of Yuma, Arizona, 5.3 miles N 15 degrees E of Ogilby Siding. Undetermined, 1961; Edward Coffee, Ogilby (1942)	Tabular shaped zone parallel to bedding in metamorphic rocks of the Precambrian(?) Tumco Formation which strikes N 60 degrees E and dips 30 degrees SE. The zone is 3–5 feet wide and is exposed for several tens of feet. It is composed principally of altered arkosite. Little shearing is evident in the zone, but it contains numerous narrow subparallel fractures that are parallel to the bedding. These have been filled with chrysocolla, malachite, azurite, and subordinate cuprite and tenorite. Narrow granite pegmatite dikes, which have been intruded parallel to the bedding planes, are common in the area. These too contain spotty, irregular mineralized zones.	Total production probably less than 200 tons of undetermined grade. Developed by 65-foot shaft inclined at 30 degrees southeast with a small stope astride the shaft at the 15-foot level. The stope extends 10 feet down dip, 15 feet northeast and 20 feet southwest of the shaft, and is 5 feet high. (Tucker and Sampson 40:17; Sampson and Tucker 42:117; Henshaw 42:191).
Colorado mine		See La Colorado mine.
Crescent Placer mine Unsurveyed section, T13S, R22E, SBM, Picacho and Picacho SW quadrangles (7½ minutes), Picacho district, Chocolate Mountains, 1.3 miles southwest of Picacho adjacent to Little Picacho Wash on the west. Undetermined, 1962; 100 acres patented 1893.	Recent stream wash gravel in deep arroyos cut in older Tertiary gravel. Gold probably was derived from various lode deposits in Picacho Basin, 3 miles to the south.	Located in August, 1891. Patented in 1893 (Survey No. 3215, vol. 3, p. 8). Production, if any, unrecorded.
Delta mine Reportedly adjacent to the Tumco mine (Golden Cross Workings) on the northwest. Probably in the S½ sec. 1, T15S, R20E, SBM, Ogilby quadrangle (15 minutes), Cargo Muchacho Mountains; not confirmed, 1962. Undetermined, 1962; Thomas Johnston, Ogilby (1914).		Uncorrelated old name; not visited, 1962. Probably never more than a prospect. (Merrill 16:729).
Desert Gold and Aluminum Corporation mine		See Vista mine (gold) and Powder Uranium and Minerals (clay). (Tucker and Sampson 40:17, 18; Sampson and Tucker 42:117, 118).
Desert King mine Reportedly in sec. 12, T15S, R20E, SBM, Ogilby quadrangle (15 minutes), Cargo Muchacho Mountains, 5 miles north of Ogilby; not confirmed, 1962. Undetermined, 1962; C. S. Walker and B. F. Harrison, Ogilby (1942).	A 3–5 foot vein that strikes N 60 degrees W and dips 55 degrees SW in schist. Abundant narrow pegmatite dikes of varied orientation cut the schist in this area.	Uncorrelated old name, but may be same as King mine; not visited, 1962. This property, which operated in 1938, is said to be developed by a 150-foot inclined shaft with horizontal workings on the 75-foot and 150-foot levels totaling 400 feet, including a 75-foot crosscut adit to the vein on the 75-foot level. A few hundred feet to the west a crosscut adit was driven 300 feet N 60 degrees E with 300 feet of appended workings, and stoped to the surface at a point 100 feet from the portal. (Tucker 26:255–256; Sampson and Tucker 42:118).
Dulciana mine		See Picacho mine.
Duncan mine		See Three C's mine (Crawford 96:335; Tucker 26:256; Sampson and Tucker 42:118, 119). See also Trio mine.
Eastern California mine		See Picacho mine.
Dos Hombres Discovery prospect SE¼ sec. 13, T12S, R19E, SBM, in the Chocolate Mountains, 12 miles N 45 degrees E of Glamis in the Paymaster district, ½ mile southeast of Imperial Gables. J. R. Sanford and Ralph R. Rusher, Box 23, Glamis (1961)	Quaternary fanglomerate probably overlying Tertiary volcanic rocks.	Developed by a vertical shaft of undetermined depth. Production, if any, undetermined.

Gold—continued

Name, location, owner	Geology	Remarks and references
Easy Pickins prospect Near the east boundary of the SW¼ of NE¼ sec. 24, T17S, R9E, SBM, In-ko-pah Gorge quadrangle (7½ minutes), Jacumba Mountains, 5.2 miles due east of Mountain Spring in Davies Valley. Undetermined, 1961.	Quaternary valley alluvium composed principally of unconsolidated sandy gravel.	Little or no production. Developed by a 15-foot vertical shaft.
El Lucero		See Rainbow mine.
Englewood mine Reportedly in sec. 18, T15S, R21E, SBM, Ogilby quadrangle (15 minutes), Cargo Muchacho Mountains, not confirmed, 1962. Undetermined, 1962; Thomas Johnston, Ogilby (1914).		Uncorrelated old name; probably included in Ogilby Group. (Merrill 16:729).
Erma mine Reportedly in sec. 21, T13S, R19E, SBM, northeast of Glamis; not confirmed, 1962. Probably near Vista mine. Undetermined, 1962. May be a part of the Desert Metals Company property (Vista mine).	Quartz veins in schist.	Uncorrelated old name; not visited, 1962. (Merrill 16:731; Tucker 26:256).
Free Gold Mining Company		See Tumco mine.
Georgia Placer mine Sec. 34, T13S, R22E, SBM (projected), Picacho Peak quadrangle (15 minutes), Picacho district, Chocolate Mountains, 2.3 miles southwest of Picacho, adjacent to Little Picacho Wash on the west. Undetermined, 1962.		Located in June 1891; patent survey No. 3216 (not patented).
Gold Basin (Silver Queen) mine NW¼ sec. 2, T12S, R20E, SBM, in the Quartz Peak quadrangle (15 minutes), Paymaster district, central Chocolate Mountains, about 18 miles northeast of Glamis, and 4¼ miles S 12 degrees E of Midway Well in Gold Basin. George Burslem, Box 1278, Brawley (1963)	Narrow quartz veins strike generally northeast and dip 60–70 degrees SE in gneiss. Veins are near a contact with a silicic rhyolite dike which underlies most of the small hill at the mine. Fractures in the rhyolite contain blue copper oxide minerals. A small body of basalt crops out south of the rhyolite but does not appear to be mineralized.	The property is developed by a vertical shaft, reported to be 100 feet deep, and a crosscut adit driven about 100 feet due south from a point southwest of the shaft. Numerous shallow shafts and test pits are present northeast and southeast of the main workings. No recorded production. (Tucker 26:257; Sampson and Tucker 42:119; Oesterling and Spurck 64:128).
Gold Chain mine Reportedly in sec. 29, T14S, R23E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962 Undetermined, 1962; Wm. Swain, Picacho (1902)		Uncorrelated old name; probably long abandoned. Probably was at or near the Golden Dream mine. (Crawford 96:337; Aubury 02:7t).
Gold Crown mine		Uncorrelated old name; probably at or near the Golden Dream mine. (Crawford 96:337; Aubury 02:7t).
Gold Delta mine		See Vista mine (Sampson and Tucker 42: 119).
Gold Eagle mine Reportedly in sec. 29, T13S, R23E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; Allen T. Smith, Picacho (1902)		Uncorrelated old name; probably long abandoned. (Aubury 02:7t).
Gold Hill, Gold King, Gold Prince, Gold Princess, Gold Queen mines		Uncorrelated old names, probably at or near the Golden Dream mine. (Crawford 96: 337).
Gold Rock mine		See Tumco mine.
Gold Rule mine		See Jaeger mine (Crawford 96:337).

Gold—continued

Name, location, owner	Geology	Remarks and references
Golden Casket mine		See Picacho mine.
Golden Cross mine		See Tumco mine.
Golden Crown mine		See Tumco mine.
Golden Dream (St. Joseph, White Gold Basin mines, Albert Polhamus, Alcyon, Alfonso, Gold Chain, Gold Crown, Gold Hill, Gold Prince, Gold Princess, Gold Queen, Golden Sunshine, Jita, Oriental, Oro Blanco, Ponce de Leon) mine. NE¼ sec. 21, T13S, R23E, SBM, Picacho quadrangle (7½ minutes), in the southeastern Chocolate Mountains about 21 miles north-northeast of Yuma, Arizona, 3.2 miles N 80 degrees E of Picacho, adjacent to the Colorado River. Undetermined, 1962; D. K. Allen and W. Swain, Picacho (1896)	A series of sub-parallel veins along shear zones that strike from N 40–60 degrees E and dip from 35 to 90 degrees SE in schist. The zones are 4–6 feet wide and can be traced as far as 600 feet on the surface. Small amounts of ore have been mined principally from three veins which are about 150 and 300 feet apart from southeast to northwest. A minor set of short, narrow veins strike N 5–35 degrees W and dip northeastward, but apparently they yielded little or no ore. A major east-trending fault cuts the area a few hundred feet south of the southernmost workings. Gold from this area was reported to be white in color because of abnormal amounts of silver in the gold (electrum), hence the name White Gold Basin.	The mines and prospects in this area were active about 1896 when the area was known as White Gold Basin. Little production resulted from these explorations. Ore was probably hauled to the Picacho mill, about 3½ miles up the Colorado river. Development consists of an inclined shaft 30 feet deep, a 50-foot vertical shaft, and a few shallow open-stopes less than 50 feet long. (Crawford 96:345; Brown 14:730).
Golden Eagle mine		See Telluride mine.
Golden Geyser SW¼ sec. 21, T15S, R21E, SBM (projected), in the Ogilby quadrangle (15 minutes), southeastern Cargo Muchacho Mountains, about 12 miles northwest of Yuma, Arizona, 4.2 miles N 74 degrees E of Ogilby. M. J. Farmer, address undetermined (1955).	Weak fracture zone parallel to foliation in quartz diorite gneiss. The zone strikes N 35 degrees W, dips 15 degrees NE and is a few feet wide.	Little if any production. Prospected by 25-foot inclined shaft.
Golden Queen mine		See Tumco mine.
Golden Queen prospect (1) Near the middle of the west edge of sec. 36, T14S, R20E, SBM, Ogilby quadrangle (15 minutes), about 17 miles northwest of Yuma, Arizona, 5.8 miles N 7 degrees E of Ogilby siding. Undetermined, 1961; Mr. Miller (1942)	An irregular zone that lies adjacent to a fault which trends east and dips steeply south in granite. Little wall rock alteration or silicification is apparent. An ore shoot(?) which trends roughly east was mined from the surface to a depth of 15 feet. It appears to have been 40 feet long and 10–15 feet wide	Total production probably less than 400 tons. Developed by 40-foot vertical shaft and an irregular stope on the 15-foot level several feet east of the shaft. A winze about 15 feet deep was sunk in the eastern part of the stope. (Tucker and Sampson 40:17; Henshaw 42:191, pl. II).
Golden Queen prospect (2) NE¼ sec. 28, T13S, R20E, SBM, in the Chocolate Mountains, 12 miles N 85 degrees E of Glamis, and south-southwest of Black Mountain. Gene Gray, address not determined (1962)	Gold(?) in deeply weathered gneiss breccia.	Minor trenching. No recorded production.
Golden Rule mine		See Picacho mine.
Golden Sunshine mine		Uncorrelated old name; probably at or near Golden Dream mine. (Crawford 96:337).
Good Luck group		See Tumco mine.
Good Site mine Reportedly in sec. 20, T13S, R23E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; Wm. Swain, Picacho (1902)		Uncorrelated old name; probably long abandoned (Aubury 02:7t).
Goshen placer mine NW¼ sec. 11, T14S, R22E, SBM, Picacho Peak quadrangle (15 minutes), southeastern Chocolate Mountains, Picacho district, about 4 miles south of Picacho, near the head of Arrastre Wash. Undetermined, 1963.		See Picacho mine. (Crawford 96:338).

Gold—continued

Name, location, owner	Geology	Remarks and references
Gray Eagle mine		See Whitecap prospect.
Graypoint mine		See under Tungsten.
Guadalupe (Guadaloupe) mine NW¼ sec. 16, T15S, R21E, SBM (projected), in the Ogilby quadrangle (15 minutes), central Cargo Muchacho Mountains, 12½ miles northwest of Yuma, Arizona, 5 miles N 60 degrees E of Ogilby. Frank Morrow and Associates, Box 338, ...lto	Vein strikes N 15 degrees E and dips 45 degrees SE in well foliated quartz diorite. The vein is about 6 feet wide and can be traced about 100 feet. It is composed mainly of quartz and fault gouge. A felsitic dike about 20 feet wide lies subparallel to the vein, 10 to 30 feet into the hanging wall. A small ore shoot was mined on the 40-foot level. It lies between 15 and 45 feet northwest of the shaft and was mined to a 10-foot height.	Located 1887 and patented in 1894. Apparently most of the development was done prior to 1902. The mine is developed by a 45 degree inclined shaft to a depth of 240 feet (partially caved at 100-foot level). On the 40-foot level drifts were driven 50 feet in opposite directions along the vein. In the southwest drift, a crosscut was driven about 20 feet into the hanging wall. In the drift northeast, crosscuts were driven 30 and 25 feet into the hanging wall from points 10 and 40 feet from the shaft. A 90-foot level of undetermined extent was driven north of the shaft (caved). (Aubury 02:7t; Merrill 16:729; Henshaw 42: 193).
Gulch Placer (California Picacho, Picacho Basin) mine Unsurveyed section, T13S, R22E, SBM, Picacho Peak quadrangle (15 minutes), Picacho district, Chocolate Mountains, 20 miles due north of Yuma, Arizona, in Little Picacho Wash at, and south of, Picacho for about 2½ miles. Undetermined, 1962; California Picacho Gold Mines Co. (1893).	Recent stream wash gravel of Little Picacho Wash. Gold probably was derived from the various lode deposits in Picacho Basin. The wash ranges from as much as 1000 feet wide near the Colorado River to a few tens of feet at its head.	Located May 1893; surveyed for patent June 1893; survey no. 3214 (not patented). All evidence of mining operations has been obscured by subsequent ephemeral stream activity.
Helen May mine		See Picacho mine.
Hess mine		See Rainbow mine.
Indian Pass placer Secs. 29, 32, T13S, R21E, SBM (projected), Quartz Peak quadrangle (15 minutes), southwestern base of the Chocolate Mountains, about 22 miles north-northwest of Yuma, Arizona, 1 mile due south of Indian Pass. Richard L. and Anna M. Singer, Glamis (1964)	Placers of undetermined tenor in Pliocene(?) fanglomerate. The fanglomerate consists of gray-buff clay to silt-sized particles containing poorly sorted angular to sub-rounded clasts of acid igneous rocks, quartzite, basalt, dumortierite, and uncommonly kyanite. The occurrence of the latter two minerals and the possible presence of gold suggest that the alluvium may have been derived from the Cargo Muchacho Mountains to the south rather than from the Chocolate Mountains. Furthermore, granitic outcrops are not locally abundant in the adjacent Chocolate Mountains whereas they underlie large areas in the Cargo Muchacho Mountains.	This property was being explored in April, 1964. No previous activity has been noted.
Iron Gold Bearer mine Reportedly in sec. 6, T14S, R22E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; B. A. Carey, Yuma (1902)		Uncorrelated old name; probably long abandoned. (Aubury 02:7t).
Jaeger (Gold Rule, Matamora, Minnie, Nugget) mine Reportedly 30 miles north of Yuma; not confirmed, 1962. Undetermined, 1962; L.J.F. (1896)		Uncorrelated old name; not visited, 1962 (Crawford 96:337, 341, 342).
Jayne mine		See Picacho mine.
Jean prospect NE¼ sec. 30, T15S, R21E, SBM, in the Ogilby quadrangle (15 minutes), southeastern Cargo Muchacho Mountains, about 12 miles northwest of Yuma, Arizona, 3 miles N 74 degrees E of Ogilby. Undetermined, 1961; formerly Mr. Ballinger, Yuma, Arizona.	Several narrow discontinuous quartz stringers parallel to the foliation in quartz diorite gneiss. These strike N 35 degrees W and dip 65 degrees NE.	Little or no production. Prospected by shallow trenches.

Gold—continued

Name, location, owner	Geology	Remarks and references
Jita mine		Uncorrelated old name; probably at or near Golden Dream mine. (Crawford 96:340).
King mine		See Tumco mine.
Kirton-Gunn prospect Reportedly in T12S, R18E, SBM, Acolita quadrangle (15 minutes), Chocolate Mountains; not confirmed 1962; may be the prospect in the middle S½ sec. 32, T11S, R18E, on the north and east sides of hill 1561, 12 miles north-northwest of Glamis. In U.S. Naval Gunnery Range; Charles Kirton, Robert Gunn, Glamis (1942)	(Not determined)	Not visited, 1962. In 1942, twenty-two tons of ore was shipped containing a total of 2 ounces of gold, 26 ounces of silver, 266 pounds of copper, and 487 pounds of lead.
La Colorado (Colorado) mine SE¼ sec. 26, T14S, R20E, SBM, Ogilby quadrangle (15 minutes), northwest tip of Cargo Muchacho Mountains, about 18 miles northwest of Yuma, Arizona, 6.6 miles N 5 degrees E of Ogilby Siding. Michael Miller, Winterhaven (1961)	Two parallel mineralized zones in foliated granite. The zones lie parallel to the regional foliation which strikes N 75 degrees W and dips 30–35 degrees SW. They are about 20 feet apart on a horizontal plane and are an average of 3–6 feet wide, although previous descriptions report thicknesses as much as 35 feet. The zones are composed mostly of quartz and slightly altered wall rock. The hanging wall is a distinct planar feature in each zone marked by less than one inch of clayey gouge. The footwall is less distinct. The zones have been exposed over a distance of a few hundred feet and projections of the zones have been explored for a total distance of 2000 feet with no apparent success. The veins are reported to contain traces of scheelite (Bateman and Irwin 54:39).	Discovered in 1914 but developed mostly in the 1930's. Production probably amounts to no more than a few hundred tons. Development at the main workings consists of a 60-foot vertical shaft with levels at 20 and 50 feet. On the 20 foot level are about 170 feet of horizontal workings including minor stoping. On the 50-foot level are 140 feet of drift and 45 feet of crosscuts. Another vertical shaft 90 feet southwest is 28 feet deep with a square-shaped stope at the bottom that measures about 25 feet on a side. About 800 feet northwest is a 50-foot vertical shaft with undetermined appended workings. About 1000 feet southeast of the main shaft is an exploratory group of horizontal workings totaling more than 300 feet off of a single adit driven initially S 10 degrees E. No stoping is evident in this group. (Tucker and Sampson 40:18–19; Sampson and Tucker 42:120–121; Henshaw 42:191; Bateman and Irwin 54:39).
Land Group (Calcite, Big Chief) SE¼ sec. 5, T13S, R19E, SBM (projected), Quartz Peak quadrangle, (15 minutes), southwestern base of the Chocolate Mountains, 31 miles east-northeast of Brawley, 6.2 miles N 47 degrees E of Glamis. H. C. Gibson and George Burslem, Box 1278, Brawley	Native gold occurs in a fracture zone that strikes N 10 degrees W and dips about 80 degrees NE. The zone occurs in Precambrian(?) gneissic and schistose rocks which have been complexly intruded by a fine-grained rock of granitic composition. The vein is exposed in the workings a distance of about 400 feet along strike and had been explored to a depth of about 100 feet. The principal fracture zone is about 6 feet wide and consists of narrow ramifying veinlets which contain quartz, calcite, hydrous iron oxides (including pyrite pseudomorphs), and erratically distributed native gold. Some of the gold occurs in rather coarse aggregates.	This property was worked as early as 1936 (Walter and George Land). Incomplete statistics indicate a production of less than 100 tons of ore of undetermined grade. The property is developed by a 100-foot vertical shaft with levels at 50 and 100 feet. The 50 foot level contains drifts 70 and 25 feet in length southeast and northwest, respectively, and a crosscut west about 100 feet long. The 100 foot level is reported to consist of drifts about 70 and 100 feet in length southeast and northwest. Little stoping was in evidence in 1964. A small pit 25 feet in diameter and 15 feet deep, 300 feet northwest of the shaft, was being explored in April 1964 in a reportedly high grade pocket. The ore was milled in a hurricane-impact mill and a dry concentrator on the property.
Little Bear prospect		See Big Bear and Little Bear prospect.
Little Glen prospect SW¼ sec. 16, T15S, R21E, SBM (projected), in the Ogilby quadrangle (15 minutes), southeastern Cargo Muchacho Mountains, about 12 miles northwest of Yuma, Arizona, 4.4 miles N 63 degrees E of Ogilby. Glen R. Roberts and Samuel E. Dewhirst, address undetermined (1959)	Two to 3-foot wide breccia zone strikes N 10 degrees W and dips 45 degrees NE in quartz diorite gneiss. The zone contains irregular discontinuous masses of quartz, which are 1–2 feet wide.	Little if any production. Developed by 30-foot drift-adit and several small cuts and pits.
Little Gold Reef mine Reportedly in sec. 6, T14S, R22E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; B. A. Carey, Yuma, Arizona (1902)		Uncorrelated old name; probably long abandoned. (Aubury 02:7t)

Gold—continued

Name, location, owner	Geology	Remarks and references
Little Tinner mine Reportedly in sec. 6, T14S, R22E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; B. A. Carey, Yuma (1902).		Uncorrelated old name; probably long abandoned. (Aubury 02:7t).
Lucky Strike SW¼ sec. 11, T13S, R20E, SBM, Quartz Peak quadrangle (15 minutes), at the southwestern base of Black Mountain in the Chocolate Mountains, 14¼ miles N 75 degrees E of Glamis, and 3 miles S 24 degrees W of Quartz Peak. Undetermined.	Weak copper stains and fracture coatings in a narrow shear zone in schist. Vein strikes N 75 degrees W, dips 85 degrees SW. It is 1 foot wide and can be traced a few hundred feet along the strike.	The deposit is prospected by test pits and trenches. No production is evident.
Madre y Padre mine		See Padre y Madre mine.
Mars mine		See Picacho mine.
Mars Extension mine		See Picacho mine.
Mary Lode mine NW¼ sec. 14, T12S, R18E, SBM, Acolita quadrangle (15 minutes), on the southwest face of the Chocolate Mountains, 9.1 miles N 4 degrees E of Glamis. Lies within the Chocolate Mountains Naval Gunnery Range; W. R. Vanderpool, Glamis (1952)	Gold was mined from an irregular quartz vein that strikes about N 65 degrees E to due east and dips 30 degrees NW and north in a hybrid granitic rock. The vein which swells and pinches follows an ill-defined shear zone and can be traced for a distance of about 200 feet. For the most part, the vein ranges in width from 4–7 feet and contains very weak iron and manganese oxide stains. Individual minor shears within the zone contain clayey gouge. Gold occurs free both in pure white quartz and intimately associated with hydrous iron oxides, which are probably derived from minor amounts of pyrite.	Total production from this mine has been about 500 tons which is reported to have averaged about $40 per ton. A rich pocket of ore from the east(?) workings averaged $200 per ton. This ore was shipped without milling. The property is developed by two inclined shafts. The east shaft was sunk 55 feet on a 30 degree incline. At the 30-foot level a crosscut was driven 42 feet N 60 degrees W. Near the intersection of the incline and crosscut, a winze was sunk 30 feet down dip. A raise from the same point was driven 20 feet to the surface. The west shaft was sunk about 80 feet N 30 degrees W at a 30 degree incline. At the 50-foot level a drift was driven 70 feet N 65 degrees E with a 25-foot winze sunk 50 feet from the shaft. Another drift was driven 23 feet S 60 degrees W from the shaft, and a raise from that drift was driven 25 feet southeastward. (Sampson and Tucker 42:122).
Matamora mine		See Jaeger mine. (Crawford 96:341)
Mayata mine Reportedly in sec. 18, T15S, R21E, SBM, Ogilby quadrangle (15 minutes), Cargo Muchacho Mountains, adjacent to the American Girl mine on the west; not confirmed, 1962. Undetermined, 1962; Thomas Johnston and H. Randolph, Ogilby (1914)		Probably included in the Ogilby Group (Merrill 16:729).
Mendeville mine NW¼ sec. 11, T14S, R22E, SBM, Picacho Peak quadrangle (7½ minutes), Chocolate Mountains, Picacho district, near the head of Arrastre Wash centered about U.S. Mineral Monument 64 (from U.S. Bureau of Land Management patent plats). Undetermined, 1962; J. Mendeville, Yuma, Arizona (1942)	Vein in silicified schist, strikes north, dips 60 degrees W.	Uncorrelated old name; not visited, 1962. Developed by a 75-foot inclined shaft and a 50-foot vertical shaft which are connected by a short drift and crosscut on the 50 foot level. (Tucker 26:258; Sampson and Tucker 42:122).
Mesquite Diggins		See Mesquite Placer mine.
Mesquite Lode mine Reported in sec. 27, T12S, R19E, SBM, 10 miles east of Glamis; not confirmed, 1962. Undetermined, 1962; R. and C. Patterson and S. Johnson, Holtville (1942)	A vein in schist that strikes N 20 degrees W and dips southwest; 2–4 feet wide.	Uncorrelated old name; not visited, 1962. Development consists of a 50-foot drift-adit and several open cuts. (Sampson and Tucker 42:123).

Gold—continued

Name, location, owner	Geology	Remarks and references
Mesquite Placer (Mesquite Diggins) mine SW¼ sec. 3, T13S, R19E, SBM, Quartz Peak quadrangle (15 minutes), Paymaster district, 9 miles northeast of Glamis.		See Vista mine. (Merrill 16:731; Tucker 26:258; Sampson 32:245; Laizure 34:244; Tucker and Sampson 40:10; Sampson and Tucker 42:117,118).
Million Dollar Gold mine Reportedly in sec. 25, T14S, R23E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; W. Swain and Lydia Smith, Picacho (1902)		Uncorrelated old name; probably long abandoned. (Aubury 02:8t).
Mina Rica mine		See Picacho mine.
Minnie mine		See Jaeger mine (Crawford 96:341).
MMJ mine Middle N½ sec. 29, T15S, R21E, SBM, in the Ogilby quadrangle (15 minutes), southeastern Cargo Muchacho Mountains, about 12 miles northwest of Yuma, 3.7 miles N 77 degrees E of Ogilby. Undetermined, 1962; G. F. Hopper and R. D. Love, address undetermined (1953)	Three to five foot vein, strikes N 50 degrees W, dips 35 degrees NE in quartz monzonite. The vein is exposed several tens of feet along the strike. The vein walls are ill-defined and have undergone moderate quartz replacement and sericitization. The southeast end of the vein is intersected by a second vein which strikes due north and dips 45 degrees E. It is 5 feet wide and can be traced several tens of feet. Neither vein appears to continue beyond the point of intersection.	Developed by two inclined shafts 30 feet apart. Both shafts are a few tens of feet deep; one in each vein. The northwest-striking vein was stoped adjacent to the surface 30 feet along strike and 20 feet down dip. A 40-foot shaft inclined 70 degrees northeast was sunk about 500 feet southwest of the above workings in barren quartz monzonite. Apparently it was sunk to explore the weak veins which are exposed in shallow workings on the opposite or west side of the ridge from the main workings. Additional shallow cuts 700 feet due north explore weak northwest trending structures.
Monte Cristo mine Reportedly in sec. 33, T13S, R22E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; W. Swain and Lydia Smith, Picacho (1902)		Uncorrelated old name; probably long abandoned. (Aubury 02:7t).
Morning Star prospect Middle S½ sec. 17, T15S, R21E, SBM (projected), in the Ogilby quadrangle (15 minutes), south central Cargo Muchacho Mountains, 13 miles northwest of Yuma, Arizona, 4.1 miles N 57 degrees E of Ogilby. George W. Hughes and Leslie V. Burleson, 221 6th Avenue, Yuma, Arizona (1955)	Weak vein strikes N 30 degrees W and dips 50 degrees NE in biotite granite.	Little or no production. Developed by a 35-foot drift-adit northwest with a connected 10-foot shaft at 15 feet. Another 10-foot shaft was sunk 30 feet northwest of the first. May be a part of the Butterfly Group.
Mother Lode mine		See Pasadena mine.
Nugget mine		See Jaeger mine.
Occidental mine SE¼ sec. 17, T15S, R21E, SBM (projected), Ogilby quadrangle, Cargo Muchacho Mountains, 4 miles N 60 degrees E of Ogilby, 13 miles northwest of Yuma, Arizona. Undetermined, 1962; Henry J. Murdenk, Los Angeles (1942)	Several parallel veins which strike N 15 degrees W and dip 35 degrees SW in quartz diorite gneiss. The veins are from 1–2 feet wide.	Not visited, 1962. Patented April 18, 1906 (Survey no. 4266). Developed by at least two shafts of undetermined depths. Production unrecorded (Sampson and Tucker 42:123).
Ogilby group Reportedly in sec. 18, T15S, R21E, SBM, Ogilby quadrangle (15 minutes), Cargo Muchacho Mountains, adjacent to the American Girl mine on the west; not confirmed, 1962. Undetermined, 1962; S. C. Samson, Ogilby (1942)	Vein in schist strikes generally northwest and dips 35 degrees S.	Uncorrelated old name; not visited, 1962. Probably includes Mayata and Englewood prospects. (Tucker 26:257; Sampson and Tucker 42:123).

Gold—continued

Name, location, owner	Geology	Remarks and references
Oriental mine		Uncorrelated old name; probably at or near Golden Dream mine. (Crawford 96:342)
Oro Blanco mine		Uncorrelated old name; probably at or near Golden Dream mine. (Crawford 96:342).
Overlook mine		See Banner Group.
Padre y Madre mine NE¼ sec. 19, T15S, R21E, SBM, Ogilby quadrangle, Cargo Muchacho Mountains, 13 miles northeast of Yuma, 3 miles N 60 degrees E of Ogilby. Holmestake Mining Company, Kenneth Holmes, 340 West 16th Street, Yuma, Arizona (1964)	Two poorly exposed sub-parallel veins in quartz diorite gneiss. The veins strike mostly N 10–30 degrees W but are reported to range from N 50 degrees W to N 50 degrees E. The dips are quite variable also but in general are between 20 degrees and 60 degrees SW and NE. In some exposures the veins appear to be parallel to the foliation. The two veins, designated the Padre y Madre, are about 300 to 500 feet apart. Scheelite in undetermined amounts has been reported present (Bateman and Irwin 54:39).	This deposit was one of the earliest discovered in Imperial County. It was reportedly worked by the Spanish settlers of Yuma in 1780–81. Most of the development apparently took place prior to 1890. Crawford, in 1896, reported this mine to be "idle for years". Development consists of several vertical shafts, the deepest of which are 325, 300, and 250 feet. The extent of the stoping is undetermined but reportedly extends several hundred feet along the strike. Numerous cuts dot the surface. (Crawford 94:242; 96:343; Aubury 02:6t; Merrill 16:729; Tucker 26:259; 38:9; Sampson and Tucker 42:121; Henshaw 42:194; Averill and Norman 51:326; Bateman and Irwin 54:39).
Pasadena (Mother Lode, Pasadena South Extension) mine Middle E½ sec. 17, T15S, R21E, SBM (projected), Ogilby quadrangle (15 minutes), central Cargo Muchacho Mountains, 12½ miles northwest of Yuma, Arizona, 4.5 miles N 56 degrees E of Ogilby. Undetermined, 1962	Two parallel silicified shear zones strike N 15–30 degrees E and dip about 35 degrees SE in quartz diorite gneiss. The zones which are poorly exposed are 1–2 feet wide and extend for at least 500 feet.	Known as early as 1890, when apparently most of the development took place. Ore in that period was hauled to a mill near the Colorado River. It was reported to have run about $16 per ton. The mine was developed by a 100-foot inclined shaft and 5 adits totaling about 1000 feet; longest was 500 feet (unconfirmed, 1961). Most of these apparently are caved. (Storms 93:386; Crawford 94:242; 96:343; Merrill 16:729; Henshaw 42:194; Sampson and Tucker 42:123).
Pasadena South Extension		See Pasadena mine.
Peg Leg prospect Middle of sec. 31, T10S, R17E, SBM, Chuckwalla Spring quadrangle (15 minutes), on the northeastern side of the Chocolate Mountains, about 16 miles east of Niland, and 1½ miles southeast of Salvation Pass. Lies within Chocolate Mountains Aerial Gunnery Range	Quartz vein strikes N 25 degrees W, dips 85 degrees NE in an alaskite dike. The dike trends parallel to the vein, is a few tens of feet wide, and a few hundred feet long at the surface. Its contacts with the enclosing fine-grained granitic rock is obscure. The vein is about 5 feet wide and is exposed a few hundred feet along its strike. The vein is composed of weakly iron stained quartz, and was reported previously to have contained small amounts of copper.	No evidence of production. Development consists of two shafts, one 50 feet deep and another 75 feet deep about 300 feet to the northwest. The northwest shaft appears to have been used for a well. (Tucker 26:260; Sampson and Tucker 42:123).
Picacho (Jayne, Picacho Basin) mine (includes Apache, California Gold King, Dulciana, Eastern California, Golden Casket, Golden Rule, Goshen, Helen May, Mars, Mars Extension, Mina Rica, St. George, Tierra Rica, Venus) NW¼ sec. 10, SE¼ sec. 3, T14S, R22E, SBM (projected), Picacho Peak quadrangle (15 minutes) in the Picacho district, southeastern Chocolate Mountains, about 17 miles north of Yuma, Arizona, 1¼ miles S 70 degrees E of Picacho. E.H. Cude, Toronto, Canada; Colorado Mining and Exploration Company, 11431 State, Lynwood (1962)	Gold occurs in three brecciated zones in early Precambrian(?) gneiss of the Chuckwalla Complex. The northernmost zone, designated the Dulciana ore body, appears to have been mined along a vertical fault zone which strikes N 40 degrees E; it is about 50 feet wide at the edges of the glory hole. It consists largely of coarsely brecciated gneiss, weakly iron stained at irregular intervals. About 100 feet northwest another less intense zone crops out parallel to the Dulciana zone but dips 45 degrees SW. That zone was apparently much less productive. A third zone crops out about 1600 feet southwest of the Dulciana ore body. It strikes about N 35 degrees W, dips 45 degrees SW, and is about 50 feet wide. It is exposed for more than 500 feet along strike, and also consists of coarsely brecciated gneiss. Apparently the ore in these three zones was originally confined to less intense fractures which were subsequently faulted and brecciated along the same general trend as the original fractures. Little evidence exists in the present zone to indicate a well defined vein or zone of alteration.	Mines in the Picacho area are reported to have operated as early as 1857. This mine is known to have operated as early as 1880 (Dewitt C. Jayne mine). Ore was hauled by narrow gauge railway to a mill operated along the Colorado River near Picacho. About 1897 the Jayne, Picacho, and other mines were consolidated resulting in a company known as California Gold King Mining Company (1902) and later the Picacho Basin Mining Company (1906). The principal period of productivity was 1904–1910 when a reported $2,000,000 in gold was extracted from ore which averaged only about $3 per ton. The Dulciana ore body was mined through access of two vertical shafts (200 and 450 feet deep), but later was glory-holed. The glory-hole is crudely square in plan, and is about 250 feet wide and 50 feet deep. One shaft is on the south rim of the hole and a second is no longer evident. The southernmost zone was developed through a 450-foot shaft inclined at 45 degrees southwest in gneiss in the footwall side of the breccia zone. Workings were

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Name, location, owner	Geology	Remarks and references
		driven at 90 and 160-foot levels and at undetermined intervals below. Water stood at the 220-foot level in 1961. Previous reports indicated levels at 50-foot intervals. The 90-foot level is accessible through a crosscut-adit a few hundred feet northwest of the shaft. The levels were developed by driving footwall drifts with short crosscuts driven southwest into the ore zone and unconnected drifts along the zone. Above the 220 level only minor stoping was done, principally northwest of the shaft. Stoping below the 220 level was not determined. (Crawford 94:232–243; 96:331–346; Merrill 16:729-730; Brown 23:7; Tucker 26:260–261; Tucker and Sampson 40:10, 20; Sampson and Tucker 42:124).
Picacho Basin mine		See Picacho mine.
Ponce de Leon mine		Uncorrelated old name; probably at or near Golden Dream mine. (Crawford 96:344).
Potholes placer mine Middle of N½ sec. 25, T15S, R23E, SBM, Bard quadrangle (7½ minutes), Chocolate Mountains, adjacent to and underlying the present course of the All American Canal, ¼ mile west of Laguna Dam. U.S. Bureau of Reclamation(?) or Yuma Indian Reservation (U.S. Bureau of Indian Affairs).	Placer gold in Quaternary gravel in a north-trending canyon. The canyon marks the trace of a large N 10 degrees W-trending fault. The ridges flanking the deposit to the west are underlain by early Tertiary(?) breccia, which apparently is barren; the east side of the Canyon is underlain by pre-Tertiary granite. The ultimate source of the gold may have been from the Three C's (Duncan) deposit, which lies one mile due north of the mine. No direct drainage to the Potholes from that area now exists, however, but may have in early Holocene or late Pleistocene times.	This deposit may have been the locality of the very earliest gold mining in the state. Placer mining in the area is reported as early as 1780 (Bryan 25:16) and again during the early and late 1800's. Total yield is reported to be $2,000,000. This total, however, probably also included production from surrounding areas. Most of the Quaternary gravels at the deposit appear to have been worked. The lower or south end of the original site is now under the All American Canal. Additional localities were worked on the Arizona side. (Crawford 94:242; 96:344; Haley 23:155; Tucker 26:261; Sampson 32b:245; Laizure 34:245; Sampson and Tucker 42:125; Wilson 33:217).
Queen mine		See Tumco mine.
Quien Sabe prospect NW¼ sec. 11, T14S, R22E, SBM (projected), Picacho Peak quadrangle (15 minutes), southeastern Chocolate Mountains, 17 miles due north of Yuma, Arizona, 2 miles S 78 degrees E of Picacho Peak. Undetermined, 1961.	Quartz vein parallel to foliation in gneiss. The vein strikes N 10 degrees W and dips 55 degrees NE. Vein is 3–6 feet wide and is exposed more than 150 feet along the strike.	Name correlation not certain. Developed by two inclined shafts which are 125 feet apart. Both are caved but volume of dump material indicates about 100 feet of combined workings. (Sampson and Tucker 42:pl. 1).
Rainbow (El Lucero, Hess) mine. SW¼ sec. 3, T15S, R23E, SBM (projected) in the Little Picacho Peak (7½ minutes) quadrangle, about 13 miles north-northeast of Yuma, in the extreme southeast end of the Chocolate Mountains, about 6.8 miles due south of Little Picacho Peak and 4½ miles west of Squaw Lake. Claude M. and James V. Clapp, Rt. 1, Box 199, Winterhaven (1961).	Narrow discontinuous gold bearing stringers in Precambrian(?) gneiss. Individual stringers have varied attitudes but appear to be a part of a larger mineralized zone. They are 6 inches to 2 feet in width and are as much as 100 to 200 feet in length. The general trend of the zone is N 30 degrees W and it extends a known distance of about 1 mile along the base of the mountain. The surface is covered with a thin mantle of debris from the basalt which overlies the gneiss on the ridge to the southwest. The ridges across the wash to the northeast are underlain by Tertiary pyroclastic rocks. The stringers are composed of chlorite, hematite, sericite, quartz, and hydrous iron oxides and minor copper staining. The gold occurs as fine leaf.	Developed by shallow shafts, trenches and cuts. Undetermined, but small production in 1964. (Tucker 26:256; Sampson and Tucker 42:119).
Red Fox mine Reportedly in sec. 13, T14S, R23E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; B. F. Page, Picacho (1902)		Uncorrelated old name; probably long abandoned. (Aubury 02:8t).

Gold—continued

Name, location, owner	Geology	Remarks and references
Rica Tierra mine		See Picacho mine.
Roadside mine Reportedly in sec. 3, T14S, R22E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; W. H. Lyons, Yuma (1902)		Uncorrelated old name; probably long abandoned. (Aubury 02:8t).
Sagebrush mine Reportedly in sec. 6, T14S, R22E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; B. A. Carey, Yuma (1902)		Uncorrelated old name; probably long abandoned. (Aubury 02:8t).
St. Anthony mine Reportedly in sec. 22, T13S, R23E, SBM, Chocolate Mountains, Picacho district, not confirmed, 1962. Undetermined, 1962; B. A. Carey, Yuma (1902)		Uncorrelated old name; may be part of the Golden Dream mine.
St. George mine		See Picacho mine.
St. Joseph mine		See Golden Dream mine.
Salamanca Consolidated		See Blossom mine.
Senator (Buena Vista) mine N½ of NW¼ of sec. 8, T15S, R24E, SBM, in the Imperial Reservoir quadrangle (7½ minutes), about N 35 degrees E of Yuma, Arizona, near the Colorado River, 1 mile northwest of Imperial Reservoir. Undetermined, 1961; W. A. Williams, San Bernardino (1942)	Quartz vein 3–8 feet wide, strikes N 20 degrees W dips 70 degrees SW and can be traced 1000 feet. The vein lies along the hanging wall of a fault zone 20–30 feet wide. The vein filling is brecciated indicating renewed movement along the fault after its emplacement. The fault marks the boundary between a quartzite-phyllite-metadiabase complex on the northeast and Triassic(?) metaconglomerate to the southwest. Adjacent to the two main shafts and to the southeast, the hanging wall of the vein is a narrow zone of highly altered, friable gray phyllite and interbedded white quartzite. Northwest of the shafts the hanging wall is composed of metaconglomerate. The contact between the schist and metaconglomerate strikes about N 10 degrees W. The footwall rocks are mostly breccia and phyllite.	The mine was located in June 1877 and surveyed for patent for the Dahlonega Mining Company in 1890 (Survey no. 2993). Production is recorded for the years 1896, 1898, 1899, and 1935, and amounts to more than 1100 ounces of gold from an undetermined tonnage of ore. The mine is developed by two inclined shafts in the vein about 260 feet apart. The more southeasterly shaft was sunk to a depth of about 300 feet with drifts on the 100-, 180-, and 270-foot levels. An undetermined amount of stoping was done mostly between the two shafts in the upper levels. (Tucker 26:261; Sampson and Tucker 42:125).
Shinebright mine **Shineright** mine		See under Tungsten.
Silver Queen		See Gold Basin mine.
Sovereign mine		See Tumco mine.
Sovereign East		See Tumco mine.
Sovereign West		See Tumco mine.
Stoneface prospect East edge of NW¼ sec. 26, T15S, R21E, SBM, Araz quadrangle, extreme southeast Cargo Muchacho Mountains, 9½ miles northwest of Yuma, 6.4 miles N 83 degrees E of Ogilby Siding, 4.8 miles N 14 degrees E of Pilot Knob substation. Charles F. Lehr, Richard Lehr, and G. W. Fisher, address undetermined (1959)	Small lenticular shaped bodies of quartz trend N 80 degrees E in quartz monzonite. The bodies are a few feet wide and a few tens of feet long in maximum dimension.	Little or no production. Development is limited to shallow shafts and pits.
Sweet Potato mine Reportedly in sec 6, T14S, R22E, SBM, Chocolate Mountains, Picacho district; not confirmed, 1962. Undetermined, 1962; B. A. Carey, Yuma (1902).		Uncorrelated old name; probably long abandoned (Aubury 02:8t).

Gold—continued

Name, location, owner	Geology	Remarks and references
Tee Wee mine Near middle of S½ sec. 16, T15S, R21E, SBM (projected), Ogilby quadrangle (15 minutes), southeastern Cargo Muchacho Mountains, 11½ miles northwest of Yuma, Arizona, 5.0 miles N 65 degrees E of Ogilby Siding at the head of Jackson Gulch. Paul Boardman, 3214 Moccasin Street, San Diego; Robert Boardman, 5625 Division Street, San Diego; Milton Kuhl, 555 Galewa Street, El Cajon; leased to Del A. V. Updyke, Box 243, Julian (1961)	Quartz vein strikes N 75 degrees W, dips 50 degrees NE in quartz monzonite. The vein is 3–5 feet wide and can be traced about 200 feet along the surface. The vein is composed principally of altered and sheared wall rock, weakly iron stained, and containing sparsely distributed copper oxides and fine free gold.	Total production is a few hundred tons. Development consists of a 65-foot drift adit S 70 degrees E with 27-, 15-, and 45-foot raises. The 27- and 45-foot raises reach the surface. (Henshaw 42:195, pl. II).
Telluride (Golden Eagle) mine. Undetermined section in western Cargo Muchacho Mountains. Undetermined, 1962; Telluride Gold Mining Company, Yuma, A. J. Griffin, president (1942).	Reported a northeast striking quartz vein in foliated granitic rocks. The vein is 2–4 feet wide and dips 15 degrees NW.	Uncorrelated old name; not visited, 1962. Developed by 50-foot vertical shaft and a 136-foot inclined shaft. (Tucker 40:21; Sampson and Tucker 42:126).
Three C's (Duncan) mine NE¼ sec. 24, T15S, R23E, SBM, in the Bard quadrangle (7½ minutes), 12 miles northeast of Yuma, Arizona, near the Colorado River, 1⅓ miles north-northwest of Laguna Dam. Claude M. and James V. Clapp, Rt. 1, Box 199, Winterhaven (1961).	Free gold-bearing brecciated quartz vein in a zone that strikes about N 50 degrees W and dips about 30 degrees SW. The vein material consists of angular fragments of white quartz which are mixed with varying amounts of brecciated wall rock in a fault zone about 10–20 feet wide. Apparently this brecciation was caused by renewed movement along the original vein fault. The hanging wall rock is Mesozoic(?) pebble metaconglomerate and the footwall is porphyroblastic metagranite. Small amounts of galena and wolframite are reported to occur in the quartz fragments. The main ore shoot mined occurred on the southeast side of the shaft and extended from the 175-foot level to the surface. It extended approximately 90 feet along the strike and was 4 feet wide at the 175-foot level but narrowed in strike length towards the surface to about 30 feet adjacent to the shaft collar.	Originally named after R. J. Duncan (Yuma) who owned the property prior to 1900. Most of the ore is reported to have been mined prior to that date although an old report states that the shaft was only 150 feet deep in 1896. The present workings consist of a 300-foot inclined shaft with levels at about 80, 175, 225, and 285 feet down the incline. Horizontal workings total about 300 feet including 50 feet northwest on the 285-foot level, 100 feet southeast on the 225-foot level, 90 feet southeast and 25 feet northwest on the 175-foot level, and a short drift southeast on the 80-foot level. (Crawford 96:335; Tucker 26:256; Sampson and Tucker 42:118, 119).
Tierra Rica mine		See Picacho mine.
Trio (Duncan) mine SW¼ sec. 19, T15S, R24E, SBM, in the Laguna Dam quadrangle (7½ minutes), near the Colorado River, 12 miles N 40 degrees E of Yuma, Arizona, about 1½ miles due north of Laguna Dam. Claude M. and J. V. Clapp, Rt. 1, Box 199, Winterhaven (1961); and Imperial Irrigation District.	Not determined, 1961. Previously reported to be a vein 3 feet wide that strikes northeast and dips 50 degrees NW. The country rock is porphyroblastic metagranite.	Most active period of development was from 1933 to 1935 under management of the Trio Mining Company. No development has taken place since the construction of the All American Canal in 1936 which resulted in flooding of the workings. Development consists of 125-foot and 60-foot inclined shafts sunk on a 45 degree incline, and a 30-foot vertical shaft. None of these was accessible in 1961. (Sampson and Tucker 42:118, 119).
Tumco mine (variously known as and/or including Free Gold Mining Company, Gold Rock, Golden Cross, Golden Crown, Golden Queen, Good Luck, King, Sovereign, Sovereign East, Sovereign West) S½ sec. 1, N½ sec. 12, T15S, R20E, SBM, Ogilby quadrangle (15 minutes), northwestern Cargo Muchacho Mountains, about 16 miles northwest of Yuma, Arizona, 4½ miles N 15 degrees E of Ogilby Siding. Robert W. Walker, Gold Rock Ranch, Winterhaven (1961).	Three principal deposits comprise the Tumco mine: the Golden Crown, Golden Cross, and Golden Queen. The Golden Crown is the southwesternmost of these, and the Golden Cross, in generally the same mineralized zone, lies about 2000 feet northeast. The Golden Queen deposits contained in a second zone lie about 1000 feet slightly west of north of the Golden Cross workings. Another slightly less productive zone is at the King property, a few thousand feet west-northwest of the Golden Queen. The mineralized zones lie parallel to bedding planes in Precambrian Tumco Formation arkosite. The arkosite is gray, fine-grained, highly indurated material composed of quartz, feldspar, hornblende, and biotite. It is intruded by numerous narrow pegmatite dikes, highly irregular in form and orientation. The bedding planes (and foliation) strike N 40–80 degrees E and dip 25–50 degrees SE. The thickness of the gold-bearing	The Tumco mines have produced about $2,863,000 in gold or approximately more than half of the total for the district and about 45 percent of the county total. The deposit was discovered in 1884 by Peter Walters and was named the Gold Rock mine. Subsequently the following changes occurred: 1892, renamed Golden Cross, operated by Golden Cross Mining and Milling Company; 1897, operated by Free Gold Mining and Milling Company; 1910, renamed Tumco, and operated by The United Mines Company; 1913–14, operated by Seeley W. Mudd; 1914–16, operated by Queen Mining Company; 1917–1937 relatively inactive; 1937–42, operated by Sovereign Mining and Development Company (Golden Cross); 1940–41, operated by T. L. Woodruff (Golden Queen); 1942 through 1962 inactive. The mine is developed by a 1200-foot inclined shaft at the Golden

Gold—continued

Name, location, owner	Geology	Remarks and references
	zones ranges from 1 to 70 feet, although the average thickness is in the range of 5–15 feet. Ore shoots are lenticular to tabular in shape. Commonly the footwall is a regular plane and the hanging wall irregular. Neither is well-defined and the mineralized zones look much like the rest of the formation. Careful sampling was necessary to determine the limits of the ore zones. The ore zones are composed simply of the country rock although the feldspars are kaolinized. The gold is very fine grained and free. Sulfide minerals are uncommon, although chalcopyrite and pyrite are present in small amounts. Near the surface the chalcopyrite has been oxidized to a carbonate-oxide assemblage.	Crown, and 1100-foot shafts at the Golden Cross and Golden Queen workings. Total horizontal workings of the three properties are reported to be more than 8 miles. The greater part of this was inaccessible in 1961. (Crawford 94:240; 96:337–339; Aubury 02:7t; Merrill 16:726–728; Tucker 26:257; 38:9; Tucker and Sampson 40:18; Sampson and Tucker 42:120; Henshaw 42:191, pl. 2).
Venus mine		See Picacho mine.
Vista (Desert Gold and Aluminum, Gold Delta, Mesquite) Placer mine About 4000 acres centered about the mine camp which is in the NE¼ of section 16, T13S, R19E, SBM (projected), Quartz Peak quadrangle (15 minutes), at the southwest base of the central Chocolate Mountains, 6¼ miles N 60 degrees E of Glamis. Desert Metals Company, c/o Chester Adams, Glamis, and Max Kofford, 8607 East Thornwood Drive, Scottsdale, Arizona (1964).	Formerly reported worked for placer gold which occurs in Quaternary older alluvium overlying deeply weathered, brecciated gneiss. Bedrock lies at depths ranging from a few feet in some dry washes to a reported few hundred feet in a drill hole northwest of camp. In the main pit, depth to bedrock is 10 feet. The entire pit, which was 200 feet long and 150 feet wide, was excavated in severely brecciated Chuckwalla gneiss which apparently was complexly intruded by acidic dikes before faulting. The breccia zone may be an extension of a major northwest-trending fault exposed about a mile to the northwest. The relationship of the faulting, if any, to gold mineralization was not apparent in pit exposures in 1964; no veins, as such, were noted.	This deposit has no recorded production. Development consists of a north-trending pit (see Geology) that was 25 feet deep in 1964 and several prospect pits and shafts. Adjacent to the pit was a 10 yard per hour trommel and jig. Water for the plant was piped about 4 miles from a well to the northeast. Churndrill holes were put down in and near the pit in 1964 by Western Equities Company, but results were not released. (Merrill 14:731; Tucker 26:258; Sampson 32:245; Laizure 34:244; Tucker and Sampson 40:10, 17, 18; Sampson and Tucker 42:117–118, 119).
Whitecap (Gray Eagle?) prospect Near center sec. 16, T15S, R21E, SBM (projected), in the Ogilby quadrangle (15 minutes), about 12 miles northwest of Yuma, Arizona, 5.2 miles N 60 degrees E of Ogilby. Undetermined, 1961	Several weak discontinuous fracture zones of variable attitude in quartz monzonite. The zones range in width from 1–2 feet wide and can be traced for about 100 feet.	Little or no production. Development restricted to short drift adits and trenching. (Henshaw 42:195, pl. II).
White Gold Basin mine		See Golden Dream mine. (Crawford 16:345; Brown 14:730).
(Undetermined) Near center of sec. 1, T15S, R20E, SBM, Ogilby quadrangle (15 minutes), northwestern Cargo Muchacho Mountains, 16 miles northwest of Yuma, Arizona, 4.9 miles N 14 degrees E of Ogilby Siding. Undetermined, 1961.	Several narrow, discontinuous mineralized zones in metamorphic rocks of the Precambrian Tumco Formation. The zones are parallel to relict bedding which strikes due east and dips 30 degrees S. The zones are 1–2 feet wide and extend a few tens of feet. They are composed of arkosite containing irregular fracture fillings of chrysocolla with minor tenorite and cuprite.	Little or no production. Developed by several shallow cuts and shafts.
(Undetermined) Middle of sec. 19, T15S, R21E, SBM (projected), in the Ogilby quadrangle (15 minutes), southeastern Cargo Muchacho Mountains, about 13 miles northwest of Yuma, Arizona, 2.7 miles N 60 degrees E of Ogilby. Undetermined, 1961.	Vein along a shear zone that strikes N 45 degrees E and dips 45 degrees NW in quartz diorite gneiss. The zone is 3 feet wide in the workings, and is exposed for several hundred feet. It contains lenticular masses of quartz as much as a foot wide along the hanging and footwalls. The hanging wall is a distinct shear plane. The footwall, though distinct, is irregular. The interior of the zone is composed largely of highly altered brecciated, iron-stained wall rock. Foliation in the gneiss strikes N 40 degrees W and dips 50 degrees SE. Apparently the gold, if present, was freemilling as no sulfide or other metallic minerals were noted.	Production undetermined though probably small. Developed by a 30-foot drift-adit driven northeast. Northeast and upslope of the adit is a 30-foot inclined shaft and a 30-foot tunnel through the ridge. Minor stoping was done adjacent to the shaft on the southwest. Across the canyon, some 500 feet northeast, is a prospect pit which may lie along the same zone.
Yuma prospect Undetermined section in Cargo Muchacho Mountains, adjoins American Girl mine on the east. Undetermined, 1962; J. Ernest, Los Angeles (1914).		Uncorrelated old name; not visited, 1962. May be part of the Pasadena or American Boy properties (Merrill 16:729).

Graphite

Graphite has been reported to occur on the southeast slope of the Coyote Mountains. This occurrence has not been confirmed, although graphite schist was reported by Mendenhall (1910, p. 343) between Alverson Canyon and Garnet Canyon. A second locality has been reported near the center of sec. 9, T. 16 S., R. 9 E., S.B.M.

Name, location, owner	Geology	Remarks and references
Stuart Graphite prospect Reportedly in T16S, R10E, SBM, 7 miles north of Coyote Wells, on the southeast slope of the Coyote Mountains; not confirmed, 1962. Undetermined, 1962; Stuart and King, San Diego (1921)	Graphite seam in schist. Seam is 4 feet wide and can be traced several hundred feet.	Uncorrelated old name; not visited, 1962. (Tucker 21:267).

Gypsum

In terms of dollar value of production gypsum is Imperial County's pre-eminent commodity. More than 8 million tons of gypsum valued at $24,000,000 was mined from the Fish Creek Mountains deposits between 1922 and 1961. In 1961 more than ½ million tons of crude gypsum representing about one-third of the total annual output from the state and more than 5 percent of the total annual domestic output of the United States was mined. Almost all of the gypsum mined in the county is used to make plaster wall board and sheet rock. A small amount is used for conditioning alkali soils.

Even though the vast gypsum deposits of Imperial County were known to exist many years prior to 1922, no successful attempt to mine the deposits was made until after the construction of the San Diego and Arizona Eastern Railroad in 1920. A narrow gauge railroad connecting the deposit with the main line was completed in October 1922 by the Imperial Gypsum and Oil Corporation. Only crude gypsum was shipped until the properties were acquired by Pacific Portland Cement Company, which completed a 300-tons-per-day calcining plant in late 1924. This company mined the deposit until July 1945 when the operation was sold to United States Gypsum Company. The United States Gypsum Company expanded and modernized the plant facilities at Plaster City and has since maintained a steady output.

The Fish Creek Mountains deposits lie exposed at the edges of a northwest-trending valley at the north end of the Fish Creek Mountains near the western boundary of the county. The deposits consist of beds of gypsum and anhydrite as thick as 200 feet between a Miocene-Pliocene sequence of rocks consisting of the non-marine Split Mountain Formation, and the marine Imperial Formation (see Fish Creek Mountains district summary). These beds, known as Fish Creek Gypsum, have been folded into a broad northwest-trending syncline. Very large undeveloped reserves exist on the northeast and southwest flanks of the syncline, which is exposed on both sides of the valley. The axial portion of the syncline, underlying the central part of the valley, is unexposed but in all probability also contains large reserves.

Other lesser deposits of gypsum are known to occur in the Coyote Mountains to the south. These deposits were noted as early as 1853 by William P. Blake on his geological reconnaissance of California; most of the beds, which occur interbedded with claystone in the Imperial Formation, are only a few feet thick.

Name, location, owner	Geology	Remarks and references
Blanc deposit		See National Gypsum Company.
Blue Diamond Corporation (Houck Tract 71) deposit. SE¼NE¼, NE¼SE¼, sec. 29, T13S, R9E, SBM, Borrego Mountain southeast quadrangle (7½ minutes), Fish Creek Mountains, 9½ miles S 20 degrees E of Ocotillo Wells, 2½ miles northeast of Split Mountain. Blue Diamond Corporation, 1650 South Alameda Street, Los Angeles (1963).	(See U.S. Gypsum mine)	No development. (Ver Planck 52:29, 122t).
California Gypsum Group		See U.S. Gypsum Company mine.

Gypsum—continued

Name, location, owner	Geology	Remarks and references
California Portland Cement Co. (Chaplin) deposit SW¼ sec. 19, NW¼ sec. 30, T13S, R9E, SBM, Borrego Mountain southeast quadrangle (7½ minutes), Fish Creek Mountains, about 32 miles west of Brawley, 9 miles S 12 degrees E of Ocotillo Wells. (The western extremity of this property lies one quarter mile into San Diego County). California Portland Cement Company, 612 South Flower Street, Los Angeles (1963).	Nearly pure massive beds of gypsum of Miocene age in a generally west-trending mass about 1 mile long and ¼ mile wide. The beds dip 30–80 degrees northward, and appear to be several tens of feet thick. The beds are underlain by non-marine arkosic sandstone of the Split Mountain Formation and overlain by sandstone of the Pliocene Imperial Formation.	This deposit has not been developed. (Ver Planck 52:29, 122t).
Campbell prospect		See under Copper.
Carrizo deposit		See National Gypsum Company deposit.
Chaplin deposit		See California Portland Cement Company.
Coyote Mountains gypsum deposit Reportedly in sec. 24, T16S, R9E, SBM, Coyote Mountains, 3 miles northwest of Coyote Wells; not confirmed, 1962. Undetermined, 1962; M.A. Turner and Associates, San Diego (1926).	Beds as much as 8 feet thick apparently in the low-lying Tertiary sedimentary rocks bordering the southern edge of the range (Imperial Formation?).	Uncorrelated old name; not visited, 1962. No reported production. (Merrill 16:740; Tucker 26:271; Sampson and Tucker 42:134; Ver Planck 52:121t).
Fish Creek Mountains mine		See U.S. Gypsum Co. mine.
Gillett deposit		See U.S. Gypsum Company mine.
Houck deposit		See Blue Diamond deposit.
Imperial Gypsum deposit E½ of NE¼ sec. 20, T13S, R9E, SBM, Borrego Mountain southeast quadrangle (7½ minutes), extreme north flanks of Fish Creek Mountains, 8¾ miles S 25 degrees E of Ocotillo Wells, 1 mile east-northeast of the U.S. Gypsum Company quarry. Imperial Gypsum Company, 1312 West 1st Street, Pomona	A northwest-trending brecciated mass of Miocene gypsum resting on Miocene Split Mountain Formation. The mass is about 1000 feet long, 500 feet wide, and 20 to 40 feet thick. Its southwest boundary is marked by a major northwest-trending fault which has downfaulted the gypsum mass and the Split Mountain Formation against foliated crystalline rocks on the southwest. As a result of the faulting, and possibly related slumping or minor landsliding, the gypsum mass has been broken and mixed to some degree with the underlying conglomerate. Most of the mixed rock is concentrated along the base of the mass. The gypsum overlying it is relatively more pure but is brecciated into large unsorted rubble. The strike of the base is about N 30 degrees W and dips 20–30 degrees NE. The fresh rock is light buff-gray fine grained, dense material composed of nearly pure gypsum.	(The Imperial Gypsum Company should not be confused with Imperial Gypsum and Oil Corporation which was an early operator of the Fish Creek Mountains mine). A small but undetermined tonnage of gypsum has been mined and marketed for soil conditioner in the Imperial Valley area. The mine is developed by a bench cut 25 feet wide, 25 feet high, and 200 feet long. Above the bench to the south, a triangular-shaped area 200 feet long on a side has been stripped. The bulldozed material is fed into a small crusher which is set up below the bench cut. It is transported by truck for local use as agricultural soil conditioner. (Ver Planck 52:pl. 20).
Imperial Gypsum and Oil Corporation		See U.S. Gypsum Company mine.
Kipp deposit		See National Gypsum Company deposit.
National Gypsum Company (Blanc, Carrizo, Kipp) deposit N½ sec. 36, T13S, R8E, (San Diego Co.); W½ sec. 31, T13S, R9E, NE¼ sec. 6, T14S, R9E, SBM, Carrizo Mountain northeast and Borrego Mountain southeast quadrangles (7½ minutes), north Fish Creek Mountains, 11 miles S 15 degrees E of Ocotillo Wells, about 1 mile southeast of Split Mountain. National Gypsum Company, Gold Bond Building, Buffalo 2, N Y (1963).	This deposit consists of nearly pure massive beds of gypsum of Miocene age (Fish Creek Gypsum) contained in a large erosional remnant capping a high northwest-trending ridge. It comprises about 250 acres, the northwestern 60 acres of which lies in San Diego County. The beds lie conformably(?) on Miocene non-marine gravels of the Split Mountain Formation. They strike about N 15–25 degrees W and dip at moderate angles southwest. The average thickness of the gypsum in this area was estimated to be a few tens of feet. The overlying Imperial Formation has been eroded off the mass, but is exposed in a down faulted block ½ mile east. On fresh surface the gypsum is light buff gray, fine to medium grained, dense material composed of nearly pure hydrous $CaSO_4$. Minor constituents	This body of gypsum is essentially undeveloped, but several roads have been cut providing access. (Tucker 26:271; Sampson and Tucker 42:134; Ver Planck 52:28–34, 121t; 57:233).

Gypsum—continued

Name, location, owner	Geology	Remarks and references
	were not determined but probably are similar to those in the U.S. Gypsum Company deposit.	
Pacific Portland Cement Company deposit		See U.S. Gypsum Company mine.
Tract 67		See California Portland Cement Company deposit.
Tracts 68, 69, 70, 78		See U.S. Gypsum Company mine.
Tract 71		See Blue Diamond deposit.
Tract 72 SE¼NE¼, NE¼NE¼ sec. 29, T13S, R9E, SBM, Borrego Mountain southeast quadrangle (7½ minutes), Fish Creek Mountains, 9½ miles S 20 degrees E of Ocotillo Wells, 2½ miles northeast of Split Mountain. Isabelle M. Wilson, RFD 127, Clarksburg, California (1952)	See U.S. Gypsum Company mine.	This deposit has not been developed. (Ver Planck 52:122t).
U.S. Gypsum Company (California Gypsum group, Imperial Gypsum and Oil Corporation, Fish Creek Mountains, Gillette, Pacific Portland Cement, Tracts 68, 69, 70, 78, Ward) mine. Parts of secs. 19, 20, 28, 29, 30, 32, 33, T13S, R9E, SBM, Borrego Mountain southeast quadrangle (7½ minutes), north end of the Fish Creek Mountains, 8½ miles S 18 degrees E of Ocotillo Wells, 2½ miles northeast of Split Mountain. United States Gypsum Company, 101 South Wacker Drive, Chicago, Illinois, 60606 (1963)	Nearly pure massive beds of gypsum of Miocene age. The gypsum beds are a part of a conformable sequence consisting of Miocene nonmarine Split Mountain Formation, Fish Creek Gypsum, and Pliocene marine Imperial Formation. The gypsum beds, in the mine area, are 100–200 feet thick and are exposed continuously on the surface a distance of about 2½ miles. Structurally they form the northeast limb of a northwest-trending syncline, the axis of which lies in the broad valley to the west. The general strike of the gypsum beds is N 10–20 degrees W and dip 25–35 degrees SW. Locally the beds are warped into minor folds. The material is a light buff-gray, fine to medium-grained compact, equi-granular rock composed almost entirely of gypsum. Minor amounts of anhydrite are present in some parts of the deposit mainly as thin beds and lenses. Very minor shreds of biotite occur disseminated in the beds and also a finely divided opaque material which is probably iron and manganese oxides. Sodium chloride is present in very small quantities. The basal 5 to 10 feet consists of interbedded shale, gypsum, and sandstone as do the uppermost beds of the formation although they are not exposed in the mine area. (Ver Planck 52:29–35).	See Gypsum text for history. In 1951 the plant capacity was estimated to be about 2500–3000 tons per day. During 1960 the deposit yielded more than ½ million tons. Three open pits had been developed by 1961: No. 1 pit was about 1800 feet long, 500 feet wide with a maximum depth of 150 feet; No. 2 pit was about 1900 feet long, 400 feet wide, with a maximum depth of 100 feet; No. 3 pit was 2500 feet long, 800 feet wide, with a maximum depth of 200 feet (estimated April, 1961). The gypsum is blasted and excavated by bulldozers and 3½ yard power shovels, then hauled by 32-yard diesel trucks to the crushing plant. After crushing, the gypsum is hauled 25 miles by narrow-gauge rail to the processing plant at Plaster City. After crushing and screening the gypsum is fractioned to three circuits. Most of the material goes to the rotary calciner, then is crushed in a roll mill, and sent to the wallboard plant. Material in the second circuit, plus fines from the primary and secondary crushers, is bagged for use as soil conditioner (land plaster) or is sent to the kettle or batch processing plant. Hardwall plaster is produced at the batch plant, which consists of five 15-ton kettles and a tube mill. Special batches are ground in a Buhr mill for use in "white goods" and for casting base. The third fraction is bagged without calcining for use as cement retarder. (Tucker 26:271–275; Sampson and Tucker 42:135,136; Ver Planck 51:119, 121; 52:29–35, 121t, 122t; 57:233, 235, 238).
Ward deposit		See U.S. Gypsum Company mine.
Waters deposit Reported in NW¼ sec. 4 and E½ sec. 5, T14S, R9E, SBM, Fish Creek Mountains; not confirmed, 1962. Undetermined, 1962; W. H. Waters, Dixieland (1926).		Not visited, 1962. Reported that gypsum was exposed to a 60-foot depth in cut (Tucker 26:275; Ver Planck 52:123t).

Iron

Iron prospects at three localities in the northwest-central Chocolate Mountains have been reported, but only one of these localities has been confirmed. It is a small tabular body of titaniferous hematite in gneiss known as the Tio Rico prospect in the S½ sec. 14, T. 11 S., R. 20 E., S.B.M.

Iron—continued

Name, location, owner	Geology	Remarks and references
Black Mint prospect		See Tio Rico prospect.
Tio Rico (Black Mint) prospect Middle of S½ sec. 14, T11S, R20E, in the Quartz Peak quadrangle (15 minutes), 36 miles northwest of Winterhaven, 1.4 miles S 70 degrees E of Midway Well. Robert J. Campbell, 9247 Palmetto, Fontana (1960)	A small tabular body of titaniferous hematite in gneiss. The body, which lies parallel to the foliation in the gneiss, strikes N 55 degrees W and dips 40 degrees SW. It is a maximum of 100 feet in length(?) and 2–4 feet thick. Several other similar occurrences are exposed in the area.	No recorded production. Development is limited to shallow pits. (Oesterling and Spurck 64:133).
Simpson-Churchill-Wear deposit Reportedly in sec. 33, T9S, R16E, SBM, 17 miles northeast of Niland in the Chocolate Mountains; not confirmed, 1962. Undetermined, 1962; Dan Simpson, Niland, J. H. Churchill and Edgar Wear, Los Angeles (1926)	Undetermined	Uncorrelated old name; not visited, 1962. (Tucker 26:262).
Undetermined Reportedly 3 miles northeast of Amos Station on the west flank of the Chocolate Mountains; not confirmed, 1962. Undetermined.	Ore mineral is magnetite.	Uncorrelated old name; not visited, 1962. (Tucker 26:262).

Kyanite

The only known commercial deposits of the aluminum silicate kyanite, Al_2SiO_5, lie at the southwestern front of the Cargo Muchacho Mountains near Ogilby in southeastern Imperial County. Here, blue kyanite crystals occur with quartz in large masses associated with quartzite and quartz-muscovite schist of the Vitrefrax Formation. Although the ore produced was reported to contain as much as 35 percent kyanite, most of the kyanite-bearing rock was in the 15 to 35 percent range.

Three separate occurrences which are within 1 mile of each other are known. One of these, the Bluebird mine, was operated intermittently from 1925 to 1946 by the Vitrefrax Corporation for the recovery of kyanite. Total production from this operation exceeded 10,000 tons valued at more than $80,000. In 1949 the Aluminum Silicates Company of Los Angeles acquired the property. McLenegan (1956) states that 21,000 tons of ore was mined from several quarries.

The kyanite-quartz rock was heated to a temperature of 1800 degrees F in a rotary kiln, quenched to cause partial separation of the two minerals, then separated more completely by crushing and screening. The kyanite concentrate was shipped to Los Angeles and used in the manufacture of ceramic insulators and high-alumina refractories which can withstand temperatures as high as 3300 degrees F and abrupt temperature changes. Such conditions occur in special furnaces, kilns, and boilers used in the glass, ceramic, cement, and metallurgical industries.

Kyanite is reported to occur also as a minor constituent in the metasedimentary rocks at the Crown uranium mine northeast of Glamis (Walker *et al.*, 1956, p. 26).

Name, location, owner	Geology	Remarks and references
Bluebird Kyanite (Ogilby Kyanite) deposit NW¼NW¼ sec. 19, T15S, R21E, SBM, Ogilby quadrangle, Cargo Muchacho Mountains, 13 miles northwest of Yuma, 2½ miles N 44 degrees E of Ogilby. Scott Poffenburg, 1739 East 1st Street, Long Beach (1962).	Clusters of large blue kyanite crystals disseminated in a quartz-kyanite quartzite of the Precambrian(?) Vitrefrax Formation. Kyanite bearing rocks of this formation crop out discontinuously for more than 1 mile in a more or less north-trending belt along the western base of the range. Where it was mined the kyanite is in quartzite; it occurs also in quartz sericite pellitic schist, and in a pyrophyllite zone northwest of the quarry (see Drifted Snow mine under Mica). At Vitrefrax Hill wherein the quarry is located, steeply-dipping kyanite-rich quartzite as much as 400 feet thick forms the core of the hill, but interbedded quartz sericite schist is present on the flanks. The beds strike generally northeast. The material which has been mined is composed of	The Vitrefrax Corporation began production from this mine in 1925, and continued operations there until 1946 when the mine was shut down. The material was used in refractory ceramic products which were marketed under the trade names "Argon" and "Durex". Total production exceeds 10,000 tons valued at $80,000. The ore was mined by opencut methods on the west side of Vitrefrax Hill where the mine workings consist of three horizontally staggered benches about 25 feet high and 100 feet long. Above the upper bench is a 75-foot vertical cut, 50 feet wide, to the top of the hill. To Ogilby Siding on the Southern Pacific Railroad, it is a nearly level 2½-mile haul to the south.

Kyanite—continued

Name, location, owner	Geology	Remarks and references
	about 35 percent kyanite with quartz comprising most of the remainder. Disseminated small grains of rutile, specular hematite, magnetite, biotite, and chlorite are present also; limonite pseudomorphs after pyrite, as much as 1 inch square, are present in the face of one of the quarries. Virtually all of the rock contains more than 15 percent kyanite (Wright 57:277).	In tests conducted by U.S. Bureau of Mines it was shown that the quartz-kyanite-sericite rock is amenable to beneficiation by flotation, yielding a product which meets the U.S. Government stockpile minimum refractory requirements of pyrometric cone 37. It was also demonstrated that milling to 150 mesh is necessary to liberate kyanite from interlocking grains of quartz and sericite. (Tucker 26:269-270, 280; Sampson and Tucker 31:451, 455-457; 42:133–134; Henshaw 42:153–155; Wright 50:117–118; 57:276–279). In 1949 Aluminum Silicates Company of Los Angeles acquired the property. 21,000 tons of ore was mined from several quarries (McLenegan 56:13).
Drifted Snow		See Bluebird Kyanite deposit.
Ogilby Kyanite deposit		See Bluebird Kyanite deposit.
Vitrefrax mine		See Bluebird Kyanite deposit.

Limestone and Marble

Limestone and marble deposits of Paleozoic(?) age occur with interbedded mica schist, quartzite, and gneiss in the Coyote, Fish Creek, and Jacumba Mountains of southwestern Imperial County and in the Santa Rosa Mountains at the northwestern corner of the county. Although these deposits are numerous and some are of good quality, none has been developed to any large extent. The marble deposits in the Coyote Mountains (Creole, Southern California Marble) were worked for a brief period in 1921 and 1922 but little production resulted. The Tyce limestone deposit in the Jacumba Mountains yielded a few hundred tons of material in 1940 and 1959 for an undetermined use. The largest and perhaps the purest deposit in the county is the Coyote Mountain deposit (see figure 8). Although at least two companies have investigated this deposit as a source of raw material for cement, little has been developed beyond road building and sampling.

Another large deposit of possible future significance is the Waters deposit which is in a rather inaccessible part of the Fish Creek Mountains (see figure 9). It is undeveloped.

The only carbonate rocks known to occur in eastern Imperial County are limestone beds which occur in three separate units. One, apparently a lacustrine deposit of Tertiary age, crops out 8½ miles southwest of Midway Well, 1 mile north of Mt. Barrow. Limestone beds in this deposit attain thicknesses of a few tens of feet and are interbedded with tuff. A second Tertiary unit, the Bouse Formation, underlies an area of low relief south of Arroyo Seco near the Colorado River. Limestone there is interbedded with clay, silt, sand, and tufa of probable marine origin (Metzger, 1968). The limy members attain thicknesses as much as 20 feet. Metzger (1964, p. 15) reported a thickness of 70 to 100 feet for the basal limestone member near Cibola, Arizona. The third unit containing carbonate rocks is the McCoy Mountains Formation of late Paleozoic(?) age. These occurrences, which are thin flaggy interbeds in meta-clastic rocks, crop out 3 miles south of Picacho and about 9 miles north of Glamis in the Chocolate Mountains.

Name, location, owner	Geology	Remarks and references
Coolidge Springs deposit Secs. 5, 6, 7, 8, 17, T9S, R9E, SBM, Rabbit Peak quadrangle (7½ minutes), Santa Rosa Mountains, between Travertine Palms and Coolidge Springs, about 1 mile west of State Highway 86. Sections 6, 8 are in Torres-Martinez Indian Reservation; section 7, Southern Pacific Land Company, 1 Market Street, San Francisco; sections 5, 17, undetermined, 1964	White to buff crystalline limestone in irregular, generally northwest-trending lenticular masses in biotite schist and gneiss of Paleozoic(?) age. Occurs in narrow beds as much as 4000 feet long and 100 feet thick. Analyses of Oesterling and Spurck from SE¼ section 7 contained 84–95.5 percent $CaCO_3$, 1.39–4.7 percent $MgCO_3$, 0.23–5.81 percent SiO_2, 0.01–0.61 percent Fe_2O_3, and 0.22–5.67 percent Al_2O_3.	No development (Oesterling and Spurck 64:176; Bowen et al., 1973).

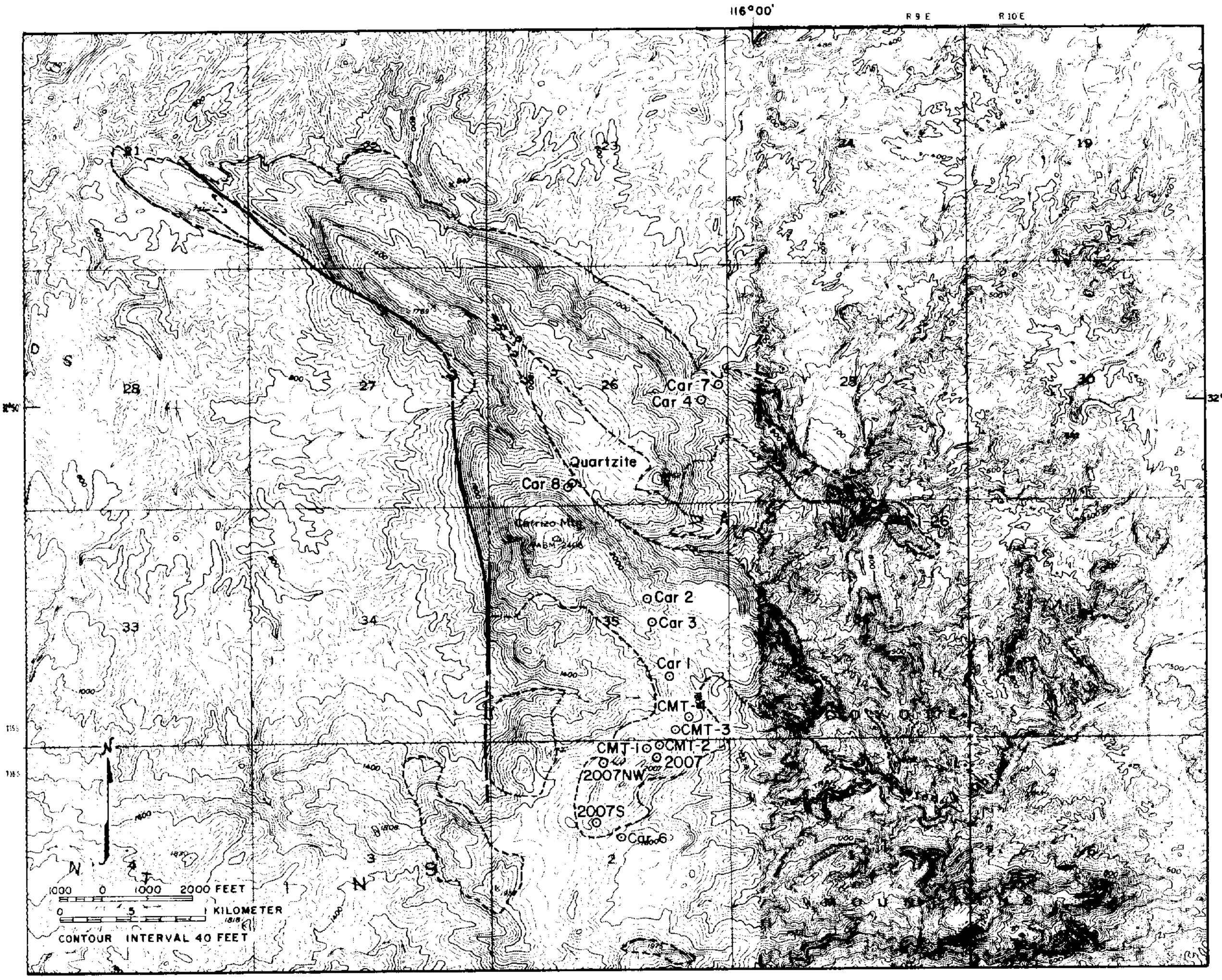

Figure 8. Map of Limestone Bodies, Carrizo Mountain Area. The reconnaissance and photo interpretation map shows the distribution of limestone bodies in an area of the Coyote Mountains. The sample numbers refer to table 11.

Limestone and Marble—continued

Name, location, owner	Geology	Remarks and references
Columbia Cement Company deposit		See Coyote Mountains deposit (Tucker 26:276, 280; Sampson and Tucker 31:438).
Coyote Mountains Limestone (Columbia Cement, Creole Marble, Golden State Mining and Marble, Southern California Marble) deposit Mostly in secs. S½ 22, SW¼ 25, 26, E½ 27, 35, 36, T15S, R9E; secs. NW¼ 1, N½ 2, T16S, R9E, SBM, Carrizo Mountain and Painted Gorge quadrangles (7½ minutes), on and near Carrizo Mountain, 5 miles due north of Ocotillo, in the eastern Coyote Mountains about 26 miles west of El Centro. Pine Tree Cement Company, H. A. Soule, Box 306, Vista; B. A. Sweet, Escondido (1961)	The deposit consists of medium to coarse-grained, crystalline, light-gray limestone occurring in a metasedimentary sequence of Paleozoic (?) age. In this area these rocks include limestone, dolomitic limestone, biotite schist, and quartzite. The lithologic sequence is difficult to determine because of the complexity of folding, faulting, and apparent rapid facies changes. Tentative data, however, indicate three units (1) a lower(?) unit comprising about 4000 feet of thickly interbedded limestone, quartzite, and biotite schist; (2) a middle unit comprised of about 2000 feet of limestone and dolomitic limestone; and (3) an upper(?) unit of an undetermined thickness of schist containing minor interbeds of carbonate rocks. The lower unit is exposed in a large northwest-trending mass that is nearly 4 miles long and	This property was promoted as a source for ornamental marble during the period prior to and after the first world war. A small amount of material was mined from the Creole quarry in the NE½ sec. 36 in 1913, and in 1922. Other development has been limited to the excavation of several dirt roads. Largely undeveloped, except for roads, but as one of the few large deposits of cement grade limestone in this region, this deposit may become an important future source to population centers in the Imperial Valley and San Diego areas. Production undetermined, but probably less than 1000 tons. (Merrill 14:733–736; Tucker 21:268; 26:276–277, 280; Sampson and Tucker 31:438; 42:137; Logan 47:240).

Limestone and Marble—continued

Name, location, owner	Geology	Remarks and references
	7/10 mile wide which lies just north of Carrizo Mountain (see fig. 8). The bedding strikes generally N 30–50 degrees W and dips 60 degrees SW to vertical, but local contortion and faulting is common. Individual members of limestone within the unit are generally less than 100 feet thick with the exception of one body at the southeasternmost end of the mass (Creole quarry). Exposed there is a 500-foot stratigraphic thickness which extends northwestward about 3400 feet. Twenty-one samples taken across the strike of this body averaged 51 percent CaO (see table 11). The middle unit adjoins the lower unit on its south end in an irregularly shaped northwest-trending mass 2 miles long and 1/2 mile wide; a southwest-trending arm, 1/4 mile wide, extends from it 3/4 mile to the head of Painted Gorge. Bedding in the arm is in general parallel to its trend, although local contortions are common; dips of the beds are quite steep both northwesterly and southeasterly because of overturned beds. Bedding in the main body of the middle unit is generally parallel to the lower unit, but most beds dip steeply northeast rather than southwest. Reversal of the dip is abrupt at the contact between the lower and middle units, and is probably caused by a fault which lies nearly along the strike. Although most of the middle unit is limestone the composition varies somewhat from one member to the next. (See fig. 8, table 11). The upper or schist unit crops out south of Carrizo Mountain and northwest of the southwest arm of the middle member. Neither the structure nor the distribution of this unit was studied. Unconformably overlying the Paleozoic(?) sequence are several erosional remnants of Tertiary coquina limestone of the Imperial Formation. These beds weather a grayish-yellow and are composed predominantly of shell debris. Most of the beds are less than 20 feet in thickness and cover as much as 40 acres in extent. On fresh surface the material is very light-gray, dense, and fine-grained. A random sample of the material indicates a calcium oxide content of 51.67 percent (see table 11). Three localities on this property appear to show the most promise for development of cement grade limestone: (1) the peak at the head of Painted Gorge (Hill 2007), (2) Carrizo Mountain, and (3) the Creole deposit.	
Creole Marble		See Coyote Mountains limestone deposit.
Dixieland deposit Reportedly in secs. 31, 32, T13S, R9E, SBM, 16 miles northwest of Coyote Wells; not confirmed, 1962. Undetermined, 1962; W. A. Waters, Pasadena (1942)		Uncorrelated old name; not visited, 1962. May be the small body of limestone in the N1/2 sec. 20, T13S, R9E. (Tucker 26:277 (Waters); Logan 47:241).
Golden State Mining and Marble		See Coyote Mountains limestone deposit.
Jumbo (L and S) deposit SW1/4 of SE1/4 sec. 31, T15S, R9E, SBM, Carrizo Mountain quadrangle (7 1/2 minutes) on the south flanks of the Coyote Mountains, 7.5 miles N 45 degrees W of Ocotillo, 4 miles S 79 degrees W of Carrizo Mountain. Undetermined, 1961; C. H. Lunsford Estate and F. W. Stern, San Diego (1942) (possibly now included in Queen Ann	A northwest-trending mass of limestone in gneiss. The mass is about 1200 feet long, 200–300 feet wide, and includes a stratigraphic thickness of about 100 feet. The beds strike N 85 degrees E and dip 65 degrees SE. The upper 50 feet is a coarsely crystalline banded white and gray limestone. Banding, paper thin to 1/4 inch wide, is apparently due to the presence of fine flakes of graphite. A grab sample of this member contained 52.3 percent CaO and 1.9 percent	Little or no production. No development noted, 1961. Previously reported as having track and loading bins (1942). These were probably on what is herein described as the LLH deposit. (Sampson and Tucker 42:137; Logan 47:241).

Limestone and Marble—continued

Name, location, owner	Geology	Remarks and references
(Jumbo) clay claims, Paul C. Estep, 1426 Broadmoor, West Covina).	MgO (see table 11). The lower 50 feet is a white, medium-grained dolomitic limestone that is buff-colored on weathered surfaces. Samples taken from the deposit prior to 1942 were reported to contain 94–98 percent $CaCO_3$ and trace to 2 percent $MgCO_3$.	
LLH deposit South edge of SW¼SW¼ sec. 31, T15S, R9E, SBM, Carrizo Mountain quadrangle (7½ minutes), south flank of the Coyote Mountains, 8.2 miles N 49 degrees W of Ocotillo, 5.0 miles S 80 degrees W of Carrizo Mountain. Undetermined, 1961 (May be R. O'Callahan, Box 131, Ocotillo)	Thin, discontinuous, white to light-gray, coarsely crystalline bodies of limestone in gneiss. The masses strike about N 80 degrees E and are nearly vertical. They are a few tens of feet thick and a few hundred feet in length.	Little or no production. Development limited to shallow cuts. Formerly equipped with track. Possibly originally a part of the Jumbo deposit (see table 11).
L. and S. deposit		See Jumbo deposit.
Mountain Spring (Tyce) deposit SW¼ of NW¼ sec. 15, SE¼ of NE¼ sec. 16, T17S, R9E, SBM, In-ko-pah Gorge quadrangle, Jacumba Mountains, about 9 miles northeast of Jacumba, 2.7 miles N 65 degrees E of Mountain Spring, on the east side of U.S. Highway 80 in In-ko-pah Gorge. Undetermined, 1961; Tycrete Chemical Corporation, Chula Vista (1942)	Coarsely crystalline white limestone in a long narrow roof pendant of metasedimentary rocks in quartz diorite. The pendant is 200 feet wide, and at least 2500 feet long. It trends west-northwest. It is composed predominantly of limestone, schist, and narrow pegmatite dikes which intrude the metasedimentary rocks parallel to the bedding. The limestone occurs as a lenticular bed which strikes N 65 degrees W and dips 45 degrees SW. It is 1600 feet long with a maximum stratigraphic thickness of 30 feet. The bed forms very nearly a dip slope on the south side of a ridge creating the illusion of a much thicker mass. The limestone is, for the most part, pure but contains minor thin lenses of schist. The limestone contains very minor microscopic blebs of graphite.	In 1939 and 1940 the property was mined by the Duralite Products Company, San Diego and by the Tycrete Chemical Corporation, Chula Vista. Only a small tonnage was mined. Development consists of 2 shallow cuts into the ridge a few tens of feet wide and high. (Tucker 26:277; Sampson and Tucker 42:137; Logan 47:241).
Southern California Marble deposit		See Coyote Mountain deposit.
Tyce deposit		See Mountain Spring deposit.
Waters deposit NW¼ sec. 1, NE¼ sec. 2, T14S, R9E, SBM, Carrizo Mountain northeast quadrangle (7½ minutes), in the Fish Creek Mountains, 28 miles due west of Brawley, 6 miles S 9 degrees E of Split Mountain, at the head of Red Rock Canyon, just north of the Anza-Borrego State Park boundary. Undetermined, 1963; W. A. Waters, Pasadena (1942).	This deposit consists of a large body of gray-white Paleozoic carbonate rock which is contained in quartz monzonite of probable Cretaceous age. The carbonate body is essentially triangular-shaped in plan, except for its northwest vertex which is drawn out into an elongate extension (see fig. 9). The beds strike N 30–40 degrees W and dip 60–80 degrees NE. They include an exposed thickness of about 2700 feet. The lower or southwestern 1200 feet consists of gray and brown-weathering dolomite. The dolomite contains numerous granite pegmatite dikes as much as 40 feet thick; these diminish in number up section. The upper or northeastern 1500 feet of section is composed of faintly banded, light-gray to gray, fine to coarsely crystalline limestone. Samples indicate this upper section to contain about 53 percent CaO, 1.2 percent MgO, 1.4 percent SiO_2, 0.1 percent Fe_2O_3, 0.1 percent Al_2O_3, and 1.8 percent P_2O_5 (see table 11).	No recorded production. Accessible only by jeep and foot trails up Red Rock Canyon (a closed area of Anza-Borrego State Park in 1963). (Tucker 26:277; Sampson and Tucker 42:137–138; Logan 47:241–242).
Wedge deposit Near center of S½ sec. 6, T16S, R10E, SBM, Painted Gorge quadrangle (7½ minutes), eastern tip of the Coyote Mountains, about ½ mile southeast of Painted Gorge, 4.8 miles N 12 degrees E of Ocotillo. Pine Tree Portland Cement Company, c/o H. W. Soule, Box 306, Vista, CA.	Several small roof pendants of limestone in a coarsely grained hybrid rock of granitic composition. The beds strike N 65 degrees E and dip 45 degrees NW. The principal mass, which is on top of a prominent east-trending ridge, contains thinly bedded white and gray limestone containing small amounts of very fine-grained graphite. The pendant extends about 600 feet along the strike. One grab sample contained 53.2 percent CaO and 1.6 percent MgO (see table 11).	Little or no production. Developed by small open cuts.
Wednesday deposit SE¼ of SE¼ sec. 10, T16S, R9E, SBM, Carrizo Mountain quadrangle (7½ minutes)	Discontinuous beds of limestone in schist and gneiss. The beds strike about N 80 degrees W and dip 60 degrees SW. The main body lies at the	No recorded production; no development.

Limestone and Marble—continued

Name, location, owner	Geology	Remarks and references
southeastern edge of the Coyote Mountains, 3.8 miles N 26 degrees W of Ocotillo, 2.9 miles S 9 degrees W of Carrizo Mountain. Ross and Minnie O'Callahan, Box 131, Ocotillo.	southeast tip of a northwest trending ridge. It is a few hundred feet in maximum diameter and a few tens of feet thick. Two smaller bodies lie near the crest of a ridge 1500–2000 feet northwestward. The limestone is banded white to gray coarsely crystalline marble containing sporadic whisps of fine-grained graphite, and minor sericite. The limestone has a slightly fetid odor.	
White Hope deposit West edge of SW¼ sec. 6, T17S, R10E, SBM, *In-ko-pah Gorge quadrangle* (7½ minutes), eastern Jacumba Mountains, about 2¾ miles south-southwest of Ocotillo, 2 miles S 25 degrees E of junction U.S. Highway 80 and State Highway 98. Pine Tree Portland Cement Company, c/o H. W. Soule, P.O. Box 306, Vista, CA.	Two parallel beds of coarse-grained white to gray limestone in coarse-grained gneiss. The limestone and foliation in the gneiss strike north to N 10 degrees W and dip 35–40 degrees W and southwest. The beds are about 20 feet thick and are separated by 300–400 feet of gneiss. The beds can be traced about 2000 feet along the strike, and project beneath Tertiary volcanic rocks to the north and south. According to the owners 8 samples of the limestone averaged about 50.0 percent CaO, 0.7 percent MgO, 0.3 percent Al_2O_3, 5.4 percent SiO_2, 0.4 percent Fe_2O_3.	Little or no production. Development is limited to a few small cuts.

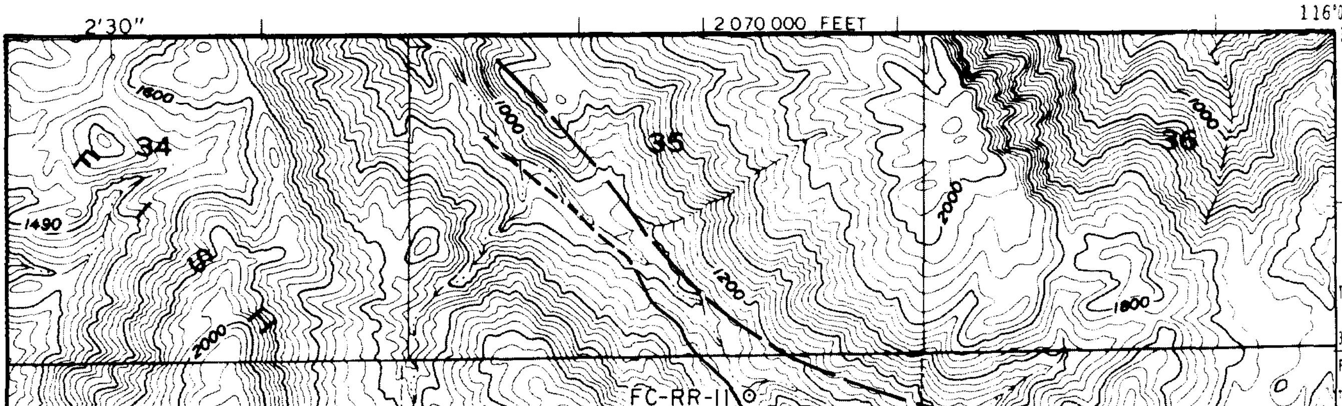

Figure 9. Map of Carbonate Rocks, Waters' Limestone Deposit. The reconnaissance and photo interpretation map shows the outline of carbonate rocks at the deposit in the Fish Creek Mountains. The sample numbers refer to table 11.

Table 11. Analyses of limestone samples from deposits in the Coyote and Fish Creek Mountains (in percent by weight).

Sample number	Location remarks (see figures 8 and 9)	CaO	MgO	SiO_2	Al_2O_3	Fe_2O_3	P_2O_5	K_2O
1*	Creole quarry westerly traverse	54.34	1.09	0.51	0.11	0.02	0.03	
2	" " " "	55.42	0.34	0.19	0.03	0.05	0.01	
3	" " " "	54.73	0.73	0.53	0.13	0.02	0.01	
4	" " " "	55.01	0.47	0.50	0.12	0.05	0.01	
5	" " " "	54.46	0.98	0.47	0.10	0.06	0.01	
6	" " " "	55.04	0.59	0.33	0.08	0.05	0.01	
7	" " " "	53.86	1.64	0.25	0.07	0.04	0.01	
8	" " " "	53.84	1.65	0.25	0.06	0.04	0.01	
9	" " " "	52.71	2.70	0.15	0.03	0.04	0.01	
10	" " " "	52.72	2.28	0.77	0.21	0.07	0.01	
11	" " " "	47.98	5.81	1.42	0.43	0.08	0.01	
12	" " " "	54.69	0.95	0.20	0.06	0.05	0.01	
13	" " " "	45.29	8.57	0.64	0.17	0.13	0.17	
14	" " " "	30.69	21.13	0.54	0.09	0.19	0.03	
15	" " " "	55.10	0.24	0.58	0.12	0.14	0.01	
16	" " " "	53.14	2.17	0.35	0.08	0.06	0.01	
17	" " " "	50.63	3.90	0.97	0.21	0.10	0.04	
18	" " " "	50.04	3.01	3.06	0.79	0.17	0.01	
19	" " " "	55.33	0.21	0.55	0.11	0.09	0.01	
20	" " " "	53.93	0.44	2.04	0.48	0.10	0.01	
21	" " " "	37.55	15.08	0.90	0.21	0.21	0.01	
22	Random samples from Creole quarry	50.26	4.61	0.38	0.10	0.03	0.02	
23	" " " " "	55.07	0.42	0.54	0.12	0.03	0.01	
24	Creole quarry westerly traverse	51.83	3.08	0.68	0.13	0.05	0.01	
25	" " " "	51.18	3.59	0.64	0.20	0.05	0.01	
26	" " " "	38.09	14.85	0.54	0.14	0.06	0.02	
Car. 7	Lower unit, lower member	49.4	4.2	1.5	0.00	0.08	0.08	0.00
Car. 4	Lower unit, middle member	40.2	11.1	2.8	0.55	0.34	0.13	0.15
Car. 8	Northeast base Carrizo Mountain (middle unit)	52.4	1.6	0.85	0.00	0.06	0.10	0.00
Car. 2	Southeast end Carrizo Mountain	30.0	20.6	0.60	0.00	0.12	0.03	0.00
Car. 3	Southeast end Carrizo Mountain	48.0	4.1	3.7	0.55	0.27	0.07	0.10
Car. 1	Southeast end Carrizo Mountain	52.8	1.4	2.1	0.25	0.30	0.07	0.10
2007NW	Northwest side Hill 2007	52.5	1.3	1.9	0.00	0.23	0.06	0.00
2007S	South side Hill 2007	38.0	13.4	2.6	0.20	0.08	0.05	0.00
Car. 6	Center section 2	50.5	2.6	3.4	0.20	0.18	0.12	0.00
2007	South arm aggregate (Hill 2007)	52.4	1.50	1.6	tr.	0.36	0.04	
CMT-1†	South arm random	35.87	14.56	2.50	1.41	0.21	0.41	
CMT-2†	South arm random	53.80	1.39	0.46	0.22	0.02	0.01	
CMT-3†	South arm coquina	51.67	1.12	3.64	1.26	0.22	0.04	
CMT-4†	Coyote Mountains southeast foothills coquina	49.61	1.22	4.92	2.03	0.87	0.08	
Jum 1	Jumbo—upper unit	52.3	1.9	1.6	tr.	0.81	0.12	
Jum 2	Jumbo—lower unit	31.3	20.2	1.3	tr.	0.45	0.07	
LLH	LLH deposit—random	54.8	0.67	tr.	tr.	0.85	0.01	
Wedge	Wedge deposit	53.2	1.6	2.7	tr.	1.6	0.01	
FC-RR1	Fish Creek Mountains, Red Rock Canyon, lower beds	30.2	21.8	4.0	0.00	0.07	0.02	0.00
FC-RR2	Fish Creek Mountains, Red Rock Canyon, lower beds	30.7	23.4	17.8	0.00	0.06	0.05	0.00
FC-RR3	Fish Creek Mountains, Red Rock Canyon, lower beds	29.9	21.7	2.5	0.00	0.10	0.07	0.00
FC-RR4	Fish Creek Mountains, Red Rock Canyon, lower beds	38.6	13.2	2.5	0.00	0.35	0.05	0.00
FC-RR5	Fish Creek Mountains, Red Rock Canyon, upper beds	52.0	2.0	2.2	0.20	0.13	0.06	0.10
FC-RR6	Fish Creek Mountains, Red Rock Canyon, upper beds	51.7	1.0	2.7	0.20	0.20	0.03	0.20
FC-RR7	Fish Creek Mountains, Red Rock Canyon, upper beds	54.0	0.60	0.85	0.00	0.08	0.60	0.00
FC-RR8	Fish Creek Mountains, Red Rock Canyon, upper beds	54.0	1.0	0.25	0.00	0.03	0.03	0.00
FC-RR9	Fish Creek Mountains, Red Rock Canyon, upper beds	30.0	21.0	0.63	0.00	0.14	0.03	0.00
FC-RR10	Fish Creek Mountains, Red Rock Canyon, lower beds	30.0	20.6	2.7	0.00	0.22	0.04	0.00
FC-RR11	Fish Creek Mountains, Red Rock Canyon, upper beds	53.9	0.60	1.3	0.20	0.12	0.09	0.00

*Samples 1-26 analyzed by Abbot A. Hanks, June, 1957.
†Abbot A. Hanks, June 30, 1955.
Remaining samples analyzed in California Division Mines and Geology laboratory.

Manganese

Manganese is one of the principal mineral commodities of Imperial County; the county ranks first in total manganese production in California. From 1917 through 1960 more than 53,000 tons of ore and concentrates, containing an estimated 1,661,000 long-ton units of manganese valued at $3,507,900, have been shipped from the county. About 84 percent of the total was mined during the period 1953–1959 under stimulus of the Federal government strategic mineral stockpiling program. Most of the ore was shipped to the Wenden, Arizona, and Deming, New Mexico, depots. As a result of termination of the program, no ore was produced from 1960 through 1963. The Pioneer mine, however, yielded an undetermined amount of ore in 1964. Other periods of production in the county were during World Wars I and II in 1917–1918 and 1941–1945, respectively.

All of the known deposits are centered in two distinct but nearly adjacent areas. The more productive of the two lies in the northern part of the Paymaster district about 40 miles northeast of Brawley (see district summary). It includes the Pioneer, Jet Black, and Virginia Dare manganese mines. The Pioneer mine is the county's first-ranking mine in total output of manganese. The deposits there are all fissure vein-filling types contained in basic volcanic rocks and conglomerate of Tertiary age.

The second area comprises the Palo Verde Mountains, which lie several miles north of the Paymaster district. In this area the deposits are more numerous and widely scattered. The most productive of these are the Chocolate Drop group, the Lugo, and Mary

Photo 13. Main Vein Pit, Pioneer Manganese Mine. The view is northeast.

Ellen mines. These deposits too are of the fissure vein filling types and are, as in the Paymaster area, contained in Tertiary basic volcanic rocks and fanglomerate. The fanglomerate is probably of Quaternary age. The older Tertiary conglomerate that is present at the Paymaster district also occurs here but it is not known to contain significant manganese deposits.

The typical ore in Imperial County is composed of psilomelane ($BaMnMn_8O_{16}(OH)_4$) and pyrolusite (MnO_2) with less common occurrences of manganite ($MnO(OH)$) and ramsdellite (MnO_2) (Hadley, 1942, p. 464; Hewett, 1964, p. 1440). The gangue minerals include calcite, chalcedony, barite, quartz, and hydrous iron oxides.

Name, location, owner	Geology	Remarks and references
Alaskan mine		See Chocolate Drop mine.
Anson prospect Reportedly near Glamis, Chocolate Mountains; not confirmed, 1962. Undetermined, 1962; W. J. Anson (1918).		Uncorrelated old name; not visited, 1962. (Trask 50:73).
Black Angus mine		See Black Widow mine.
Black Beauty mine		See Lugo mine.
Black Hill mine		See Pioneer mine.
Black Label mine SE¼ sec. 6, T9S, R20E, SBM (projected), Palo Verde quadrangle (15 minutes), 23 miles southwest of Blythe, in the northwestern edge of the Palo Verde Mountains, on the crest of an east-trending hill, 5½ miles south of Wiley Well. Nicolas A. Caproni, Blythe (1957)	Two fissure-filling veins in narrow shear zones. The west vein strikes N 40 degrees E, dips 80 degrees SE. It consists of a zone of narrow discontinuous stringers of black manganese oxides in small fractures and coating pebbles in Tertiary non-marine conglomerate. The zone is 20 feet wide and is exposed over a distance of at least 100 feet. Another vein, 1000 feet east of the west vein, strikes N 10 degrees W, dips 55 degrees SW in a well-defined shear zone 4–5 feet wide in andesite agglomerate. Black manganese oxides occur as fracture filling and coatings in a strongly brecciated zone that apparently has undergone additional movement after deposition. The vein is exposed for at least 150–200 feet along the strike. Iron content in both veins appears high.	Apparently this deposit has been explored only since 1952. No production is recorded. The west vein is explored by a trench about 25 feet wide, 100 feet long, and 6 to 10 feet deep. The eastern vein is exposed in a trench approximately 5 feet wide, 150 feet long, and 4–8 feet deep.

Manganese—continued

Name, location, owner	Geology	Remarks and references
Black Widow (Black Angus) mine W½ of NE¼ sec. 23, T9S, R19E, SBM, Palo Verde quadrangle (15 minutes), northwestern edge of the Palo Verde Mountains, about 25 miles southwest of Blythe, 8.5 miles S 22 degrees W of Wiley Well. L. Cornwall and Walter Scott, Blythe (1962)	Fissure filling in a shear zone that strikes due north and dips 35 degrees W in Tertiary pyroclastic rocks. The vein is 6 feet wide and is exposed for more than 500 feet. The vein is composed of the psilomelane-pyrolusite-type manganese oxides and abundant calcite.	In 1954 this mine yielded more than 350 tons of concentrates averaging from 26 to 58 percent MnO_2. The mine is developed by an open cut 30 feet long and 10 feet wide and 10 feet deep and an inclined shaft on the vein 30 feet deep that is stoped a lateral distance of 30 feet near the surface. Production is undetermined but probably less than 400 tons.
Borrego group S½ sec. 19, T9S, R21E, SBM, Palo Verde Mountains quadrangle (15 minutes), 20 miles southwest of Blythe, 3½ miles northwest of Palo Verde Peak. Walter Scott, Blythe	Grossly irregular, sparse and discontinuous fracture filling and coatings of manganese oxides in Quaternary fanglomerate. Mineralization occurs sporadically over a wide area that in general trends N 60 degrees W.	May be the same as the Desert Bloom group (Sampson and Tucker 38:129). Explored by several shallow bulldozer cuts. Little production if any. (Oesterling and Spurck 64:139).
Bright Star deposit NW¼ sec. 33, T9S, R21E, SBM, Palo Verde Mountains quadrangle (15 minutes), eastern Palo Verde Mountains, 20 miles south of Blythe, 2 miles north-northeast of Palo Verde Peak. George Ringwall, address undetermined (1959)	Fissure-filling in a shear zone that strikes N 10 degrees E and dips 70 degrees SE in andesite. The zone is 5–7 feet wide and is exposed for at least 100 feet along the strike. Black manganese oxides occur mostly in the finer fraction of the breccia in the shear zone.	This deposit was explored during the U.S. government purchase program (1953–1959). Workings consist of a 70-foot inclined shaft, sunk northeastward on a 20 degree incline. Most of the back has been stoped to the surface except above the last 10 feet. The deposit has yielded less than 100 tons of ore which averaged about 40 percent MnO_2. (Oesterling and Spurck 64:139).
Chipmunk mine		See Chocolate Drop mine.
Chocolate Drop (Alaskan, Chipmunk, Ebony, Tadpole, War Eagle) mine S½ sec. 7 and N½ sec. 18 T9S, R20E, SBM (projected), Palo Verde Mountains quadrangle (15 minutes), northwestern Palo Verde Mountains, about 23 miles southwest of Blythe, 2.5 miles S 83 degrees W of Thumb Peak. Individual parts by Charles L. Mills, Palo Verde; Bud Williams; and Walter King, Searchlight, Nevada (1961).	Several narrow fissure-filling veins in Quaternary fanglomerate. The veins lie in an area about 1500 feet wide and 4000 feet long which trends about N 30 degrees E. Individual veins strike between N 30 degrees W and N 30 degrees E and are nearly vertical. They range in thickness from 6 inches to 10 feet but average 2–4 feet. Most of the vein-faults can be traced no more than a few hundred feet and the ore shoots are in general less than 150 feet in length and extend to depths of less than 50 feet. The vein walls are distinct fault surfaces with little brecciation of the adjacent country rock. The veins are composed of fault gouge in which the open spaces have been filled with psilomelane, pyrolusite, and calcite. Replacement is minor. The wall rock in most of the veins is gently tilted Quaternary fanglomerate composed of poorly sorted, angular to sub-rounded clasts principally of andesite and latite porphyry. Clasts are as much as 2 feet in diameter but average 2–4 inches. The wall rock in at least two veins is a buff-colored coarse-grained non-marine sandstone which unconformably underlies the fanglomerate. One vein at the western edge of the property is in amygdaloidal andesite of Tertiary age which underlies both of the other two rock types.	The mine was first developed about 1917 when 300 tons of ore with a reported average of 46 percent MnO_2 was shipped. Other production is recorded for 1942, and for the years from 1955 through 1959 when most of the development took place. During the latter period the mine was operated as several different operations variously known as the Alaskan, Chipmunk, War Eagle, and others. Ore shipped averaged between 41–43 percent MnO_2, 2–4 percent Fe, and 7–10 percent SiO_2. Much of the ore shipped, however, was in the form of concentrates. Development consists of several trenches and open cut stopes; the larger ones measure 100–150 feet long, 30–40 feet deep and 3–5 feet wide. One vein in the southwestern part of the property is developed by a bulldozer cut 150 feet long, 10 feet deep, and 10 feet wide. (Bradley et al 18:34–35; Tucker 26:264–265; Sampson and Tucker 42:128; Trask 50:74–76).
Curley M group		See Pioneer mine.
Desert Bloom group Reportedly in sec. 24, T9S, R20E, SBM, Palo Verde Mountains district. Undetermined, 1962; H. L. Jackson, Rowley, and Edward Rochester, Winterhaven (1950)	Manganese oxides in a zone that strikes N 45 degrees E and dips 35 degrees SE in conglomerate. The zone is 8 feet thick and averages 20 percent manganese.	Uncorrelated old name. Not visited, 1962. No recorded production. Explored by open cuts. (May be same as Borrego group). (Sampson and Tucker 42:129; Trask 50:76).
Ebony group		See Chocolate Drop mine.
Everharty mine		See Pioneer mine.
Hanks Lost Mine prospect NE¼ of NE¼ sec. 25, T14S, R9E, SBM,	Manganese oxides in a fault zone separating pre-Tertiary gneissic rocks on the west from mas-	Little or no production. Developed by a nearly vertical shaft about 50 feet deep.

Manganese—continued

Name, location, owner	Geology	Remarks and references
Plaster City northwest quadrangle (7½ minutes), Anza-Borrego State Park, southeast Fish Creek Mountains about 14 miles north-northeast of Ocotillo, near the crest of the steep southeast front of the range east of the east fork of Barrett Canyon. State of California, Anza-Borrego State Park.	sive sedimentary rocks of Miocene age on the east. The zone strikes N 65 degrees E, is nearly vertical, and is about 10 feet wide.	Other small prospects along the fault (see Bonanza Queen under Copper).
Hodges prospect		See Jet Black mine.
Hyduke prospect SE¼SW¼ sec. 18, T11S, R21E, SBM, Quartz Peak quadrangle (15 minutes), north part of the central Chocolate Mountains, about 45 miles northeast of Brawley, 3.5 miles S 78 degrees E of Midway Well. Undetermined, 1962.	Irregular fracture fillings of manganese dioxide in andesite breccia.	Two shallow cuts about 100 feet long. No recorded production.
Jack Ass mine		See Lugo mine.
Jet Black (Hodges, Turtle) mine SW¼ sec. 16, T11S, R21E, SBM, Quartz Peak quadrangle (15 minutes), in the north part of the central Chocolate Mountains, about 29 miles south-southwest of Blythe, 5.5 miles S 85 degrees E of Midway Well. David Balez, T. H. Gragnon, Albert McIntyre, W. E. Bradford, addresses undetermined (1957).	Fracture filling and minor replacement along a shear zone that strikes N 10 degrees W and dips 60–70 degrees SW. The country rock is andesite breccia along most of the vein except the most southerly exposures where a buff-colored pumice lapilli-tuff forms the hanging wall. The vein is exposed more than 1000 feet along the strike, but is not a continuous structure. It appears to occur along a zone of three separate but nearly contiguous faults. The average width of the vein is about 6–8 feet. The hanging wall is a clearly defined break where tuff forms the wall, with most of the fissure filling in the andesite breccia footwall. Where breccia forms both walls either or both walls may be well defined planes. The manganese appears to "bottom out" at depths ranging from 20 to 40 feet. The ore consists predominantly of psilomelane and minor pyrolusite which form around and between angular fragments of the wall rock and gouge. Coarsely crystalline calcite, introduced later than the manganese, is abundant. The pyrolusite occurs mainly in velvety masses coating the walls of small voids in massive psilomelane. Most of the psilomelane is massive although botryoidal forms are present along the walls of the vein.	This deposit was known as early as 1913 when it was owned by the Hodge brothers of Yuma, though no ore was reported shipped until 1955. More than 800 tons of ore and concentrates averaging 40 percent MnO_2 were reported mined between 1955 and 1959. Open ground, however, indicates the removal of at least 5000 tons. The deposit is developed principally by four open cuts and one open stope. The most northwesterly working is an open cut about 230 feet long, 5–15 feet deep, and 8–10 feet wide. The floor of the cut is inclined 12 degrees NW, roughly parallel to the profile of the slope. A few hundred feet southeast at the crest of the hill is an open stope 85 feet long, 5–6 feet wide, and 30 feet deep. Random pillars support the walls. A short drift was driven southeastward from the bottom of the stope for an undetermined distance. At the southeast end of the stope (at the surface), an open cut was excavated 200 feet long, about 12 feet wide, and 20 feet deep. The walls of the cut and the open stope are inclined at about 60 degrees southwest. Several tens of feet southwest of the south end of this cut is a third open cut which is 140 feet long, 10 feet wide, and 10–15 feet deep. Across a small wash at the southeast end of this cut is a fourth cut which is 90 feet long, 8 feet wide, and 6–10 feet deep. This latter cut appears to be in the footwall of the vein and trends N 35 degrees W, whereas the other workings trend N 10–15 degrees W. (Hadley 42:461; Trask 42:119; 50:77; Oesterling and Spurck 64:139–140).
Johnson mine Reportedly 30 miles northeast of Glamis, 10 miles east of the Paymaster mine, 5 miles west of the Colorado River; unconfirmed, 1962. Undetermined, 1962; Johnson, Glamis (1918)	Two narrow stringers and small kidney shaped bodies.	Uncorrelated old name. May be the same as Jet Black mine. (Bradley et al 18:35).
Lincoln prospect		See Pilog Knob prospect (Trask 50:77).
Little Tree prospect SW¼ sec. 28, T9S, R21E, SBM, Palo Verde Mountains quadrangle (15 minutes), 20 miles southwest of Blythe on the northeastern flanks of the Palo Verde Mountains, 2½ miles north of Palo Verde Peak. Ray P. Mole, Box 131, Blythe (1961)	Fissure-filling vein strikes N 30 degrees E dips vertically in andesite. It is 4–5 feet wide and is exposed 300 feet along the strike. The vein consists of sparse fracture-filling of black manganese oxides in a brecciated zone.	Explored by several trenches, bulldozer cuts, and test pits. (Oesterling and Spurck 64:139).

Manganese—continued

Name, location, owner	Geology	Remarks and references
Lost Donkey		See Lugo mine.
Lugo (Black Beauty, Jack Ass, Lost Donkey, Palo Verde) mine E½ of sec. 35 and W½ sec. 36, T9S, R20E, (proj.), SBM, Palo Verde Mountains quadrangle (15 minutes), about 20 miles southwest of Blythe, in the summit area of the Palo Verde Mountains, 3 miles northwest of Palo Verde Peak. Walter D. Scott, Joe Cornwall, Bud Williams, Blythe (1953)	Several sub-parallel fissure veins strike generally N 45 degrees E and dip 60–80 degrees SE in an andesite flow. The veins are in shear zones 2–10 feet wide and are exposed over a distance of as much as 600 feet along their strike. The veins consist of fracture filling of manganese oxides and calcite. The principal ore mineral is psilomelane with minor pyrolusite. The five principal veins intersect a small northwest-trending canyon, and are numbered below from the north end of the canyon southward towards its mouth. Vein (1). Strikes N 45 degrees E, dips 65 degrees SE, is 2–4 feet wide. Abundant coarsely crystalline calcite. Footwall heavily ironstained and shows vertical striae in 1-foot wide breccia zone. Vein extends at least 500 feet along strike. Vein (2). Strikes N 40 degrees E, dips 75 degrees SE, is 5–10 feet wide. Crops out 200 feet southeast of vein No. 1. Mineralization spotty and irregular along 200 feet of exposure. Merges on its southwest end with vein (3) near the small canyon. Vein (3). Strikes N 50 degrees E, dips 60 degrees SE, is 4–5 feet wide. Exposed along the strike a distance of about 600 feet. Vein branches from vein (2) at the surface near the small canyon and branches again N 60 degrees E at a point 100 feet northeast of the canyon. Principal mineralization is in N 50 degrees E and N 60 degrees E trenches. Vein (4). Crops out 250 feet southwest of vein (3). Strikes N 50 degrees E, dips 80 degrees SE, is 4–10 feet wide between quite irregular but well-defined walls. Extends at least 500 feet along strike. Vein (5). Crops out 100 feet southeast of vein no. 4. Strikes N 65 degrees E, dips 60 degrees SE, is 3–5 feet wide, and extends at least 500 feet along strike.	Earliest recorded production was 150 tons during 1918 when Lugo and Justice Smith owned the mine. During the period 1953–1958, about 2800 tons of ore and concentrates were shipped under stimulus of a U.S. Government purchase program. Most of the workings were developed from a narrow northwest-trending canyon. Vein (1) was developed by a drift driven 85 feet northeastward from which ore was stoped upwards in irregular open stopes as high as 50 feet to the surface. Vein (2) was explored by a 45-foot opencut driven northeastward and a 150-foot drift-adit extension of the cut. Ore was stoped from above the drift to irregular heights from the adit northeastward 120 feet. The stope was mined to the surface at some points, about 50 feet above the drift. Vein (3) was developed by a 200-foot drift driven southwestward from the small canyon; ore was stoped above the drift to the surface; a second drift across the canyon was driven 200 feet northeastward and connects there with a stope mined from a lower level on the opposite (northeast) side of the ridge. Vein (4) was explored in shallow trenches along much of its strike, and was mined in an opencut 100 feet long, 50 feet deep and 4–10 feet wide. Vein (5) was developed by an adit driven about 150 feet southwestward from a gulley directly northeast of the previously mentioned canyon. Ore was stoped to a height of about 75 feet to the surface and downwards a few tens of feet below the drift at a point midway to the face. (Bradley, et al 18:59; Jones 19:185–189, 200–201; Tucker 21:269; Tucker 26:265–266; Sampson and Tucker 42:129; Trask 50:76)
MacDonald prospect Reportedly in sec. 12, T9S, R20E, SBM, about 20 miles southwest of Blythe; not confirmed, 1962. Undetermined, 1962; Edward MacDonald, Brawley (1942)	Manganese oxides in a 2-foot-wide vein in andesitic breccia. The vein strikes N 45 degrees W and is vertical.	Uncorrelated old name; not visited, 1962. Developed by shallow open cuts. No recorded production. (Sampson and Tucker 42:130; Trask 50:77).
MacIntyre deposit NW¼ sec. 33, T9S, R21E, SBM, Palo Verde Mountains quadrangle (15 minutes), eastern Palo Verde Mountains, about 20 miles south of Blythe, 1¾ miles northeast of Palo Verde Peak. Paul Henderson, address undetermined (1958)	Fissure-filling in a shear zone that strikes N 45 degrees E and dips 65 degrees NW in andesite. The zone which is 3–5 feet wide, has very sharp and persistent hanging wall and footwall, and is exposed for at least 300 feet along the strike. The ore consists principally of psilomelane.	Explored and developed during the U.S. government purchasing program (1953–1959). Workings consist of an open stope 115 feet long, 5 feet wide, and 30 feet deep, and shallow trenches and test pits. (Oesterling and Spurck 64:139).
Mary Ellen mine SE¼ sec. 29, T9S, R21E, SBM, Palo Verde Mountains quadrangle (15 minutes), about 20 miles southwest of Blythe on the southeastern flanks of the Palo Verde Mountains, 2½ miles north of Palo Verde Peak. Mary Ellen and Charles Lee Mills, Palo Verde	Fissure-filling vein in shear zone that strikes N 30 degrees W, dips 85 degrees NE. Vein is 5–7 feet wide and is exposed along its strike at least 100 feet. At the surface the hanging wall is Tertiary andesite and the footwall is Quaternary fanglomerate. Another vein exposed several tens of feet northeast strikes N 50 degrees E, dips vertically in brecciated and altered andesite. The mineralized zone is about 5 feet wide and extends along the strike at least 60 feet. Ore minerals consist of black manganese oxides, principally psilomelane.	This mine was discovered and developed during the years 1953–1959 under impetus of the U.S. government stockpiling program. An estimated 800 tons of ore have been mined from which about 260 tons of concentrates were shipped that contained an average 42 percent MnO_2. Workings consist of two open stopes mined underhand from the surface. On the southwestern vein the stope is about 100 feet long, 7 feet wide, and is 30 feet in maximum depth. The stope on the northeastern vein is about 50 feet long, 5 feet wide and is 25 feet in maximum depth. (Oesterling and Spurck 64:139).

Manganese—continued

Name, location, owner	Geology	Remarks and references
Pacific Coast Manganese mine		See Pioneer mine.
Palo Verde deposit		See Lugo mine.
Pilot Knob (Lincoln, Well Earned) prospect Reportedly in T12S, R19E, SBM, 15 miles northeast of Glamis; not confirmed, 1962 Undetermined, 1962; M. C. Turner, San Diego (1918)		Uncorrelated old name; not visited, 1962. Ore reportedly was 35 to 40 percent MnO_2 and 15 percent SiO_2. (Trask 50:77).
Pioneer (Black Hill, Curly M., Everharty, Pacific Coast Manganese, Tolbard, Tres Amigos, War Manganese, Whedon) mine SE¼ sec. 18, NE¼ sec. 19, T11S, R21E, SBM, in the Quartz Peak quadrangle (15 minutes), Paymaster district, northeast part of the central Chocolate Mountains, 30 miles southwest of Blythe, 4 miles S 75 degrees E of Midway Well. Gene De Zan, P.O. Box 217, leased to Atlas Leasing Corp., Joseph J. Strauss, pres., Phoenix (?) (1964).	Manganese oxides occur as fissure fillings and minor replacement in two sets of minor northeast-trending faults. The southwest set lies between two north-trending normal faults of large displacement. The western of these, the Pioneer fault, can be traced for more than a mile. The second fault lies about 500 feet to the east, and can be traced 2500 feet. In the vicinity of the mine the intervening area is underlain by andesite and andesite breccia. The west or upthrown side of the Pioneer fault is underlain by a complex of intensely folded Precambrian gneiss, schist, and a fine-grained granitic intrusive rock. A post-andesite Tertiary non-marine conglomerate underlies the area east of the eastern fault. Mineralization has taken place largely along numerous faults and fractures which trend about N 50 degrees E and dip steeply northwest. The southernmost of these branches from and joins the two normal faults and forms the contact between conglomerate and andesite. The South Pit orebody is at the northeast end of this fault. The main vein (photo 13) lies along a parallel fault about 200 feet northwest. These two veins are the largest of the orebodies mined; they are 40 to 50 feet wide, several hundred feet long, but were mined only to a depth of about 50 feet. Two large high grade ore bodies were mined from the Pioneer fault zone west and northwest of the main vein. In general, the veins consist of psilomelane, pyrolusite, braunite, and manganite which occur as fracture-filling and coatings in a selvage of closely spaced, subparallel, ramifying shears and intervening breccia. Horses of unbroken, unmineralized andesite as much as 3 by 10 feet by 10 feet occur within the larger veins. The second set of veins occurs in a system of ramifying and subparallel en-echelon minor faults which crop out in an area measuring more than 1500 by 3000 feet. The area begins a few hundred feet northeast of the first described and trends about N 30 degrees E, parallel to most of the included structures. The veins are an average of 2–6 feet wide, 100–250 feet in length and have been mined to depths of less than 50 feet. The veins consist of a brecciated zone, with at least one and commonly two well-defined walls, in which the fissures have been filled by psilomelane, pyrolusite, ramsdellite, and manganite. Cobbles and pebbles of the host conglomerate within the zone are mostly unreplaced, but are coated with a thin layer of psilomelane. Mamillary or botryoidal structures are common on the vein walls or other surfaces exposed to open spaces. Calcite is the most common gangue mineral with minor chalcedony and unidentified iron oxides. According to Hewett and Fleischer (1960, p. 11) psilomelane at the Pioneer mine is probably of hypogene origin; however the veins have undoubtedly been enriched by downward percolating surface waters as is evidenced by decreas-	Reportedly discovered by Tom Clark and L. L. Morse at an undetermined date. J. J. Everharty acquired the claims and began production in early 1917. Later the same year O. S. Tolbard began production on claims southeast of the Everharty group. These two groups were intensively developed through 1918, but unfavorable marketing conditions after the end of World War I caused a shutdown of operations. The claim previously known as the War Manganese mine, at the extreme south end of the Pioneer property, was also mined during World War I. The next activity of consequence was during the second world war from 1941–1944 when about 5000 tons averaging 39 percent manganese was mined from all the properties now comprising the Pioneer mine. During that period all the mines except War Manganese were consolidated and known as the Whedon mine. No ore was mined from 1946 through 1951, but from 1952–1959, through incentive of the Federal stockpiling program, more than 22,000 tons of ore and concentrates which averaged about 43 percent manganese were shipped. Ore was concentrated in a mill about 6 miles northeast of the mine near the Colorado River. The mill consisting of jaw and cone crushers, two jigs, and a magnetic separator, was intact and in working order in 1961. The property is developed largely by open stoping methods. Little timber other than a few stulls was used, and most stopes are open to the surface. Three veins in the major fault zone were mined by bulldozer cuts. They are from southeast to northwest, about 75 feet wide, 250–300 feet long, 50 feet deep; 50 feet wide, 250 feet long, 50–60 feet deep; and 40–50 feet wide, 150 feet long, 20–30 feet deep. (Jones 19:185–189; Tucker 26: 265, 266; Tucker and Sampson 40:10, 21, 22; 42:130; Hadley 42:459–472; Trask, Wilson, and Simons 43:78, 118–120; Trask 50:78–80; Engineering and Mining Journal 54:91; Hewett and Fleischer 60:11, 25, 29; Oesterling and Spurck 64:140).

Manganese—continued

Name, location, owner	Geology	Remarks and references
	ing grade with depth. No sulfides or other clearly hypogene minerals have been reported. Hewett also reported the presence of 0.56 percent tungsten oxide in a sample from the Tolbard mine (1960, p. 29).	
Ringwall(?) deposit NW¼ sec. 33, T9S, R21E, SBM, Palo Verde Mountains quadrangle (15 minutes), ...ern Palo Verde Mountains, about 21 ...es south of Blythe and 1½ miles north ...Palo Verde Peak. George Ringwall, address undetermined, 1960	Manganese oxides in several irregular and discontinuous closely spaced veinlets in a weak fracture zone that trends generally east. Individual veinlets are 1–6 inches wide and occur in a zone about 20 feet wide exposed only a few tens of feet along its strike. The country rock is andesite.	This deposit may have been included in the Bright Star or MacIntyre mines. Explored during the U.S. government purchase program (1953–1959). Development consists of several bulldozer cuts and a bench opencut 100 feet long, 30 feet wide, and 20 feet high at the face. (Oesterling and Spurck 64:139).
Southern Pacific Land Co. prospect Reportedly in E½ sec. 33, T9S, R20E, ...M, 8 miles southwest of Palo Verde; not ...firmed, 1962. (May be R21E). Undetermined, 1962; Southern Pacific ...d Company (1942)	Manganese oxides in 6–12-inch stringers in andesite. The stringers strike N 70 degrees E and are vertical.	Uncorrelated old name; not visited, 1962. Developed by shallow cuts. No recorded production (Sampson and Tucker 42:130; Trask 50:77; Oesterling and Spurck 64:139).
Tadpole mine		See Chocolate Drop mine.
Tolboard mine		See Pioneer mine.
Tres Amigos mine		See Pioneer mine.
Turtle prospect		See Jet Black mine.
Virginia Dare mine NE¼SW¼ sec. 18, T11S, R21E, SBM, ...rtz Peak quadrangle (15 minutes), north ...ral Chocolate Mountains, about 45 ...s northeast of Brawley, 2.9 miles S 83 ...rees E of Midway Well. Mr. E. J. Beutler, 948 South Kern Ave., Los Angeles (1962)	Fissure-filling of manganese dioxide in a fault zone that strikes N 25 degrees W and dips 65 degrees NE. The fault forms the contact between Tertiary non-marine conglomerate on the northeast (hanging wall) and the older Tertiary andesite breccia on the southwest (footwall). It is 3–4 feet wide and can be traced at least ½ mile southeastward to the Pioneer mine. Fractures on both sides of the main zone have been filled, but the central zone of movement, essentially fine gouge, is unmineralized. The aggregate thickness of the mineralized zone and the central zone is from 10 to 15 feet. The andesite breccia appears to be the most heavily mineralized, although discontinuous stringers of manganese dioxide are numerous in the conglomerate. The veins are composed of the typical pyrolusite-psilomelane assemblage of manganese oxides present as coatings on the larger fragments and as fine impregnations.	Little or no production. Developed by several small cuts the longest of which is 50 feet long, 20 feet wide, and less than 10 feet high. The vein is not well exposed, especially to the southeast where it is little explored.
War Eagle mine		See Chocolate Drop mine.
War Manganese mine		See Pioneer mine.
Well Earned prospect		See Pilog Knob prospect.
Whedon mine		See Pioneer mine.
Undetermined prospect no. 1 SW¼ sec. 28, T9S, R21E, SBM, Palo ...de Mountains quadrangle (15 minutes), ...rn Palo Verde Mountains, 20 miles ...hwest of Blythe, 2¼ miles north-north... of Palo Verde Peak. Undetermined, 1960.	Irregular fracture-filling in weak shear zone that strikes N 20 degrees W and dips 75 degrees SW in andesite. The zone is 3–5 feet wide and can be traced only a few tens of feet.	The zone is explored by a 20-foot trench leading to a shallow shaft. No apparent production.
Undetermined prospect no. 2 ...½ sec. 9, T9S, R20E, SBM, Palo ...de Mountains quadrangle (15 min...), about 22 miles southwest of Blythe ...e northern part of the southwestern ...s of the Palo Verde Mountains, 0.8 ...N 85 degrees W of Thumb Peak. Undetermined, 1961.	Shear zone 4–5 feet wide strikes N 10 degrees W, dips 70 degrees SW in andesite. Sparsely distributed manganese and iron oxides in fractures.	Explored by a short drift-adit driven a few tens of feet S 10 degrees E.

Manganese—continued

Name, location, owner	Geology	Remarks and references
Undetermined prospect no. 3 SW¼SW¼ sec. 11, T11S, R20E, SBM, Quartz Peak quadrangle (15 minutes), north edge of the central Chocolate Mountains, 1 mile northeast of Midway Well, 30 miles southwest of Blythe. Southern Pacific Company, 1 Market Street, San Francisco, 94105 (1964)	Sparse manganese oxides with calcite gangue in a fractured andesite dike. The dike strikes N 10 degrees W and dips 6 degrees W, in gneiss.	Not visited. Prospected by bulldozer cuts and a 6-foot shaft. (Oesterling and Spurck 64:139).
Undetermined prospect no. 4 S½ sec. 11, T11S, R21E, SBM, Picacho Northwest quadrangle (7½ minutes), north edge of the central Chocolate Mountains, 7 miles east of Midway Well. Southern Pacific Company, 65 Market Street, San Francisco, 94105 (1964)	Manganese oxides in fractured volcanic rocks of Tertiary age.	Not visited, 1962. Explored only by pits. (Oesterling and Spurck 64:139).

Mercury

Mercury minerals are unknown in Imperial County although one prospect was explored in search of mercury. The prospect area (T. 9 S., R. 20 E., S.B.M.) is underlain by a monolithologic breccia of highly altered andesite, heavily stained with hematite (iron oxide) to a brick-red color. The hematite may have been mistaken for cinnabar, the mercury sulfide.

Name, location, owner	Geology	Remarks and references
Cone Mountain (Cone Point) prospect NE¼ sec. 28, T9S, R20E, SBM (proj.), Palo Verde Mountains quadrangle (15 minutes), in the Palo Verde Mountains about 22 miles southwest of Blythe along the western base of Flat Tops Mountain.	The prospect area is underlain by a monolithologic breccia of highly altered andesite (?) which in turn is overlain by a flat-lying vesicular basalt. Talus from the basalt covers most of the breccia except where it has been stripped off during excavations. The breccia is a highly altered, friable mass of angular fragments heavily stained with hematite to a brick-red color. The average size of fragments is 1 x 2 inches. The mass is poorly cemented by calcite and gypsum and 1–2-inch seams of gypsite are common.	The commodity sought and period of activity was not satisfactorily determined, but development and campsite evidence indicate the prospect was active for a substantial length of time, probably during the 1930's or early 1940's. Mercury is reported to have been the commodity sought here although little evidence exists for its presence; hematite may have been mistaken for cinnabar. No mercury production is recorded by the U.S. Bureau of Mines from Imperial County. Workings consist of an opencut in the breccia, about 150 feet horizontally across the slope, 30 feet deep, and about 200 feet up slope. Another opencut in Holocene fanglomerate a few hundred feet east of the first cut is about 100 feet in diameter and 20 feet deep.

Mica

Two adjacent deposits of nearly pure sericite mica schist occur in the Precambrian(?) Vitrefrax Formation at the southwestern front of the Cargo Muchacho Mountains.

The sericite occurs in an interbedded series of quartzite, sericite schist, quartz-mica schist, kyanite-bearing quartzite, and kyanite-bearing quartz-mica schist.

The presence of strikingly different rock types in a limited area, the layered character of these rock types, and the close resemblance of the total composition of these rock types to that of silty sandstone, point toward the theory that the Vitrefrax Formation was derived from sediments (Henshaw, 1942).

These deposits have yielded more than 36,000 tons of sericite valued at about $270,000 in intermittent activity since 1925. The material was utilized for backing on roofing paper and as a whitener in paint.

Mica—continued

Name, location, owner	Geology	Remarks and references
Bluebird Group		See Drifted Snow mine.
Drifted Snow (Bluebird Group) mine Center sec. 18, T15S, R21E, SBM, Ogilby quadrangle (15 minutes), at the southeast base of the central Cargo Muchacho Mountains, 13 miles northwest of Yuma, 3.4 miles N 42 degrees E of Ogilby. Robert K. Foster, Box 575, Winterhaven; under lease to John G. Jebson, Box 681, Winterhaven (1961).	Relatively pure zones of sericite occur in sericite schist of the Precambrian(?) Vitrefrax Formation. The sericite schist containing the pure zones, which have irregular boundaries, is intercalated with quartz sericite schist and quartzite. Locally irregular zones occur in the schist that contain long, bladed kyanite crystals, small prismatic crystals of black tourmaline, and foliated bodies of apple-green pyrophyllite, and quartz. A small quartz-feldspar pegmatite dike intrudes the deposit on the northeast.	Intermittent activity. Since 1955 this deposit has yielded several hundred tons of material valued at $70–80 per ton. The material was used in paint. The material is mined in an open pit by bulldozer and is processed in a cyclone classifier for separation of pure sericite. The Drifted Snow mine is a part of the Bluebird group which includes the Drifted Snow mine and the Bluebird Kyanite mine. (Henshaw 42:154).
Western Non-Metallic mine N½ sec. 18, T15S, R21E, SBM, Ogilby quadrangle, Cargo Muchacho Mountains, 13 miles northwest of Yuma, Arizona, 3½ miles N 37 degrees E of Ogilby, on Mica-ite Hill. California Western Non Metallics, 2723 Fresno, Yuma, Ariz.	Relatively pure bodies of sericite mica schist occurring in the Vitrefrax Formation which underlies an area of about 100 acres at the western edge of the range. The sericite bodies, which have indefinite boundaries, occur in an interbedded series of quartzite, sericite schist, quartz-mica schist, kyanite-bearing quartzite, and kyanite-bearing quartz-mica schist. The layers of sericite schist contain variable amounts of quartz, but zones comparatively free of quartz are present as much as 100 feet thick and a few hundred feet along the strike. The mined material is white, very fine grained, and friable.	This property was first productive in 1929. It was worked nearly continuously through 1960. Activity was intermittent from 1960 through 1962. Total production is estimated at 30–40 thousand tons. Most of the mica was used as a lubricant dust for the surfaces of rolled roofing material. The mine is developed by five open pits which are several tens of feet wide, 20–30 feet deep and 100–200 feet long. No blasting is required. The pits are excavated by power shovels and the material trucked a few thousand yards to the mill. The mill is a dry grinding plant consisting of a jaw crusher, mechanical separator, and vibrating screens. Fifty-five percent of the milled product passes a 200-mesh screen. Bagging is done by hand. (Henshaw 42:153–154; Sampson and Tucker 42:139; Averill 51:325).

Mineral Paint

Red and yellow ocher resulting from Holocene hot spring activity is reported to occur at the now inundated base of Mullet Island in the south end of the Salton Sea. No production is recorded.

Name, location, owner	Geology	Remarks and references
Mullet Island Paint deposit SW¼ sec. 10, T11S, R13E, SBM, Niland quadrangle (7½ minutes), on the north part of Mullet Island in the southeast end of the Salton Sea, about 5 miles west of Niland. Undetermined, 1962; Captain Charles Davis, Niland (1930)	Yellow and red ocher has been deposited at several sites as a product of hot spring activity.	Not visited, 1962. Mullet Island in 1962 was more than a mile from shore, and this deposit is inundated. No recorded production. (Tucker 26:277–278; Symons 30:153).

Nickel

Two nickel deposits are known in Imperial County. Both are at the southeastern front of the Coyote Mountains. The better-known deposit is the Coyote Mountains Nickel prospect which consists of a hydrothermally altered zone between peridotite and quartz monzonite; it contains garnierite ($H_2(Ni,Mg)_3SiO_4 + H_2O$) and morenosite ($NiSO_4.7H_2O$). The second occurrence, the Edwards prospect, consists of an unidentified black copper-manganese-nickel-bearing material contained in a small pod within a large fault zone separating quartz monzonite and Tertiary marine sediments. No production has been recorded for either deposit.

Nickel—continued

Name, location, owner	Geology	Remarks and references
Coyote Mountains Nickel (Copper Contact Lode) prospect NW¼NW¼ of sec. 11, T16S, R9E, SBM Carrizo Mountain quadrangle (7½ minutes), Coyote Mountains district, in the southeastern Coyote Mountains, about 26 miles west of El Centro, in Fossil Canyon, 2 miles S 5 degrees W of Carrizo Mountain. Ross, Minnie, and Lloyd O'Callaghan of Ocotillo; Tilmon Roark, El Centro; and George Graham, Imperial. (Exact details of ownership not determined.)	Nickel mineralization has occurred along a hydrothermally altered contact zone between quartz diorite on the southwest and pyroxenite on the northeast. The zone strikes N 80 degrees W and appears to be vertical. The two igneous masses appear to be less than ½ mile in diameter. Both bodies are bounded on the west by a major fault zone that strikes N 40 degrees W and dips steeply southwest. The downfaulted southwest block consists of yellow marine claystone of the Imperial Formation. The mineralized zone, which is also terminated by the fault, can be traced about 1000 feet east of the fault. Exposures of nickel bearing material is limited thus far to small occurrences a few hundred feet apart. The most westerly of these consists of irregularly dispersed blebs of garnierite and morenosite in highly altered and brecciated pyroxenite composed of enstatite, olivine, chlorite, chrysotile, antigorite, and minor gypsum and epsomite (S. J. Rice, p.c., 1962). Copper was found to be present intimately mixed with the garnierite, but the mineral species was not determined. The easternmost occurrence is exposed in a prospect pit near a saddle in a north-trending ridge. It is similar to the occurrence on the west except that the pyroxenite is not brecciated. A third occurrence is exposed just below a spur crest midway between the other two deposits. It consists of altered pyroxenite containing veinlets of garnierite. South of this in a roadcut is an exposure of garnierite in quartz diorite where it occurs in fractures and is associated with manganese oxides. Two crude channel samples, one from easternmost and westernmost occurrences, contained about 1 percent of nickel (S. J. Rice, California Division Mines and Geology, personal communication).	This deposit was located in 1911 by James Smith as a copper prospect(?). It was surveyed for patent in 1934 but no patent was granted (patent survey 5107). Nickel was noted at the locality in January 1956 by the present owners. Several large companies investigated the property but no further activity developed. Development consists of an adit driven eastward about 60 feet from the westernmost exposure and several shallow cuts and pits.
Edwards prospect		See under Copper.

Perlite

Perlite is a glassy volcanic rock formed by the rapid chilling of volcanic flows. Its composition is variable and it possesses a distinctive "onion skin" fracture which causes it to break into spherical fragments.

When heated in a furnace under controlled conditions, perlite expands into frothy, lightweight globules which are used as aggregate in building materials (blocks, wall and floor panels, and plaster).

Perlite is reported to occur in the Black Hills in the northeastern corner of the county and may occur elsewhere in the volcanic rocks exposed extensively throughout the eastern half of the county.

Name, location, owner	Geology	Remarks and references
Black Hills Perlite prospect Reportedly in secs. 2, 3, T9S, R18E, SBM, Chuckwalla Spring quadrangle, 9 miles southwest of Wiley Well; not confirmed, 1963. Undetermined, 1963; N. A. Anderson, Laurence Raines, Blythe; Ray Cornell, Los Angeles (1945).	Perlite and expansive obsidian in Tertiary volcanic rocks. The unit crops out a distance of 2 miles, and is about 30 feet thick.	Not visited, 1963; information from an unpublished Field Report by W. B. Tucker, 1945.

troleum

Although no productive oil or natural gas wells t in Imperial County, exploration was being conted as late as 1968. More than forty exploratory ls have been drilled in the county since the early 0s (see table 12). The deepest of these was Stand-l Oil Wilson drilled 6 miles southeast of Brawley to epth of 13,442 feet. Although not producing hydrotions, this hole encountered very high temperature thermal fluids, and has yielded a vast amount of a for geothermal exploration.

Most petroleum exploration in the county is based on the possible presence of oil in the marine Imper-Formation of Pliocene age. The distribution of this mation beneath Imperial Valley is not adequately own. Thick sections are visible in the west valley s, but drill holes as deep as 6000 feet at the southeast end of the Salton Sea apparently do not cut the formation. Evidence for the presence of the formation in other holes in the eastern Imperial Valley is lacking suggesting that the eastern limit of the Pliocene gulf lies toward the western part of the Imperial Valley. However, Pliocene marine rocks of the Bouse Formation, which underlies areas near Yuma and Milpitas Wash, are a possible correlative of the Imperial Formation (Metzger, 1968).

On the basis of results thus far obtained in the county, and considering the less than 4000 feet of marine sediments present in the valley, it would appear that oil possibilities are somewhat limited. The limitations are even greater in light of the preponderance of relatively impermeable clays in the marine section.

*Table 12. Exploratory wells drilled for petroleum through December 31, 1968.**

San Bernardino B. & M.							
R.	Sec.	Operator	Well no.	Elev. (feet)	Date started	Total depth (feet)	Stratigraphy (depth in feet) Age at bottom of hole
12E	9	Pacific Dry Ice Co.	"Pacific Dry Ice" 1	—150	May 1946	1,505	Pleistocene
	11	O'Quinn & Hadley	"All American Acres Comm." 1	—125	July 1944	1,452	Pleistocene
	11	Pacific Dry Ice Co.	"Pacific Dry Ice" 2	—150	July 1946	1,510	Pleistocene
	11	Pacific Dry Ice Co.	"Pacific Dry Ice" 3	—150	April 1947	1,560	Pleistocene
9E	26	The Pure Oil Co.	"Truckhaven Unit" 1	107	May 1944	6,100	Basement (granite) 6,039
13E	24	E. J. Piatt	1	—160	Dec. 1933	173	Pleistocene
	34	Anthony-Rivers Development Co.	"Anthony" 1	—237	May 1945	553	CO_2 gas sand 531; Pleistocene
9E	25	Jesse M. Nelson	1	100	Feb. 1920	3,085	Pliocene
	27	Standard Oil Co. of Calif.	"Southern Land Co." 1	157	April 1944	4,531	Basement (conglomerate)
10E	10	Harry B. Mortimer and R. L. Rasmussen	"Truck Haven" 1	—205	July 1950	2,547	Imperial (Lower Miocene)
	31	Texaco Inc.	"Pure (NCT-1)" 1	162	Jan. 1952	4,314	Lower Imperial sandstone 3,345; Miocene
	32	The Imperial Valley Oil and Developing Association	1	100	Aug. 1919	4,115	Miocene
	33	Imperial Valley Pet. Corp.	1	150	Feb. 1929	4,160	Miocene
13E	23	Joseph I. O'Neill, Jr.	"Sportsman" 1	—213	Jan. 1961	4,720	Miocene
14E	19	J. P. Chandler and Lee Staton	1	220	July 1935	590	Pliocene
16E	5	Barth Oil Co., Inc.	"Barth" 1	750	Feb. 1934	2,855	Pliocene
	7	Irex Oil Co.	1	650	April 1947	1,375	Pliocene
	7	D. H. Wood	"Melson" 1	650	June 1931	900	Pliocene
21E	6	A. M. Campbell, R. J. Egger and I. Rottman	"Federal" 1	570	Nov. 1953	1,320	Pliocene
	6	Bernard J. Patton	"Midway Well" 1	568	Jan. 1961	3,809	Basement (volcanics)
13E	10	Kent Imperial Corp.	"Sinclair" 1	—220	Nov. 1957	4,725	Borrego (Pliocene)
	24	Sardi Oil Co.	"Biff" 1	—166	Oct. 1962	6,350	Brawley (Pleistocene)
	24	Sardi Oil Co.	"Sardi" 1	—160	Nov. 1960	5,620	Brawley (Pleistocene)
14E	9	Amerada Petroleum Corp.	"Veysey" 1	—142	Dec. 1944	8,350	Miocene
17E	2	Ajax Oil and Development Co.	"U.S.L. Phyllis" 1	272	Oct. 1955	3,315	Basement (metamorphics) 2,060
12E	4	Texaco Inc.	"Brawley Unit-Stipek" 1	127	Feb. 1952	8,648	Lower Pliocene
15E	20	Standard Oil Co. of Calif.	"Wilson (et al.)" 1	—110	Mar. 1963	13,443	Pliocene
16E	11	104 Oil & Drilling Co.	1	53	June 1920	1,911	Pliocene
	11	104 Oil & Drilling Co.	2	50	Oct. 1921	1,000	Pleistocene
	11	104 Oil & Drilling Co.	3	—12	May 1922	989	Pleistocene
10E	9	San Diego and Imperial Valley Oil Co.	1	110	Aug. 1915	2,500	Upper Miocene
11E	6	Southwestern Petroleum and Pipe Line Co.	1	95	Jan. 1921	700	Pliocene
12E	6	Texaco Inc.	"F. D. Browne" 1	—34	April 1952	7,806	Lower Imperial sandstone 7,732; Altered granite 7,742; Basement (granite)
14E	28	Amerada Petroleum Corp.	"Timken" 1	—5	May 1945	7,323	Miocene
16E	8	Texaco Inc.	"Grupe-Engebretsen" 1	8	Jan. 1945	12,313	Pliocene
17E	16	H. W. Schafer	"Barbara" 1	94	Oct. 1958	8,017	Miocene
11E	19	de Anza Oil Co., Ltd.	"F.G.W. de Anza U.S.L." 1	343	June 1959	1,245	Nonmarine Palm Springs 1,150; Miocene
	20	Clarence E. Harrison	"Barkett" 2	350	May 1962	1,200	Pleistocene
	20	Clarence E. Harrison	"Yuha" 1	350	April 1961	3,210	Miocene
14E	18	Texaco Inc.	"Jacobs (NCT-1)" 1	—10	Nov. 1951	7,505	Basement (granite)
10E	2	Petrodynamics Associates	"Straw" 1	375	April 1964	1,060	Pleistocene
17E	27	American Petrofina Explor. Co.	"U.S.A." 27-1	85	April 1966	10,624	Borrego 900-10,624 (Nonmarine Upper Pliocene)
11E	22	J. B. Nelson	"Snow Government" 1	101	Dec. 1967	1,160	Miocene

om California Division of Oil and Gas, 1964, p. 10.

Pumice

Pumice is a vesicular volcanic glass formed by the rapid chilling of gas-charged volcanic flows. Its composition is variable. Although pumice is mainly glass, crystals of quartz, feldspar, biotite and hornblende may occur as phenocrysts.

Pumice occurs in two Quaternary volcanic domes at the southeast end of the Salton Sea. Both occurrences have been mined, but most of the pumice has come from detrital material deposited on the flanks of Obsidian Butte, the larger of the two domes. Mining of the deposits was begun in 1915 and continued through 1937. During this early period the material was utilized for abrasives. The deposit remained inactive from that time until 1951 when Superlite Builders Supply established a concrete block plant in Calipatria utilizing the pumice for lightweight aggregate. The plant and deposit were acquired in 1960 by Aricalite Building Supply Company which remained active through 1963. Total output from both sources from 1915 through 1960 exceeds 187,000 tons valued at more than $1,012,000.

Name, location, owner	Geology	Remarks and references
Aricalite Building Supply Company		See Obsidian Butte mine.
Brand and Stevens		See Obsidian Butte mine.
California Pumice deposit		See Obsidian Butte mine.
Chamberlain Company		See Obsidian Butte mine.
Kalite Company deposit		See Obsidian Butte mine.
Obsidian Butte (Brand and Stevens, California Pumice, Chamberlain Company, Kalite, Stevens, Superlite Pumice, When-Miller-Underwood) deposit NE¼ sec. 32, T11S, R13E, SBM, Obsidian Butte quadrangle (7½ minutes), at Obsidian Butte, 8 miles N 65 degrees W of Calipatria. Imperial Irrigation District, leased to Aricalite Builders Supply Company, Sam Schmitt, owner, Box BB, Calipatria.	Pumice is mined from interbedded pumice conglomerate, pumice breccia, sand, and gravel on a low wave-cut butte adjacent to the southeast shore of the Salton Sea (see photo 4). The core of the butte consists of a small volcanic dome composed of pumice, scoria, and obsidian. On the flanks of the dome is a sequence of poorly consolidated pumiceous sediments which have been divided by Chesterman (1956, p. 86) into 3 sections (from bottom to top): at least 10 feet of pumice breccia, composed of angular fragments of pumice and scoria ranging from ash to 12 inches in diameter, and minor quartz sand; 5-10 feet of pumice conglomerate, composed of subrounded to angular pumice fragments (¼ inch to 5 inches diameter) and moderate amounts of sand and gravel; and 10-15 feet of well-bedded sand and gravel containing only minor pumice. Apparently the beds are of very limited extent and have a moderate to gentle initial dip away from the dome. Most of the pumice mined has been from the pumice conglomerate (Chesterman, 1956, p. 86), although the breccia has also been mined in recent years. A wide range of vesicularity is apparent, but the average weight of the crushed and screened material is reported to be about 50 pounds per cubic foot (common gravel weighs about 100 lbs/cu ft; water is 62.5 lbs/cu ft).	This deposit was first operated by Brand and Stevens in 1915, and during the twenties by When-Miller-Underwood and California Pumice. From 1930 to 1935 the deposit was operated by the Kalite Company and from 1935 to 1938 by the Chamberlain Company. During these early periods the pumice was utilized primarily as an abrasive material. After an inactive period from 1938 to early 1949, the property was leased and operated by the Superlite Builders Supply Company of Phoenix, Arizona. This company set up a crushing and screening plant at the property and hauled the product to Calipatria where it was utilized for lightweight aggregate in concrete blocks and other concrete products. The operation was purchased in 1960 by Sam Schmitt and is operated under the name of Aricalite Building Supply Company (1962). The deposit is developed by various-sized cuts on the east and south sides of the butte. The largest cut is a few hundred feet long and 20 feet high. The pumice is crushed and screened to minus ⅜ to plus 3/32 inch. Undersized material goes to a waste pump where it is directed to a modified sand cone which retrieves 60 percent of fines in the size range above 100 mesh. The crushed and screened material is trucked to the block plant at Calipatria where it undergoes a soaking process to remove the alkali imparted by Salton Sea water. The plant has a maximum rated capacity of 500 tons per day. (Tucker 21:270,271; 24:33; 26:280; Kelley and Soske 36:496–509; Sampson and Tucker 42:138; Chesterman 56: 81, 82, 86; Oesterling and Spurck 64:181).
Superlite Pumice mine		See Obsidian Butte mine.
Rock Hill deposit Center of sec. 23, T11S, R13E, SBM, Niland quadrangle (7½ minutes), about 7 miles S 60 degrees W of Niland at the southeast shore of the Salton Sea, adjacent to Vail 4-A drain lateral.	Small volcanic dome of pumice and scoria.	Source of material for lightweight aggregate (see Obsidian Butte deposit). Developed by a bench cut 150 feet long, 30 feet high and 100 feet wide.

Pumice—continued

Name, location, owner	Geology	Remarks and references
Imperial Valley Irrigation District, leased to Aricalite Builders Supply Company, Box BB, Calipatria.		
When-Miller-Underwood deposit		See Obsidian Butte mine.

Pyrophyllite

Pyrophyllite is a hydrous aluminum silicate ($Al_2Si_4O_{10}(OH)_2$), with many properties similar to talc. It is relatively soft, soapy, micaceous and chemically inert. The talcy sericite layers in the Vitrefrax Formation were derived by metamorphism perhaps from dolomite beds, although a basic igneous rock would be an equally adequate initial type (Henshaw, 1942).

Small zones containing abundant pyrophyllite occur at two localities in the county. At the Drifted Snow mine (see under Kyanite), at the southwest front of the Cargo Muchacho Mountains, pyrophyllite is associated with kyanite, tourmaline, and sericite in the Vitrefrax Formation. At the Crown uranium mine, in the Paymaster district of the Chocolate Mountains, pyrophyllite occurs with yellow uranium oxides, gypsum, and minor fluorite in metasedimentary rocks. A small production is recorded from the latter deposit.

Pyrophyllite competes with talc in many markets. It can be used in ceramic products, wall tile, paints, and as a filler or insecticide carrier.

Name, location, owner	Geology	Remarks and references
Bluebird Group		See Drifted Snow mine under Mica.
Crown Uranium mine		See under Uranium.
Drifted Snow Group		See Drifted Snow mine under Mica (Sampson and Tucker 42:138).

Roofing Granules

Colored volcanic rock used for roof granules and decorative gravels has been mined at three localities in Imperial County. Production has been low, however, and probably amounts to not more than several thousands of tons.

Most of the production came from the Navajo deposit near Painted Gorge in the Coyote Mountains. The material there consists of a grayish-purple andesite and dark, brick-red andesite agglomerate, of the Miocene Alverson Andesite. Another deposit lies several miles to the south in the eastern Jacumba Mountains. It consists of dark-gray olivine basalt. The third deposit, consisting of dark, brownish-red scoria, occurs in Quaternary basalt on Black Mountain about 18 miles northeast of Glamis.

Name, location, owner	Geology	Remarks and references
Navajo deposit SW¼ of SE¼ sec. 31, T15S, R10E, and middle of NW¼ sec. 36, T15S, R9E, SBM, Painted Gorge quadrangle (7½ minutes), eastern tip of Coyote Mountains, 5.7 miles N 15 degrees E of Ocotillo, 2.2 miles S 74 degrees E of Carrizo Mountain. Donald Weaver, Jacumba	Grayish-purple andesite flow from the Alverson Andesite of probable Miocene age. The rock crops out in several square miles along the eastern base of the mountains. The flows trend generally northwest and are tilted at moderate angles to the northeast. Younger sediments of the Imperial Formation crop out east of the quarry. A dark, brick-red andesite agglomerate which crops out about a mile northwest has also been mined. Both rocks appear to be relatively sound, evenly colored, finely textured, hard, non-porous, and finely jointed.	A crushing plant was operated a few hundred yards southeast of the purple rock quarry during the latter part of the 1950's, but was removed about 1958. The deposit was worked by bulldozer in two irregular bench cuts 50 to 100 feet long and ten feet high. The quarry in the red material is a few tens of feet in diameter.

Roofing granules—continued

Name, location, owner	Geology	Remarks and references
Weaver deposit W½ of SW¼ sec. 5, T17S, R10E, SBM, Coyote Wells quadrangle (7½ minutes), eastern Jacumba Mountains, 2.7 miles S 9 degrees E of Ocotillo, at the mouth of Davies Canyon. Donald Weaver, Jacumba (1961)	Dark-gray to black olivine basalt. Moderately altered by weathering but tough, moderately hard, and light weight.	Moderately small production during the 1950's. Developed by bulldozer cuts.
(Undetermined) NW¼ sec. 27, T12S, R20E, SBM, Quartz Peak quadrangle (15 minutes), in the Paymaster district, central Chocolate Mountains, about 18 miles N 60 degrees E of Glamis, and 2½ miles N 72 degrees W of Quartz Peak. Undetermined, 1961.	Dark, brownish-red scoria. Extremely cellular, lightweight, brittle, and highly fractured material of poor soundness. Average size of fragmented material is about 1 inch in diameter with abundant fines. The deposit is exposed along the base of a bank in a dry wash. It is overlain by a large vesicular basalt flow of which it forms a lower part.	The property appears to have been worked during the middle 1950's. The workings consist of a cut 30 feet into the bank 100 feet long, 25 feet high. Because of the highly fractured nature of the rock the material probably was merely screened to the desirable size. Probably not suitable for roofing purposes. (Oesterling and Spurck 64:164).

Salines

In 1970 the Salton Sea, a dry lake before the advent of irrigation in Imperial Valley, had an estimated salinity content of 37,500 parts per million, more saline than sea-water (see also table 8 under Geothermal Resources). The brine's composition differs from sea water, however, in its higher sulfate, carbonate, and calcium content and in its slightly lower chloride and magnesium content. The chemical composition of the lake has been quite variable since its formation in 1905–1906. This has been attributed to the initial dissolving process of playa lake salts, the influx of Colorado River water, and gradual leaching of irrigated land in Imperial and Coachella Valleys. The salinity in recent years has been increasing steadily.

Salt was recovered by evaporation of the Salton Sea brines as early as 1919, but the principal period of production was from 1934 through 1944, when both the Mullet Island and Imperial Salt Works were in operation. In all, less than 25,000 tons were produced which was valued at $3 to $4 per ton.

Sodium sulfate, occurring principally in the form of the mineral thenardite (Na_2SO_4), has been mined from deformed lacustrine beds of the Borrego Formation of Pliocene age. Natural deposits of sodium sulfate and other "salts" are frequently found in arid regions. The "salts" were originally leached from the surrounding rocks by surface or spring waters and transported to a low point in the interior drainage system. If input exceeded evaporation an alkali lake or pond was formed. If evaporation exceeded input, the water was vaporized and the "salt" remained as a residual deposit, often buried by later sediments.

The Bertram deposit, 18 miles northwest of Niland, was the only mine developed. It yielded less than 1,000 tons during its three productive years, 1923, 1941, and 1942. Some shipments were made to Berk and Company, a chemical manufacturer in New York. The principal use of sodium sulfate is in the preparation of Kraft pulp for paper-making. Other uses are in detergents, glass-making, and various chemicals.

Beginning in 1964, pilot plant investigations were conducted for the recovery of sodium chloride, potassium chloride, and calcium chloride from geothermal steam well brines near Niland (see under Geothermal Resources). It is believed that the elements in the brines accumulated by intensive leaching of trace quantities from the Cenozoic sedimentary rocks underlying the Salton Trough.

Sodium chloride, common salt, is the basic raw material in the chemical industry from which sodium and chlorine compounds are made. Potassium chloride is a source of potash for fertilizers and is used in making other potassium chemicals. Calcium chloride in solid form is a good water absorbent and is used to de-ice roads, to control dust, and to prevent the loss of moisture during the setting and curing of concrete. In liquid form it is used in a variety of ways, including as an additive to drilling muds.

Name, location, owner	Geology	Remarks and references
Bertram mine In the NE¼ sec. 19, T9S, R12E, SBM, Durmid quadrangle (7½ minutes), 18 miles N 55 degrees W of Niland, 1.4 miles N 80 degrees E of Bertram Siding. C. D. Adams, 7839 Calle Casino, Cucamonga.	A nearly pure sodium sulfate evaporite deposit in lacustrine Pliocene Borrego Formation. The formation in this area consists of interbedded clay, sandstone, and evaporites which have been tilted and contorted. The beds at the deposit strike mostly N 60 degrees W and dip at moderate steep angles southwest although local contortions are common. Much of the folding is	Discovered on property of the Southern Pacific Railroad in 1903 by Havens. The deposit was not developed until purchased by E. N. Smith in 1919, but the first shipment apparently was not made until 1923 by E. W. Otto and Company, lessee. No further shipments were made until 250 tons were shipped in 1941 and 1942 by the American Sulfates Company;

Salines—continued

Name, location, owner	Geology	Remarks and references
	probably related to movement along the San Andreas fault zone which passes within a mile northeast of the deposit. The sodium sulfate beds are exposed within an area 3,000 feet (parallel with the strike) by 2500 feet, although the mined zone is a few tens of feet wide normal to the strike. Individual beds of sodium sulfate are a few inches to 6 feet thick and consist principally of thenardite (Na_2SO_4). In the western end of the deposit, however, a 4–5 foot bed reported to be mostly blodite ($MgSO_4.Na_2SO_4.4H_2O$) was mined. This bed was determined by drilling to lie at 20- to 60-foot depths along a strike length of 1000 feet. Mirabalite ($Na_2SO_4.10H_2O$) is also common at the deposit, especially in surface encrustations and lining cavities and fractures.	the property was idle through 1962. Among the difficulties encountered with the deposit is an unfavorable magnesium content and steeply dipping beds. Large reserves remain. Development consists of two main pits. The east pit, the earliest developed, is about 600 feet long, 20 feet wide and 15 feet deep. The west pit, which is about 2000 feet northwest, was mined in 1941 and 1942 and is about 700 feet long, 20 feet wide, and 20 feet deep (previously reported to have been mined to 45 feet). Numerous test pits and trenches are present between the two pits which are 2000 feet apart. (Sampson and Tucker 42:140–143; Tucker 21:271; 24:87–91; 26:281–283; Ver Planck 54:8–9; 57:543; Oesterling and Spurck 64:186).
Imperial Salt Works (Western Salt Company) N½ sec. 6, T10S, R13E, SBM, Frink quadrangle (7½ minutes), along the southeast shore of Salton Sea, 12 miles northwest of Niland, 2 miles southwest of Frink Siding. Imperial Irrigation District, El Centro	Salt from evaporation of Salton Sea brine.	The Imperial Salt Works was begun by Seth Hartley and his son Chester Hartley in the early 1930's. First production was recorded in 1935. The plant was purchased in 1943 by the Western Salt Company. The operation was abandoned in 1947 after difficulties with sodium sulfate. The water level in 1962 was above that of the levees of the ponds. Salt was obtained through a process of crystallizing by solar evaporation of Salton Sea brine. The brine was drawn from the lake through a canal and pumped to two separate series of nine ponds each. Gravity flow from one concentrating pond to another was achieved through use of gates between levees. Final concentration before withdrawing the pickle to the crystallizing ponds was 28.95 percent Be. Harvesting was done once a year by dragline scraper into side dump rail cars. Plant capacity was 16,000 tons per year from a total of 160 acres of concentrating ponds and about 15 acres of crystallizing pond. (Sampson and Tucker 42:138; Ver Planck 57:486; 58:73–74, 115).
Miller deposit Reported to be somewhere southeast of Durmid Station which is barely into Riverside County, along the eastern shore of Salton Sea; not confirmed, 1962. Undetermined, 1962; G. E. Miller, Niland (1921)	Reportedly sodium sulfate beds 1 to 8 feet thick, overlain by sand and gravel.	Uncorrelated old name; probably an abandoned prospect. (Tucker 21:27).
Mullet Island Salt Works (Mullet Island Point Company, Mullet Island Development Company, Reeder Salt Company) Reportedly in sec. 9, T11S, R13E, SBM, Niland quadrangle, 6 miles west of Niland, west of Mullet Island; not confirmed, 1962. (Probably flooded by the Salton Sea)	Salt from evaporation of Salton Sea brine.	Small early production is recorded from this locality in 1919 and 1934. From 1940 through 1942 the Reeder Salt Company operated the plant continuously. Salton Sea water was supplemented by an artesian well on Mullet Island and concentrated by solar evaporation in three ponds. A 70 percent pickle was pumped to crystallizing ponds. Much of the product was consumed locally for use in connection with the icing of refrigeration railroad cars. (Sampson and Tucker 42:138; Ver Planck 58:15, 17, 74, 115).
Reeder Salt Company		See Mullet Island Salt Works.
Western Salt Company		See Imperial Salt Works.

Sand and Gravel

The sand and gravel industry accounted for over a third of the total value of mineral production in Imperial County during the 10-year period ending 1968 (see table 13). A total of 11,165,041 tons of sand and gravel valued at $12,314,886 was mined during this period.

Table 13. Sand and gravel production compared with total mineral production, 1959 to 1968.

Year	Tons	Value	Total value all mineral commodities
1959	510,969	$479,147	$3,348,440
1960	469,279	493,986	2,302,673
1961	1,189,091	1,161,742	3,180,856
1962	888,363	967,978	3,157,286
1963	932,339	955,033	3,296,101
1964	927,000	940,000	3,261,101
1965	714,000	699,000	2,856,839
1966	895,000	959,000	2,815,964
1967	3,160,000	4,090,000	5,931,506
1968	1,479,000	1,569,000	4,058,299
10-year totals	11,165,041	$12,314,886	$34,209,065

The principal source of sand and gravel in the county is vestigial shoreline deposits of ancient Lake Cahuilla. The shoreline, which manifests itself in physical features ranging from travertine deposits to long narrow mounds of gravel, lies at an elevation of about 40 feet and circumscribes a basin about 100 miles long and as much as 37 miles wide. The present day Salton Sea lies in the center of this basin. The area included trends northwest and extends from its northern limit just north of Indio in Riverside County, southward through Imperial County to several miles south of Mexicali in Mexico. Those sections of the shoreline that lie in the county are the east and west shores.

The most important sources of quality sand and gravel are the east shore gravels from about lat 33° N. to the Mexican border. These deposits are contained in a low-profiled ridge about 500–1000 feet wide and 15–25 feet thick at the crest. In cross section the ridge is a very gentle rise from the valley floor and drops off gently but more abruptly from its crest to the east. The beds are structurally undeformed but exhibit their gentle westward initial dip. A thin veneer of fine sand overlies the gravel in the ridge, but the remainder of the ridge is composed of gravel. In general the gravel beds in this area coarsen with depth and from south to north. Most of the mined material is excavated from cuts 10 to 20 feet deep. The deposits are comprised of unconsolidated, thinly bedded, cross-bedded, lenticular beds of sand and gravel which contain from 50 to 70 percent of medium to coarse sand (see photo 14). The gravel fraction contains well- to subrounded pebbles as much as 3 inches in diameter. A very low percentage of fines are present. The coarse fraction is composed predominantly of dacitic and andesitic hypabyssal rocks and granitic rocks. Calcareous sandstone and gneiss are present in minor amounts (Goldman, 1968, p. 34).

This beach line deposit probably originated as a result of: (1) relatively rough water on the eastern shore of Lake Cahuilla caused by prevailing southeast-

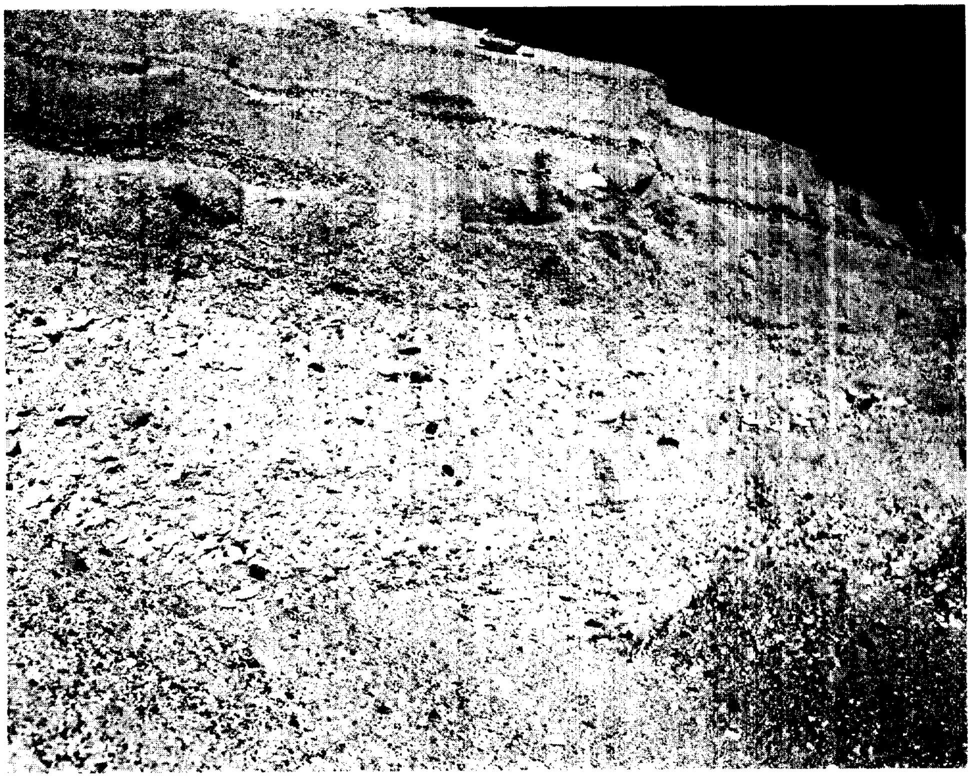

Photo 14. East Shoreline, Lake Cahuilla. The photo shows a pit face in an east shoreline gravel deposit.

ward winds; (2) south to north east-shore currents like those that exist today in the Salton Sea; (3) introduction of coarse sediments from the east and southeast, strongly influenced by the inflow of the primordial Colorado River. Correspondingly, the west side of Lake Cahuilla was deficient in coarse sediments because of south currents, calmer waters, and the introduction of finer, reworked Tertiary sediments from the west side of the basin.

West shoreline deposits have been utilized mostly for bituminous aggregate, road base, subbase, and imported borrow. These deposits occur mostly between Plaster City and Salton City and are much more subdued in topographic expression than are their eastern counterparts. The material consists mostly of sand and fine gravel, which is composed of pebble clasts of calcareous sandstone, pegmatitic granite, and minor amounts of metamorphic rocks (see photo 15).

Other sources of sand and gravel in Imperial County are largely fan deposits, and are of minor importance. These will become more important sources in the future, however, as the shoreline deposits are diminished in quantity and quality. The alluvial fans flank the several mountain ranges that border Imperial Valley on the east and west. One such fan utilized recently is northeast of Glamis at the base of the Chocolate Mountains. There, a thin deposit of gravel has been deposited on a pedimented surface. Where developed, the deposit is from 3 to 5 feet thick and is composed mostly of sand. The gravel fraction is harshly angular material (Goldman, 1968, p. 22) consisting of non-vitric volcanic rocks, gneiss, and schist. The gravels have been the object of some placer gold activity (see Gibson deposit and Placer Gold section). The average maximum size is 4 inches although boulders as much as 2 feet in diameter are present. Most of the material has been utilized for bituminous aggregate and road base.

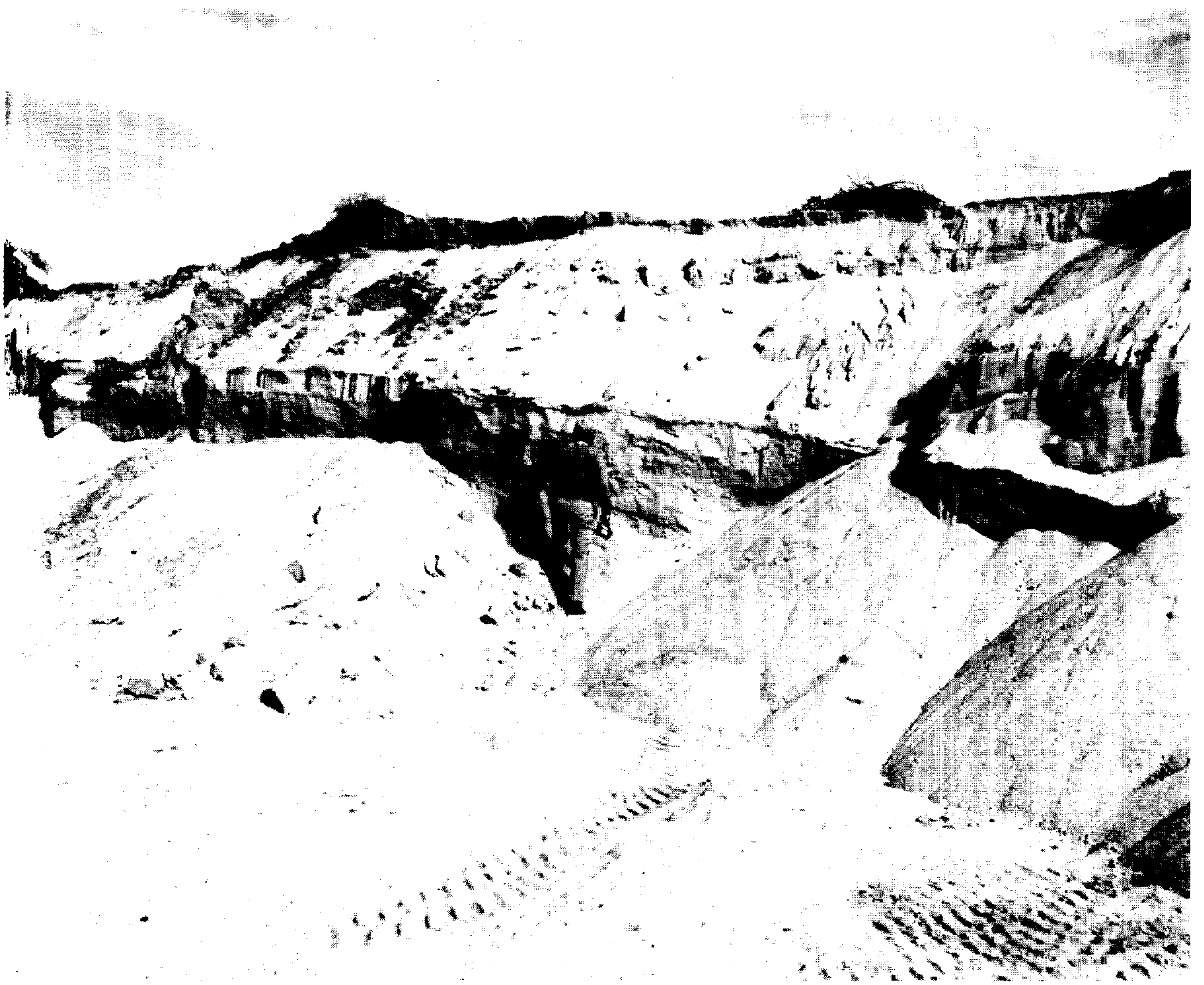

Photo 15. West Shoreline, Lake Cahuilla. The photo shows a pit face of coarse sand in west shoreline deposits.

Sand and Gravel—continued

Name, location, owner	Geology	Remarks and references
Henry Abeyta decomposed granite, north deposit. W½ sec. 7, T16S, R11E, SBM, Painted Gorge quadrangle (7½ minutes), 18 miles due west of El Centro, 1½ miles west of Plaster City, adjacent and north of U.S. Highway 80. Federal lease to Henry Abeyta, 1268 El Dorado, El Centro.	Unconsolidated granitic debris in older alluvium which has emanated from the granitic areas several miles to the southwest. No overburden; the flat-lying material appears to be from 5 to 8 feet thick. The average grain size is about 1/16 inch but coarsens from east to west. The material is made up of grains ranging in size from that of fine sand to ¼-inch granules and minor pebbles 1 inch in diameter. It is composed principally of subangular to subrounded grains of feldspar and quartz. Similar material is exposed in pits as far south as 1½ miles (Abeyta south deposit). Shallow pits ½ mile northwest contain coarser, more unsorted material.	Intermittent activity. Pit size is about 400 to 500 feet in diameter and 5 to 8 feet deep. State Plaster City pit is adjacent to the south (see pl. 1).
Henry Abeyta decomposed granite, south deposit NW¼ sec. 19, T16S, R11E, SBM, Painted Gorge quadrangle (7½ minutes), about 18 miles west-southwest of El Centro, and about 2 miles southwest of Plaster City. Federal lease to Henry Abeyta, 1268 El Dorado, El Centro.	Unconsolidated, poorly sorted, flat-lying granitic debris in older alluvium derived from the Jacumba Mountains to the west. Cobbles as much as 8 inches in diameter are present in a coarse granular matrix of subangular grains of feldspar and quartz (similar to north deposit). The gravel is overlain by a 2-foot layer of caliche.	Inactive, 1962. Pit is 8–10 feet deep, 100 feet wide and 300 feet long.
Dixieland Sand and Gravel Company Reportedly 3 miles west of Dixieland near U.S. Highway 80; not confirmed, 1962. Undetermined, 1962; E. S. Cook, El Centro (1926)		Uncorrelated old name; not visited, 1962 (Tucker 26:284).
Farmers Gravel Company deposit SE¼SW¼ sec. 28, T13S, R12E, SBM, Calipatria southwest quadrangle (7½ minutes), 6 miles S 70 degrees W of Westmorland near the eastern tip of the Superstition Hills. Federal lease to Farmers Gravel Company, 18404 Gothard Street, Huntington Beach.	Shoreline deposit along ancient Lake Cahuilla's west shore. The deposit is an essentially flat-lying, poorly consolidated, fairly well-bedded, well-sorted, coarse-grained, pebbly sand. The bed is 15 feet thick and underlies an area of about 80 acres. Little or no overburden is present. The bed is underlain by a silty layer. A small percentage of well-rounded gravel is erratically interbedded in thin lenses and cross beds as much as 6 inches thick. These contain clasts as much as 1½ inches in diameter, but most of the pebbles are ¾ inch. They are composed predominantly of calcareous sandstone and moderate amounts of granitic and gneissic rocks.	Excavation is done with a front end shovel loader and no stripping is necessary. Pit run material is trucked to Brawley via 3 miles of graded dirt road to State Highway 86. The pit trends north, is 200–300 feet wide, about 750 feet long, and 10 to 15 feet deep. After screening, the sand is used as a filter media around drain tile.
H. C. Gibson—Highline Pit deposit NE¼ sec. 27, T13S, R16E, SBM, Alamorio northeast quadrangle (7½ minutes), 13 miles due east of Brawley, 1½ miles north of Brawley-Glamis road. U.S. Bureau of Reclamation; leased to H. C. Gibson, Box 1287, Brawley.	Lakeshore gravel along the east shoreline of ancient Lake Cahuilla. (See general discussion under Sand and Gravel above).	The sand to gravel ratio is 1:1; maximum size 3 inches; contains 5 percent of plus 1½ inch gravel. Front-end shovel loaders excavate material from 5–15 feet depth to the plant. A bulldozer feeds conveyor belt to standard vibrating screens, to radial stacker. The capacity is reported to be 150 yards per day of concrete aggregate. A smaller plant with half the capacity is used to produce oil-well packing granules.
H. C. Gibson—Glamis Pit deposit SE¼ sec. 5, T13S, R19E, SBM (projected), Quartz Peak quadrangle (15 minutes), at the southwest edge of the Chocolate Mountains, about 31 miles east-northeast of Brawley, 6.2 miles N 47 degrees E of Glamis. H. C. Gibson, P.O. Box 1287, Brawley	Three to 5 feet of fanglomerate resting on pedimented gneiss (?). The gravel is reported to be auriferous in part. Several placer gold prospects are located in the surrounding area. The fanglomerate is comprised mostly of sand, but the gravel fraction is very sound, angular material consisting of andesite and other volcanic rocks, gneiss, schist, and minor quartz, and quartzite rocks. Maximum size of the clasts is 4 inches with uncommon occurrence of boulders as much as 2 feet in diameter.	No stripping is necessary. Excavation is done intermittently and material is processed in portable crushing plant for use in asphalt concrete and road base.

Sand and Gravel—continued

Name, location, owner	Geology	Remarks and references
J. McElvaney deposit NW¼SE¼ sec. 28, T13S, R12E, SBM, Calipatria southwest quadrangle (7½ minutes), about 6 miles S 70 degrees W of Westmorland, near the eastern tip of the Superstition Hills. Federal lease to J. McElvaney, P.O. Box 818, El Centro.	Shoreline deposit along the west shoreline of ancient Lake Cahuilla. (See Farmers Gravel Company for description of geology).	Excavation is done with a dragline. The pit is about 200 feet in diameter and 25 feet deep. The operation is intermittent.
J. B. Nelson—North Plant deposit Mostly in the W½ sec. 2, T14S, R16E, SBM, Alamorio northeast quadrangle (7½ minutes), at the western edge of East Mesa and just east of the East Highline Canal, 12 miles N 25 degrees E of Holtville. U.S. Bureau of Reclamation; leased to J. B. Nelson, Holtville	Lakeshore gravels along the east shoreline of ancient Lake Cahuilla. (See general discussion under Sand and Gravel above.)	A D-8 tractor shovel feeds a bucket ladder-type conveyor, triple deck standard vibrating screen separating 6 sizes of material. The pit is excavated to a depth of 10 feet. Capacity is reported to be 100 yards of gravel and 150 yards of sand per 8 hour shift. The material is utilized for concrete aggregate, filter gravel, drain gravel, and oil-well packing sand. A bagging plant for oil-well packing granules northwest of pit has a capacity of 60 yards per 10 hours. (Averill and Norman 51:326).
J. B. Nelson—South Plant deposit NE¼ sec. 36, T15S, R16E, SBM, Holtville East quadrangle (7½ minutes), 5 miles due east of Holtville, just east of East Highline canal. U.S. Bureau of Reclamation; leased to J. B. Nelson, Holtville.	Lakeshore gravels along the east shoreline of ancient Lake Cahuilla. (See general discussion under Sand and Gravel above).	Contains about 60 percent sand. Maximum size of gravel is 2 inches in diameter. Material is excavated with a front-end shovel loader to a depth of 20 feet. From a bucket ladder-type conveyor, material feeds to standard vibrating screens; separate rescreening plant for bagging well-packing gravel. Capacity is reported to be 170 cubic yards per 8 hour shift. The material is utilized for concrete pipe, oil-well packing, plaster, filtering, blast sand, and drain gravel. (Averill and Norman 51:326).
Orange County Rock Company deposit SE¼NE¼ sec. 30, SW¼NW¼ sec. 29, T9S, R13E, SBM, Frink quadrangle (7½ minutes), 18 miles northwest of Niland, a few hundred feet northeast of Frink Siding. Undetermined, 1962; Orange County Rock Company, Orange (1926)	Holocene fanglomerate derived from the Chocolate Mountains to the north. Material is mostly gneiss, schist, rhyolite, and andesite.	A crushing and washing plant with a capacity of 1500 yards per day was operated at Frink in 1926. Water was obtained at Frink Spring, one mile to the northeast. (Tucker 26: 284).
R. T. Pinner and Son deposit SE¼ sec. 27, T13S, R16E, SBM, Alamorio NE quadrangle (7½ minutes), 13 miles due east of Brawley, about ½ mile north of the Brawley-Glamis road. U.S. Bureau of Reclamation; leased to R. T. Pinner and Son, Box 115, Brawley.	Lakeshore gravels along the east shoreline of ancient Lake Cahuilla. (See general discussion under Sand and Gravel above).	Intermittent production from simple dry screening plant.
Raley deposit pit SE¼ of NW¼ sec. 14, T16S, R9E, SBM, Carrizo Mountain quadrangle (7½ minutes), southeast edge of Coyote Mountains, 3.2 miles N 22 degrees W of Ocotillo, 4 miles due south of Coyote Mountain at the mouth of Fossil Canyon. Wm. H. Raley, 280 N. Imperial, El Centro (1962)	Unconsolidated, moderately well-bedded Holocene fan gravel composed of clasts of crystalline volcanic rock, gneiss, granitic rock, and minor limestone. The gravel consists of about 50 percent angular to subrounded pebbles which average from ½ to 1 inch in diameter. Boulders 2 feet in diameter are present, though rare.	The pit is about 500 feet long, 150 feet wide, and 10 feet deep. A small dry portable screening plant is used without crushing or washing. In 1962 the material was used in an asphalt concrete hot plant at Seeley.
Salton Paving Co. deposit NE¼ sec. 13, T10S, R9E, SBM, Truckhaven quadrangle (7½ minutes), about 2 miles northwest of Salton City, 0.8 mile N 45 degrees W of Truckhaven, west of State Highway 86. Federal lease to Salton Paving Company, Salton City.	Thin layers of gravel in a broad dissected fan Clasts are principally granitic detritus with a maximum size of 4 inches. Boulders as much as 2 feet in diameter are present but uncommon.	Excavation is done with front-end shovel loaders to a depth of 4 feet. Material is trucked to a portable hot mix plant with a reported capacity of 175 tons per hour. Oversize is crushed in a jaw crusher, jaw and roll crushers, and screened. Fines are obtained from Palm Wash to the south. The material does not meet state specifications for soundness (high Rattler loss). The deposit was estimated by company to be depleted in 1962. (Goldman 61:unpub.)

Sand and Gravel—continued

Name, location, owner	Geology	Remarks and references
Valley Transit Cement Company, Inc., deposit SW¼ sec. 2, T14S, R16E, SBM, Alamorio northeast quadrangle (7½ minutes), about 13 miles east-southeast of Brawley, just east of Highline Canal and about 1 mile south of the Brawley-Glamis road; also SE¼ sec. 11, T14S, R16E, SBM, 1.2 miles south of above location. U.S. Bureau of Reclamation; leased to Valley Transit Cement Company, Inc., Box 1489, El Centro.	Lakeshore gravel on the east shoreline of ancient Lake Cahuilla. (See general discussion under Sand and Gravel above).	Each location has its own plant, each of which is fed by tractor shovel to bucket-ladder-type conveyor and double-deck vibrating screens. The south plant has a sand drag for washing sand. Both plants excavate to a 10-foot depth. Both pits appear to contain less than 50 percent gravel, the maximum size of which is plus 2 inches in the north deposit and 1½ to 2 inches in the south pit. Reported capacity of the plants is 300 yards per 8 hours at the north plant, and 200 yards per 8 hours at the south plant. Drain-tile sand and concrete aggregate are produced.
Valley Sand and Gravel deposit NE¼ sec. 2, T16S, R22E, SBM, Bard quadrangle (7½ minutes), 5 miles due north of Yuma, adjacent to the All American Canal, in Picacho Wash. U.S. Bureau of Reclamation, leased to Valley Sand and Gravel, 1213 2nd Avenue, Yuma, Arizona.	Holocene sand and gravel of Picacho Wash. The usable material is at least 15 feet thick and lies at the surface. The wash is 1800 feet wide and extends northwestward several miles. The sediments consist in large part of reworked material from extensive older gravels which underlie most of the drainage area. The older gravels are, in themselves, poor but the reworked material contains remarkably clean sand. The material consists of crudely stratified thin beds of coarse sand and well-rounded pebbles which are a maximum of 3 inches in diameter. Sparse cobbles as much as 6 inches in diameter occur erratically through the deposit. The gravel fraction consists of weathered gneiss, granitic rocks, assorted volcanic rocks, quartz, and quartzite.	The material is excavated by front-end loader, passes through a 2-inch screen directly into a truck. This material is hauled to Yuma where it is rescreened. The sand is used "as is" for concrete block and for aggregate in ordinary concrete. The gravel, for the most part, is unsound material and little is recovered.

Silica

Silica as quartz sand and crushed quartz amounting to probably a few thousand tons was mined from Imperial County deposits in 1921–22 and 1928–29. The two known deposits yielding material are the Coyote Mountain and Snow White deposits, both of which are in the Coyote Mountains. The Coyote Mountain deposit consists of a silica sand bed in the marine Pliocene Imperial Formation, which crops out on the east flanks of the range, and perhaps elsewhere. Snow White, a quartz deposit, occurs in tabular pegmatitic dikes along the Elsinore fault zone on the south margin of the range.

During 1958, a small silicon plant (6½-ton-per-day capacity) operated at Dixieland on a pilot basis. The plant consisted of a cylindrical electric steel furnace about 10 feet tall and about 10 feet in diameter inside. The charge of quartz, coke, and charcoal was melted by three large carbon electrodes in the carbon-brick-lined vessel. Silicon was tapped from the bottom. Vein quartz for the operation was mined from the Jacumba Mountains in San Diego County (Weber, 1963, p. 211, 214). A small but undetermined amount of silica was sold and shipped to Los Angeles. In 1964 the plant was idle. BKK Mining (Paul C. Estep), West Covina, was reported to be the owner in 1964.

Silicon is used in transistors, metal alloys, and chemicals.

Name, location, owner	Geology	Remarks and references
Chocolate Mountains Silica deposit Reportedly in sec. 7, T12S, R18E, SBM, 10 miles north of Glamis, Chocolate Mountains; not confirmed, 1962. Undetermined, 1962; Charles Kurton, Bob Gunn, R. D. Glick, 1056 North 7th Street, Colton (1942).	Quartz vein in schist.	Uncorrelated old name; not visited, 1962. The location given is in Chocolate Mountains Aerial Gunnery Range. (Sampson and Tucker 42:139).
Columbia Cement Company deposit		See Coyote Mountains Silica.
Coyote Mountains silica (Southern California Marble and Development Company deposit)	A clean quartz sandstone unit, probably a part of the Alverson Andesite, unconformably underlying Pliocene Imperial Formation. It is at least 50	This deposit is reported to have yielded 1200 tons of material in 1921 and 1922, but little or no silica has been shipped subse-

Silica—continued

Name, location, owner	Geology	Remarks and references
NW¼NW¼ sec. 1, T16S, R9E, SBM, Carrizo Mountain quadrangle (7½ minutes), Coyote Mountains, 25 miles west of El Centro, 5 miles north of Ocotillo, 1 mile southeast of Carrizo Mountain. Pine Tree Cement Company, c/o H. W. Soule, P.O. Box 306, Vista; B. A. Sweet, Escondido	feet thick and crops out over an area of only 100 to 200 feet in diameter. The beds strike N 65 degrees W and dip 30–35 degrees SW. The base of the unit is not exposed. It is a white, medium-grained, poorly cemented, friable sandstone composed of subrounded, well-sorted grains of quartz (80–90 percent) feldspar (10–20 percent) with very minor muscovite. Magnetite and other ferromagnesian constituents are absent or rare and the iron oxide content is low.	quently. (Tucker 21:271; Sampson and Tucker 31:438; 42:139).
Elliot prospect SW¼ of SW¼ of sec. 5, T18S, R9E, SBM, In-ko-pah Gorge quadrangle (7½ minutes), Jacumba Mountains extreme southwest corner of the county, 5 miles due east of Jacumba, and 3.4 miles S 8 degrees E of Mountain Spring. J. E. Elliot, address undetermined (1961)	A pegmatite dike in quartz diorite. The dike trends N 30 degrees W and is about 100 feet long by a few tens of feet wide. It consists of a central zone of pure quartz, about 25 feet in diameter. This is bordered by a feldspar-quartz zone containing books of muscovite as large as 4–6 inches in diameter.	Little or no production. The only development consists of a shallow cut on the northwest side of the hill.
Fish Creek Mountain deposit Reported in secs. 10, 15, 21, T14S, R9E, SBM, 14 miles north of Coyote Wells; not confirmed, 1962 Undetermined, 1962; W. A. Waters, Pasadena (1942)		Uncorrelated old name; not visited, 1962 (Tucker 26:281; Sampson and Tucker 42: 139–140).
Snow White deposit Middle of N½ sec. 8, T16S, R9E, SBM, Carrizo Mountain quadrangle (7½ minutes), south flank of Coyote Mountains, 5.9 miles N 43 degrees W of Ocotillo, 3.4 miles S 55 degrees W of Carrizo Mountain. L. O'Callahan, address undetermined, 1961. Possibly could be contacted through Ross O'Callahan, Box 131, Ocotillo.	Three sub-parallel pegmatite dikes in gneiss. The dikes lie within and approximately parallel to the northwest-trending Elsinore fault zone which marks the contact between Pliocene Imperial Formation to the southwest and gneiss to the northeast. The dikes are somewhat deformed and sheared but have an overall strike of N 20–30 degrees W and a nearly vertical dip. They are several tens of feet wide and measure 100–200 feet along the strike. Both the Imperial Formation and the gneiss-pegmatite rocks are overlain by mildly deformed fanglomerate. The dikes are composed mainly of quartz, potash feldspar, biotite, and muscovite. Irregular bodies of pure quartz occur within two of the dikes. The larger of these bodies, 50–75 feet in diameter, is exposed at the head of the north-trending canyon containing the mine road. A dike composed predominantly of feldspar crops out a few hundred feet up slope and northeast. The dike containing the smaller quartz deposit crops out a few hundred feet southeast of the large quartz body.	An estimated 200–400 tons of silica has been mined from the property in 1928–29. Development consists of an open pit 50 feet by 75 feet and several smaller open cuts.
Southern California Marble and Development Company deposit		See Coyote Mountains deposit.

Silver-Lead

From 1907 through 1960 in Imperial County 97,250 ounces of silver and an undetermined amount of lead were mined. Production of silver is recorded for nearly every year from 1907 through 1942. Prior years were doubtless more productive; but county totals are not available, as Imperial County was then a part of San Diego County.

Earliest known production was in 1867, at the Paymaster mine, which continued to produce until 1880. It remains through this writing the most productive silver and lead operation in the county. If a rough estimate of production from the Paymaster mine is included, total production from the county would be about 250,000 ounces of silver.

The Paymaster mine is in the Paymaster district about 3 miles southwest of Midway Well. Other silver deposits in the same area are the Homestake, Little Buckaroo and True Friend-Silver Moon and Silver King prospects. The two remaining known silver-lead mines are the Mayflower and Marcella mines.

Silver—Lead—continued

Name, location, owner	Geology	Remarks and references
Consolidated Buena Suerte		See Rainbow prospect.
Emilia mine		See Paymaster mine.
Hazel mine		See Paymaster mine.
Homestake prospect Middle of N½ of NE¼ sec. 19, T11S, R20E, SBM, Quartz Peak quadrangle (15 minutes), in the Paymaster district, 2.6 miles S 70 degrees W of Midway Well, 18 miles north-northeast of Glamis. Undetermined, 1961; V. Laughlin and V. Bloomer, Brawley (1942).	Vein strikes N 75 degrees E, dips 70 degrees southeast in coarsely grained granitic rock. The vein consists principally of altered wall rock, quartz, calcite, hydrous iron oxides and minor amounts of lead and silver.	Workings consist of a 30-foot shaft and a 25-foot crosscut-adit driven S 30 degrees E through the vein. Little or no production. Apparently abandoned. (Tucker 26:262; Sampson and Tucker 42:127; Goodwin 57:448t; Oesterling and Spurck 64:150)
Imperial Buttes mine		See Marcella prospect.
Little Buckaroo prospect Approximately T11S, R20E, SBM, Quartz Peak quadrangle (15 minutes), central Chocolate Mountains; not confirmed, 1962. W. D. Morrison, Box 1187, Yuma, Arizona (1952)		Not visited, 1962. One ton of ore containing about 10 ounces of silver and 300 pounds of lead was reported shipped in 1952.
Marcella (Imperial Buttes) prospect NW¼ sec. 30, T9S, R15E, SBM, Iris Pass quadrangle, 10 miles N 20 degrees E of Niland at the southern tip of a small hill at the southwestern base of the Chocolate Mountains. Lies within Chocolate Mountains Aerial Gunnery Range; Marcella Mining Company, Niland (1916)	Quartz vein in schist strikes due north and dips 45 degrees W. The vein is 3–5 feet wide and is exposed along the strike for more than 150 feet. It is parallel to the foliation in the schist and is composed almost entirely of quartz. Sparse blue copper staining is present in some parts of the vein, but no sulfide minerals were observed. A narrow rhyolitic dike is exposed on top of the hill several tens of feet to the west, and was encountered at an undetermined place in the workings.	This property has a recorded production of more than 100 tons of ore containing an average of 7.4 percent lead, 2.4 percent copper, 0.96 ounces of silver and 0.11 ounces of gold per ton. It is developed by an inclined shaft at least 75 feet deep with undetermined appended workings.
Mayflower mine NW¼ sec. 22, T13S, R23E, SBM, Picacho quadrangle (7½ minutes), southeastern Chocolate Mountains, about 21 miles north-northeast of Yuma, Arizona, 3.8 miles N 85 degrees E of Picacho, about 0.3 miles south of the Colorado River. Undetermined, 1962; W. H. Trenchard, San Diego (1942)	Two veins strike N 60 degrees E in schist; the southeast vein dips 45 degrees SE and the northwest vein is nearly vertical. The veins are about 100 feet apart at the surface, and the southeast vein, the most prominent, can be traced at least 500 feet. The vein consists of iron-stained fault gouge containing calcite and, reportedly, cerussite and argentiferous galena. The veins lie within ½-mile-wide major east-trending fault zone which extends 2 miles east and west of the deposit (see geologic map pl. 1).	Discovered and developed about 1900. Total reported production is less than 100 tons of ore containing an average of 0.36 ounces of gold and 0.30 ounces of silver per ton. Ore containing 90 ounces of silver per ton has been reported earlier but not substantiated. Ore was probably hauled to the Picacho mill, about 4 miles up river. The southeast vein is developed by two 50-foot shafts, a 25 and a 30-foot shaft (all 50 feet apart) and a 30-foot open stope 10 feet deep. The northwest vein is explored by a vertical shaft of undetermined depth which may be the 90-foot shaft mentioned in early reports. (Aubury 02:7t; Merrill 16:732; Tucker 26:262).
Paymaster (Emilia, Hazel, President) mine SE¼ sec. 19, NW¼ sec. 30, T11S, R20E, SBM, Quartz Peak quadrangle (15 minutes), northeast arm of the central Chocolate Mountains, 3½ miles N 34 degrees E of Mount Barrow, 3 Miles S 62 degrees W of Midway Well. Harold S. Jackson, 5595 Oasis Ave., P.O. Box 283, Twenty-nine Palms (1961)	A fissure vein along a contact between gneiss (footwall) and a foliated fine to medium-grained granitic rock. The vein ranges from 3–42 feet in width and has been explored for at least 4000 feet along the strike. Average width is 4–10 feet. It strikes from N 35 degrees E in its southwestern parts to N 65 degrees E at its northeast end, and dips 65–75 degrees NW. Both walls of the vein are severely brecciated for as much as 10 feet on either side of the vein. The primary ore minerals contained in the vein are galena, argentite and minor chalcopyrite and sphalerite. Secondary ore minerals include cerrussite, cerargyrite, and various copper oxides. Gangue minerals include quartz, calcite, barite, pyrite and hydrous iron oxides (private report). The productive parts of the vein are divided into three parts, the Paymaster, President, and Hazel workings. The Paymaster workings contained one principal ore shoot. It was essentially vertical in its longest	This mine was worked as early as 1867, and its principal period of activity was from that date until 1880; but no official record of production is available. A 15-stamp mill was erected on the property during that period. This and other supplies and equipment were shipped from San Francisco by boat via the Gulf of California and the Colorado River to a point near Arroyo Seco about 13 miles northeast of the mine. Water was pumped from the same point to the mill. After the mine closed in 1880 the mill was disassembled and removed to the Cargo Muchacho mine in the Cargo Muchacho Mountains. Production is recorded also for the years 1919–1921 and 1938–1939. In 1922 and 1923 tailings from the millsite were cyanided. Total production based on rough calculation of open ground is about 25,000 tons, valued at $170,000. Value is based upon the average grade of ore mined

Silver—Lead—continued

Name, location, owner	Geology	Remarks and references
	dimension. The President workings, about 1400 feet northeast, contained two principal ore shoots, a hanging wall streak and a main streak. Ore shoots at the Hazel which is 1500 feet northeast of President workings, were not determined. Areas between the three workings apparently are unexplored, except for surface trenching and shallow shafts.	during the years since 1919 using 50 cents per ounce of silver, 3 cents per pound of lead and 5 cents per pound of zinc. Tonnage estimate may be as much as 50 percent in error because of poor stope width data, etc.; value is subject to even more error. The Paymaster workings are developed by a 325-foot inclined shaft and several hundred feet of other workings. A stope 125 feet long and 8–15 feet wide extends from the 2nd level to the surface (about 225 feet). The President workings are developed by a 450-foot inclined shaft with levels at 50-foot intervals totaling at least 1000 feet of horizontal workings. Ore has been stoped discontinuously from the 400 level to the surface. The greatest lateral extent mined was about 150 feet. The Hazel deposit was explored by a 50-foot and a 100-foot shaft with undetermined lateral workings. (Irelan 88:516; Merrill 16:732; Newman 22:47; Oesterling and Spurck 64:150; Tucker 26:262–264; Tucker and Sampson 40:20; Sampson and Tucker 42:126, 127, 128; Goodwin 57:448t; Oesterling and Spurck 64:150).
President		See Paymaster mine.
Rainbow (Consolidated Buena Suerte) prospect Reportedly in sec. 24, T11S, R20E, SBM, Quartz Peak quadrangle (15 minutes), north side of central Chocolate Mountains, about 3 miles southeast of Midway Well; not confirmed, 1964 Undetermined, 1964	Four-foot-wide vein extending 700 feet at an undetermined attitude; associated with an andesite dike.	Not visited. Developed by a 40-foot shaft. (Oesterling and Spurck 64:150).
Silver King prospect Reportedly in sec. 23, T12S, R19E, 14 miles northeast of Glamis; not confirmed, 1962. Undetermined, 1962; Charles Kurton, Glamis; R. D. Gunn and R. D. Glick, Colton (1942).	Irregular occurrences of galena, gold, and copper oxides along fractures in an aplite dike that strikes N 10 degrees W and dips 60 degrees SW.	Uncorrelated old name; not visited, 1962. Explored by a 29-foot shaft in the footwall side of the dike. (Sampson and Tucker 42:128).
True Friend and Silver Moon mine Reportedly in NW¼ sec. 25, T11S, R20E, SBM, Quartz Peak quadrangle (15 minutes), north side of the central Chocolate Mountains, Paymaster district, about 4 miles southeast of Midway Well; not confirmed, 1962 Undetermined, 1962; Frank Beal, Brawley (1926)	Undetermined silver minerals in a vein composed largely of manganese and iron-stained barite along the contact between gneiss and porphyry. The vein strikes N 20 degrees E and dips 80 degrees NW.	Uncorrelated name; not visited, 1962. Development consists of an adit driven 150 feet S 50 degrees W with a 50-foot crosscut west at 70 feet. Two hundred feet south of the portal over the top of the ridge is a 50-foot shaft. (Newman 22:47; Tucker 26:267; Sampson and Tucker 42:131; Oesterling and Spurck 64:150).

Stone

Building stone was mined from one locality in Imperial County, about 3½ miles southwest of Midway Well. The material is a white, flaggy tuff interbedded with flaggy tuffs and thin beds of limestone in a lacustrine sequence of Tertiary age.

This material was used in the construction of structures at the Paymaster mine prior to 1900. A small quantity was sold in the 1950s for an undetermined use.

Name, location, owner	Geology	Remarks and references
Undetermined Location NW¼NW¼ sec. 30, T11S, R20E, SBM, Quartz Peak quadrangle (15	The material mined consists of white flaggy tuff which occurs interbedded with a Tertiary lacustrine sequence consisting of well-bedded	Undetermined but low production. Development limited to a small surface cut. Apparently this material was utilized for various

Stone—continued

Name, location, owner	Geology	Remarks and references
minutes), about 36 miles southwest of Blythe, 3.5 miles S 60 degrees W of Midway Well, northwest of the Paymaster mine. George Burslem, Box 1278, Brawley	white to gray flaggy tuffs and thin beds of gray and brown limestone. In this area the unit crops out in a northeast-trending body about 500 feet wide and 1 mile long. The white tuff member is less than 50 feet thick. The material cleaves readily into plates ½ inch to 2 inches thick. Large slabs would be difficult to extract, as the rock is only moderately well-consolidated and tends to break into pieces about 1 foot in diameter. No overburden is present.	structures at the Paymaster mine prior to 1900. It was sold for undetermined use in the 1950's.

Strontium

Strontium in the form of celestite ($SrSO_4$) occurs as thin beds capping the massive gypsum beds at the northwest end of the Fish Creek Mountains. Stratigraphically the gypsum lies between Miocene nonmarine Split Mountain Formation and Pliocene marine Imperial Formation. Only one locality is known, the Roberts and Peeler mine, which lies partly in San Diego County. Production was intermittent from 1916 to 1945 and totals about 8,000 tons valued at an average of $16 per ton.

Name, location, owner	Geology	Remarks and references
Peters and Roberts mine		See Roberts and Peeler mine.
Roberts Celestite deposit		See Roberts and Peeler mine.
Roberts and Peeler (Peters and Roberts, Roberts Celestite) mine NE¼ sec. 13, T13S, R8E, (San Diego County) and SW¼ of NW¼ sec. 18, T13S, R9E, SBM (Imperial County), Borrego Mountain southeast quadrangle (7½ minutes), extreme northwest Fish Creek Mountains, 7 miles S 15 degrees E of Ocotillo Wells, transected by the San Diego-Imperial County line. M. N. Roberts, et al, 291 South Morengo Avenue, Pasadena (1963); leased to John A. Stephens, 3451 East 26th Street, Los Angeles (1963)	Six erosional remnants of a relatively pure bed of celestite resting on a 50–65-foot (stratigraphic) thickness of gypsum. Isolated bodies of celestite, as much as 150 feet by 200 feet in plan, cap five small peaks within an area 1000 feet in diameter. The gypsum beds containing the celestite rest conformably upon the Miocene Split Mountain Formation. A transition zone about 10 feet thick separates the two units. The gypsum body itself is an isolated remnant underlying about 20 acres. It is cut by a vertical fault trending north-northeast which downdrops the western block about 15 feet on north and 40 feet on the south. The beds in the western block strike due north and dip about 1–2 degrees E, and those in the eastern block strike N 10 degrees W and dip 7–9 degrees NE. The contact between the gypsum and celestite appears to be relatively sharp, but the lower few inches of celestite contains reentrant masses of gypsum. The celestite is light-gray with a slightly yellowish cast, fine-grained, mostly granular, massive, fairly dense material which averages 5 feet in thickness. Small vugs a few millimeters in diameter are common. These are lined with fine needle-like crystals of celestite; long prismatic crystals and radiating aggregates are not uncommon in the dense portions. The celestite weathers to a slightly brownish color, darker than the underlying gypsum. The average grade of the deposit exceeds 93 percent celestite or about 53 percent SrO.	This deposit was operated as early as 1916 when 40 tons were shipped to Los Angeles, but most of the material was mined by Pan Chemical Company from 1939 to 1945. About 8000 tons have been mined and shipped from the property. Development consists of shallow open cuts a few tens of feet in diameter. (Tucker 21:271; Moore 36:154, 155; Sampson and Tucker 42:136; Durrell 53:5–7; Ver Planck 52:28, 29, 32, 34, 35; 57:607–611; Weber 63:268–270).

Sulfur

Although three deposits of sulfur have been reported previously in Imperial County, none was visited in 1962. One is reported to be in the Chocolate Mountains east of Niland, another 6 miles north of 4S Ranch and 1½ miles west of the Colorado River, and a third 7 miles north of Coyote Wells in the Coyote Mountains. An undetermined amount was mined for agricultural use from the latter deposit in 1940 and 1941.

Sulfur–continued

Name, location, owner	Geology	Remarks and references
Coyote Mountains Sulfur (Swallow) deposit Reportedly in sec. 6, T16S, R10E, Coyote Mountains; 7 miles north of Coyote Wells; not confirmed, 1962. Undetermined, 1962; M. A. Turner and Associates, San Diego (1926); Vesubio Mining Corporation Ltd. leased (1957)	Sulfur reportedly occurs with gypsum along a fault zone 8–10 feet wide that strikes N 70 degrees E for a distance of 100 feet. It is more resistant to weathering than the surrounding granitic rocks, schist, and limestone.	Uncorrelated old name; not visited, 1962. Developed by a short crosscut adit, pits and an open cut. Small amounts reportedly were mined for use in conditioning alkali soils. Total yield unrecorded. (Tucker 26:284; Murdoch and Webb 56:317; Lydon 57:614).
Full Moon prospect Reportedly in sec. 36, T10S, R16E, SBM, southeast flank of the Chocolate Mountains, east of Niland; not confirmed, 1962.	Solfatarically deposited sulfur along fractures in tufa.	Uncorrelated old name; not visited, 1962. (Tucker 26:285; Sampson and Tucker 42:144; Murdoch and Webb 56:317).
Swallow mine Undetermined, 1962; J. Thebo, La Mesa (1926)		See Coyote Mountains Sulfur
Undetermined Reportedly in the Chocolate Mountains, 4 miles north of the 4S Ranch and 1½ miles west of the Colorado River. Undetermined, 1962.	Occurs in a vein with claudetite, kaolin, gypsum and halloysite.	Not visited, 1962; mineral occurrence only. (Palache 34:194–205; Kelley 36:137–138; Murdoch and Webb 56:317).

Tungsten

Although over-all county production is small, tungsten deposits are found at several scattered localities in Imperial County. Most of the 2,128 tons of recorded production came from the P.K. mine in the Jacumba Mountains in the extreme southwestern corner of the county. The remainder came from deposits in the Cargo Muchacho Mountains (Cargo Muchacho mine), the Potholes area (White Rock mine), the Paymaster district (Bluntach mine), and the Chipmunk and "Grand Beds" prospects (localities not reported). Another prospect, with no recorded production, is the Black Hawk in the Chocolate Mountains north of Glamis.

The P.K. deposit consists of scheelite ($CaWO_4$) in tactite of a small roof pendant in quartz diorite. At the Cargo Muchacho mine and other prospects in that area, scheelite occurs in gold-bearing quartz veins. Placer scheelite is reportedly present in the "Mesquite Diggins" area of the Paymaster district. The remaining occurrences are of undetermined types.

All of the recorded production for the county was mined in 1953–55 during the Federal stockpiling program.

Name, location, owner	Geology	Remarks and references
Black Eagle prospect Center E½ sec. 32, NW¼ sec. 33, T11S, R18E, SBM, Acolita quadrangle (15 minutes), central Chocolate Mountains, 28 miles northeast of Brawley, 4 miles due south of Blue Mountain. (Lies within the Chocolate Mountains Aerial Gunnery Range)	Undetermined tungsten minerals in a quartz vein in actinolite schist.	Prospected about 1942 by a short west-trending adit and shallow surface cuts. Not visited, 1962.
Bluntach mine Undetermined, 1964; reportedly in the Paymaster district near Mesquite Diggins placer gold deposit. D. L. Bluntach, Box 25, Glamis (1954)	Reported to be a placer deposit.	Small production amounting to less than 20 tons in 1953.
Cargo Muchacho mine		See under Gold.
Chipmunk prospect Undetermined B. J. Recker, address undetermined		Not visited 1961. Small production amounting to less than 20 tons in 1954.
Elliott mine		See PK mine.

Tungsten—continued

Name, location, owner	Geology	Remarks and references
"Gravel Beds" Undetermined H. R. West, address undetermined (1953)		Small production amounting to less than 25 tons in 1953. (U.S. Bureau of Mines files).
Graypoint mine Undetermined section in the Cargo Muchacho Mountains. Undetermined	Scheelite in gold bearing quartz veins.	Uncorrelated name; not visited, 1962. No recorded production (Bateman and Irwin 54:39).
La Colorado mine		See under Gold.
PK (Elliott) mine NE¼ of NE¼ sec. 8, T18S, R9E, SBM, In-ko-pah Gorge quadrangle (7½ minutes), Jacumba Mountains, 6½ miles east of Jacumba, 3.8 miles S 22 degrees E of Mountain Spring, about 1000 feet north of the Mexican border. J. R. Elliott, address undetermined.	An irregular tactite body in a small roof pendant in Mesozoic quartz diorite. The pendant is about 200 feet wide and 400 feet long and trends about N 70 degrees E. It has an irregular reentrant boundary that is roughly rectangular in shape. Schist, tactite, and thin beds of limestone make up the bulk of the pendant. Migmatized zones are common especially near the contacts with the quartz diorite. Irregular clusters of disseminated scheelite occur in an irregular tactite zone that trends about N 75 degrees E. The zone is near the central part of the pendant and is 30-50 feet wide and 50–60 feet long.	Originally a gold prospect. Opened and developed for tungsten during government purchase program between 1951 and 1958. Total production is about 2000 tons of ore averaging 0.33 percent WO_3. Developed by an open pit 30 feet wide, 50 feet long with a maximum depth of 25 feet. A 50-foot drift-adit was driven S 75 degrees W 40 feet below and slightly northwest of the pit. The drift is connected to the bottom of a 25-foot vertical shaft. Appended to the 15-foot level of the shaft is about 70 feet of horizontal workings which connect with the northwest wall of the open pit. Several other shallow cuts and shafts explore zones peripheral to the roof pendant.
Roark mine SW¼ of SW¼ sec. 16, T17S, R10E, SBM, Coyote Wells quadrangle (7½ minutes), eastern Jacumba Mountains, 4.9 miles S 17 degrees E of Ocotillo. Mr. Edward T. Roark, El Centro (1958)	A weakly silicated zone in a limestone bed which strikes N 60 degrees W and dips 55 degrees SW. The bed is at least 25 feet thick, but is poorly exposed because of surface debris. The footwall is a 5–10 foot wide dike of acidic composition and the hanging wall is schist. The zone contains disseminated spotty occurrences of scheelite. The lateral extent of the zone was not determined.	Discovered and developed during the period of the General Service Administration purchase program (1951–1958). Little or no production. Explored by a 30-foot vertical shaft with 80 feet of horizontal workings at the 30-foot level.
Shinebright mine Undetermined section in the Cargo Muchacho Mountains. Undetermined.	Scheelite in gold bearing quartz veins.	Uncorrelated name; not visited, 1962. (Bateman and Irwin 54:39).
Shineright mine Undetermined section in Cargo Muchacho Mountains Undetermined, 1962	Scheelite in gold bearing quartz veins.	Uncorrelated name; not visited, 1962 (Bateman and Irwin 54:39).
White Rock mine Undetermined, reportedly in the Potholes mine area (see under Gold). Donald Chaney, address undetermined, 1955		Small production reported in 1955 (U.S. Bureau of Mines files).
Undetermined prospect no. 1 NW¼ of SE¼ sec. 31, T15S, R9E, SBM, Carrizo Mountain quadrangle (7½ minutes), on the south flanks of the Coyote Mountains, 7.7 miles N 43 degrees W of Ocotillo, 4.1 miles S 82 degrees W of Carrizo Mountain. Undetermined, 1961	Several discontinuous calc-silicate zones in a gneiss-schist-limestone complex. The zones apparently are aligned roughly in an east-west direction from the top of a relatively flat hill eastward to the bottom of a northwest-trending wash, a distance of about 2000 feet. As the limestone bodies in the general area also trend eastward, a strong possibility exists that the mineralized zone lies in a remnant resulting from assimilation of a former limestone bed.	Little or no production. Developed by several bulldozer cuts and a 20-foot crosscut adit driven northwestward. Prospected during the period 1953–58.
Undetermined prospect no. 2 NW¼ of NW¼ sec. 20, T17S, R10E, SBM, Coyote Wells quadrangle (7½ minutes), Jacumba Mountains, 5.0 miles S 5 degrees E of Ocotillo, east of Davies Valley. Undetermined, 1961	Tactite zone in a 6-foot limestone bed which strikes N 5 degrees W and dips 25 degrees SW. The hanging wall and footwall rock is quartz muscovite biotite schist. The tactite zone is discontinuous, but is exposed in two localities 800 feet apart.	Little or no production. Developed by a 25-foot inclined shaft at the top of an east-trending ridge. A 10-foot vertical shaft was sunk 800 feet southwest of the inclined shaft.

Tungsten—continued

Name, location, owner	Geology	Remarks and references
Undetermined prospect no. 3 NE¼ sec. 19, T17S, R10E, SBM, Coyote Wells quadrangle (7½ minutes), Jacumba Mountains, 5.1 miles due south of Ocotillo, east rim of Davies Valley. Undetermined, 1961	Weakly silicated zone in gneiss. Tungsten content undetermined.	No production. Explored by shallow cuts.

Uranium

Although no uranium production has come from mines in Imperial County, several occurrences are known. These crop out mainly in the central Chocolate Mountains, and one lies in the Cargo Muchacho Mountains.

Three of the deposits are in an area associated with acid igneous rocks, and two are in metasedimentary rocks that have been intruded by Tertiary dikes. All of the deposits occur in hydrothermally altered shear zones. Among the minerals identified by the Atomic Energy Commission are torbernite ($Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$), metatobernite ($CuO \cdot 2UO_3 \cdot (PO_4)_2 \cdot 8H_2O$), autunite ($Ca(UO_2)_2(PO_4)_2 \cdot 10H_2O$), and carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$) (Walker, Lovering, and Stephens, 1956, p. 26–27).

Name, location, owner	Geology	Remarks and references
American Girl mine		See under Gold.
Crown Uranium (Teen-Cal Group) prospect NW¼ sec. 36, T12S, R19E, SBM, Quartz Peak quadrangle (15 minutes), Chocolate Mountains, Paymaster district, about 35 miles northeast of Brawley, 10 miles S 25 degrees W of Midway Well. State of California (school section) (1965); formerly leased by W. H. Fielden, P.O. Box 341, Brawley	Torbernite and yellow uranium minerals in a hydrothermally altered zone near the contacts of quartzite, sericite schist, and a small basic dike. The contact between the schist and quartzite is a fault that strikes nearly east-west and appears to be nearly vertical. The basic dike lies adjacent to this contact and mostly within the quartzite at the surface in an area several tens of feet west and southwest of the workings. It is about 50 feet wide parallel to the contact and 150 feet long from north to south. Another much larger dike intrudes the schist across a wash to the south. The highest uranium content appears to occur in a poorly defined pyrophyllite-rich zone within the quartzite unit 15 to 100 feet east of the basic dike and 50 to 100 feet north of the quartzite-schist contact. Atomic Energy Commission samples indicate a uranium content as much as 0.293 percent. Other minerals present within the zone include gypsum, pyrophyllite, kyanite and minor fluorite, iron, and manganese oxides.	The property is developed by a bench cut about 80 feet long and 30 feet wide and 10 to 15 feet high at the face and several smaller cuts the largest of which is about 50 feet long, 20 feet wide, and 6 feet deep. A vertical shaft a few tens of feet deep connects with a drift-adit driven an undetermined distance westward. In March 1959 about 1000 tons of material (presumably pyrophyllite) was shipped to Mexicali for use as an insecticide carrier. No other production is recorded. (Walker, Lovering, and Stephens 56:26; Anonymous, undated A.E.C. maps).
Fair Diane SW¼ sec. 12, T10S, R15E, SBM, 11 miles N 60 degrees E of Niland, Iris Pass quadrangle (15 minutes), ½ mile west of Lion Head Mountain, at the southwestern base of the Chocolate Mountains, just northwest of the point where the Niland-Blythe road enters the range. Lies within the Chocolate Mountains Aerial Gunnery Range; Stan Bergman, 817 East Empire, Spokane, Washington (1962)	Shear-zone marking contact between a hybrid granitic rock on the southwest and quartz monzonite on the northeast. The zone strikes N 40 degrees W and dips 55 degrees SW. No uranium minerals were identified.	Explored by two crosscut-adits driven northeast. The southeastern one was driven about 70 feet towards the zone but did not intersect it. About 100 feet north, the other adit was driven about 100 feet northeastward with an appended heading driven 30 feet northeastward near the end of the crosscut. The shear zone was intersected in the crosscut at a point about 40 feet from the portal but was not explored farther. No production was apparent in 1961.
Lady Katy prospect Reportedly in sec. 7, T9S, R14E, SBM, Frink quadrangle (15 minutes), about 18 miles northeast of Niland, about 6 miles northeast of Frink; not confirmed, 1962.	Metatorbernite(?) in hydrothermally altered fractures in acidic igneous rocks. Gangue minerals include quartz and hydrous iron oxides.	Radiation intensity where metatorbernite is found is 45 times background count. Atomic Energy Commission samples contained as much as 0.374 percent U_3O_8 (Walker, Lovering, and Stephens 56:10t, 26–27).

Uranium—continued

Name, location, owner	Geology	Remarks and references
Chocolate Mountains Aerial Gunnery Range; claimed by Larry Cronkhite and Grover Burgoyne, Brawley (1956)		
Lucky Star prospect		See McKnight clay deposit.
Tenn-Cal Group		See Crown Uranium prospect.

Zinc

Sphalerite (ZnS) is reported to occur in a 6-inch stringer in limestone in the vicinity of the Imperial-San Diego-Mexican border. This occurrence has not been substantiated.

Name, location, owner	Geology	Remarks and references
Southern Star Group prospect Reportedly in secs. 30 and 36, T17S, R8 and 9E, SBM, near the Mexican and San Diego-Imperial County borders; not confirmed, 1962. Undetermined, 1962; C. E. Weaver, 105 East 1st Street, Los Angeles (1926)	Sphalerite in a 6-inch stringer in "limestone" (?).	Completely uncorrelated name and location; not visited, 1962. Reportedly discovered in 1911 but not worked on until 1925. Probably long abandoned. (Tucker 26:267).

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