STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

GEOLOGY OF THE SALTDALE QUADRANGLE CALIFORNIA

BULLETIN 160
1952

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

SAN FRANCISCO | BULLETIN 160 | SEPTEMBER 1952

GEOLOGY OF THE SALTDALE QUADRANGLE, CALIFORNIA

By T. W. DIBBLEE, JR.

and

MINERAL DEPOSITS OF SALTDALE QUADRANGLE

By T. W. DIBBLEE, JR. and T. E. GAY, JR.

LETTER OF TRANSMITTAL

To His Excellency
The Honorable Earl Warren
Governor of the State of California

Dear Sir:

I have the honor to transmit herewith Bulletin 160, *Geology of the Saltdale Quadrangle, California*, prepared under the direction of Olaf P. Jenkins, Chief of the Division of Mines, Department of Natural Resources. The report includes a colored geologic map and many sections, charts, and other illustrations. The area lies partly in Kern County and partly in San Bernardino County. The author, T. W. Dibblee, Jr., and T. E. Gay, Jr., have contributed also an accompanying chapter on *Mineral Deposits of the Saltdale Quadrangle*. Maps and descriptions of the mineral deposits show the area to contain metallic ores of copper, gold, and silver and in addition several nonmetallic minerals, i.e. volcanic ash, perlite, pumice, gypsum, salt, borax, clay, flagstone, a little coal, and some ornamental minerals.

This report represents one of the outstanding accomplishments of the Division of Mines in its program of mapping the geology of the state by quadrangles, and relating the occurrences of mineral deposits to the structure and history of the rock formations.

Respectfully submitted,

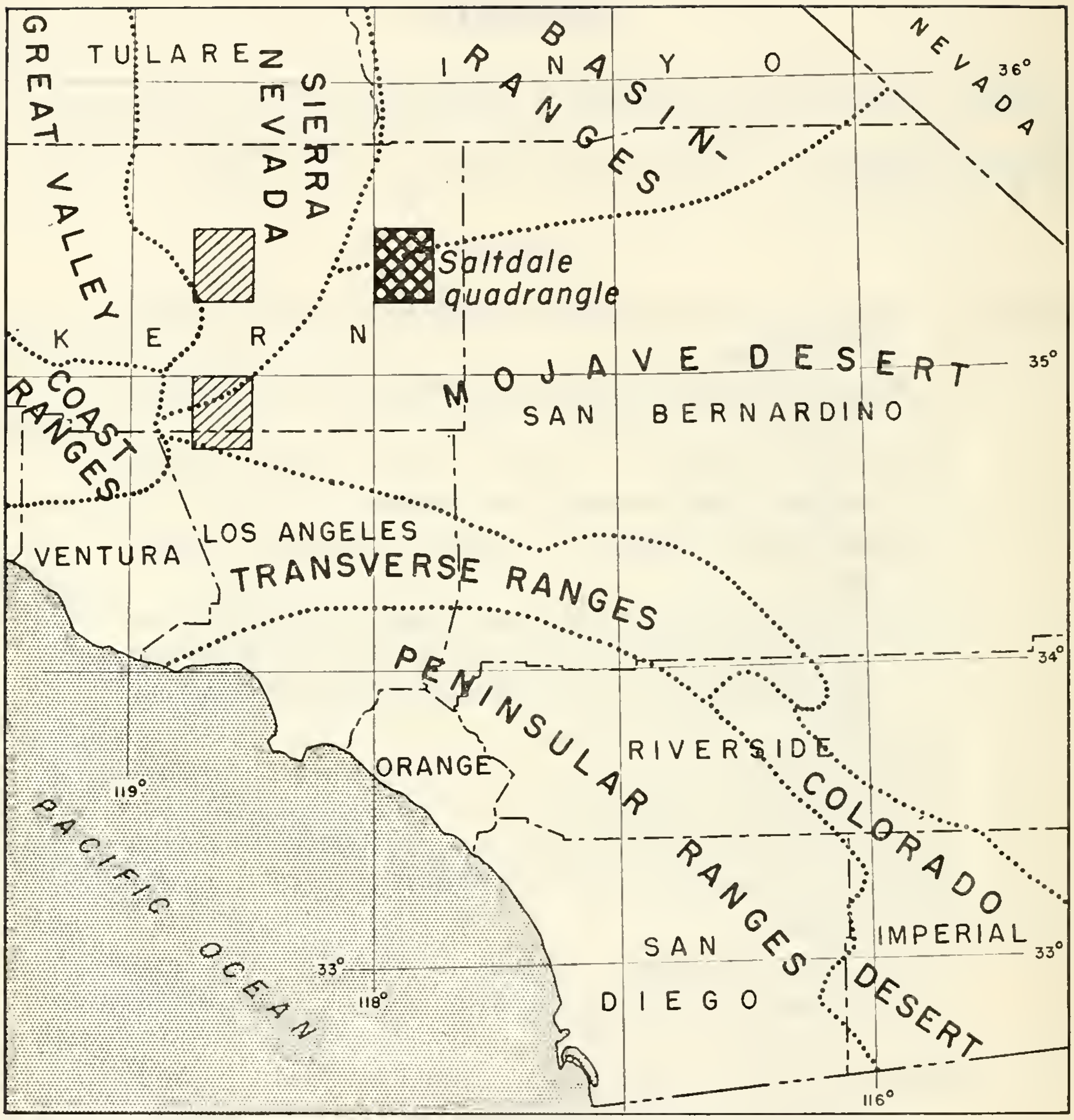
Warren T. Hannum, Director
Department of Natural Resources

July 16, 1952

CONTENTS

PLATES

2—58349



Index map of part of southern California showing geomorphic provinces and the location of the Saltdale quadrangle (heavy cross-hatch). Shown also (shaded) are the Neenach quadrangle recently published by the Division of Mines, and the Breckenridge Mountain quadrangle, in press.

GEOLOGY OF THE SALTDALE QUADRANGLE, CALIFORNIA

By T. W. Dibblee, Jr. *

OUTLINE OF REPORT

Illustrations

---

* Geologist, Richfield Oil Corporation. Manuscript submitted for publication March 1950.

ABSTRACT

The Saltdale quadrangle is in the southwestern Basin Ranges and northwestern Mojave Desert geomorphic provinces, in Kern County, California. It comprises parts of four physiographic features, which trend about N. 60° E. across the quadrangle. These are, starting from the north, Indian Wells Valley, the greater part of El Paso Mountains, Cantil Valley (an undrained alluvium-filled basin about 6 miles wide, which contains Koehn or Salt Dry Lake), and the southwestern part of the Rand Mountains. Elevations range from 1,950 feet at the dry lake to 5,050 feet in El Paso Mountains.

Formations within the Saltdale quadrangle may be divided into two main groups, a pre-Cretaceous basement complex, and a Cenozoic series of continental sediments and volcanics. The basement complex consists of pre-Cambrian (?) Rand schist, pre-Cambrian (?) Mesquite schist, the late Paleozoic Garlock series (23,000+ feet of shale, chert, quartzite, limestone, and volcanics), and plutonic intrusive rocks, probably Jurassic, ranging from granite to quartz diorite. The Garlock series, Mesquite schist, and plutonic rocks crop out in El Paso Mountains; but only the Rand schist and plutonic rocks are exposed in the Rand Mountains. The Cenozoic rocks consist of the Goler formation (6,500 feet of continental sediments, probably Miocene), the Ricardo formation (7,000 feet of Pliocene to Pleistocene continental sediments, tuff, and lava), and the Black Mountain basalt (100 feet of Pleistocene lava). These three formations crop out in El Paso Mountains, and are separated by unconformities.

El Paso Mountains constitute a block uplifted along El Paso fault at its southeastern base, and tilted northwestward. The Mesquite schist and Garlock series strike about N. 20° W. and dip steeply east. Most of the intrusive bodies that crop out in El Paso Mountains likewise follow this trend. The Cenozoic rocks crop out on the northwestern flank of the mountains and dip northwestward toward Indian Wells Valley.

The Rand Mountains within Saltdale quadrangle probably constitute a block uplifted along a buried fault at its northwestern base, and tilted gently southeastward. Within the quadrangle, these mountains consist mainly of granitic rocks; but one remnant of Rand schist is exposed in the northeastern portion of the block.

The Garlock fault trends about N. 60° E. through the northwestern margin of Cantil Valley. It is concealed by alluvium along most of its course, except for a small scarp at Garlock Station. Small northeast-trending depressions in the uplifted alluvial fan immediately north of this scarp are tension-grabens developed by left-lateral shearing along the Garlock fault.

Deposits of economic value consist of low-grade ores of copper and silver in brecciated zones in the basement rocks; gold-bearing gravels; and volcanic ash (seismotite) of abrasive quality and perlite in the Ricardo formation. Gypsum and alkaline salts are concentrated by evaporation in Koehn Dry Lake.

INTRODUCTION

Geologic Setting. The Saltdale quadrangle, located in the western margin of the undrained Great Basin, straddles the southwestern corner of the Basin-Ranges geomorphic province and the northwestern margin of the Mojave Desert geomorphic province. The recently active Garlock fault separates the two provinces. From Lebec, where it leaves the San Andreas fault, the Garlock can be traced northeastward for about 150 miles through the desert; it passes through the middle of the Saltdale quadrangle.

Movement on the Garlock fault has been essentially left lateral, the southeastern or Mojave Desert block having moved relatively to the northeast. The movement is measurable in miles; but neither the total displacement nor the earliest period of faulting is definitely known. Vertical uplifts and depressions have been developed along the fault, but they are local. The Basin Ranges province northwest of the break is an area of north-trending valleys and mountain ranges, most of which are bounded by normal faults. In marked contrast, the Mojave Desert province southeast of the break is essentially a great peneplain; its hills and low mountains have no definite trend, but appear to be erosional remnants of a surface that was once higher.

The basement complex in the general vicinity of Saltdale quadrangle is essentially a granitic batholith containing local remnants of early Mesozoic, Paleozoic, and pre-Cambrian (?) metasediments and metavolcanics. It is overlain by Tertiary nonmarine sedimentary, pyroclastic, and volcanic rocks, deposited in local basins. El Paso Mountains, within Saltdale and Randsburg quadrangles, contain a Paleozoic series about 38,000 feet thick, and two Tertiary formations totaling more than 13,000 feet in thickness. The Tertiary section in El Paso Mountains is one of the thickest known in the Mojave Desert region.

Location and Culture. The Saltdale quadrangle map (1943) is one of the 15-minute series, scale 1:62,500 (1 inch = 1 mile), issued by the War Department, Corps of Engineers, U. S. Army; it covers the northwest quadrant of the southwest quadrant of the old Searles Lake quadrangle, a 60-minute map, scale 1:250,000 (1 inch = 4 miles), issued by the U. S. Geological Survey in 1915.

Saltdale quadrangle is traversed by two paved roads: U. S. Highway 6, running north near the western border, and a secondary highway running northeast through the central part of the quadrangle. Branching off from these highways are many dirt roads.

In the 242 square miles covered by the quadrangle, there are no towns. The largest settlements are Cantil, Gypsite, Saltdale, and Garlock stations along the Southern Pacific Railroad, which runs northeast through the central part of the quadrangle. Randsburg, a mining town 6 miles beyond the eastern border of the quadrangle, and Mojave, a railroad junction 20 miles beyond the southern border, are the nearest towns. Los Angeles is about 130 miles distant to the south.

As the area is strictly desert, industry is confined mainly to quarrying and mining. A small amount of alfalfa is raised near Cantil, where sufficient water is obtained from wells.

Climate. The climate of Saltdale quadrangle is typical of the Mojave Desert. The air is dry and clear the year round; fog and dew are almost unknown. Summers are very hot, and the summer daytime temperatures generally exceed 100°; winters are mild to cold, and the winter nighttime temperatures usually fall below freezing.

Average annual precipitation is less than 5 inches. Rain seldom falls; the winter storms, many of which bring rain in the mountains to the west, pass over the desert as high winds. Nevertheless, heavy downpours do come occasionally. Electrical storms, which sometimes develop local cloudbursts, may take place any time from April through October.

Vegetation. Vegetation in Saltdale quadrangle is the typical scanty sagebrush characteristic throughout the Mojave Desert—creosote bush (*Larrea divaricata*), burro bush (*Fransaria dumosa*), and buckwheat (*Erigonum*). This flora is uniform and constant throughout the quadrangle, and is not influenced by physical or geologic factors. However, in Inyokern Valley and on the northern slopes of El Paso Mountains, especially in sandy places, is an admixture of *Ephedrium* and other species of brush; also Joshuas (*Yucca*), chollas, and, following winter rains, some grasses and flowering annuals.

Exposures. Exposures are excellent throughout the hills and mountains, which are almost devoid of soil and are undergoing rapid erosion. The various rock formations react differently to weathering and erosion under arid conditions. Granitic rocks weather by rapid mechanical disintegration, and form round-crested hills with smooth slopes, and steep-walled canyons that contain the only prominent exposures. Metamorphic rocks disintegrate and tend to form rounded hills covered with loose fragments and talus. Resistant chert forms prominent ledges. The soft Tertiary sedimentary rocks are rapidly eroded to badlands in which resistant lava flows crop out prominently.

Previous Literature. In 1896 Fairbanks [1] published a brief description of the sediments and interbedded tuffs and volcanic flows on the north slope of El Paso Mountains. Fossil leaves from these beds were identified by F. H. Knowlton,[2] who determined that they were Tertiary, probably Eocene, in age. Four years later, in 1900, Smith [3] named the series the "Mojave formation". In 1902, Hershey [4] studied the Tertiary sediments near Rosamond and named them the Rosamond series; in the same report he named the Barstow formation, from its occurrence near Barstow. In 1912 Baker [5] described the physiography and some of the geology of the southern Sierra Nevada and western El Paso Mountains.

In 1909 Hess [6] named the Garlock fault, which he recognized at Garlock while mapping the Randsburg quadrangle. He did not complete the mapping, but Hulin later continued the work, and in 1925 published a description of the geology and ore deposits.[7] Hulin extended his mapping over much of the old Searles Lake quadrangle, including that portion covered by the Saltdale quadrangle; it was never published, however, except on the geologic map of California, scale 1:500,000.[8] In 1934, Hulin published a paper on the geology of the gold-bearing gravels of El Paso Mountains.[9]

In 1917, Merriam [10] named and described the Ricardo formation, from which he collected Pliocene mammalian fossil bones. In 1934, Simpson [11] mapped and described the geology of the Elizabeth Lake quadrangle, which is in the Mojave Desert province south and west of Saltdale quadrangle.

---

1 Fairbanks, H. W., Notes on the geology of eastern California: Am. Geologist, vol. 17, p. 63, 1896.
2 In Fairbanks, H. W., Op. cit., pp. 67-68.
3 Smith, J. H., The Eocene of North America west of the 100th meridian (Greenwich): Jour. Geology, vol. 8, pp. 455-456, 1900.
4 Hershey, O. H., Some Tertiary formations of southern California: Am. Geologist, vol. 29, pp. 365, 369-370.
5 Baker, C. L., Physiography and structure of the western El Paso Range and the southern Sierra Nevada: Univ. California Dept. Geol. Bull., vol. 7, pp. 117-142, 1912.
6 Hess, F. L., Gold mining in Randsburg quadrangle, California: U. S. Geol. Survey Bull. 430, pp. 23-47, 1909.
7 Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle, California: California Min. Bur. Bull. 95, pp. 1-152, 5 maps, 1925.
8 Jenkins, Olaf P., Geologic map of California, scale 1:500,000, California Div. Mines, 1938.
9 Hulin, C. D., Geologic features of the dry placers of the northern Mojave Desert: California Div. Mines Rept. 30, pp. 417-426, 1934.
10 Merriam, J. C., Relationship of Pliocene mammalian faunas from the Pacific Coast and Great Basin provinces of North America: Univ. California Dept. Geol. Bull., vol. 10, pp. 421-443, 1917.
11 Simpson, E. C., Geology and mineral deposits of the Elizabeth Lake quadrangle, California: California Div. Mines Rept. 30, pp. 371-415, map, 1934.

PHYSIOGRAPHY

The Saltdale quadrangle includes parts of four topographic features, which trend in a general northeasterly direction. These, in order from southeast to northwest, are the Rand Mountains, Cantil Valley, El Paso Mountains, and Indian Wells Valley.

Rand Mountains. The low range known as the Rand Mountains extends southwest from Randsburg quadrangle into the southeastern part of Saltdale quadrangle. The northwestern flank of this range rises abruptly from Cantil Valley to an even crest line about 2 miles southeast, which attains an elevation of about 3,800 feet near the eastern border of Saltdale quadrangle. Southward from this crest line the terrain slopes very gently and blends into the extensive peneplain of the Mojave Desert. The comparatively abrupt northwestern flank is a younger erosion surface; it is in the late-mature stage of the erosion cycle. The base of the northwestern flank is buried under a great thickness of piedmont alluvial-fan material, which slopes toward Cantil Valley, and which extends far up the canyons.

Cantil Valley. Cantil Valley is an almost level, undrained, alluvium-filled basin about 6 miles wide, which trends approximately N. 60° E. between Rand Mountains and El Paso Mountains. Toward the southwest it opens into the Mojave Desert; toward the northeast it gradually rises to a low pass in the Randsburg quadrangle. Koehn (Salt) Dry Lake is in Cantil Valley, at an elevation of 1,920 feet—the lowest in Saltdale quadrangle.

El Paso Mountains. El Paso Mountains trend about N. 60° E. through the northern part of Saltdale quadrangle. Toward the northeast they extend into the Randsburg quadrangle; toward the southwest they taper down to a low gap, at the border of Saltdale quadrangle. The Tehachapi Mountains rise beyond the gap, and extend to the southwest.

The southeastern base of El Paso Mountains is remarkably straight, trending N. 60° E., and averaging about 2,250 feet in elevation. The southeastern flank rises abruptly within 2 miles to a line of peaks 3,250 to 5,050 feet in elevation. These are made up of metamorphic and granitic rocks, and constitute the core or main mass of the mountains. The range is characterized by the steep V-shaped canyons and slightly rounded peaks and ridges of the mature erosion stage.

The northwestern flank of El Paso Mountains slopes gently toward Indian Wells Valley over a distance of about 4 miles. Canyons are shallow, and the larger ones are alluviated. This area is made up mostly of soft sedimentary rocks dipping northwest. Here rapid erosion has formed the beautifully picturesque badland topography for which Last Chance and Redrock Canyons are famous. Resistant lava flows within the sediments form prominent strike ridges.

The Black Hills rise high above the low hills of the northwestern flank of El Paso Mountains to an elevation of 4,938 feet at Black Mountain. They have been preserved from erosion by a resistant lava cap, which dips gently northwestward into Indian Wells Valley.

The drainage system in El Paso Mountains is unusual in that the flanks of the range are not drained by normal consequent canyons starting at

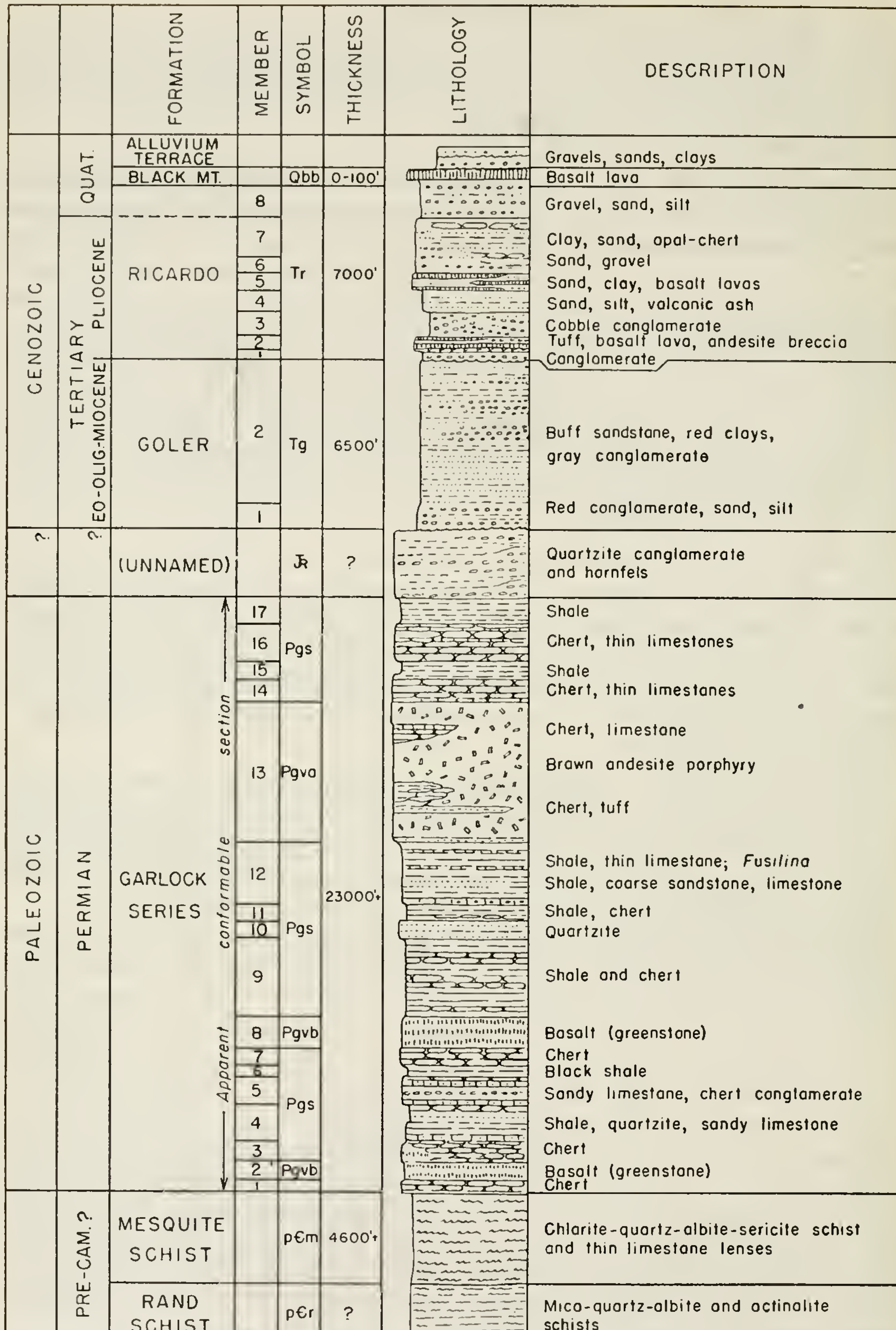


FIG. 1. Columnar section, Saltdale quadrangle.

the crest of the main mass, or basement core. Instead, the resistant core is cut through by the deep, narrow, antecedent gorges of Goler Gulch, Last Chance Canyon, and Redrock Canyon, which drain southward from the main drainage divide formed by Black Hills and the low hills to the east and southwest. This divide is considerably north of the basement core of El Paso Mountains.

Indian Wells Valley. The nearly level alluviated area in northwestern Saltdale quadrangle is a small part of a large, roughly triangular desert valley known as Indian Wells Valley, which contains the small town of Inyokern near its center. The portion lying within Saltdale quadrangle is slightly over 3,000 feet in elevation, and slopes gently northeastward. West of U.S. Highway 6 it is being dissected by the headwaters of Redrock Canyon.

STRATIGRAPHY

Pre-Cambrian (?)

Rand Schist

The Rand schist was mapped, named, and described by Hulin,[12] who reported an exposure 1,500 to 2,000 feet thick southwest of the town of Randsburg, in the Rand Mountains. In that region the most abundant rock is a silvery gray mica-albite-quartz schist in which schistose cleavage parallel to bedding is very prominent.[13] This rock is composed predominantly of anhedral grains of albite and quartz in a matrix of small flakes of muscovite and light-brown biotite. In general, the micas are oriented parallel to schistosity; locally, however, they curve around grains of albite and quartz. Greenish-gray actinolite schist is also a common rock type. The uppermost part of the exposed section contains a few thin beds of limestone and quartzite, some of which are several feet thick. The limestone is blue gray, but has white laminae, and is remarkably little metamorphosed as compared with the schists. The quartzite is buff colored and fine grained, and contains thin layers of mica. Lenticular veins of brittle white quartz as much as 5 feet in thickness are common in the Rand schist;[14] some are parallel to the schistose cleavage, but most cut across it.

In lithology, the Rand schist is identical with the Pelona schist of the Sierra Pelona Mountains[15] and Cajon Pass area. The two are probably correlative.

Exposures of Rand schist extend westward into Saltdale quadrangle for about 3 miles, where they crop out on the north slope of the Rand Mountains. Here a partial section, totaling about 2,000 feet, is exposed. The schist is compressed into several folds, and the uppermost layers are in contact with intrusive quartz monzonite. The greenish-gray actinolite facies, which is so abundant in Randsburg quadrangle, is not common in Saltdale quadrangle.

[12] Hulin, Carlton D., Geology and ore deposits of the Randsburg quadrangle, California: California Min. Bur. Bull. 95, 152 pp., 5 maps, 1925.
[13] Hulin, C. D., op. cit. 1925, pp. 23-26.
[14] Hulin, C. D., op. cit. 1925, p. 38.
[15] Simpson, E. C., Geology and mineral deposits of the Elizabeth Lake quadrangle, California: California Div. Mines Rept. 30, pp. 371-415, map, 1934.

Mesquite Schist

At Mesquite Canyon in El Paso Mountains, about 4,500 feet of chlorite-quartz-albite-sericite schist, herein named the Mesquite schist, is exposed. It is dark steel-gray when fresh, but weathers to light silvery gray. It is prominently and thinly bedded, and cleaves into thin slabs that have a silvery sheen. In the uppermost 500 feet are many interbeds of fine crystalline limestone, some as much as 10 feet in thickness.

The Mesquite schist dips to the east under the Garlock series. Contact with the overlying Garlock chert is well exposed in a short prospect tunnel on the west bank of Mesquite Canyon. It is sharp, but concordant, and is an important stratigraphic break, probably a disconformity. Apparently there has been some movement along it, for the formations are separated by about a foot of fault breccia. The lower part of the schist is granitized, or has been intruded by granite.

The Mesquite schist is finer grained than the Rand schist, and appears to be less metamorphosed. It is composed mainly of sericite, and is mottled with numerous dark greenish-gray spots of chlorite and quartz.[16]

The Mesquite chlorite-quartz-albite-sericite schist belongs to the green schist facies of metamorphism as described by Turner,[17] and formed as a result of low-grade regional metamorphism of argillaceous sediments. The calc-silicate hornfels zones in the recrystallized limestone are metamorphosed argillaceous impurities.

Age of the Schists

Neither the Rand schist nor its probable correlative the Pelona schist has yielded any fossils; for this reason, and because of their generally metamorphosed condition, they have been assigned a pre-Cambrian (?) age. According to C. W. Chesterman,[18] the Rand schist probably overlies the Johannesburg gneiss of supposed Archean age in the Randsburg area.

The Mesquite schist in El Paso Mountains has likewise yielded no fossils. Broadly speaking, it is similar to the Rand schist of the Rand Mountains; both are thin-bedded mica schists containing thin interbeds of fine-grained banded limestone and quartzite. In mineralogical content, however, the Rand and Mesquite schists are dissimilar; the latter, which represents a lower grade of metamorphism, is probably stratigraphically higher than the former. It is remotely possible that the Mesquite schist may represent the stratigraphically highest portion of the Rand schist, which is not exposed in the Rand Mountains.

---

[16] C. W. Chesterman, who collected and examined specimens of the schist, describes it as follows:

"Under the microscope the chlorite-quartz-albite-sericite schist is seen to be composed predominantly of small plates of sericite and xenoblastic grains of quartz and albite. The sericite is light colored, and forms flow-like streams around knot-like clusters of chlorite and quartz. Albite twinning is uncommon, but is found in a few of the grains of albite. The quartz is in the form of xenoblastic grains scattered throughout the rock, as narrow veins cutting the foliation, and in clusters with chlorite. Chlorite is common, most of it occurring as pale green pleochroic flakes and irregular patches. Chloritoid, on the other hand, is not as abundant as the sericite and chlorite. It occurs as dark bluish-green pleochroic grains, most of which are oriented more or less normal to the foliation. Inclusions of quartz and magnetite are common in the chloritoid.

"The limestone beds in the chlorite-quartz-albite-sericite schist consist almost wholly of crystalline limestone, which contains highly contorted ribs and bands of calc-silicate hornfels. The hornfels is for the most part a granoblastic aggregate of calcite, quartz, and zoisite grains, and needles of tremolite. Sphene, sericite, and phlogopite are all present in minor amounts."

[17] Turner, F. J., Mineralogical and structural evolution of the metamorphic rocks: Geol. Soc. America Mem. 30, pp. 96-99, 1948.

[18] Oral communication, 1950.

The Mesquite schist is either pre-Cambrian or early Paleozoic—more likely pre-Cambrian, as it disconformably underlies the Garlock series, which is a tremendous thickness of slightly metamorphosed sediments and volcanics of Paleozoic (in part Permian) age. That the sudden stratigraphic break between these two series represents an important time gap is indicated by the absence of schists from the Garlock series.

Paleozoic

Garlock Series

A tremendously thick series of slightly metamorphosed Paleozoic sediments and volcanics, in part if not all of Permian age, crops out in the northeastern part of El Paso Mountains within Saltdale quadrangle. This sequence, herein named the Garlock series, is exposed continuously from Mesquite Canyon northeastward, striking about N. 20° W. across El Paso Mountains and dipping steeply to the northeast. About 22,000 feet of section is exposed, if it is not isoclinally folded; but the possibility of repetition by isoclinal folding within the section, or even by strike faulting, should not be overlooked. The Garlock series extends into Randsburg quadrangle, where an additional 13,000 feet is exposed; there it was mapped by Hulin [19] as "undifferentiated Paleozoic."

Section of Garlock series in eastern El Paso Mountains, Randsburg quadrangle. *

	Feet
Quartz monzonite or quartz diorite (intrusive)	
Member 21	
Limestone, white, medium crystalline, metamorphosed	0– 500
Siltstone, dark brown, micaceous, sandy, hard, poorly bedded; fracture schistose	1000–2000
Member 20	
Shale, gray, hard; contains numerous thin interbeds of gray, cream, and brown chert and limestone, and some brown quartzite	1200
Chert, black, gray, and brown, bedded; lenses out southeastward	0– 200
Member 19	
Shale, cherty, cream white to light gray, thin bedded, hard; cherty fracture; contains minor lenses of dark chert	4500
Member 18 (total thickness 3700 ft.)	
Chert-shale, dark gray to brown, thin bedded; contains minor thin interbeds of limestone	500
Chert, black, thin bedded; contains local interbeds of gray limestone	0– 200
Chert-shale, light gray to cream white, bedded	300
Chert-shale, dark gray to brown, thin bedded	700
Shale, gray, thin bedded, slaty	0– 200
Chert-shale, dark gray to brown, thin bedded	700
Basalt, dark green-brown; altered to greenstone	0– 100
Chert-limestone; chert dark brown, thin bedded; interstratified limestone well bedded, gray, impure, in beds up to 50 ft. in thickness, containing crinoid fragments, lensing out southward	0– 600
Chert, dark gray to brown, thin bedded; contains interbeds of hard dark-gray shale	1000
Member 17	
Shale, dark gray, weathering to brown, thin bedded, slaty, micaceous	1600
Members 16 and 15 (see Saltdale quadrangle section)	
Total thickness (members 17 through 21)	13,000

[19] Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle, California: California Min. Bur. Bull. 95, pp. 31-33, pl. 1, 1925.

* This section, mapped by Hulin as "undifferentiated Paleozoic", is part of the Garlock series. It starts with the northeasternmost exposures, or the top of the exposed section, where it is in contact with intrusive quartz monzonite.

Section of Garlock series in El Paso Mountains, Saltdale quadrangle.

	Feet
Member 17	
Shale, light brown, thin bedded, fissile, micaceous; extends southeastward into Randsburg quadrangle	1000+
Member 16	
Chert, tan, brown, gray, thick to thin bedded; contains minor interbeds of hard, thin-bedded micaceous shale	900–2000
Member 15	
Shale, light gray to light brown, thin bedded, slaty, micaceous	500– 700
Member 14	
Chert, brown to black, well bedded; contains interbeds of hard brown to gray slaty shale, rare thin layers as much as 2 ft. thick of chert-pebble conglomerate in sandstone or hard shale matrix	600–1300
Member 13 (total thickness 4950± ft.)	
Andesite,[20] dark gray, dense, aphanitic, massive; weathers to dark brown; contains numerous small white feldspar phenocrysts; exposed in Goler Wash, thins southeastward (possibly intrusive)	900
Limestone, dark green, massive, fine grained	50
Chert, black, thick bedded	300
Andesite, as above; thickens to 3100+ ft. southeastward (intrusive?)	1100
Chert, black to brown, and light pink-gray thin-bedded tuff containing some lentils of tuff breccia	800+
Andesite, as above; exposed in Iron Canyon (intrusive)	1300
Tuff breccia, pink-gray, thin bedded; contains volcanic fragments as much as 1 in. in size	500
Member 12 (total thickness 2050 ft.)	
Shale, gray to brown, thin bedded, slaty; contains thin interbeds of chert and greenish-tan limestone with fossil fragments; includes thin lentils of chert-pebble conglomerate	1100
Conglomerate, drab gray, schistose; made up of poorly sorted flattened pebbles as much as 2 in. in size of hard shale, chert, and quartzite; forms prominent outcrops; grades northward into coarse gritty sandstone	250
Shale, tan, thin bedded to fissile	500
Limestone, green gray, fossiliferous; contains flattened chert pebbles as much as 2 in. in size, crinoid stems, fusulinids, and some limestone pebbles containing above fossils; minor shale interbeds	200
Member 11	
Shale and chert, tan to brown, thin bedded	700
Member 10	
Quartzite, tan, thick bedded to massive, very fine grained; forms prominent outcrops west of Iron Canyon; contains interbeds of tan, bedded chert, minor interbeds of gray shale	700
Member 9 (total thickness 2800 ft.)	
Shale, gray to brown, hard, thin bedded, micaceous; contains minor interbeds of brown chert	1500
Chert, black to brown, bedded	500
Shale, gray to brown, hard, thin bedded, micaceous; interbedded with hard brown to black chert; thickens northward	1100+
(Probable fault here may repeat part of member 9)	
Chert, tan, massive to thick bedded; lenses out southward	200
Chert, brown, thin bedded; contains interbeds of shale	500
Member 8	
Metabasalt, drab green, dense; contains numerous small vesicles; altered to greenstone with calcite veinlets and fillings in vesicles, schistose fracture	0–1500
Member 7	
Chert, brown, gray, rusty tan, thin bedded	600
Member 6	
Shale, gray-black, micaceous, argillaceous, slaty, fissile	500

Section of Garlock series in El Paso Mountains, Saltdale quadrangle (cont.)

	Feet
Member 5 (total thickness 600 ft.)	
Chert, gray to brown, thin bedded	200
Limestone, dark green-gray, impure, thick bedded; contains numerous rounded grains of quartz; forms highest peak in El Paso Mountains	50
Chert-breccia, dark gray; fracture platy; made up of angular fragments and slabs as much as 2 in. long of chert, shale, and limestone in dark chert or hard shale matrix; grades northward into chert and limestone	300+
Limestone, same as last above	0– 50
Member 4	
Chert-shale, dark gray to black, thin bedded; contains local lenses of brown to dark gray quartzite, also of fine chert breccia	2000
Limestone, dark green-gray, impure, sandy, thick bedded; contains interbeds of black chert; lenses out northward	0– 300
Member 3	
Metabasalt, similar to member 8, lenses out southward	0– 500
Chert, black, brown, gray, bedded; contains local phases of chert breccia; lenses out locally	0–1000
Member 2	
Metabasalt, similar to member 8	900+
Member 1	
Chert, black, gray, brown, bedded, brecciated; contains minor lenses of fine chert breccia	300+
Accordant contact with underlying Mesquite schist (1 to 2 ft. of pulverized rock occurs at contact exposed in Mesquite Canyon)	
Total thickness exposed in Saltdale quadrangle (Members 1 through 17)	22,000
Total thickness exposed in Randsburg quadrangle (Members 17 through 21)	13,000
Total thickness of Garlock series (Members 1 through 21)	35,000

The Garlock series is a large inclusion within a granitic batholith. Its sediments and volcanics are remarkably little metamorphosed, considering that they occur within an extensive area of plutonic rocks. What metamorphism did take place was largely static, and was caused by heat resulting from deep burial and compression. Basalt within the Garlock series was chloritized and altered to greenstone, in the vesicles and fractures of which secondary calcite was deposited; sandstone was more or less silicified to quartzite; but the andesite porphyry,[20] shale, limestone and chert were not much affected—although the chert is probably silicified shale or tuff. The rocks were strongly deformed by tectonic forces, especially the thin-bedded brittle chert and cherty shale, which are undulated and brecciated.

The Garlock series may include several formations, although the abundance of shale, chert, and volcanics throughout the sequence suggests that it is of one age. One locality in Iron Canyon, two-thirds of a mile east of the Apache mine, has yielded crinoid stems and fusulinids. The latter were identified by C. W. Merriam as *Schwagerina* sp., indicating

[20] Under the microscope the hornblende andesite was found to have a porphyritic texture and to be made up principally of broken subhedral crystals of acid andesine enclosed in a microcrystalline groundmass of devitrified glass. Many of the feldspar crystals are altered in part to sericite and calcite. The hornblende, for the most part, is highly altered and now consists almost wholly of secondary magnetite and pale green chlorite. In addition to devitrified glass, the groundmass also contains aggregates of small crystals of twinned and untwinned andesine, irregular areas of calcite, and small shreds of chlorite. Accessory minerals are apatite and zircon.

Although the hornblende andesite has been altered since it was emplaced, the degree of alteration or metamorphism was not sufficient to destroy the original mineralogical composition and texture of the rock. *C. W. Chesterman.*

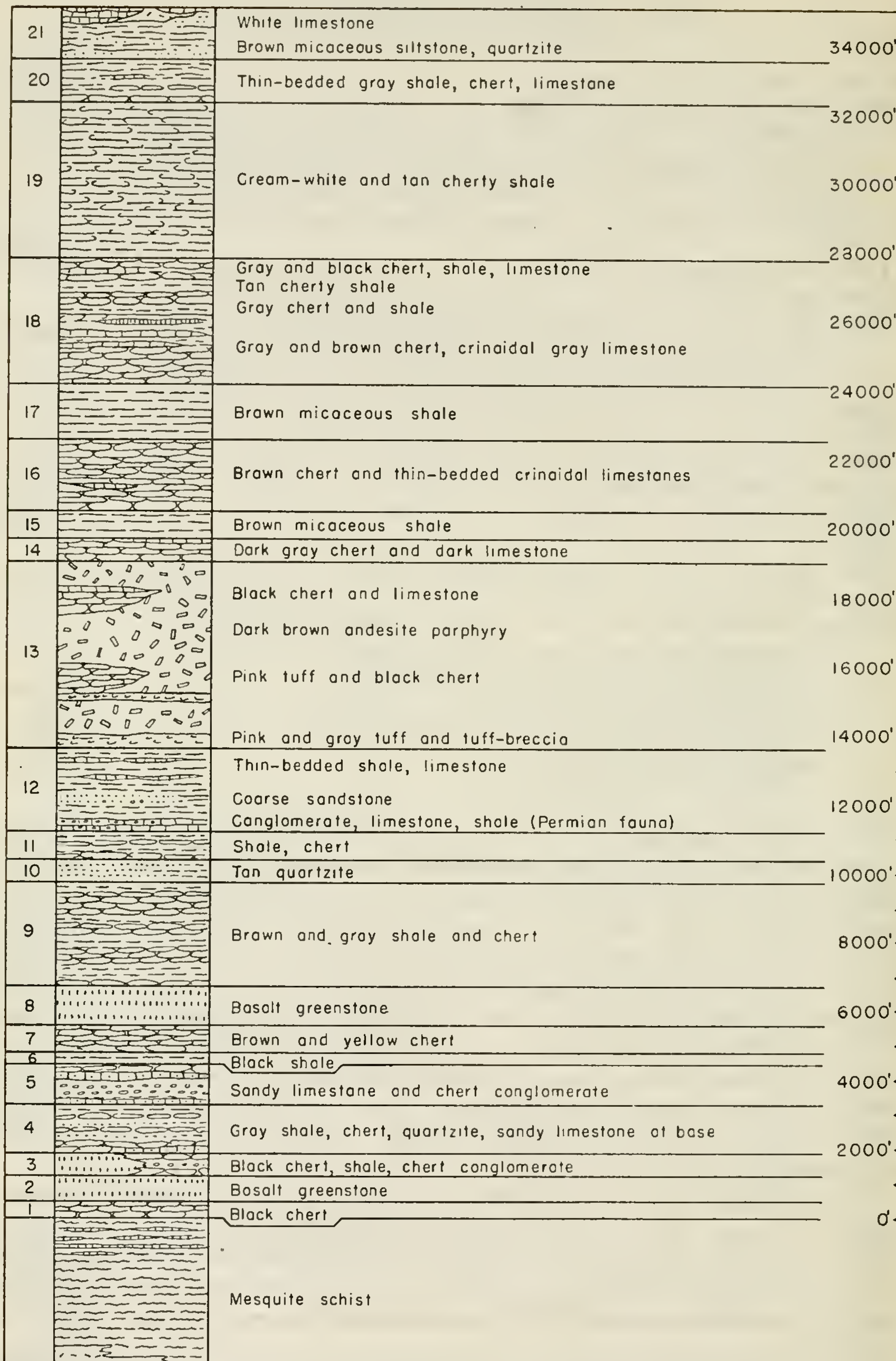


FIG. 2. Columnar section, Garlock series in El Paso Mountains.

middle or lower Permian age.[21] These fossils are in a thin pebbly limestone layer at the base of Member 12. No other fossils were found below this horizon. Crinoid fragments are abundant in thin limestone interbeds from the base of Member 12 to Member 18, so this part of the Garlock series is most likely of Permian age. The part of the series below Member 12 is probably Paleozoic, but may be older than Permian.

The Garlock series is unlike any other Paleozoic section in the Mojave Desert and southern Great Basin region, chiefly because of its tremendous thickness, large quantities of chert, and small percentage of limestone. It was probably deposited in a rapidly sinking basin under conditions different from those in other areas.

Paleozoic (?)

Metasediments

About 2,000 feet of steeply east-dipping metasediments of unknown age, comprising quartzite conglomerate and a dense rock, probably hornfels, are exposed adjacent on the east to the granophyre east of Redrock Canyon. The conglomerate is in lenticular masses ranging up to 800 feet in thickness. It consists of rounded gray-white quartz pebbles as much as 2 inches in length, which have been strongly flattened, probably parallel to bedding, in a matrix of dark-gray quartzite. The rock is brittle, and has a parallel or schistose fracture. The hornfels associated with the conglomerate is very hard, massive, and dense, and is dark-brown to gray in color. It is irregularly jointed except locally, where the jointing may be rudely parallel to the bedding.

Although the metasediments are assigned a questionable Paleozoic age, it was not possible to correlate them with any rocks in the mapped area.

Tertiary

Two series of northwest-dipping Tertiary continental sediments, separated by an angular unconformity, crop out on the northwest flank of El Paso Mountains. These are the Miocene (?) Goler formation (conglomerate, sand, and clay) and the Pliocene and Pleistocene (?) Ricardo formation (lacustrine and pyroclastic sediments and lavas).

Goler Formation

The continental sediments mapped as Rosamond series by Hulin [22] on the northwestern flank of El Paso Mountains in Randsburg quadrangle extend southwest into Saltdale quadrangle, across the head of Goler Gulch, to Last Chance Canyon. It is very doubtful that these sediments correlate with the type Rosamond as mapped by Simpson [23] near the town of Rosamond, for they are lithologically different. The terrestrial series in Saltdale quadrangle, therefore, is named the Goler formation, after Goler Gulch, where the thickest, most complete section is exposed; the type section is designated as the one exposed in the drainage area of Goler Gulch and northwestward to the east slope of the Black Hills.

---

[21] Fusulinids from the Saltdale area transmitted to me for determination are referred to the genus *Schwagerina*. As at present understood, the genus is restricted to the Permian but with a long range from Wolfcampian upward. In the absence of *Parafusulina*, which occurs in the Inyo Mountains within the upper range of *Schwagerina*, it appears probable that the Saltdale zone is lower Permian and correlative with the Permian portion of the Bird Spring formation as well as the lower part of the McCloud limestone. *C. W. Merriam.*

[22] Op. cit., 1925.

[23] Op. cit.

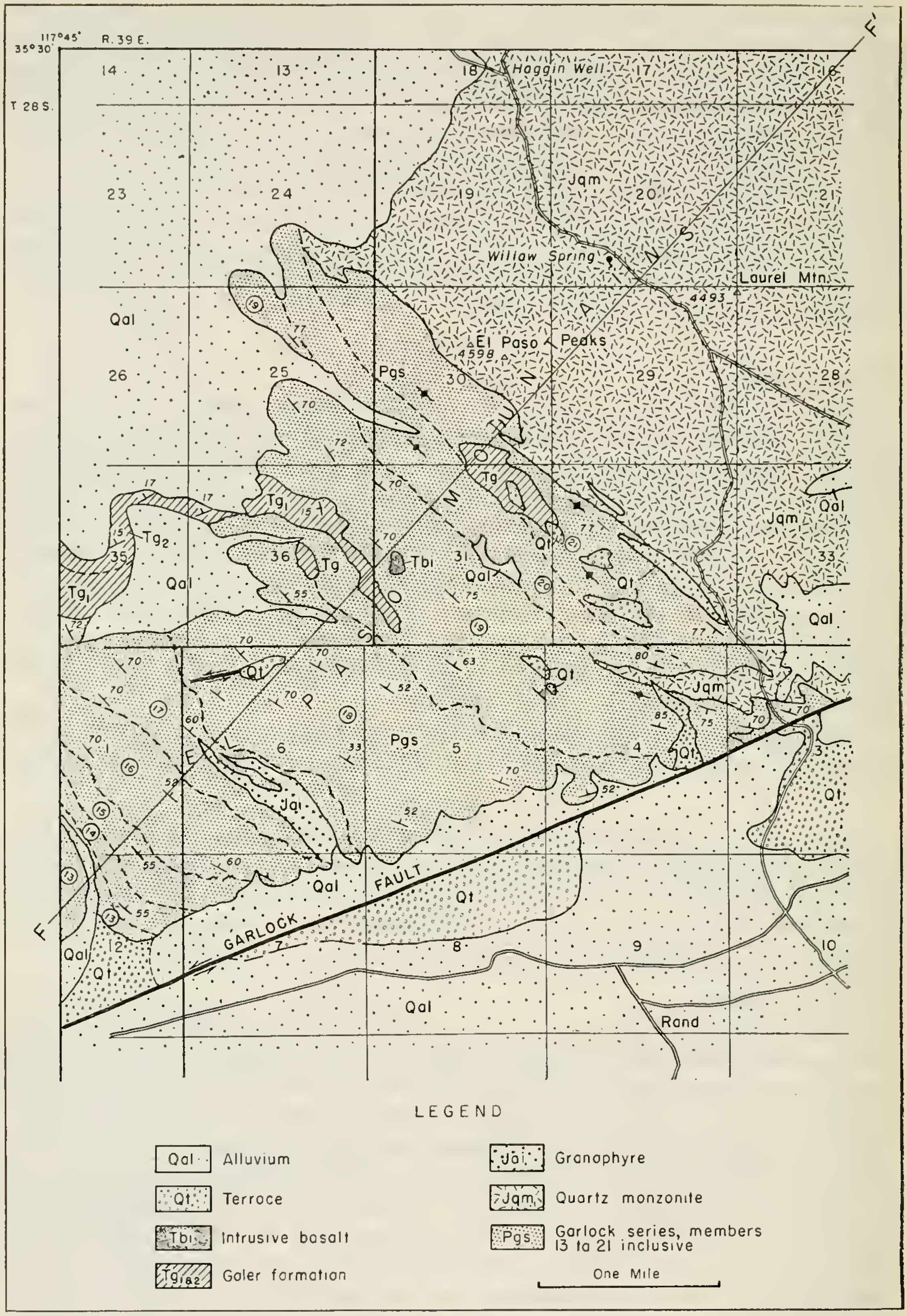


FIG. 3. Map showing upper portion of Garlock series in northwest part of Randsburg quadrangle.

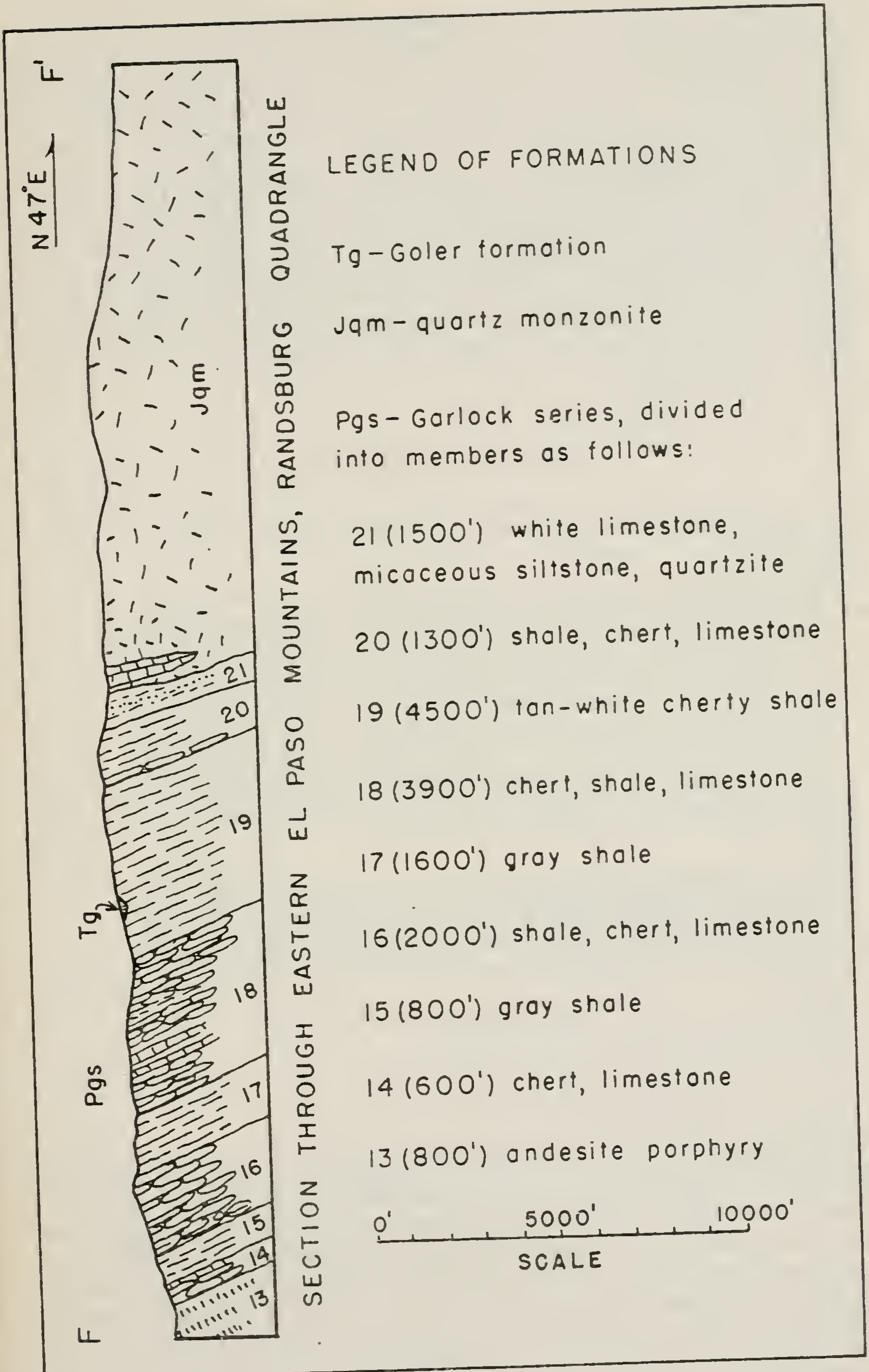


FIG. 4. Section through eastern El Paso Mountains, Randsburg quadrangle.

It consists of some 6,500 feet of terrestrial conglomerate, sandstone, and clay, probably middle or early Tertiary in age, lying unconformably above the basement rocks and unconformably below the Ricardo formation. The Goler formation contains no volcanic or pyroclastic rocks. Southwest from the type section, the Goler is overlapped by the younger Ricardo formation.

The Goler formation comprises two members which are fairly distinct throughout the quadrangle. The lower, mapped as Member 1, is essentially a basal alluvial fanglomerate, which ranges from less than 1 foot to 50 feet in thickness. The upper, mapped as Member 2, consists of two units of arkosic buff sand and red clay, and, east of Goler Gulch, cobble gravels. These two units become indistinguishable west of Goler Gulch, where the thick gravel beds grade into sand. Member 2 is about 5,500 feet in total thickness.

Goler formation exposed in Goler Gulch.

	Thickness in feet
ANGULAR UNCONFORMITY between Goler formation and overlying Ricardo formation	
Member 2	
Sand, clay, gravel, interbedded: Sand arkosic, buff colored, well bedded, indurated; weathering cavernous; contains many dark-brown concretions up to 2 feet in diameter; commonly pebbly; in beds up to 50 feet in thickness. Clay maroon, rarely greenish, silty to sandy, in beds up to 15 feet thick. Gravel gray, made up of well-rounded cobbles up to a foot in diameter of quartzite, chert, limestone, and granitic rocks, and of aphanitic porphyries of dacite, andesite, and basalt; in beds up to 500 feet thick, the thickest of which is at the base, and lies with possible slight angular discordance on the beds below; all gravels are east of Goler Gulch, all grade into pebbly arkosic sand toward the west	4000±
Sand, clay: Sand arkosic, similar to that described above; maroon clay, well bedded	2000±
Member 1	
Gravel: Unsorted fanglomerate, made up of well-rounded boulders and cobbles up to 2 feet in diameter of granitic rocks, quartzite, chert, limestone, and some aphanitic porphyries; west of Goler Gulch is essentially light-brown fanglomerate; east of Goler Gulch becomes maroon cobble gravel with some maroon clay and red arkosic sand in upper portion	0– 500
GREAT ANGULAR UNCONFORMITY on irregular erosion surface of Garlock series	
TOTAL THICKNESS OF GOLER FORMATION	6500

Member 1 of the Goler formation is not present everywhere in El Paso Mountains, as it was deposited by torrential rains only in the canyons or stream channels of a very irregular surface cut into the basement rocks. One of these channels was in the vicinity of Goler Gulch. To the west, in the vicinity of Apache mine, the fanglomerate is missing; apparently the basement rocks formed a ridge there. In Last Chance Canyon Member 1 reappears; here it is 1,500 feet thick, and attains its best development. In this area it consists of a basal fanglomerate grading upward into deep maroon-colored coarse arkosic sand. The boulders and cobbles of Member 1 are almost entirely from the basement rocks now exposed in El Paso Mountains.

Member 2 is largely arkosic material, the sand of which was derived from granitic rocks. There is some doubt as to the source of the various porphyritic volcanic cobbles * in the thick gravel lentils exposed east of Goler Gulch. These were probably derived mainly from basement rocks, although some may have come from Tertiary volcanic rocks. Member 2 also contains many wood fragments, and some carbonaceous material. The base of the Goler formation a mile north of Gerbracht Camp contains about 20 inches of soft coal, with which fossil leaves are associated.

The Goler formation is weakly resistant to erosion. The gravel forms hillsides of loose cobbles, and the buff sandstone crops out as prominent ledges; sandstone interbedded with red clay forms badland topography.

Neither the Goler formation in Saltdale quadrangle nor the equivalent Rosamond series in Randsburg quadrangle [24] resembles the type Rosamond series of the Elizabeth Lake quadrangle,[25] which contains a large amount of pyroclastic sediments and lavas. It is possible, however, that Member 2 of the Goler formation in Saltdale quadrangle, the Rosamond series in Randsburg quadrangle,[24] and the upper Miocene Barstow formation of the western Calico Mountains [26] may be correlative. These three formations, which consist of a great thickness of arkosic sediments with interbeds of red clay, were deposited in a large trough extending from El Paso Mountains southeastward through the Calico Mountains.

The probable correlation of Cenozoic formations in El Paso and Calico Mountains, based on comparative lithology and sequence, is shown in the accompanying correlation chart. The deep maroon-colored basal Member 1 of the Goler formation strongly resembles the Coyote formation of the Calico Mountains, as well as the lower Miocene-Oligocene-upper Eocene dark-maroon arkosic beds of such formations as the Vasquez (Escondido), Tecuya, and Sespe in the Coast Ranges.

The sudden appearance of coarse cobble gravel containing abundant volcanic debris in Member 2 at Goler Gulch suggests an important stratigraphic break; the gravel may represent the base of the Miocene in this series of sediments.

The earliest determination of the age of the sediments mapped as Goler formation in this report was based upon fossil leaves, which F. W. Knowlton identified as Tertiary, probably Eocene. J. Hervey Smith, in naming the Mohave formation, wrote one of the first descriptions of these sediments: [27]

> "A formation in southeastern California described by H. W. Fairbanks [28] as consisting of 'a series of beds of clays, sandstone, volcanic tuffs, and interbedded lava flows, probably 1,000 feet or more in thickness,' occurring 'on the northern slope of the El Paso Range, between Mojave and Owens Lake,' and probably extending over a considerable area between the El Paso Range and the Sierra

---

* Recent work in the area about 25 miles southeast of Goler Gulch reveals that these porphyritic rock types crop out in Fremont Peak Range as numerous pre-Tertiary (?) dikes cutting plutonic rocks, and are found as cobbles in the upper Miocene Barstow gravels to the east. *T. W. Dibblee, Jr.*

[24] Hulin, Carlton D., Geology and ore deposits of the Randsburg quadrangle, California: California Min. Bur. Bull. 95, 152 pp., 5 maps, 1925.

[25] Simpson, E. C., Geology and mineral deposits of the Elizabeth Lake quadrangle, California: California Div. Mines Rept. 30, pp. 371-415, map, 1934.

[26] McCollough, T., Geology of the southern portion of Lane Mountain quadrangle, California, unpublished map, 1949.
Dibblee, T. W. Jr., Geology of the Opal Mountain quadrangle, California, unpublished map, 1951.

[27] Smith, J. H., The Eocene of North America, west of the 100th meridian (Greenwich): Jour. Geology, vol. 8, pp. 455-456, 1900.

[28] Fairbanks, H. W., Notes on the geology of eastern California: Am. Geologist, vol. 17, pp. 63, 67-68, 1896.

	EL PASO MOUNTAINS This report		WESTERN CALICO MOUNTAINS McCollough, T., Geology of southern Lane Mountain quadrangle. Dibblee, T. W., Jr., Geology of Opal Mountain quadrangle.	
PLEISTOCENE	BLACK MOUNTAIN BASALT		BLACK MOUNTAIN BASALT & QUATERNARY GRAVEL	
	angular unconformity		angular unconformity	
PLEISTOCENE ?	RICARDO	"Ricardo" of Garlock Station Member 8 Arkosic sediments		
PLIOCENE	RICARDO	Members 4, 5, 6, 7 Clay, sand, gravel, calcareous & siliceous beds, tuff, basalt (contains Pliocene vertebrate fauna)		
PLIOCENE	RICARDO	Members 1, 2, 3 Volcanic gravel, sand, tuff, red andesite, basal conglomerate	RED MOUNTAIN DACITE	
	angular unconformity		angular unconformity	
MIOCENE	GOLER	Member 2 Arkosic sand, gravel, red & green clay	BARSTOW	Upper member Arkosic sediments, thin tuff beds (contains upper Miocene vertebrate fauna)
MIOCENE	GOLER		BARSTOW	Lower member Arkosic sediments & fanglomerate (contains upper Miocene vertebrate fauna)
? OLIGOCENE & EOCENE	GOLER			Pyroclastic sediments, volcanic agglomerate, arkosic fanglomerate
OLIGOCENE & EOCENE	GOLER	Member 1 Dark maroon-red arkosic sandstone & fanglomerate	COYOTE	Dark maroon-red & green arkosic sediments
	angular unconformity		angular unconformity	
	METAMORPHIC & PLUTONIC ROCKS		METAMORPHIC & PLUTONIC ROCKS	

Chart showing probable correlation of Cenozoic sections of El Paso and Calico Mountains.

ARKOSIC RED SANDS OF THE GOLER FORMATION
Last Chance Canyon, east of Cudahy Camp.
Photo by C. W. Chesterman.

A, TWIN BASALT DIKES

Cutting Goler red beds (below) and Ricardo conglomerate, tuff, and andesite breccia. Last Chance Canyon, east of Cudahy Camp. *Photo by C. W. Chesterman.*

B, NORMAL FAULT

Dipping east (to left), between Ricardo formation (gray and white exposures at right) and Goler red beds (center). North side of Last Chance Canyon near Holly Camp. *Photo by C. W. Chesterman.*

BASAL GRAY CONGLOMERATE
Ricardo formation Member 1. Last Chance Canyon, east of Cudahy Camp. *Photo by C. W. Chesterman.*

A, ANDESITE BRECCIA

Flow A of Ricardo formation. Underlain by tuff (Member 2) and basal conglomerate (Member 1) of Ricardo formation; basalt and lake beds above. Last Chance Canyon. *Photo by C. W. Chesterman.*

B, ANDESITE BRECCIA

Flow A of Ricardo formation; contains perlite. Flow dips west (toward the left) under lake beds exposed at left. Last Chance Canyon. *Photo by C. W. Chesterman.*

A, LAKE BEDS

Containing layers of white volcanic ash (pumicite); Member 4, Ricardo formation. Andesite breccia in foreground. View northwest across Last Chance Canyon. *Photo by C. W. Chesterman.*

B, LAKE BEDS

Containing volcanic ash (pumicite) beds; Member 4, Ricardo formation. Cudahy Company seismotite deposit, west side of Last Chance Canyon. *Photo by C. W. Chesterman.*

A, GRAY AND RED BLUFF-FORMING SANDSTONE
Member 5 of Ricardo formation. Redrock Canyon. *Photo by C. W. Chesterman.*

B, LAKE BEDS
Member 7, Ricardo formation. West side of Last Chance Canyon.
Photo by C. W. Chesterman.

SANDSTONE CAPPED BY BASALT FLOW E
Member 5, Ricardo formation. Redrock Canyon.
Photo by C. W. Chesterman.

EAST SIDE OF BLACK MOUNTAIN

Viewed from southeast. Ricardo formation (light-colored outcrops overlain by Black Mountain basalt (black outcrops), in which there are many landslides. *Photo by C. W. Chesterman.*

Nevada. Finely exposed in Red Rock Canyon and about Black Mountain; tilted northward at an angle of 15°-20°. Fossil plants identified by F. H. Knowlton as without doubt Tertiary and as probably Eocene."

It is obvious that the Mohave formation, as described by H. W. Fairbanks and named by J. Hervey Smith, includes both the Goler and Ricardo formations of this report. The fossil plants referred to are associated with the 20-inch coal bed at the base of the Goler formation 1 mile northeast of Gerbracht Camp. Fossil leaves have recently been collected from this locality and identified by D. I. Axelrod,[29] who states that they are Eocene in age:

"The Mohave formation described by Fairbanks (but named by Smith) from El Paso Mountains was originally considered Eocene on the basis of two plants, but this assignment has not generally been accepted. An Eocene age is clearly demonstrated by a small flora (*Anemia, Anona, Myrica, Persea, Parathesis*) whose species resemble those now in the warm-temperate to subtropical forests of Mexico and Central America."

The only vertebrate fossil obtained from the Goler formation is a turtle of inderterminable age. It was found about a mile north of Holland Camp, in Goler Gulch.

On the basis of field relationship, lithologic correlation, and meager fossil evidence, the writer concludes that the Goler formation is most likely Miocene, but that it may also contain upper Eocene strata. Basal Member 1 is probably Eocene or Oligocene; Member 2 below the gray cobble gravel might be Oligocene or Miocene; the upper part of Member 2, which contains gravel lentils carrying volcanic cobbles, may possibly be upper Miocene.

Ricardo Formation

The Ricardo formation, named by Merriam,[30] is a series of continental and lacustrine sediments containing lava flows and tuff of supposed Pliocene age, separated from the underlying Goler formation by a great angular unconformity. It is well developed on the northwest flank of El Paso Mountains. extending from Redrock Canyon northeast through Last Chance Canyon to the Black Hills. A maximum thickness of 7,000 feet of Ricardo is exposed from Holloway Camp in Last Chance Canyon northwest to the head of Redrock Canyon. Northeast from Last Chance Canyon the formation thins rapidly, to less than 1,000 feet in the Black Hills. This may be the result of overlap of the upper members by Black Mountain basalt. as only the two lowest members outcrop in these areas.

The Ricardo formation may be divided into two parts: a lower portion (Members 1 through 5), consisting of a basal arkosic conglomerate (Member 1), overlain by a series of pyroclastic sediments, lava flows, volcanic conglomerates, sands, and some lacustrine beds (Members 2 through 5); and an upper portion (Members 6 through 8), consisting of terrestrial sediments of arkosic and volcanic debris and lacustrine sediments.

The lacustrine sediments of the Ricardo formation are essentially thin-bedded calcareous sandstone, clay, silicified mud and ash, impure limestone, cherty limestone, and opal chert, restricted to the vicinity of Last

[29] Axelrod, D. I., Eocene and Oligocene formations in the western Great Basin (abstract): Geol. Soc. America, Proc. Cordilleran Section, p. 11, 1949.

[30] Merriam, J. C., The occurrence of Tertiary mammalian remains in northeastern Nevada: Univ. California Dept. Geol. Sci. Bull., vol. 8, pp. 275-281, 1914.

Chance Canyon. Lake beds comprise almost all of Member 7, as well as parts of Members 4 and 5. The silica that impregnates many of the lake beds was derived either from siliceous springs associated with volcanic eruptions of lava and ash, or from fine volcanic ash dissolved in the lake water. The opal cherts are silicified beds of mud or ash that contain numerous remains of roots, chiefly palm roots. The lake beds are grayish white in color; the terrestrial beds are light gray to pinkish gray. Some individual sand beds, such as those in Member 4 in Redrock Canyon, are indurated by iron oxide and stained brick red; but this color does not predominate in the Ricardo sediments. The formation is devoid of any maroon clays like those of the Goler formation. Terrestrial sediments of the Ricardo are poorly consolidated.

Ricardo formation exposed at Redrock and Last Chance Canyons.

	Thickness in feet
TOP OF SECTION eroded or buried by alluvium	
Member 8	
Terrestrial gravel, sand, clay: Interbedded light-gray granitic gravel, sand, and light-brown micaceous gritty clay; at Army Ground Observation Station, basal 100 feet grades up-dip into gravel of brown volcanic (andesite) cobbles	1500
Member 7	
Lake beds: Predominantly light-gray nodular clay and interbedded gray-white calcareous sandstone; also layers of white tuffaceous siltstone, impure limestone and opalized mud with conchoidal fracture; layers up to 2 feet in thickness of hard, white to translucent opal chert common northeast of Army Ground Observation Station	1500
Member 6	
Terrestrial sand and gravel: Bedded light pink-gray fine- to coarse-grained sand; some hard indurated layers of calcareous sandstone; layers of brown gravel of andesite pebbles common near basal portion; southwest of Redrock Canyon entire series becomes gray sand and gravel of volcanic debris; northeast of Redrock Canyon upper portion grades laterally into lake beds of Member 7	0–2000
Member 5	
*Basalt (Flow F): Dense to fine-grained, black, weathers dark brown; contains olivine; vesicles abundant; amygdules of analcite, natrolite, chalcedony, and opal up to half an inch in size common; thins out to northeast	0– 100
Sand: Light gray and fine grained; tuffaceous silt, gray white, with some thin layers of opal chert; thins out southwest of Redrock Canyon	0– 100
Basalt (Flow E): Similar to Flow F; thins out to northeast	0– 100
Sandstone: Pink-gray, fine to coarse grained, pebbly, well bedded, moderately indurated; pebbles of volcanic material; interbeds up to 3 feet thick of indurated bright-red sandstone; lower portion conglomerate of rounded cobbles, up to 12 inches in size, of red to dark-brown andesite in soft, pink-gray sandstone matrix	200– 500
Basalt (Flow D): Similar to Flow F above; traceable for 3 miles, thins out to northeast and southwest	0– 50
Lake beds: Gray-white, fine-grained, calcareous sandstone with white to translucent opal chert near base; thins to southwest	0– 100
Basalt (Flow C): Similar to Flow F above; traceable for 3 miles, thins out to northeast and southwest	0– 50
Tuff-breccia: Gray to pink, hard; made up of fragments of pumice, red rhyolite, and brown andesite, up to 2 inches in size, in fine-grained tuff matrix; thins out to northeast; best developed at Redrock Canyon 1 mile below Ricardo	0– 50
(Total thickness of Member 5 750 feet)	

Ricardo formation exposed at Redrock and Last Chance Canyons (cont.)

	Thickness in feet
Member 4	
Lake beds: Similar to Member 5; thin-bedded gray-white sandstone predominant; contains in addition six layers, up to 9 feet in thickness, of white, thin-bedded, even, fine-grained, soft ash (seismotite), of which the thickest (9-ft.) bed occurs at the top; traceable for about 7 miles, thins out to southwest and northeast	0– 600
Member 3	
Conglomerate: Pink-gray, cross bedded, made up of rounded cobbles of pink to brown rhyolite, andesite, and basalt-andesite, in a soft, pink to gray sandstone matrix; contains a 30-foot lens of white tuff breccia near middle, 1 mile southwest of Cudahy Camp; conglomerate traceable from big bend of Last Chance Canyon southwest for 8 miles to Redrock Canyon wash	0–1100
Member 2	
*Andesite (Flow B): Similar to flow A described below; lenticular, crops out discontinuously	0– 50
Tuff-breccia: Gray-white, compact, made up of fragments as much as 2 inches in size of pumice and red to brown andesite; traceable for 4 miles in Last Chance Canyon; passes through Cudahy Camp	0– 200
*Andesite (Flow A): Red-brown; brecciated throughout; numerous feldspar phenocrysts in dense groundmass without flow structure; locally finely vesicular; veinlets of chalcedony common; contains local phases of mottled gray and red massive, dense to glassy rhyolite, commonly associated with gray perlite; traceable for about 10 miles; great local variation in thickness	0– 200
Tuff-breccia: Orange-pink to gray-white; made up of fragments of pumice and pink to brown andesite and rhyolite in fairly hard tuff matrix; best developed in Last Chance Canyon and in Black Hills	0– 50
Tuff and ash: Pure white, well bedded, fine grained, partly altered to bentonite (seismotite); traceable from a point 2 miles east of Ricardo for 7 miles to the northeast	0– 50
(Total thickness of Member 2 600 feet)	
Member 1	
Basal conglomerate: On southwest spur of Black Hills consists of 500 feet of light green-gray conglomerate made up of rounded cobbles as much as 18 inches in diameter of predominantly granitic rocks, but also quartzite, andesitic porphyry, and chert, in soft granitic sand matrix; at Last Change Canyon and on east rim of Black Hills, consists of 50 to 300 feet of poorly sorted light green-gray gravel and sand similar to the above, but with smaller cobbles, and greenish sandy clay interbeds; buttresses out southwest in Redrock Canyon; lies unconformably upon Goler formation with as much as 30° angular discordance	50– 500
TOTAL THICKNESS OF RICARDO FORMATION	7000

* Specimens of Basalt Flow F, Andesite Flow B, and Andesite Flow A were examined under the microscope by C. W. Chesterman, who describes them as follows:

Basalt Flow F: Coarse grained, texture diabasic; composed of intermediate to acid labradorite and augite; feldspar partly altered to kaolin, and augite to dark brownish-green serpentine-like material; spherulites of feldspar and amygdules partly filled with glassy natrolite and analcite, chalcedony and opal scattered throughout; olivine present, but most of it altered more or less completely to serpentine.

Andesite Flow B: Porphyritic, with laths of plagioclase in fine-grained groundmass of feldspar and augite; feldspar phenocrysts are intermediate andesine, groundmass feldspar is basic oligoclase to acid andesine; twinning common in phenocrysts, but rare in groundmass feldspar; augite somewhat altered to pale green chlorite; pseudomorphs of iddingsite after olivine scattered throughout rock.

Andesite Flow A (Unbrecciated): Porphyritic and trachytic; feldspar phenocrysts intermediate to basic andesine, in separate subhedral laths or in glomeroporphyritic clusters, zoning and twinning common; groundmass feldspar basic oligoclase to acid andesine, as small anhedral crystals and laths showing albite and carlsbad twinning; hornblende more or less completely altered to limonite and chlorite; minor amounts of apatite and magnetite.

Andesite Flow A (Brecciated): Fragmental, brecciated, porphyritic; phenocryst feldspar intermediate to acid andesine, euhedral and irregular crystals as much as 2 mm in length, zoning common, especially in larger more complexly twinned crystals; hornblende almost wholly altered to limonite and chlorite; angular and rounded fragments of partly devitrified andesitic and rhyolitic glass scattered throughout rock; groundmass, composed in part of glass in various stages of devitrification, shows well-developed salt-and-pepper effect and fluidal banding and structure.

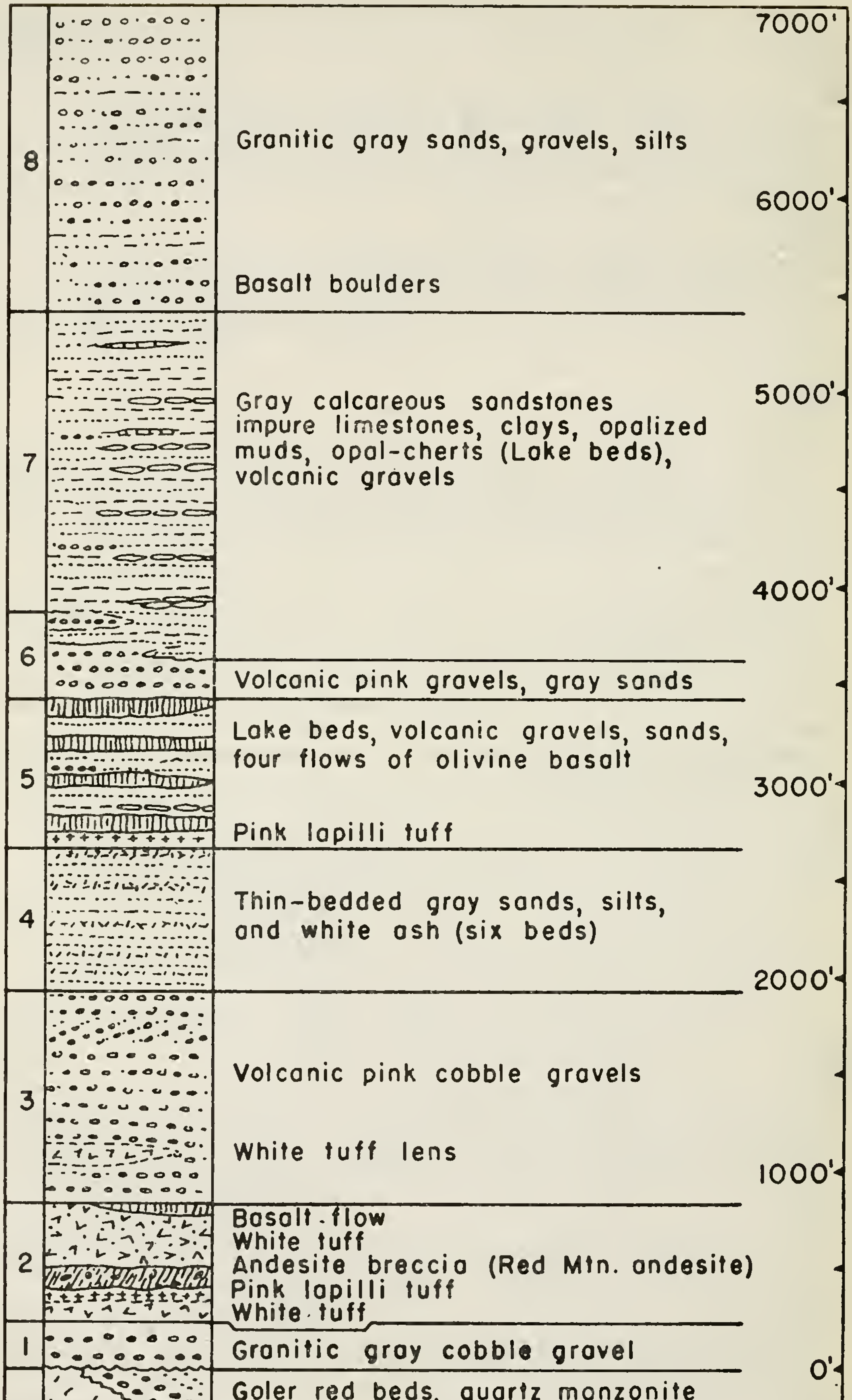


FIG. 5. Columnar section, Ricardo formation in Last Chance Canyon.

The Ricardo formation has yielded a large lower Pliocene mammalian fauna which has been described by Merriam.[31] Most of the remains were found in the upper part of the formation. In addition, there are many fragments of silicified wood, chiefly palm and some hardwoods, that indicate a hot, semi-arid climate.

According to Merriam,[32] the Ricardo formation is younger than the Barstow formation, which contains an upper Miocene vertebrate fauna. It is generally thought to be younger than the Rosamond series of Elizabeth Lake quadrangle, which was correlated with the Vasquez formation (Escondido series) and assigned to the middle Miocene.[33,34]

The Ricardo formation is unique in that it is the only completely exposed series of sediments and volcanics of known Pliocene age that attains such a great thickness within the Mojave Desert region. The Ricardo appears to have been deposited in a very local, subsiding basin. The great angular unconformity at the base is striking and is apparently regional. The only other probable correlative of the Ricardo is the Red Mountain andesite in the Randsburg quadrangle,[35] mapped in the Calico Mountains by McCollough[36] and Dibblee[37] as the Red Mountain (?) dacite. Hewett[38] assigns the Red Mountain (?) dacite to the very late Pliocene. However, the Red Mountain andesite and Red Mountain dacite are separated from underlying rocks by a great regional angular unconformity similar to and probably the correlative of the one at the base of the Ricardo formation.

The brecciated andesite (Flows A and B) in Member 2 of the lower Ricardo formation is similar lithologically to the Red Mountain andesite of Red Mountain east of Randsburg, and is probably its correlative. The Red Mountain andesite lies above the Rosamond series (Goler formation equivalent) unconformably, and below the Black Mountain basalt unconformably; Hulin[39] assigns it to the early Pliocene or late Miocene.

Recently vertebrate remains were collected from the small exposure of Ricardo beds at Garlock Station. Dr. Chester Stock, who identified the fossils, assigned them a Pleistocene age.[40] The beds which yielded this

[31] Merriam, J. C., Relationship of Pliocene mammalian faunas from the Pacific Coast and Great Basin provinces of North America: Univ. California Dept. Geol. Bull., vol. 10, pp. 421-443, 1917.

[32] Op. cit., 1917.

[33] Hershey, O. H., Some Tertiary formations of southern California: Am. Geologist, vol. 29, pp. 350-355, 1902.

[34] Simpson, E. C., Geology and mineral deposits of the Elizabeth Lake quadrangle, California: California Div. Mines Rept. 30, p. 401, 1934.

[35] Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle, California: California Min. Bur. Bull. 95, 1925.

[36] McCollough, C. C., Geology of the southern portion of Lane Mountain quadrangle, California, unpublished map, 1949.

[37] Dibblee, T. W. Jr., Geology of the Opal Mountain quadrangle, California, unpublished map, 1951.

[38] Hewett, D. F., Oral communication, 1951.

[39] Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle, California: California Min. Bur. Bull. 95, pp. 55-58, pl. 1, 1925.

[40] "The small collection of vertebrate remains obtained by Messrs. Richard Tedford and Robert Shultz at California Inst. Vertebrate Paleontology Loc. 483, near Garlock Station along the Garlock fault, Saltdale quadrangle, California, consists of the following:

"The most diagnostic specimen is a lower premolar representing a large individual of the genus *Equus*. The tooth measures, exclusive of the external cement, 35.2 millimeters in length and 16.3 millimeters in greatest transverse diameter. As determined by features of its enamel pattern the tooth definitely belongs, in stage of evolution, to the Pleistocene *Equus* rather than to *Plesippus* or to a still earlier genus in the history of the horse family.

"The remainder of the collection of horse materials consists of skeletal parts. These again pertain to an equid more advanced than those commonly found in the Ricardo lower Pliocene. The proximal third of a metacarpal is comparable in size to this end of the metapodial in *Equus pacificus*, the Pleistocene horse from Fossil Lake. A scaphoid represents a large type of camel, perhaps *Camelops*.

"The small collection taken from the Garlock locality represents, therefore, a late stage in the history of life of the Mojave Desert region, and is Pleistocene or perhaps upper Pleistocene in age. It is certainly later in age than the Barstow Miocene or the Ricardo Pliocene." *Written communication from Dr. Chester Stock.*

fauna may be younger than any of the sediments mapped as Ricardo, but field relationships suggest that they may be equivalent to the youngest of the Ricardo beds. The sediments at Garlock Station are poorly consolidated arkosic silt, sand, and gravel, and are faulted and folded. These sediments are similar to Ricardo Member 8, which likewise consists of poorly consolidated granitic gravel, sand and silt in Redrock Canyon, and are undisturbed except for slight tilt. At both places the sediments are unconformably overlain by older alluvium or terrace gravel. If any part of Ricardo Member 8 is correlative with the Pleistocene beds near Garlock Station, then part if not all of Ricardo Member 8 is Pleistocene rather than Pliocene.

Quaternary

Black Mountain Basalt

The Black Hills and the two flat-topped hills in the northeastern portion of Saltdale quadrangle are capped by the Black Mountain basalt flow, 50 to 100 feet thick, which was mapped and named by Baker.[41] The basalt dips gently northward toward Indian Wells Valley. There are no superjacent strata.

The Black Mountain basalt consists of black to gray-black fine-grained diabase-textured vesicular basalt. Small lath-shaped phenocrysts of feldspar and ferro-magnesian minerals are common. Vesicles average from a quarter of an inch to half an inch in diameter; many of them are filled or partly filled with calcite, opal, chalcedony, or zeolites. The rock is not much brecciated. Some of the jointing is hexagonal, but most of it is irregular; the entire lava flow is broken into angular blocks that average about 1½ feet across. This jointing causes numerous step-like landslides and talus slopes in canyons and on the slopes of the Black Hills.

The Black Mountain basalt in the mapped area is probably Pleistocene. Hulin [42] assigned it a very late Pliocene or early Pleistocene age. The flow is younger than the Ricardo formation, but considerably older than the oldest terrace deposits of the area, which are composed of boulders of the basalt. It appears to gradually overlap Member 2 of the Ricardo formation up-dip, although there is no visible angular discordance.

Terrace Gravel and Alluvium

Quaternary alluvium and terrace gravel in Saltdale quadrangle occur at several levels. This condition was brought about by recurrent differential uplifts and resultant erosion during Pleistocene time.

Older Terrace Gravel. Small isolated erosional remnants of a once-extensive fanglomerate occur east and southeast of the Black Hills, from which they slope gently away. This old gravel has been elevated by late Pleistocene uplifts to form the highest terrace. Remnants occur at a number of places within the quadrangle; there are several south of Black Mountain, at an elevation of over 4,200 feet; several east of this mountain; two east of Goler Gulch; and several very small ones on the ridge east of Iron Canyon. The gravel is about 25 feet thick and is made up

[41] Baker, C. L., Physiography and structure of the western El Paso Range and southern Sierra Nevada: Univ. California Dept. Geol. Bull., vol. 7, pp. 117-142, 1912.
[42] Op. cit., 1925.

almost entirely of boulders of Black Mountain basalt in a matrix of soft brown clay. An exposure of this old fanglomerate, consisting of large basalt boulders, crops out a mile east of Redrock on the south side of El Paso Mountains, where it is slightly tilted to the south.

The older terrace gravel is considerably younger than the Black Mountain basalt from which it was derived; it is probably of middle or late Pleistocene age.

Younger Terrace Gravel and Older Alluvium. The younger fanglomerate is fairly widespread on the north side of El Paso Mountains in the vicinity of the Black Hills. This gravel, which slopes away from the hills, was dissected into many remnants by erosion, following late Pleistocene uplift of El Paso Mountains. The gravel is as much as 100 feet thick. It consists of unsorted boulders of Black Mountain basalt and rounded cobbles derived from conglomerates of the Goler and basal Ricardo formations, as well as from the basement complex of El Paso Mountains.

The surface slope of the younger terrace gravel blends into that of the alluvium of Indian Wells Valley, so these formations were deposited contemporaneously. The alluvium of the valley is almost entirely coarse- to medium-grained sand derived from the granitic rocks of the mountains to the west.

The gravel west of Garlock, elevated by movement on the Garlock fault, is probably contemporaneous with the younger gravel on the north side of El Paso Mountains. This gravel is about 50 feet thick and was derived from the basement rocks of El Paso Mountains.

The younger terrace gravel and alluvium of Indian Wells Valley are late Pleistocene. The thin deposit of granitic alluvial sand on the south slope of the Rand Mountains is probably of the same age. Contemporaneous alluvial sediments must underlie the later or Recent alluvium in Cantil Valley.

Recent Alluvium. An unknown thickness of Recent alluvium covers Cantil Valley and extends far up the alluviated canyons that drain into it from both sides. Cantil Valley is a perfect sedimentary basin in which all types of clastic sediments are being deposited, ranging from gravel and coarse sand adjacent to the mountains, to fine silt and clay in the middle of the basin, to alkali mud in Koehn (Salt) Dry Lake. During late Pleistocene time most of the area below the 2,000-foot contour was a lake in which, at the northeastern margin near Toby, a prominent sand bar developed.

Intrusive Igneous Rocks

Four main types of plutonic rock make up the basement complex within Saltdale quadrangle. These are, in order of areal extent, quartz monzonite, quartz diorite, granophyre, and granite. The quartz monzonite underlies most of the western Rand Mountains; two distinct types of quartz diorite crop extensively in El Paso Mountains just north of El Paso fault, and two kinds of granophyre also occur in this range; small intrusive bodies of granite are found in both mountain ranges.

The plutonic rocks are in general bounded by sharp contacts, suggesting that they are segregates of the Sierran batholithic invasion that took place at the close of Jurassic time. The order in which they were segregated was probably as follows: (1) hornblende-quartz diorite, (2) quartz monzonite, biotite-quartz diorite, and granophyre, and (3) granite.

Quartz Monzonite.[43] A gray-white granitic rock mapped as quartz monzonite crops out extensively in the Rand Mountains. In the adjoining Randsburg quadrangle it was mapped as the Atolia quartz monzonite by Hulin.[44] This rock is widespread throughout much of the Mojave Desert south of the Garlock fault.

In Saltdale quadrangle quartz monzonite underlies much of the western Rand Mountains, where it intrudes the Rand schist. In El Paso Mountains it forms only small bodies and local phases within the quartz diorite. A granitic rock mapped by Hulin as quartz monzonite crops out in eastern El Paso Mountains within the Randsburg quadrangle, where it intrudes the Garlock series.

The quartz monzonite is closely jointed throughout, but in no definite pattern. It readily disintegrates mechanically, forming rounded crests and generally smooth topography.

The quartz monzonite in the Rand Mountains is a massive medium- to coarse-grained even-textured light-gray rock, consisting chiefly of quartz, feldspar, and biotite. The ratio of feldspar to quartz is about 2:1; euhedral crystals of biotite make up 5 to 50 percent of the rock. The quartz is translucent and colorless, and the feldspar is opaque white. Some hornblende is present.

The quartz monzonite contains local dark phases rich in hornblende and biotite. Most of these are developed in marginal areas of the intrusion, but some occur well within it. The texture of these darker phases varies considerably; they appear to be masses of incompletely digested inclusions within the quartz monzonite invasion. At certain localities in the Rand Mountains, especially south of Koehn Dry Lake, the quartz monzonite contains numerous large phenocrysts of gray-white orthoclase or microcline averaging about an inch in length. The rock contains no pegmatite dikes; aplite dikes are not common, and are only a few inches thick.

Quartz Diorite.[45] The main mass of granitic rock exposed in El Paso Mountains within Saltdale quadrangle is quartz diorite. This rock forms an elongate body 6½ miles long within the core of the mountains. The quartz diorite is generally massive, although some northeast-trending flow structures are developed in the area 1 to 3 miles west of Schmidt Camp, and flow structure trending almost due north shows in an exposure

---

[43] Under the microscope the quartz monzonite is seen to be composed of quartz and almost equal proportions of orthoclase and plagioclase. The latter has the composition of acid andesine. The potash feldspar is largely orthoclase, only a small amount of microcline being present. The biotite is strongly pleochroic, and more or less altered to chlorite. The quartz shows strain effect, and the albite-twinning lamellae of the plagioclase are curved. Zircon, sphene, magnetite, and apatite are present in minor amounts. *C. W. Chesterman.*

[44] Op. cit., 1925.

[45] Under the microscope the biotite-quartz diorite is seen to be composed of plagioclase and quartz in a ratio of about 2:1. The feldspar is andesine, which occurs as irregular and subhedral grains showing albite, carlsbad, and pericline twinning. The feldspar has been partly altered to sericite. The quartz is in irregular grains, which show weak strain effects. Biotite and hornblende are also present, biotite being the more abundant and occurring as brown pleochroic plates more or less altered to pale green chlorite. The hornblende is in bluish-green anhedral grains. Zircon, sphene, apatite, and magnetite are present in minor amounts.

The hornblende-quartz diorite, on the other hand, is characterized by much hornblende and some potash feldspar, and contains less quartz than the biotite-quartz diorite. The plagioclase is intermediate to acid andesine. It occurs in angular and subhedral crystals more or less altered to sericite and kaolin. Carlsbad and albite twinning are common. The potash feldspar is microcline perthite. It makes up only a small part of the rock and is present in the form of irregular crystals partly altered to sericite. The quartz shows strain shadows. Hornblende is present as dark-green pleochroic subhedral crystals altered in part to epidote and chlorite. Some pale green chlorite that is an alteration product of biotite is also present. There are minor amounts of magnetite, apatite, sphene, and zircon. *C. W. Chesterman.*

east of Redrock Canyon. Two types of quartz diorite were recognized and mapped: biotite-quartz diorite, and hornblende-quartz diorite.

The biotite-quartz diorite is a gray-white medium-grained equigranular massive rock. It forms the large light-colored mass of granitic rock exposed in the vicinity of Last Chance Canyon. It is made up of quartz and white feldspar, and contains scattered euhedral crystals of biotite averaging about three-sixteenths of an inch across. Hornblende occurs in very small amounts. This rock appears similar megascopically to the quartz monzonite of the Rand Mountains, and disintegrates mechanically with the same ease and in the same manner.

The hornblende-quartz diorite is a dark-gray medium-grained equigranular rock. Two masses crop out in El Paso Mountains, one on each side of the light-colored biotite-quartz diorite of the Last Chance Canyon area. The dark hornblende-quartz diorite appears to be a roof-pendant in the light-colored biotite-quartz diorite, as all contacts dip under the darker rock in the Schmidt Camp area. This relationship suggests that the darker rock is the older of the two facies and that the lighter rock has intruded it from below. The hornblende-quartz diorite is of the same mineralogical composition as the biotite-quartz diorite except that it contains a large amount of hornblende, and lesser amounts of biotite and quartz.

The hornblende-quartz diorite is in many places highly mineralized with green veinlets of epidote. Quartz veins several feet thick are also common, especially in the Schmidt Camp area. Many of these veins are brecciated and impregnated with brown and red iron oxides and some copper oxides. Near the northeastern margin of the Schmidt Camp exposures, there are numerous aplite dikes that trend about N. 20° W. and average about a foot in thickness. These dikes consist mainly of fine-grained cream-white to pinkish orthoclase and quartz. Dikes of quartz-orthoclase pegmatite are commonly associated with the aplite dikes. Occurring with these different dikes are veinlets of secondary quartz, many of which contain epidote and some garnet.

The hornblende-quartz diorite in the Schmidt Camp area is probably intrusive into the schist of Mesquite Canyon; it appears to grade along its eastern margin into a buff-white foliated gneissoid granitic rock, which in turn grades into the schist. The bedding planes of the schist appear to pass through the gneissoid rock into the hornblende-quartz diorite, the attitude of the foliation gradually swinging from due south in the schist to northeast in the plutonic rocks. The foliated granitic rock may be a marginal facies of the quartz diorite.

Granophyre.[46] Dikes, sills, and stocks of granophyre are scattered in the basement complex of El Paso Mountains. The largest body is exposed in the mouth of Redrock Canyon, where it forms a stock measuring roughly a mile or more in diameter. The next largest body forms a band about 2,000 feet wide between foliated granite and quartzitic conglomerate about 1½ miles east of Redrock Canyon. There are also many lenticular sills in the Garlock series. The largest, about 500 feet wide, is just

[46] The granophyre at Redrock Canyon is composed essentially of quartz and orthoclase. The texture is granophyric and porphyritic; rounded phenocrysts of quartz are enclosed in a granophyric intergrowth of quartz and orthoclase. Quartz is in anhedral grains and contains numerous small, dust-like inclusions. Most of the orthoclase forms intergrowths with quartz. An occasional subhedral crystal is found whose interior is altered and contains grains of sphene and aggregates of tiny sericite plates. Acid oligoclase also occurs, either as rounded phenocrysts or as intergrowths with quartz. Sphene, magnetite, and zircon occur as accessory minerals. This rock is a rhyolite granophyre or alaskite granophyre. *C. W. Chesterman.*

east of Mesquite Canyon; and there are many small ones only a few feet thick—too small to map—from Iron Canyon eastward.

Two types of granophyre crop out in the area. The large exposure at Redrock Canyon is a very hard, fine-grained massive quartzose rock that forms jagged but closely jointed outcrops. It is light gray on a fresh-broken surface, but weathers to buff and is nearly always stained along its numerous joints or cracks to various shades of brown, pink, and purplish-gray. It is very fine-textured and highly quartzose, so much so as to resemble quartzite. However, it contains scattered small phenocrysts of feldspar, and also rounded phenocrysts of translucent quartz. These are rarely more than an eighth of an inch long. This rock is generally of the same mineral composition as the foliated granite, and is probably a fine-textured facies of it.

The other exposures of granophyre scattered throughout El Paso Mountains differ from the large one at Redrock Canyon. The granophyre of these exposures is a light-gray porphyritic rock with rectangular phenocrysts of white feldspar averaging about a quarter of an inch in length, and of hornblende, set in a fine-textured groundmass of feldspar, quartz, biotite, and hornblende. The percentage of white and black minerals shows considerable local variation. The rock is probably of the same mineral composition as quartz diorite. The smaller dikes generally terminate in a fine-textured dark rock resembling diabase. The granophyre of these scattered sills and dikes is apparently a fine-grained facies of the large bodies of quartz diorite of El Paso Mountains, and is thus a dacite granophyre or quartz diorite granophyre.

Granite. Prominently foliated buff-weathering granite crops out as two bands, each nearly a mile wide, which trend about N. 20° W. within the basement complex of El Paso Mountains. One is about a mile east of Redrock Canyon, and the other is about a mile west of Mesquite Canyon. Both are adjacent to hornblende-quartz diorite and may be related to it; they are probably of different origin than the massive pink granite described in a following paragraph.

The foliated granite is composed of quartz and a cream-white feldspar, probably orthoclase. Most of it contains many small flakes of biotite and muscovite. The rock ranges from fine grained to coarse grained, but is in general even-textured. The very prominent granular foliation gives it a gneissoid cleavage. Foliation in the granite east of Redrock Canyon strikes about N. 20° W., parallel to the contacts.

The foliated granite west of Mesquite Canyon apparently was intruded between the Mesquite schist on the east and hornblende-quartz diorite on the west. The northern portion of this granitic mass appears to be a sill, with foliation parallel to the contact of the schist. However, the narrow southeastern portion cuts diagonally across the strike of the schist, the contact being gradational and the strike of the foliation continuous with both the foliation of the adjacent hornblende-quartz diorite and the cleavage of the adjacent schist. The contact with the foliated diorite is also highly gradational throughout its extent. From the relationships described above, it appears that this mass of granite is a facies of the quartz diorite formed by its counteraction with the Mesquite schist which it intruded. The schist adjacent to the granite apparently was granitized by the intense thermal action of the magma in which the foliation is relict to the cleavage of the schist. If this is the case, the foliated granite is the contemporary of the quartz diorite.

Massive granite with a light pinkish tinge crops out in the western Rand Mountains as small irregular masses within quartz monzonite, which it probably intruded. Two small irregular masses of similar rock cutting quartz diorite are exposed in El Paso Mountains 2 miles north of Toby. The granite forms reddish-buff exposures which stand out in marked contrast to the prevailing gray-white exposures of quartz monzonite. It is generally more coherent and thus more resistant to erosion than the quartz monzonite.

The rock is even-textured but ranges from medium grained to fine grained. It is composed of translucent quartz and pinkish orthoclase feldspar, which determines the pink color. Small flakes of muscovite are present, and locally small flakes of biotite.

The pink granite contains many veinlets of pegmatite made up of quartz and pink orthoclase. These pegmatites commonly extend beyond the granite into the quartz monzonite and quartz diorite, indicating that the granite is younger and intrusive into these rocks. The many orthoclase-bearing aplite and pegmatite dikes in the quartz diorite east of Schmidt Camp are probably offshoots from the pink granite, which is apparently the final phase of the Sierran granitic invasion.

Gneiss. The hornblende-quartz diorite 2 miles southwest of Last Chance Canyon in western El Paso Mountains contains three small inclusions of quartz-biotite gneiss that trend about N. 30° W. The gneiss appears to be injected within the diorite, but may be of sedimentary origin.

Lamprophyre. Lamprophyre dikes, some as much as 10 feet thick, cut the quartz diorite in El Paso Mountains and the quartz monzonite in the Rand Mountains. The largest occur 2 miles east of Holloway Camp, and 2 miles north of Saltdale. Most of the dikes, however, are only a few feet or inches wide, and are too small to map. They generally occur in shear or fault zones, and consist of very fine-grained black basic rock which weathers to dark brown.

The hornblende-quartz diorite exposure 3 miles east of Redrock Canyon contains several lamprophyre dikes as much as 10 feet in thickness, which trend about N. 20° W. The largest crops out conspicuously and can be seen from the valley to the south. The rock contains numerous long phenocrysts of hornblende set in a dense to fine-grained dark-gray goundmass.

The lamprophyre dikes are younger than the quartz monzonite and quartz diorite which they cut, and were apparently intruded long after these rocks cooled and solidified. The lamprophyres are probably early Cretaceous or even younger.

Basalt.[47] Dikes of Tertiary basalt occur in Last Chance Canyon, and also on the west slope of Black Hills near the northern border of the map.

[47] Under the microscope the basalt shows a diabasic texture. It is composed essentially of plagioclase and augite. The plagioclase is acid labradorite, which occurs in partly altered lath-shaped crystals. The augite, which is pale green in color, is in large anhedral crystals slightly altered to chlorite. Olivine is in subhedral crystals almost completely altered to serpentine and iddingsite. *C. W. Chesterman.*

In Last Chance Canyon, $1\frac{1}{2}$ miles east of Cudahy Camp, is a large dike about 800 feet wide, which intrudes the Goler formation at and near its fault contact with biotite-quartz diorite. This dike runs north for about a mile; at both ends it branches into several thin dikes which cut Members 1 and 2 of the Ricardo formation and extend into andesite Flow A of Member 2. Other dikes occur just west of Holloway Camp, and about a mile south of Holly Camp. These cut the Ricardo formation below andesite Flow A, but do not get through the flow; one forms a thin sill just below it. Two miles east of Black Hills well, two basalt dikes cut the tuff of Ricardo Member 2.

The basalt is dense to fine-textured, massive and black, and has a tendency to develop a platy fracture. It commonly contains veinlets of chalcedony. This intrusive is probably of the same composition as the basalt flows in the Ricardo formation, and may be of the same age.

In the main mass of the Last Chance Canyon dike, the rock is olivine basalt. However, it changes considerably in composition in the two branches and thin sills beneath and between the andesite flows. In the branch dikes and sills, the rock is an augite andesite composed essentially of intermediate andesine and augite. Feldspar phenocrysts range from acid labradorite to basic andesine, while the groundmass feldspar is intermediate andesine. The augite is fresh and occurs as anhedral crystals scattered among the feldspar laths.

STRUCTURE

The Saltdale quadrangle takes in portions of three major tectonic units; mainly El Paso Mountains, Cantil Valley, and Rand Mountains. The Garlock fault, a major left-lateral fault traceable for some 150 miles through the Mojave Desert, passes under the northwestern margin of Cantil Valley.

El Paso Mountains

Structure of the Basement Complex. El Paso Mountains constitute a tectonic block elevated at its southeastern base and tilted northwest toward Indian Wells Valley along El Paso fault. The pre-Cretaceous basement complex is exposed along the core or highest elevated portion of this uplifted block, within 2 to 4 miles of the fault. The Paleozoic Garlock series of the basement complex is exposed northeastward from Mesquite Canyon; it is homoclinal, trends about N. 30° W., and dips steeply northeast. Although this trend is at right angles to the trend of El Paso Mountains tectonic block, it conforms to the regional trend of the pre-Cretaceous metamorphic rocks of the southern Sierra Nevada, the Inyo Mountains, and the Panamint Mountains. The Mesquite schist is exposed on the west side of Mesquite Canyon, where it dips east under the Garlock series; farther southwest, where the schist is metamorphosed and partly digested by the granitic intrusion, its trend is southwest. In the southwestern portion of El Paso Mountains the basement complex consists of intrusives and metamorphics that trend approximately north-northwest.

Structure of the Tertiary Formations. On the northwest flank of El Paso Mountains the Goler sediments strike about N. 65° E. and dip about 20° NW away from the basement complex which they overlie. In the vicinity of the big bend of Last Chance Canyon the lower portion of the Goler formation is buttressed out against a buried mass of basement rocks.

The Ricardo formation, which overlies the Goler formation, strikes about N. 50° E. and dips about 15° NW toward Indian Wells Valley. It overlaps and truncates the more steeply dipping Goler formation from northeast to southwest, finally lapping onto the basement complex in Redrock Canyon. West of Redrock, the Ricardo beds are folded around the basement complex into a west-plunging anticline. The only other fold in the Ricardo beds in El Paso Mountains is a minor one on the western margin of the Black Hills, which trends due north.

Black Hills. Black Mountain, the Black Hills, and the two flat-topped hills near the northeastern corner of Saltdale quadrangle are all erosional remnants of a once-extensive flow of Black Mountain basalt underlain by soft, easily eroded sediments of the Ricardo and Goler formations which are tilted gently northward. The lava exposed along the rim of the Black Hills mesa, together with the underlying tuff, has formed numerous step-like landslides over the underlying soft sediments. These masses of basalt appear from a distance to be lava flows on the mountain slopes; but their highly broken condition, and the presence of the tuff bed under almost all of them, indicate that they are landslides.

El Paso Fault. El Paso Mountains are abruptly terminated on the southeast by El Paso fault, which follows the remarkably straight base line of the steep mountain front. The fault trends about N. 60° E. The mountains on the northwest constitute the uplifted block. East of Redrock Canyon the fault is exposed for about a mile, and the relationship of the basement rocks to Ricardo formation can be seen. Elsewhere the Ricardo formation and the fault are concealed by alluvial material washed down from the mountains. El Paso fault shows no evidence of recent lateral movement. Movement on El Paso fault has been for the most part, if not entirely, vertical. Within Saltdale quadrangle displacement is greatest at the eastern border; it gradually decreases southwestward, and finally dies out about 1½ miles west of Redrock. Maximum vertical displacement is not known, but is roughly estimated to be about 10,000 feet.

El Paso fault is well exposed on the east side of Redrock Canyon, and again in a canyon a mile to the east, where basement rocks on the north have been brought in contact with Ricardo beds on the south. The basement rock within 50 feet of the fault is highly brecciated and even pulverized. The fault itself is marked by about 5 feet of rusty yellow gouge and pulverized rock. No fault grooves were observed. The fault dips from 77° N. to vertical. A small drag syncline is developed in the Ricardo beds close to the fault, and the beds adjacent to it are upturned vertically. El Paso fault is again exposed, between basement rocks and terrace gravels, 1½ miles east of Last Chance Canyon, where it dips steeply southward.

El Paso fault is probably a branch of the Garlock fault, which closely parallels it on the southeast, branching off from it just beyond the eastern border of the map and gradually diverging from it in a westerly direction.

Minor Faults in Last Chance Canyon. The basement complex between Holly Camp and Copper Basin mine is bounded on the southwest by a fault trending N. 30° W. for about 3 miles. This fault brings basement rocks on the northeast in contact with Goler beds on the southwest. The Goler beds strike directly into it from the southwest. The fault does not cut the Ricardo formation, which extends over it unaffected. Therefore it is younger than the Goler formation and older than the Ricardo formation. It can be seen 1½ miles northeast of Holly Camp, where it is vertical, and is marked by about 30 feet of gouge and sheared rock. Here a large dike of basalt has come up along the course of the fault for nearly a mile. From the dike the fault probably extends northwest for another mile under the Ricardo formation, immediately southwest of the small exposures of basement rocks that underlie the Ricardo near the big bend of Last Chance Canyon.

Another minor fault a mile west of Holly Camp is traceable from Last Chance Canyon wash for about 1½ miles, cutting both the Ricardo and Goler formations, and dipping about 50° E. The upthrown block is on the west. Maximum vertical displacement is about 500 feet.

Cantil Valley

Cantil Valley is a basin deeply filled with alluvium, between Rand Mountains and El Paso Mountains. A thick series of piedmont alluvial fans derived from the adjacent mountain ranges slopes into it on both sides; this alluvial debris is especially thick and extensive on the southeast side. The valley appears to be sinking relative to the surrounding areas, as it is an enclosed basin that has no outward drainage. It is bounded on the northwest by El Paso fault, and on the southeast by a possible buried fault at the base of the Rand Mountains; if the buried fault exists, the valley is a graben about 6 miles wide. The Garlock fault passes through the northwestern portion of Cantil Valley about a mile south of El Paso fault.

The alluvial deposits of Cantil Valley are underlain by sediments of the Ricardo formation. Between the Garlock and El Paso faults north and northwest of Cantil and also near Garlock, the upper portion of the Ricardo has been exposed, probably as a result of local uplift caused by squeezing movements between the two faults. Several compressive folds whose axes trend approximately east have been developed in the Ricardo formation near Cantil. A well drilled to 2,640 feet on the axis of the largest of these anticlines about a mile north of Cantil encountered Ricardo sediments all the way. Near Garlock Station the uppermost portion of the Ricardo formation is exposed under the uplifted and dissected terrace gravels immediately north of the Garlock fault, dipping gently northward away from the fault. Three wells drilled in Cantil Valley near Cantil penetrated sediments down to a depth of 3,000 feet.

Garlock Fault. The Garlock fault, a master left-lateral shear fault traceable for some 150 miles from Lebec northeast to the Avawatz Mountains, passes under the northwestern margin of Cantil Valley. Within Saltdale quadrangle it is concealed by alluvium, except for a well-defined scarp near Garlock. This great fault was first recognized in Saltdale quadrangle by Hess,[48] who states:

> At Garlock about two miles west of the (Randsburg) quadrangle, a large alluvial fan cut by the fault shows a face 280′ high (barometric measurement). From its prominence at this point, the fault will be referred to as the Garlock fault.

[48] Hess, F. L., Gold mining in Randsburg quadrangle, California: U. S. Geol. Survey Bull. 430, p. 25, 1909.

The well-defined southeast-facing scarp just west of Garlock is the result of local uplift of the northwestern block to 280 feet above the valley floor. The straight base of this 2-mile-long scarp follows the Garlock fault, along which several springs are located. Elevated terrace gravels and the underlying soft sediments of the Ricardo formation on the northwestern block have been dissected by erosion; west of Mesquite Canyon wash the scarp has been completely destroyed. At the town of Garlock, the extreme northeastern tip of the scarp is reversed, so that it faces northwest instead of southeast, indicating recent left-lateral movement on the Garlock fault. East of Mesquite Canyon wash several elongate lens-shaped shallow depressions trending about N. 30° E. (or at an angle of about 30° to the N. 60° E. trend of the Garlock fault) are developed in the terrace gravels. These are grabens developed adjacent to the Garlock fault by local tension or stretching resulting from left-lateral horizontal drag on the fault.

Elsewhere within Saltdale quadrangle the Garlock fault is concealed under the alluvium of Cantil Valley; however, it is believed to project about S. 60° W. from the scarp at Garlock. The position of the fault is probably marked by the elevated terrace gravels at Daly mine north of Gypsite, and by the anticline in the Ricardo sediments northwest of Cantil. The fault is believed to pass under the gravels, which were elevated by local movement, and beneath or near the axis of the fold, which was probably formed by compressive movement.

The Garlock fault is well expressed northeast of Goler, in Randsburg quadrangle, where for about 3 miles it has formed a prominent scarp that faces northwest. Hulin [49] states that the southeastern fault block has moved northeast about 6 miles relative to the northwestern block, and cites as evidence the offsetting of the contact between Paleozoic rocks and quartz monzonite.

Rand Mountains

Within Saltdale quadrangle, all of the Rand Mountains but the northeastern portion is made up of granitic rock, largely quartz monzonite, which is part of the granitic batholith that extends southward throughout the greater portion of the Mojave Desert. The granitic rock exposed in the Rand Mountains is typically massive and has no definite flow structure.

Within Randsburg quadrangle, the Rand Mountains are made up largely of Rand schist which consistently dips south at a low angle. This schist exposure extends for about 3 miles into Saltdale quadrangle along the north flank of the mountains, where the structure consists of several gentle folds whose axes trend northeast. In the extreme northern foothills are two domed anticlines. Farther up the slope to the southeast is a southwest-plunging anticline which is cancelled by a syncline near the eastern border of the quadrangle. The irregular contact between Rand schist and quartz monzonite dips to the south.

The topography of the Rand Mountains—the generally steep northwest flank and very gentle southeast slope—suggests that a block was uplifted along a fault or zone of faults at its northwestern base and tilted gently toward the southeast. The scarp of this supposed fault has been eroded

[49] Hulin, Carlton D., Geology and ore deposits of the Randsburg quadrangle, California: California Min. Bur. Bull. 95, p. 62, 1925.

back, and the base of the range has been buried by debris, except at the extreme west end; there some evidence of the northwest-facing fault scarps remains. At the west end of the range, movements on several northeast-trending faults have thrown up blocks on the southeast, which form abrupt slopes that face northwest. The blocks of basement complex between these faults form ramps that slope northeast into Cantil Valley. The faults are believed to be branches of the supposed buried fault which trends N. 60° E. along the northern base of the Rand Mountains.

GEOLOGIC HISTORY

Pre-Cambrian (?) Deposition. The earliest geologic event that can be deciphered within Saltdale quadrangle is the deposition, probably during pre-Cambrian time, of a thick series of muds, along with lesser amounts of lime and fine sand, under a widespread sea. This is recorded in the Rand schist, the oldest formation in the area. During the later pre-Cambrian or early Paleozoic, a series of somewhat similar sediments was deposited in El Paso Mountains. This series was later mildly metamorphosed to form the Mesquite schist exposed just west of Mesquite Canyon.

Late Pre-Cambrian (?) Orogeny. It is not clear just what happened within Saltdale quadrangle following deposition of the sediments that now form the Rand schist. By the close of pre-Cambrian time this formation may have been built up to a great thickness, and the lower portion may have been altered to slate or even to schist by static metamorphism caused by the great load. That the Mesquite schist was not greatly deformed is indicated by the lack of angular discordance between it and the overlying Garlock series. The contact between the metamorphosed Mesquite schist and unmetamorphosed Garlock series in El Paso Mountains probably represents a period of uplift and erosion of some duration.

Paleozoic Deposition. Sometime during the Paleozoic era part if not all the area of Saltdale quadrangle was resubmerged under a widespread sea. The floor of this sea apparently received a tremendous thickness—at least 35,000 feet—of fine-grained sediments, tuffs, and lava flows. These strata, which make up the Garlock series, accumulated in part, if not in whole, during the Permian period; the lowest may have been laid down during an earlier Paleozoic period.

Siliceous sediments (now cherts), along with muds, impure lime, and some fine sand, accumulated rapidly on the floor of the Paleozoic sea. Numerous angular fragments of shale, chert, and limestone in some of the layers indicate that there was strong current and wave action. Two basalt flows, probably under the sea, interrupted this sedimentation, but the accumulated strata (Members 1 to 11 inclusive of the Garlock series) total some 10,000 feet in thickness. Limestone, conglomerate, and coarse sand, in addition to argillaceous and siliceous sediments, were subsequently deposited. Marine life was abundant during the Permian period, as evidenced by the numerous crinoid stems, fusulinids, and other fossils in the calcareous sediments. Sedimentation was interrupted or accompanied by volcanism, during which tuff and tuff breccia were laid down, and andesite porphyry was extruded. Thereafter more siliceous, argillaceous, and calcareous sediments were deposited. This series of sediments and volcanics (Members 12 through 21, extending into Randsburg quadrangle) totals some 25,000 feet in thickness.

The Garlock series is remarkable for its large percentage of siliceous sediments, now cherts and siliceous shales. These are in many respects similar to the Miocene siliceous shales and cherts of the California Coast Ranges—particularly in their great thicknesss, and in their association with tuffs and volcanic rocks. These cherts were deposited by microscopic siliceous organisms, and silicified by compaction; or deposited as tuffs and subsequently silicified; or chemically deposited as silica or silica gel, much in the same manner that calcium carbonate is deposited to form limestone. The source of the enormous amount of silica which makes up these sediments remains an unsolved problem, although the association of the cherts with tuffaceous and volcanic rock suggests that volcanism may have contributed the silica.

Triassic-Jurassic (?) Deposition. It is not definitely known whether or not the Triassic and Jurassic periods are represented by strata within Saltdale quadrangle, although marine sediments of those ages are known to occur in the southern Sierra Nevada and in the White Mountains.

Jurassic Orogeny. At the close of Jurassic period, the Nevadan orogeny took place. This was a time of great regional disturbance marked by emergence, intense deformation, plutonic intrusion, and metamorphism, over a large part of the western Cordilleran region. During this orogeny, strata of the Rand and Mesquite schists and Garlock series within Saltdale quadrangle were deformed, folded deeply into the earth's crust, and altered by mild static metamorphism. Rocks buried at great depths were invaded by the granitic magmas which make up the Sierran granitic batholith; these were intruded in several waves. The first intrusion was probably a basic magma of hornblende-quartz diorite; this was followed by very widespread biotite-quartz diorite and quartz monzonite intrusions, which were in turn followed by small intrusions of granite.

Cretaceous-Eocene Erosion. Events of the Cretaceous-Eocene left no record in the Saltdale quadrangle region. It is probable that during a very long period of erosion the mountains formed in the Nevadan revolution were worn down to a peneplain. There may have been several uplifts during this long interval, which was terminated by an orogeny in the late Eocene or Oligocene.

Oligocene-Miocene Deposition. The Eocene-Oligocene (?) orogeny was followed, during Oligocene (?) and Miocene time, by deposition of more than 6,500 feet of terrestrial gravel, sand, and red clay of the Goler formation in a valley now occupied by El Paso Mountains and Indian Wells Valley. Debris in the Goler formation was derived from granitic rocks and the Garlock series now exposed in El Paso Mountains. However, the cobbles in the Goler conglomerate are well rounded, indicating that they have been transported for a considerable distance. Cross-bedding in sand of the Goler formation suggests deposition by rivers flowing southwestward. The Goler formation was first laid down as a terrestrial boulder fanglomerate (Member 1), which filled canyons eroded into the basement complex, and then as cobble-pebble gravel, granitic sand, and red clay (Member 2). The latter were deposited under alternating wet and dry conditions. There is no evidence within Saltdale quadrangle of volcanic activity during this period of deposition.

Miocene or Pliocene Disturbance. Deposition of the Goler sediments was followed by an orogeny resulting in uplift, perhaps the first uplift, of El Paso Mountains by northward tilt sometime during or soon after the Miocene. El Paso fault and the Garlock fault may have been initiated during this orogeny, if not during the previous one. The minor faults east of Cudahy Camp developed during this orogeny. With the elevation of El Paso fault block to form El Paso Mountains, the Goler sediments were attacked by erosive forces, which cut through to the basement rocks in the area of maximum uplift.

Pliocene Deposition. Following the late Miocene-early Pliocene orogeny, the Ricardo formation was deposited in Indian Wells Valley and Cantil Valley, during Pliocene, and perhaps during early Pleistocene time. Sedimentation first started with deposition of fanglomerate (Member 1) derived from the basement rocks of El Paso Mountains. This was followed by volcanism which resulted in deposition of ash (Member 2) and extrusion of red andesite lava and breccia, followed by local accumulation of volcanic conglomerate (Member 3) ; then sands, clays, and ash (Member 4) were deposited in a lake which began to develop north of Ricardo. Accumulation of lacustrine and terrestrial sediments continued (Member 5), and renewed volcanism formed tuff breccia and four flows of basalt. Volcanic activity then ceased, but terrestrial sediments (Member 6) were laid down south of Ricardo and in Cantil Valley; and calcareous sand, clay, and opal chert (Member 7) were deposited in the lake which persisted in Indian Wells Valley north of Ricardo. This deposition was followed by the accumulation of purely terrestrial gravelly sediments (Member 8), probably in the early Pleistocene.

A total of 7,000 feet of Ricardo sediments and volcanics accumulated in the subsiding basin which is now the southwestern portion of Indian Wells Valley. Subsidence of the basin was probably contemporaneous with the elevation of El Paso Mountains.

Pleistocene Disturbance. Deposition of the Ricardo formation was followed by renewed uplift and erosion of El Paso Mountains during early Pleistocene time, this being the local effect of the early phase of the Coast Ranges orogeny. That great disturbance was initiated by widespread extrusion of basic lava, the Black Mountain basalt, which spread out as a thin flow. It was during this disturbance that the Garlock and El Paso faults probably became active, and the Rand Mountains were uplifted, possibly by southward tilt from a fault along their northwestern base. Cantil Valley became a basin in which sediments accumulated throughout Pleistocene time.

The early Pleistocene uplift was followed during middle Pleistocene time by a period of relative quiescence. The Rand and El Paso Mountains were eroded to the late maturity stage. During this interval, Indian Wells and Cantil Valleys, and the elevated peneplain on the south flank of the Rand Mountains were probably at about the same elevation. All canyons on the northwest flank of El Paso Mountains, including the westward-flowing portion of Last Chance Canyon and the head of Goler Gulch, drained directly into Indian Wells Valley. The oldest (highest) and second oldest terrace gravels, alluvium of Indian Wells Valley, alluvium on the south flank of the Rand Mountains, and the older (concealed) alluvium of Cantil Valley were deposited during this interval.

The Coast Ranges orogeny culminated during late Pleistocene time. Not only El Paso Mountains, but the entire area north of El Paso fault, including Black Hills and Indian Wells Valley, was elevated to its present height. Uplift occurred in several stages, as indicated by several levels of terrace gravels. This uplift caused rejuvenation and renewed erosion of the middle Pleistocene erosion surface, and caused the main south-draining streams to deepen their channels. Last Chance Canyon was deepened, and eroded headward until it captured the drainage system which during middle Pleistocene time flowed westward, straight out into Indian Wells Valley 2 miles north of Cudahy Camp. The undrained basin of Cantil Valley below the 2,000-foot contour was a shallow lake during late Pleistocene, as indicated by the gravel bar deposited along its eastern shoreline.

Movement along the Garlock fault was entirely horizontal during the late Pleistocene orogeny; there is no evidence of vertical movement within Saltdale quadrangle.

There is some inconclusive evidence that the Rand Mountains underwent renewed uplift during the late Pleistocene orogeny; but the northern scarp, supposedly initiated during the early Pleistocene disturbance and rejuvenated during the late Pleistocene, has been almost completely eroded back and destroyed. The northern base of the range has been buried by its own alluvial debris which was deposited as a large piedmont fan extending far up the canyons.

REFERENCES CITED

Axelrod, D. I., Eocene and Oligocene formations in the western Great Basin (abstract): Geol. Soc. America, Proc. Cordilleran Sec., p. 11, 1949.

Baker, C. L., Physiography and structure of the western El Paso Range and the southern Sierra Nevada: Univ. California Dept. Geol. Sci. Bull., vol. 7, pp. 117-142, 1912.

Fairbanks, H. W., Notes on the geology of eastern California: Am. Geologist, vol. 17, pp. 63-74, 1896.

Hershey, O. H., Some Tertiary formations of southern California: Am. Geologist, vol. 29, pp. 349-372, 1902.

Hershey, O. H., The Quaternary of southern California: Univ. California Dept. Geol. Sci. Bull., vol. 3, pp. 1-29, map, 1902.

Hess, F. L., Gold mining in Randsburg quadrangle, California: U. S. Geol. Survey Bull. 430, pp. 23-47, 1909.

Hulin, C. D., Geology and ore deposits of the Randsburg quadrangle, California: California Min. Bur. Bull. 95, pp. 1-152, 5 maps, 1925.

Hulin, C. D., Geologic features of the dry placers of the northern Mojave Desert: California Div. Mines Rept. 30, pp. 417-426, 1934.

Merriam, J. C., The occurrence of Tertiary mammalian remains in northeastern Nevada: Univ. California Dept. Geol. Sci. Bull., vol. 8, pp. 275-281, 1914.

Merriam, J. C., Relationship of Pliocene mammalian faunas from the Pacific Coast and Great Basin province of North America: Univ. California Dept. Geol. Sci. Bull., vol. 10, pp. 421-443, 1917.

Merriam, J. C., Tertiary mammalian faunas of the Mohave Desert: Univ. California Dept. Geol. Sci. Bull., vol. 11, pp. 437-585, 1919.

Simpson, E. C., Geology and mineral deposits of the Elizabeth Lake quadrangle, California: California Div. Mines Rept. 30, pp. 371-415, map, 1934.

Smith, J. H., The Eocene of North America, west of the 100th meridian (Greenwich): Jour. Geology, vol. 8, pp. 444-471, map, 1900.

Tucker, W. B., Sampson, R. J., and Oakeshott, G. B., Mineral resources of Kern County: California Jour. Mines and Geology, vol. 45, pp. 203-251, 1949.

MINERAL DEPOSITS OF SALTDALE QUADRANGLE

By T. W. Dibblee, Jr. and T. E. Gay, Jr.*

OUTLINE OF REPORT

INTRODUCTION

Although there has been much mining activity in Saltdale quadrangle in past years, only two properties are now being operated; these produce gypsum and volcanic ash. Mineral commodities which have been produced in this area in the past also include borax, clay, copper and silver, gold, opal and other ornamental minerals, pumice, and salt. One small deposit of low-grade coal has been mined for local consumption. Flagstones have also been used locally but none have been produced commercially. Large bodies of perlite are in the quadrangle but have not been exploited.

Literally hundreds of mine workings are scattered over the quadrangle, few of which show signs of recent activity other than annual assessment labor. El Paso Mountains are virtually covered with current claims. Only the more recent or significant workings are shown on the economic mineral map. In many cases one map symbol represents all the various workings in an entire group of claims.

Many mineral deposits which are described in the literature as being within this quadrangle are not shown on the economic deposit map, as it was impossible to identify some of the unmarked workings from descriptions of past activities.

On the economic mineral map and in the accompanying tabulated summary, locations of various properties are referred to by township and section number. Such locations are based on survey lines projected from the Randsburg quadrangle, which borders this area on the east, and from several known section corners in the southwest part of the Saltdale quadrangle. Therefore all descriptions of locations by section numbers, except those of the oil wells southwest of Koehn, are projected, and are subject to correction.

MINERAL DEPOSITS

Borax

Only token shipments of borax have been made from Saltdale quadrangle, but this locality was among the first in the state to produce borax.

* Junior mining geologist, California State Division of Mines.

Balls of ulexite ($NaCaB_5O_9 \cdot 8H_2O$) from 1 inch to 3 inches in diameter are formed near the surface of the soil by solar evaporation of saline liquids drawn upwards by capillary action. Since these so-called "cotton balls" of silky ulexite form only after rainwater has dissolved other borate minerals deeper in the earth, none has been produced during the recent drought years.

The Cotton Ball borax mine, sec. 8, T. 30 S., R. 38 E., was located in 1896 by Charles Koehn of Cantil and worked by him sporadically from 1898 to 1929. After the surface was turned up with a plow the balls of ulexite were picked by hand from the earth and sacked for shipment. Total production from this property was about three carloads, which were sent to San Francisco for refining.

Clay

Production of clay from Saltdale quadrangle has amounted to several thousand tons which have been used chiefly in oil-refining processes, and to a less extent in the hard rubber industry. White clay was mined from the twenties to the mid-forties, but none has been produced since World War II. All clay deposits are in the altered pyroclastic sediments of Member 2 of the Ricardo formation (Tr_2).

Although many clay deposits are noted in the literature on this area,[1] production is known from only three—the Snow White, Hancock, and Brown-White (including Iron Canyon Bentonite) deposits. These were all worked by the Los Angeles Clay Company. The White Clay No. 1 and No. 2 are two patented claims formerly owned by the Los Angeles Pressed Brick Company which was purchased by Gladding, McBean & Company in 1927. No work has been done since then and data on the characteristics of the clay are not available.

Coal

Only one very minor occurrence of low-grade coal is known in the Saltdale quadrangle. This is a thin lens of sandy lignite located near the base of the Goler formation (Tg_2 on geologic map) northeast of Gerbracht Camp on the property of C. E. French of Randsburg. Samples collected were too earthy to burn but material of higher quality is said by several residents to have been mined for local consumption. No work has been done since 1900 and little trace of the operation remains.

Copper and Silver

Although many prospects and exploration openings in this quadrangle show traces of copper and silver mineralization, no commercial production of these metals is recorded. Throughout the pre-Tertiary rocks of El Paso Mountains are numerous brecciated zones and brecciated quartz veins, many of which are mineralized with sulfides and oxides of iron, copper, and silver. They occur in practically all formations of the basement complex, but are most abundant in brittle or fractured formations or near contacts. Numerous prospects have been dug into these brecciated zones and veins, but none has yielded copper or silver in commercial quantities. It is believed that gold was actually the principal objective of many of these workings, but assay tests to confirm this are lacking.

At Redrock Canyon there is a prospect in the granophyre showing blue stains of copper carbonates. About a mile east are many prospects dug

[1] Tucker, W. B., Kern County: California Div. Mines and Mining Rept. 25, pp. 67-68.

into brecciated zones, and some quartz veins containing sulfide and oxide coatings of iron and copper in the quartzite conglomerate-hornfels series. The mineralization was probably supplied by the series of granophyre sills which intrude these rocks. Yield of copper here was small and all workings are now inactive.

The quartz monzonite in the Rand Mountains and biotite-quartz diorite in El Paso Mountains are almost devoid of mineralization. At only one locality in a canyon north of Saltdale in the latter rock there is a quartz vein showing slight copper stains. This vein is adjacent to a lamprophyre dike and has been explored by several deep shafts.

The hornblende-quartz diorite contains numerous copper-stained quartz veins which have been prospected on the claims in the vicinity of Copper Basin mine in sec. 14, T. 29 S., R. 38 E. The veins of this area are generally highly brecciated and contain coatings of iron and copper sulfides and oxides. Most of these deposits are of too low grade to be of commercial value although samples from the 2,000-foot drift of the Copper Basin mine show appreciable amounts of chalcopyrite. These workings are idle.

Prospects on the claims in the vicinity of the Smith (Schmidt) mine in sec. 1, T. 29 S., R. 38 E., have been developed along mineralized zones and veins in the Mesquite schist; some have also been developed in the adjacent foliated granite. These zones are mineralized with sulfides of copper and also of silver. Mineralization seems to be associated with granitic dikes originating in the foliated granite. Small amounts of ore have been produced.

Scattered throughout the Garlock series are numerous prospects along brecciated zones which generally follow bedding planes and occur in all types of rocks throughout the series. Many of these are mineralized with sulfides and oxides of iron and copper. Some, such as those east of the mouth of Mesquite Canyon and at Apache mine in sec. 31, T. 28 S., R. 39 E., M. D., are associated with granophyre intrusions or dikes, suggesting that this rock may be the source of the mineralization. All workings are now idle.

Flagstone

The Mesquite schist exposed in Mesquite Canyon is possibly suitable for flagstones and is close to the Southern Pacific Railroad. Slabs of this rock have been used locally in buildings, walls, and patios, but none have been quarried for commercial purposes. The schist cleaves into slabs of any desired thickness and up to several feet across, with a mottled surface that has a bright silvery sheen.

Gold

Gold has been the most commonly sought mineral commodity in Saltdale quadrangle, despite the relatively small amount of gold actually produced. In several areas the earth is literally riddled with gold-mine tunnels but very few of the mines actually showed a profit. Recovery of gold has been substantial from placer operations, but only token production is known from lode mines in this quadrangle. The low production results from the low average value of gold in the gravels and veins of the area, and from the lack of water for placer mining. The expense of procuring water and the inefficiency of dry-washing processes make placer operations financially unattractive except during periods of economic depression.

Gold mining reached a peak in Saltdale quadrangle from 1895 to 1905, and again during another, less productive, surge of activity in the depression years. Since then the only activities have been small-scale placer operations or testing programs preliminary to establishing full-scale mines. Test operations were conducted as recently as 1950 in Redrock Canyon and Goler Gulch.

In El Paso Mountains placer gold has and is being mined from Tertiary and Quaternary fluviatile boulder gravels. The gold occurs in the form of small nuggets, and has been quarried largely by hand, from gravels in Goler Gulch, and Last Chance and Redrock Canyons. Numerous open workings and tunnels can be seen in the gravels of these canyons, which were dug by many miners who entered the area long ago. Most of these hardy individuals received little if any reward for their efforts, as the gold content of the gravels is low—generally only a few cents a yard.

The largest yield of placer gold from El Paso Mountains has been obtained at Goler Gulch from boulder gravels of the basal Goler formation, previously assigned to the Ricardo formation by Hulin.[2] These gold-bearing gravels occur as two large exposures on the west side of Goler Gulch and as several small isolated erosional remnants, all within 3 miles of the mouth of the canyon. Most of the gold was found upon the surface of the basement rocks under the gravels, but some was found within the gravels. The gold has been found as nuggets as much as an inch long, some of which show effects of abrasion. The largest yield of gold has come from the lower of the two large gravel exposures, in which there are numerous diggings.

In Last Chance Canyon there are many diggings for gold; most are in Quaternary terrace gravels, but a few are in the basal gravel (Member 1) of the Ricardo formation. All are now abandoned.

Basal gravel (Member 1) of the Ricardo formation has yielded some gold in the east fork of Redrock Canyon north of Ricardo. Erosional remnants of these gravels lying in canyons eroded into the basement rocks contain numerous diggings, and most of the gold was apparently found at the base of the gravels. In 1950 one locality 2 miles from the highway was being worked, but when tests proved unencouraging the project was abandoned.

The auriferous gravels of the basal Goler formation at Goler Gulch are perhaps comparable to the auriferous Eocene gravels of the western foothill belt of the Mother Lode region of the Sierra Nevada, which were derived from the gold-bearing rocks of the Mother Lode and deposited upon a surface having undergone a very long period of erosion. The basal gravels of the Goler formation, which may also be of Eocene age, were likewise derived from gold-bearing rocks and deposited upon a basement surface having undergone very long erosion. The gold was left behind and concentrated in old canyon bottoms as the enclosing basement rocks weathered and were eroded away. The Goler formation was deposited upon an eroded surface of moderate relief in which only the canyons and valleys became filled with boulder gravels. The gravels at Goler Gulch were deposited in one of these valleys which cut across the low range of hills that now forms El Paso Mountains. The minor canyons

[2] Hulin, C. D., Geologic features of the dry placers of the northern Mojave desert: California Jour. Mines and Geology, vol. 30, pp. 417-426, 1934.

running into this valley, such as that filled by gravels of the lower exposure west of Goler Gulch, were apparently quite deep. Boulder gravels may have filled and been washed out of canyons such as this several times by torrential storms; thus gold was brought in with each deposit and left behind upon the basement surface. In this manner the gold has become concentrated in irregularities in the basement surface, chiefly on the bottoms of these old boulder-filled canyons.

Placer gold in the basal Ricardo boulder gravels at Redrock Canyon was probably concentrated in the same way. Gold in the terrace gravels of Last Chance Canyon was probably derived from the reworking of the basal gravels of the Ricardo and Goler formations.

Gypsum

Gypsum, of the earthy variety known as gypsite, has been produced from one property in Saltdale quadrangle in small but consistent amounts since the early 1900s. The source of the gypsite is a former lake-margin deposit at the south end of Koehn Lake. The gypsite occurs as horizontal beds of white, fine-grained gypsiferous material the consistency of packed snow. These beds cover an area of about a square mile and are as much as 8 or 9 feet deep.

A. D. Daly owns and operates the deposit. Mining is entirely by open pit, a loader filling trucks directly for shipment. No crushing or refining is required to prepare the material for use. Prior to the first world war, gypsum was calcined on the property for use in plaster, but since then it has been used almost exclusively for agricultural purposes. Distance of the deposit from a large market is a handicap; nevertheless consistent production of several hundred tons a year has been maintained. From 60 to 70 percent gypsum content has been guaranteed to buyers of the material.

One other deposit of gypsite has been claimed just west of the Redrock Canyon highway several miles north of Ricardo. Bulldozer cuts expose gypsiferous sandy soil, but nothing has been produced on a commercial scale.

Ornamental Minerals

Saltdale quadrangle has several features of interest to amateur mineral collectors, and has been a popular collecting locality for various decorative minerals. Agate, jasper, petrified wood, opal, zeolites, and other mineral substances have been found in the quadrangle. Several establishments in the area offer local mineral materials for sale to collectors. Several shafts have been sunk in sec. 12, T. 29 S., R. 37 E., and sec. 18, T. 29 S., R. 38 E., from which opal has been produced at times.

The vicinity of Last Chance Canyon was for many years a collecting ground for agate, jasper, and petrified wood gathered by many rock-hounds for cutting into polished stones. The agate occurs in the form of thin veinlets of colorless to white banded chalcedony as much as an inch in thickness, in the red andesite breccia Flow A of Member 2 of the Ricardo formation. Some also occurs in the basalt dike 2 miles east of Cudahy Camp.

Jasper of rusty yellow and red color, much of it showing moss patterns, occurs at several places in the andesite breccia Flow A; the largest amount occurs 1 mile west of Holly Camp. Rusty yellow jasper also occurs in some of the basalt flows and dikes of the Ricardo formation. The Black Mountain basalt is devoid of jasper or chalcedony.

The opal chert of Members 7 and 5 shows interesting markings and much of it encloses silicified palm roots. Some has been gathered for polishing. It occurs in great quantities, but lacks color.

Petrified woods were once abundant in various sedimentary members of the Ricardo formation, chiefly Members 4, 5, and 7. These consisted of palm woods and roots, and hardwoods such as juniper and oak. One mile northwest of Cudahy Camp were petrified logs in place in Member 4 of the Ricardo. For many years these were preserved on a private claim as a "petrified forest" and used as a tourist attraction. However, during late years all traces of these petrified logs have disappeared. The Last Chance Canyon area has been visited by so many rockhounds that practically all loose pieces of petrified wood, jasper, and agate have been gathered and carried away, and very little remains on the surface today.

Fire opals of gem quality have been mined from basalt 1½ miles west of Cudahy Camp. The opal occurs as amygdules as much as half an inch in diameter in the uppermost of the four basalt flows of Member 5 of the Ricardo formation. The opal-filled vesicles occur within a mile of the northern termination of the flow. Opal is also found in vesicles in Member 7 of the Ricardo formation. The opals are translucent and show a strong play of colors, but are generally too fractured to be of gem quality. A few flawless specimens of gem quality have been found, however. Quarrying of the enclosing basalt is difficult, and care is necessary to avoid fracturing the opals.

Besides fire opals the uppermost basalt flow contains numerous amygdules filled with various kinds of zeolites throughout most of its areal extent. The zeolites are mainly analcite and natrolite. Many vesicles are filled with calcite, chalcedony, and common opal.

Perlite

Perlite crops out in Last Chance Canyon between Holly and Cudahy Camps. This rock consists of steel-gray volcanic glass thoroughly fractured along curved surfaces, and has the property of expanding to many times its volume when heated. It is used in the manufacture of lightweight aggregate, loose-fill insulation, acoustical plaster, and for other industrial purposes. The rock occurs locally as a lenticular flow as much as 30 feet thick at the top of the red andesite breccia Flow A of Member 2 of the Ricardo formation. It is associated with irregular ejections of rhyolite breccia, and is generally overlain by tuff, sometimes by andesite and basalt. The perlite is exposed over broad areas on the dip-slope of the westward-dipping andesite breccia.

The perlite deposits are shown on the economic map although there has been no production from them. They occur within two groups of claims known as the Black Eagle and Gray Eagle placer claims, in secs. 4, 8, 9, and 17, T. 29 S., R. 38 E., and sec. 32, T. 28 S., R. 38 E., owned by R. L. Meuer and Della Gerbracht.

Pumice

Gray pumice of abrasive quality occurs as numerous fragments in white tuff near the top of Member 2 of the Ricardo formation north of Last Chance Canyon. The pumice-bearing tuff is as much as 50 feet thick.

A large deposit of pumice tuff occurs on the Black Mountain group of placer claims in sec. 5, T. 29 S., R. 38 E., and secs. 31 and 32, T. 28 S., R. 38 E., north of Holly Camp. This deposit is 50 feet thick and dips 20°

W. It continues southward west of Holly Camp and crops out 30 feet thick on the adjacent Opal placer claims in secs. 4, 5, and 8, T. 29 S., R. 38 E., and sec. 32, T. 28 S., R. 38 E. Both groups of claims are owned by R. L. Meuer and Della Gerbracht, Randsburg, California. Only a few cubic yards of the material have been quarried from the Black Mountain claim, and none has been sold.

A small deposit of pumice-bearing tuff about 30 feet thick crops out on the north side of a small hill 2 miles east of Black Hills Well at the north border of the map. This deposit, known as the Ora No. 1 claim, has been developed for open pit mining, but only a few yards of the material have been removed.

Salt

Salt was produced from the brines of Koehn Dry Lake from 1920-48 except during drought years. It is expected that operations will be resumed as soon as the present drought conditions are ended by sufficient precipitation to produce brine in the lake. Yearly average production has been several thousand tons of crude salt.

Long Beach Salt Company is the sole owner and operator of the salt works, having bought out Freemont Salt Company in 1926 and Consolidated Salt Company in 1931.

Salt is taken into solution from the saline minerals present in the dry lake basin when water is present. The salt-bearing brine is pumped into ponds where solar evaporation concentrates and precipitates the salt and other minerals. The precipitated solid material is broken into cakes from the bottom of which gypsum and other impurities are removed by hand. The remaining salt in the cakes is crushed and sold. Some of the salt is further dried in a rotary kiln and sold as semi-refined salt. The product is not pure enough for table use but is in demand for many commercial purposes.

Volcanic Ash

Pure volcanic ash of commercial quality occurs in Members 2 and 4 of the Ricardo formation and crops out in Last Chance Canyon. The largest deposit is 20 feet thick and lies immediately below the red andesite agglomerate of Member 2. It consists of white, pure, fine-grained ash, both massive and bedded. Its outcrops may be traced from a point 2 miles east of Ricardo for some 7 miles northeastward to a point a mile north of Holly Camp. White bentonite is locally associated with this ash bed. Member 4 of the Ricardo formation contains six layers of pure white ash cropping out over a distance of 3 miles. The thickest of these is 9 feet thick, and occurs at the top of the member.

The volcanic ash of Member 2 has been prospected and quarried at a number of places. The largest quarrying operation, and the only one now active, is at Holly Camp on the property of Calsilco Corporation which owns nine claims in sec. 33, T. 28 S., R. 38 E. and sec. 4, T. 29 S., R. 38 E. The ash here is 20 feet thick, dips about 20° W., and is very compact. It is being quarried by steam shovel in a large open cut, and processed at the plant which consists of a hammer mill, a bunker, a $\frac{3}{8}$-inch screen, cyclone collectors, and a packing machine. The ash is pulverized and sifted through assorted meshes, and made into insulation for ceilings, acoustical plaster, soil conditioner, Holly cleanser, wood filler, paint, and abrasives in tooth powder.

Wells drilled in Saltdale quadrangle.

Map No.	Operator	Well	Year drilled	Elevation (in feet)	Depth (in feet)	Remarks
1	Redrock Canyon Oil Co.	----------	1940	----------	2,648	Four cores 2,353-2,420 ft. gray sand and green to red clay-stone, 70° dip (?) 2,375 ft. One core 2,480-96 ft. gray coarse arkosic sandstone. One core 2,628-48 ft. pink-gray coarse arkosic sand.
2	Western Research Lab., Inc.	Cruickshank A1	1949	2,230	1,859	One core 967-87 ft. sandy clay and sand. One core 1,332-52 ft. brown sand and green clay.
3	J. & S. Exploration Co.	Cruickshank 2	1949	2,119	2,905	Reported top Miocene 1,147 ft.
4	J. & S. Exploration Co.	Cruickshank 3	1949	2,195	3,090	Reported top Miocene 1,090 ft.

Cudahy Packing Company quarried the 9-foot ash bed at the top of Member 4 from 1923-47. This ash is very fine grained and compact and was used in Old Dutch Cleanser under the trade name "seismotite". Cudahy owned 15 adjacent claims in secs. 5 and 8, T. 29 S., R. 38 E., but mined entirely from two claims at the northeast end of the group.

A few hundred tons of volcanic ash was shipped from the property of George J. Colton in sec. 24, T. 29 S., R. 37 E. This was used as an abrasive in cleanser, but a steady market did not develop.

The Parrott and Allee silica mine in sec. 18, T. 29 S., R. 38 E., under various managements, produced minor amounts of volcanic ash—less than 1,000 tons in all—for use as abrasive in cleansers and as concrete aggregate. It has been idle for more than a decade.

Oil and Gas

Four wells were drilled for oil and gas in the Saltdale quadrangle, all within a mile and a half of Cantil. All were drilled into, and probably bottomed in, sediments of the Ricardo formation, and none obtained showings of oil or gas that could be verified. Data on these wells are indicated in the accompanying table.

Marine Tertiary sediments do not crop out, and the Paleozoic rocks are highly deformed in this quadrangle. No oil or gas seepages are known.

TABULATED LIST OF MINERAL DEPOSITS IN SALTDALE QUADRANGLE

The following list is arranged alphabetically by mineral commodity. The number in the first column refers to the economic deposit map, plate 2. Numbers in parentheses are not shown on the map because no definite location is available. Due to the fact that public land survey lines are not complete on the base map, all locations are projected.

References given in the last column use the abbreviation R which refers to the *Report of the State Mineralogist*, or *California Journal of Mines and Geology*, California Division of Mines, San Francisco. The number preceding the colon is the volume referred to, the number following the colon is the page reference. Personal communications from Martin C. Engel, Cantil P. O., and others are gratefully acknowledged.

BORAX

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
(1)	Cotton Ball	Charles Koehn, Gypsite (deceased)	8	30S	38E	MD	Abandoned. Production about 3 carloads from 1898 to 1929. (M. C. Engel, personal communication, herein)

CLAY

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
2	Brown-White (includes Iron Canyon bentonite)	E. M. Brown, et al., P.O. Box 11, Cantil	25	29S	37E	MD	Idle. Production several thousand tons, 1920-24. (R 25:67; R 45:276—Iron Canyon bentonite; herein)
3	Hancock	Hancock Oil Co., P.O. Box 810, Long Beach 1	30	29S	38E	MD	Idle; filter clay produced. (E. M. Brown, Cantil, personal communication)
	Iron Canyon bentonite						(See Brown-White)
4	Koehn (including Red Rose and White Rose claims)	A. D. Daly, P.O. Box 1047, Lancaster	20	29S	38E	MD	Idle; no production recorded. (R 25:67)
(5)	McKinney (2 claims)	Charles McKinney, Saltdale (deceased)	20	29S	38E	MD	Idle; no production recorded. (R 25-67)
6	Snow White (5 claims)	O. J. Salisbury, Cantil	30	29S	38E	MD	Idle; produced large tonnage of filter clay before World War II. (R 25:68; R 45:277; herein.)
(7)	Stevens (4 claims)	William Stevens, Cantil (deceased)	?	29S	38E	MD	Idle; no production recorded. (R 25:68)
(8)	White Bluff (2 claims)	Walter Tisch, Cantil	18	29S	38E	MD	Idle; no production recorded. (R 25:68)
(9)	White Clay No. 1 and White Clay No. 2. (40 acres total)	Gladding, McBean & Co., 2901 Los Feliz Blvd., Los Angeles 26.	29, 30	29S	38E	MD	Idle; no production recorded. (Richard Brooks, personal communication; herein.)

COAL

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
10	French deposit	C. E. French, Box 291, Randsburg	6	29S	39E	MD	Idle; small production before 1900 for local consumption. (R 12:457; herein.)

COPPER AND SILVER

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
11	Apache (Holland)	L. B. Williams, 6127 Sepulveda Blvd., Van Nuys	31, 32	28S	39E	MD	Idle; mill erected in sec. 30, treated some ore for gold, but production is unknown. (R 45:208)
12	B. Copper, (member of Iron Hat group of 6 claims)	William Schmidt, Randsburg; leased to Walter Bickle, Randsburg	1	29S	38E	MD	45′ inclined shaft in fractured shale. Minor mineral showings. Recent development, no production. (See Iron Hat)
13	College Girl (former Voss holding)	Real Goulet, P.O. Box 864, Bishop	18	29S	39E	MD	Idle; no production.
14	Copper Basin group (26 claims)	William Schmidt and Mike E. Lee, P.O. Box 105, Randsburg	14, 15, 23	29S	38E	MD	Idle; no production recorded. (R 45:208)
15	Copper Chief group (4 claims, including Zundra group of 3 claims)	Della G. Gerbracht, P.O. Box 346, Randsburg; leased to D. C. Weiss, et al., 1514 North Myers, Burbank	12 8	29S 29S	38E 39E	MD MD	Idle; no production recorded (R 45:209)
16	Copper Queen	Isaac Blum, Los Angeles	27	29S	38E	MD	Idle; one carload shipped in 1921. (M. C. Engel, personal communication)

17	Copperola group (including Run Around 1 to 8, Run Around Ext. 1 and 2, Run Around millsite, Copperola 1, 2, 11, and 12)	Della G. Gerbracht, P.O. Box 346, Randsburg	13, 24	29S	38E	MD	Idle; no production recorded. (R 45:208)
18	Crystal Springs	Frank Curtis, Bakersfield	22	29S	38E	MD	Idle; no production.
19	French group, including Copper King, Silver Streak, Black Crow, Enterprise No. 1 and No. 2, and Covellite No. 1 claims (formerly Layman; Walsh; and Walsh and McClaude groups)	C. E. French, P.O. Box 291, Randsburg	36 5, 6	28S 29S	39E 39E	MD MD	Idle, no production recorded (R 17:308, R 25:23, 24, R 45:253—Layman; Walsh; and Walsh and McClaude groups)
20	Galena (3 claims)	Della G. Gerbracht, P.O. Box 346, Randsburg	7	29S	39E	MD	Idle; no production.
21	Decker	Della G. Gerbracht, P.O. Box 346, Randsburg	18	29S	39E	MD	Idle; no production.
22	Gladys	Frank Curtis, Bakersfield	11	29S	38E	MD	Idle; no production.
23	Gold Peak	Della G. Gerbracht, P.O. Box 346, Randsburg	6, 7	29S	39E	MD	Idle; no production.
24	Golden Eaglet and Queen	Della G. Gerbracht, P.O. Box 346, Randsburg	5	29S	39E	MD	Idle; no production.
25	Golden View (8 claims)	Della G. Gerbracht, P.O. Box 346, Randsburg	4	29S	39E	MD	Idle; no production.
26	Grandad group (3 lode and 3 placer claims.)	Della G. Gerbracht, P.O. Box 346, Randsburg	31	28S	39E	MD	Idle; no production.
	Holland						(See Apache)
	Iron Hat group (6 claims, including Smith or Schmidt and B. Copper mines)	William Schmidt, Randsburg	1	29S	38E	MD	Idle; no production recorded. (R 45:225)
	Layman						(See French group)
27	Loophole	Della G. Gerbracht, P.O. Box 346, Randsburg	31, 32	28S	39E	MD	Idle; no production.

COPPER AND SILVER—Continued

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
(28)	Orange Blossom (8 claims)	Mrs. J. S. Bishop (deceased), A. H. Bishop, H. D. Cook, Mojave	6 1	30S 30S	38E 37E	MD MD	Idle; no production recorded. (R 45:208)
	Prospect						(See Zuna)
29	Run Around claims (members of Copperola group)	Della G. Gerbracht, P.O. Box 346, Randsburg	24	29S	38E	MD	Idle; no production recorded. (R 45:208—Copperola)
30	Smith (Schmidt) (member of Iron Hat group of 6 claims)	William Schmidt, Randsburg	S½1	29S	38E	MD	Idle; no production recorded. (R 45:225—Iron Hat group)
31	Voss properties	Real Goulet, P.O. Box 864, Bishop	9, 16	29S	39E	MD	Idle; production unknown.
	Walsh; Walsh and McClaude						(See French group)
32	Zuna A and Zuna Extension ("Prospect mine" on map)	Della G. Gerbracht, P.O. Box 346, Randsburg	12	29S	38E	MD	Idle; no production recorded. (R 45:208—Copperola group)
	Zundra group						(See Copper Chief group)

GOLD, LODE

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
(33)	Brymer	A. F. Forrest, Randsburg (?)	22	29S	38E	MD	Idle; no production. (M. C. Engel, personal communication)

(34)	Confidence group (6 claims)	Real Goulet, P.O. Box 864, Bishop	31 (?)	29S	38E	MD	Idle; no production recorded. (R 29:296, 297)
(35)	Croesus group (3 claims, including Little Charlie claim)	Jack Bishop, Trona	6	30S	38E	MD	Idle; production unknown. (R 45:217)
36	Demand Note (former Voss holding)	Real Goulet, P.O. Box 864, Bishop	11	29S	39E	MD	Idle; no production.
37	Eagle Roost	Mrs. Catherine Jewell, Randsburg	2	29S	39E	MD	Idle; production unknown.
38	Gateway (formerly Lutz) (7 claims)	Della G. Gerbracht, P.O. Box 346, Randsburg	17	29S	39E	MD	Idle; no production.
(39)	Golden Badger	Herman Gowin, Garlock (deceased)	13	29S	38E	MD	Idle; about $4,000 produced in 1940-41 (M. C. Engel, personal communication)
40	Golden Thorn	Herman Gowin, Garlock (deceased)	16	29S	39E	MD	Idle; no production.
41	Jumbo group (3 claims)	William Hubber, 4223 Eagle Rock Blvd., and Ray Bennett, 2918 Laclede Ave., Los Angeles	2, 3	29S	39E	MD	Idle; no production recorded. (R 45:226)
	Little Charlie						(See Croesus group)
(42)	Little Jimmy	Mrs. Josie Bishop, Mojave (deceased)	1	30S	37E	MD	Idle; no production recorded.
43	Mountain group (3 lode, 2 placer claims)	Lee Mountain, 1661 Olive St., Bakersfield	15	29S	38E	MD	Idle; no production.
(44)	Old Garlock	Unknown	16	29S	39E	MD	Idle; extensive development but no production. (M. C. Engel, personal communication)
(45)	Rattlesnake group (2 claims)	Mrs. J. S. Bishop, Mojave (deceased)	26	29S	38E	MD	Idle; production unknown. (R 25:59; R 45:266, 271)

GOLD, PLACER

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
(46)	Black Mountain	Chas. Brewer, mgr., Black Mountain Placers, Inc., Los Angeles	10	29S	38E	MD	Idle; production unknown. (R 25:29)
	Bond Buyer						(See Voss Consolidated)
	Cash Register						(See Voss Consolidated) (R 45:209—Orange Blossom)
	Chamberlain group of placer claims, including New Dawn, Saddle, Saddle Amended, and six 160-acre claims on Nugget Flat.	William Hubber, 4223 Eagle Rock Blvd., and Ray Bennett, 2918 Laclede Ave., Los Angeles	2, 11, 33, 34	29S 28S	39E 39E	MD MD	Idle; large past production of nugget gold, amount unknown. (R 45:217, 223—Goler Canyon Placers)
47	Cunningham group of placer claims, (one 160-acre, and three 20-acre claims)	Mrs. Catherine Jewell, Randsburg	1, 2 27*	29S 28S	39E 39E	MD MD	Idle; production of nugget gold reported $1,500 in 1930-34. (R 45:217)
48	Daly	A. D. Daly, P.O. Box 1047, Lancaster	8	29S	38E	MD	Idle; production unknown.
49	Golden Rule	Earl Holloway, Olancha	20	29S	38E	MD	Idle; no production recorded.
50	Grubstake (Grubstake Hill) placer (2 claims)	A. D. Daly, P.O. Box 1047, Lancaster	17	29S	38E	MD	Idle; production unknown. (R 25:35, 36)
51	Janney group of placer mines (70 160-acre placer claims in Goler Canyon and Summit Diggings districts) (East of this map)	John Janney, Pioche, Nevada; superintendent: S. M. Mingus, P.O. Box 94, Randsburg	†1, 2, 3 10, 11, 12, 23, 24, 25, 26	29S	39E	MD	Idle; intermittent production 1934-41 but figures not available. (R 45:225)
(52)	New Dawn						(See Chamberlain group)

53	Nugget Flat placers (included in Chamberlain group)	William Hubber, 4223 Eagle Rock Blvd., and Ray Bennett, 2918 Laclede Ave., Los Angeles	33, 34	28S	39E	MD	Idle; produced nugget gold of unknown value. (R 45: 217—Chamberlain group)
54	Pasadena Mine Products Company	R. A. Roberts, 1107 E. Colorado St., Pasadena 1	8	29S	38E	MD	Idle; production unknown.
55	Rand placer (80 acres)	Yellow Aster Mining and Milling Company, 650 S. Grand Ave., Los Angeles	12	29S	39E	MD	Idle; leased to D. V. Cole, Randsburg, in 1949; production unknown. (S. M. Mingus, Randsburg, personal communication)
56	Ricardo Placers (2,000 acres of patented placer ground, including Ricardo, Deep Channel, Ricardo Deep Channel No. 1, and Tufa Quarry claims)	Mrs. Nora B. Hagen, Bakersfield	35 2	29S 30S	37E 37E	MD MD	Idle; production unknown. (R 12:456-458; R 13:195; R 25:46; R 30:246, 247)
57	Saddle and Saddle Amended claims (included in Chamberlain group)	William Hubber, 4223 Eagle Rock Blvd., and Ray Bennett, 2918 Laclede Ave., Los Angeles	11	29S	39E	MD	Idle; production unknown. (R 45:217—Chamberlain group)
58	Stardust	Mrs. Catherine Jewell, Randsburg	2	29S	39E	MD	Idle; production unknown.
59	Unnamed placers in Upper Last Chance Canyon near Bonanza Gulch	Unknown	3, 4, 9, 10	29S	38E	MD	Idle; production unknown.
60	Voss Consolidated placer mines (including Bond Buyer and Cash Register groups, totaling 7 claims)	Real Goulet, P.O. Box 864, Bishop	1 6	30S 30S	37E 38E	MD MD	Idle; coarse nugget gold produced in unknown amount. (R 25:51; R 29:276)

* Location unknown.
† Properties held in Saltdale quadrangle.

GYPSUM

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
61	A. D. Daly Gypsum (formerly Mojave Desert Agricultural Gypsum)	A. D. Daly, Box 1047, Lancaster	28	30S	38E	MD	Operating, producing agricultural gypsite. (R 25:69; R 45:248; herein)
62	Atlas No. 1	Albert E. Droubie, Atlas Mines, 416 National Title Bldg., Los Angeles 13	11	29S	37E	MD	Idle; located in 1948 but no production known. (Herein)

OPAL

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
63	Opal mines	Herman Pearson, Cantil, and Harry Cowden, East Los Angeles (?)	13 18	29S 29S	37E 38E	MD MD	Irregular operation; collectors' specimens produced.

PERLITE

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
64	Black Eagle deposit	R. L. Meuer, and Della Gerbracht, P.O. Box 864, Randsburg	8, 9, 17	29S	38E	MD	Idle; no production. (R 45:249; herein)
65	Grey Eagle deposit	R. L. Meuer, and Della Gerbracht, P.O. Box 864, Randsburg	4, 9 32	29S 28S	38E 38E	MD MD	Idle; no production. (R 45:249; herein)

PUMICE

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
(66)	Black Mountain deposit (4 lode and several placer claims)	R. L. Meuer, and Della G. Gerbracht, P.O. Box 864, Randsburg	31, 32 5	28S 29S	38E 38E	MD MD	Idle; no production. (R 45:249; herein)
67	Opal Extension and South Opal	R. L. Meuer, and Della G. Gerbracht, P.O. Box 864, Randsburg	4, 5, 8 32	29S 28S	38E 38E	MD MD	Idle; no production. (R 45:250)
68	Ora No. 1	Ora L. Hopkins and Fred W. Bower, P.O. Box 7, Inyokern	16	28S	38E	MD	Idle; production negligible. (Herein)

SALT

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
69	Long Beach Salt Company deposit (formerly Freemont and Consolidated Salt Company workings.)	Long Beach Salt Company, 1245 National Ave., San Diego	1, 2, 3, 9-16	30S	38E	MD	Idle during drought years. (R 25:81; R 45:250; herein)
			34, 35	29S	38E	MD	

VOLCANIC ASH

Map No.	Claim, mine, or group	Owner name, address	Location				Remarks
			Sec.	T.	R.	B & M	
70	Calsilco (Holly) (9 claims)	Calsilco Corp., 445 Amalia Ave., Los Angeles	4	29S	38E	MD	Operating; large production for abrasive, aggregate, filler, etc. (45:250; herein)
			33	28S	38E	MD	
71	Cudahy deposit (15 claims)	Cudahy Packing Co., 803 E. Macy, Los Angeles	5, 8	29S	38E	MD	Idle since 1947 after producing cleanser abrasive for 25 years. (R 25:76; R 45:250; herein)
	Holly						(See Calsilco)
72	New Joshua	E. M. Brown and W. R. Brown, P.O. Box 11, Cantil	5	29S	38E	MD	Idle; no production.
(73)	Parrott and Allee Silica (6 claims)	Frank Allee, Weldon	18	29S	38E	MD	Idle; minor past production for abrasive, aggregate. (R 25:76; M. C. Engel, personal communication; herein)
74	Queenie No. 2	George J. Colton, 65 East 52d St., Long Beach 5	24	29S	37E	MD	Idle; slight production for cleanser abrasive. (Herein)

INDEX

GEOLOGIC QUADRANGLE MAPS AND REPORTS PUBLISHED BY THE STATE DIVISION OF MINES

Scale 1:31680

Geology of the Lebec quadrangle, California, by John C. Crowell: Special Report 24. 1952. Map and report. Price 75¢.

Scale 1:62500

Geology of the San Benito quadrangle, California; by Ivan F. Wilson: California Jour. Mines and Geology, April 1943. Map and report. Price 60¢.

Geology of the Jamesburg quadrangle, Monterey County, California, by W. M. Fiedler: California Jour. Mines and Geology, April 1944. Map and report. Price 60¢.

Geology of the San Juan Bautista quadrangle, California, by J. E. Allen: Bulletin 133, 1946. Geologic and economic maps and report. Price $1.50 (paper-bound), $2.25 (cloth-bound).

Geology of the Tesla quadrangle, California, by A. S. Huey: Bulletin 140. 1948. Geologic and economic maps and report. Price $1.50 (paper-bound).

Geology of the Hollister quadrangle, California, by N. L. Taliaferro: Bulletin 143. Maps only (geologic and economic). Price 75¢.

Geology of the Copperopolis quadrangle, California, by N. L. Taliaferro: Bulletin 145. Maps only (geologic and economic). Price 75¢.

Geology of the Lake Elsinore quadrangle, by Rene Engel: Bulletin 146. Maps only (geologic and economic). Price 75¢.

Geology of the Quien Sabe quadrangle, California, by C. J. Leith: Bulletin 147. 1949. Geologic and economic maps and report. Price $1.75.

Geology of the Blue Lake quadrangle, California, by G. A. Manning and B. A. Ogle: Bulletin 148. 1950. Geologic and economic maps, and report. Price $1.50.

Geology and mineral deposits of an area north of San Francisco Bay, California (Vacaville, Antioch, Mt. Vaca, Carquinez, Mare Island, Sonoma, Santa Rosa, Petaluma, Pt. Reyes quadrangles), by Charles E. Weaver: Bulletin 149. 1949. Geologic and economic maps and report. Price $4.00.

Geology of southwestern Santa Barbara County, California (Pt. Arguello, Lompoc, Pt. Conception, Los Olivos, Gaviota quadrangles), by T. W. Dibblee Jr.: Bulletin 150. 1950. Geologic and economic maps and report. Price $5.00.

Geology and mineral resources of the Neenach quadrangle, California, by John H. Wiese: Bulletin 153. 1950. Geologic and economic maps and report. Price $1.75.

Geology of the Cuyamaca Peak quadrangle, San Diego County, California, by D. L. Everhart: Bulletin 159. 1951. Geologic and economic maps and report. Price $3.00.

Geology of the Saltdale quadrangle, California, by T. W. Dibblee Jr.: Bulletin 160. 1952. Geologic and economic maps and report. Price $2.00.

Geology of the Healdsburg quadrangle, California, by W. K. Gealey: Bulletin 161. 1952. Geologic map and report. Price $2.00.

Scale 1:125000

Geology of the Macdoel quadrangle, California, by Howel Williams: Bulletin 151. 1949. Geologic and economic maps and report. Price $1.75.

o

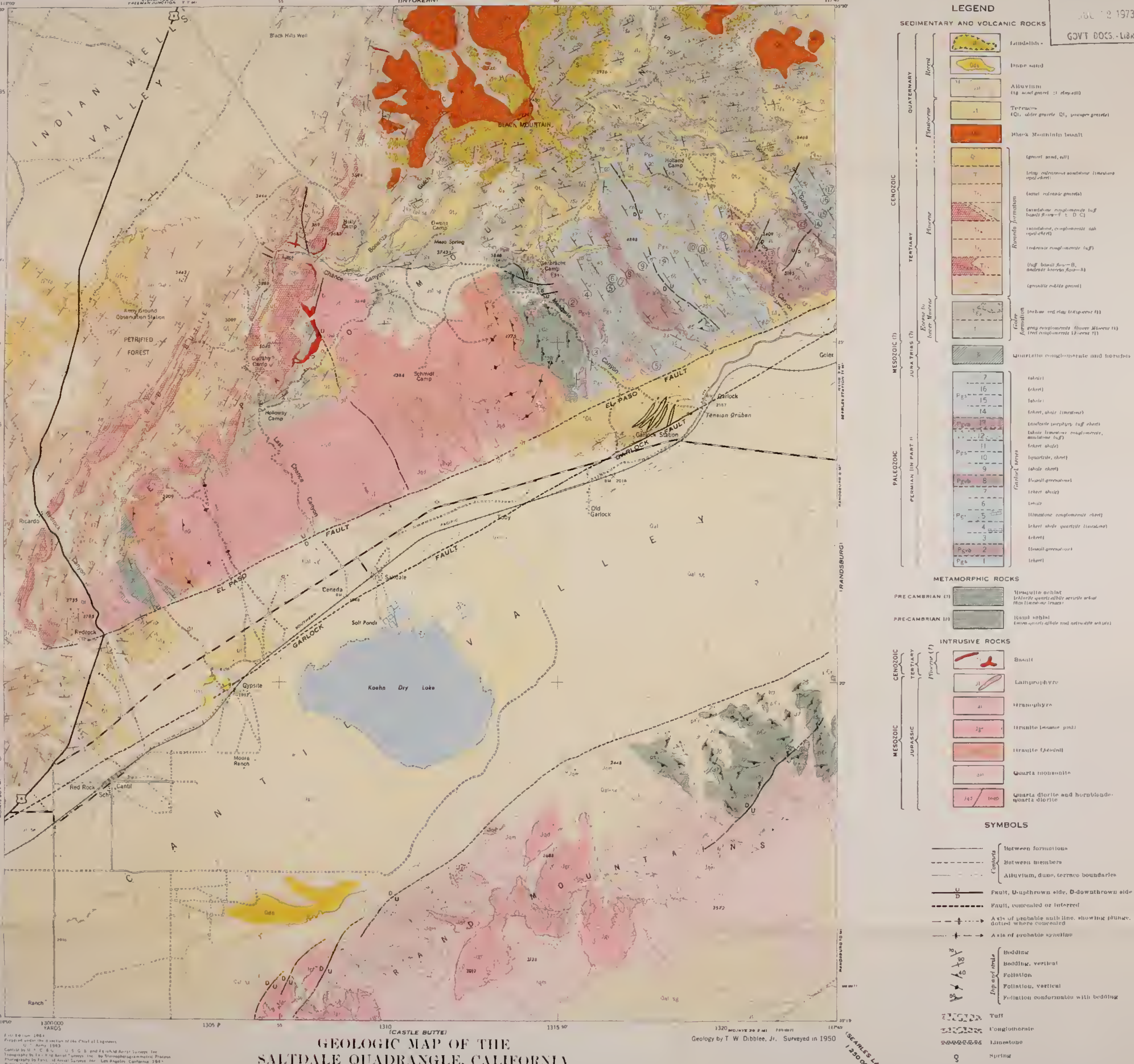
printed in CALIFORNIA STATE PRINTING OFFICE

58349 3-52 2M

DIVISION OF MINES
OLAF P. JENKINS, CHIEF

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

BULLETIN 180 PLATE 1



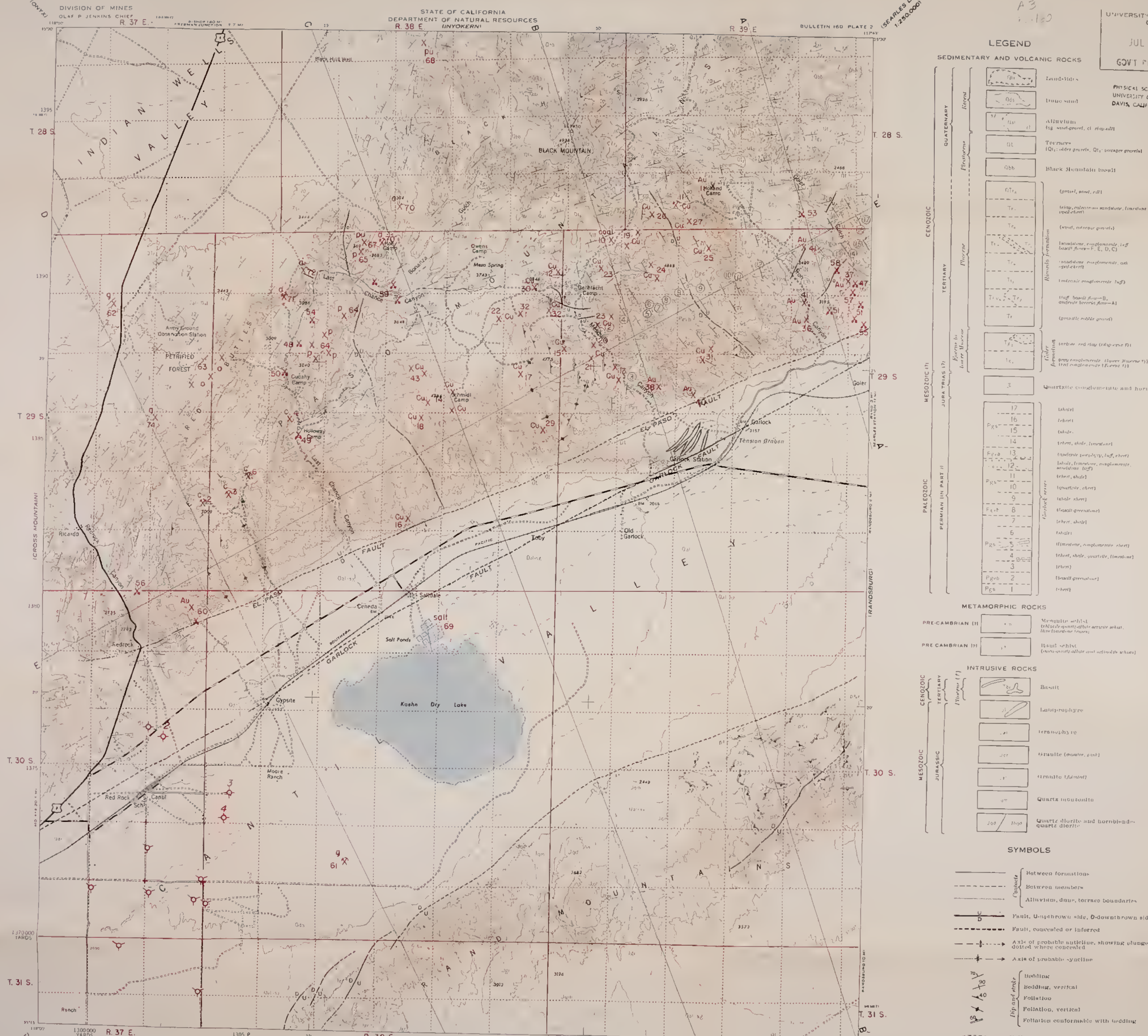
Geology by T. W. Dibblee, Jr. Surveyed in 1950

GEOLOGIC MAP OF THE SALTDALE QUADRANGLE, CALIFORNIA

By T. W. Dibblee, Jr.

Scale 1:62500

Contour interval 50 feet
Datum is mean sea level



ECONOMIC MAP OF THE SALTDALE QUADRANGLE, CALIFORNIA

By T. W. Dibblee, Jr.

Scale 1/62500

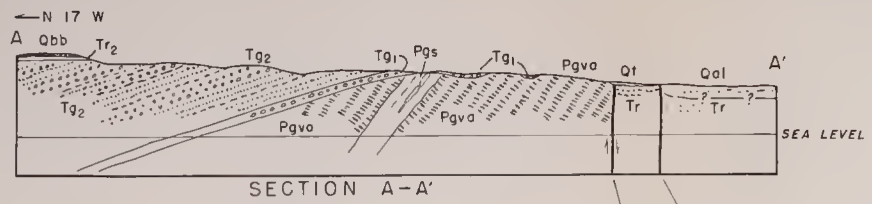
Contour interval 50 feet
Datum is mean sea level

Geology by T. W. Dibblee, Jr. Surveyed in 1950

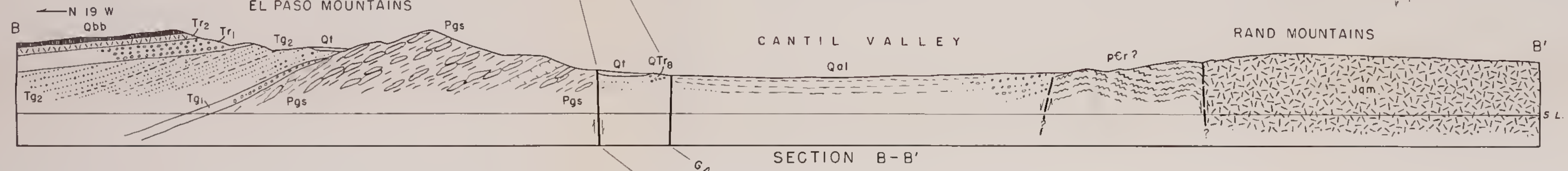
Township and section lines are projected from Randsburg quadrangle and section corners located south of Cantil.

GEOLOGIC STRUCTURE SECTIONS ACROSS SALTDALE QUADRANGLE KERN COUNTY, CALIFORNIA

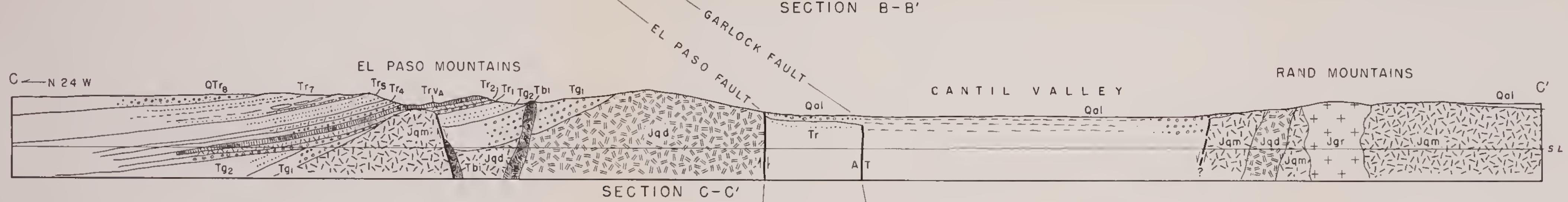
T.W. Dibblee Jr. JANUARY 1950



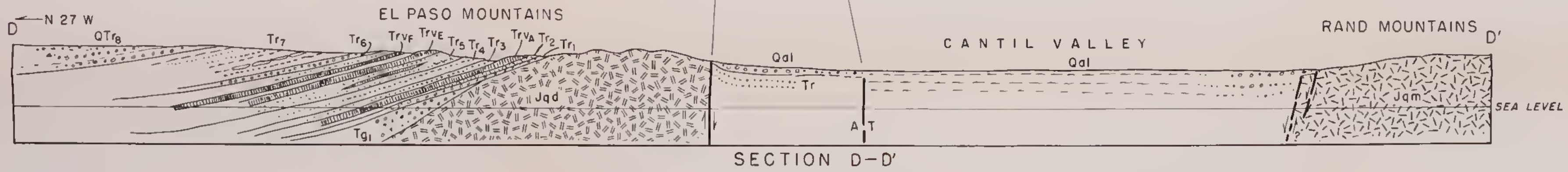
SECTION A–A'



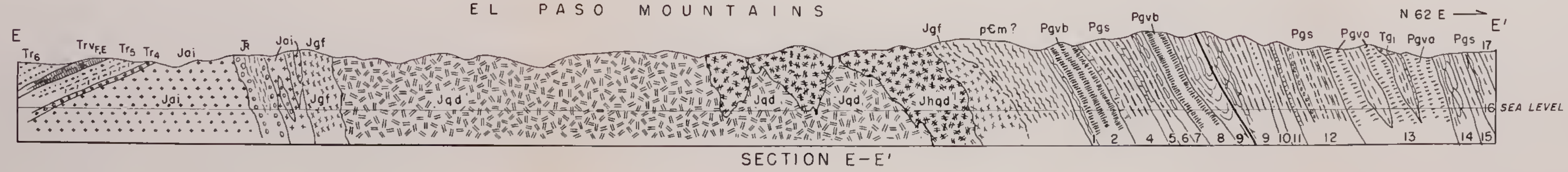
SECTION B–B'



SECTION C–C'



SECTION D–D'



SECTION E–E'

EXPLANATION

Quaternary
- Qal — Alluvium
- Qt — Terrace
- Qbb — Black Mt basalt
- QTr8 — Ricardo formation

Pliocene
- Tr7-1 — Ricardo formation

Eo Olig. Mio.
- Tg2,1 — Goler formation

Jura-Triassic
- Jk — Unnamed

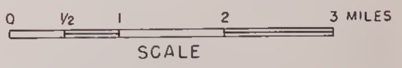
Permian
- Pgs17-1 — Garlock series

Pre-Cambrian ?
- p€m — Mesquite schist
- p€r — Rand schist

INTRUSIVE ROCKS

Pliocene
- Tb1 — Intrusive basalt

Jurassic
- Jai — Granophyre
- Jgr — Pink granite
- Jgf — Foliated granite
- Jqm — Quartz monzonite
- Jhqd — Hornblende quartz diorite



el, cl: clay-silt)
avels, Qt2: younger gravels)
untain basalt
, sand, silt)
calcareous sandstone, limestone,