Geology of the Hames Valley, Wunpost and Valleton Quadrangles Monterey County, California

By DAVID L. DURHAM

CONTRIBUTIONS TO GENERAL GEOLOGY

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A study of stratigraphy and structure of Cenozoic sedimentary rocks in part of the Salinas Valley

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GEOLOGY OF THE HAMES VALLEY, WUNPOST, AND VALLETON QUADRANGLES, MONTEREY COUNTY CALIFORNIA

By David L. Durham

ABSTRACT

The Hames Valley, Wunpost, and Valleton quadrangles lie side by side across the southern Salinas Valley at the latitude of the San Ardo oil field.

Monterey Shale is exposed west of the Salinas River in high hills and locally east of the river in canyons. Diatomaceous mudstone beds near the top of the Monterey form a distinctive member. The Monterey is at least as thick as 5,800 feet west of the river. It is marine and contains fossils that indicate late Miocene age.

The Pancho Rico Formation conformably overlies and probably intertongues with the Monterey Shale. The Pancho Rico is chiefly sandstone and is 100–650 feet thick. It contains marine fossils indicative of Pliocene or early Pliocene age.

The Paso Robles Formation overlies the Pancho Rico Formation with apparent conformity, except in the southwest part of the Hames Valley quadrangle, where the Paso Robles unconformably overlies the Monterey Shale. The Paso Robles contains conglomerate, sandstone, mudstone, and limestone, and is as thick as 1,000 feet. It is considered nonmarine in origin and Pliocene and Pleistocene (?) in age.

The thick sequence of faulted and folded Monterey Shale and other rocks that overlies the basement complex west of the Salinas River contrasts markedly with the comparatively thin sequence of unfaulted and broadly folded or tilted strata east of the river. Beds just west of the river and in the southwestern part of the Hames Valley quadrangle are severely deformed near large faults.

The San Ardo oil field, which contains more than 800 wells, is in the Hames Valley and Wunpost quadrangles. The field yielded about 125 million barrels of oil and 43 million Mcf of gas between 1947, when it was discovered, and 1962.

INTRODUCTION

PURPOSE AND SCOPE

U.S. Geological Survey investigation in the Salinas Valley area is concerned mainly with recording the nature, distribution, and structure of Cenozoic sedimentary rocks exposed there. The purpose of this investigation is both to assist in realizing the economic mineral potential of the area and to contribute to geologic knowledge of the California Coast Ranges. Cenozoic sedimentary rocks crop out in the area from north of the latitude of Arroyo Seco southeastward for more than 80 miles to beyond the town of Santa Margarita. These strata contain oil and gas in commercial quantities at the San Ardo, King City, and Lynch Canyon oil fields, and the prospect of finding additional petroleum or other commercial mineral commodities in the Salinas Valley area is favorable.

This report describes the geology of the Hames Valley, Wunpost, and Valleton quadrangles and includes geologic maps and structure sections of the three quadrangles (pls. 1, 2, and 3). Similar reports describe the Reliz Canyon, Thompson Canyon, and San Lucas quadrangles (Durham, 1963), the Cosio Knob and Espinosa Canyon quadrangles (Durham, 1964), and the Jolon and Williams Hill quadrangles (Durham, 1965).

LOCATION OF AREA

The Hames Valley, Wunpost, and Valleton 7½-minute quadrangles lie side by side across the Salinas Valley at the latitude of the San Ardo oil field, southern Monterey County, Calif. (fig. 1). They include high hills west of the Salinas River and part of the mesalike area of more subdued relief east of the river. The San Ardo oil field is in the Hames Valley and Wunpost quadrangles, and part of the smaller Lynch Canyon oil field is in the Wunpost quadrangle.

PREVIOUS WORK

Earlier geological investigations concerned specifically with part of or all the map area were related mainly to mineral resources. Goodyear (1888, p. 86) reported bituminous sandstone in the hills southwest of San Ardo in or near the Hames Valley quadrangle. Angel (1890, p. 345) noted that placer gold had been taken from Big Sandy Creek, which flows through the Valleton quadrangle. Watts (1900, p. 145) mentioned an oil seep on Big Sandy Creek, probably outside the map area, and listed exploratory oil wells just west of the Salinas River near the north edge of the Hames Valley quadrangle. Nutter (1901 p. 335) reported fossils of Pliocene age in railroad cuts near the south edge of the Wunpost quadrangle, and fossils of Miocene age on the west bank of the Salinas River opposite Wunpost. Hamlin (1904, p. 47) remarked on the depth of the canyon cut by the Salinas River south of Wunpost and the widening of the valley north of there. Waring (1914, p. 426) noted an anticline near Valleton, and he (p. 423) described beds in the Indian Valley and Big Sandy Creek areas that he assigned to the Etchegoin and Jacalitos Formations. He (p. 435) also listed information on wells drilled for oil west of the Salinas River near the north edge of the Hames Valley quadrangle. Diller and others (1915, p. 119) recognized evidence suggestive of a large fault along the Salinas River, and they (p. 120) mentioned fossiliferous sandstone beds south of San Ardo that they considered part of the

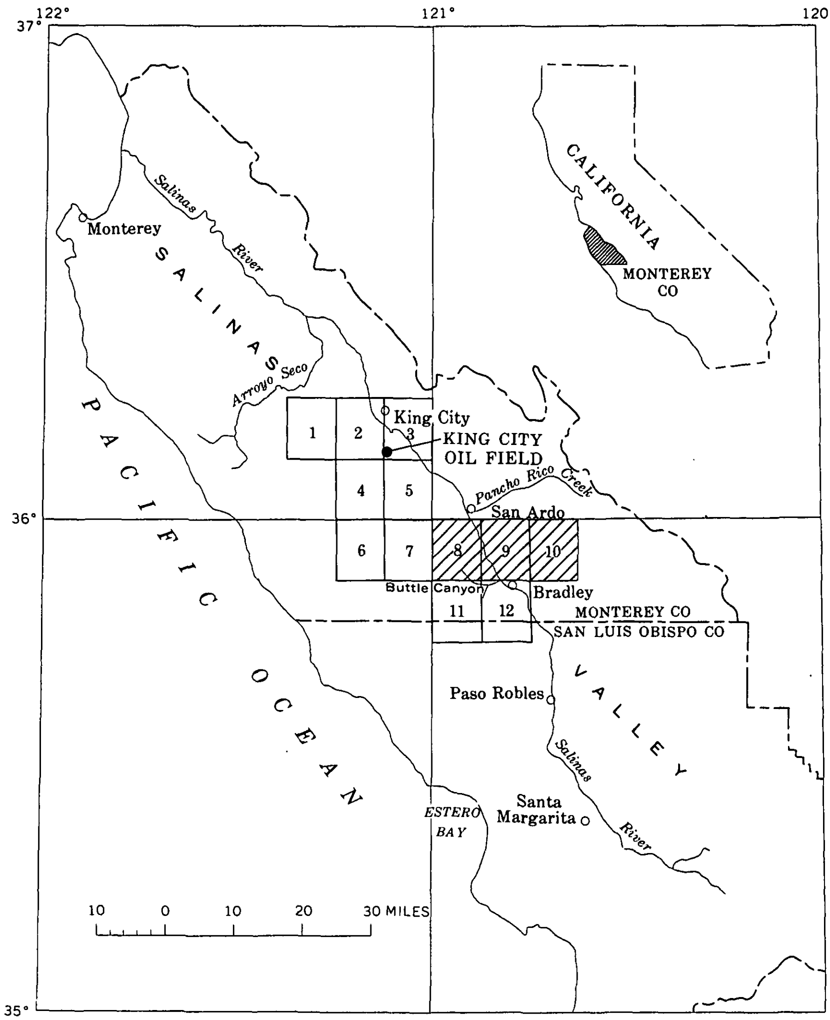

FIGURE 1.—Index map showing location of following quadrangles: (1) Reliz Canyon, (2) Thompson Canyon, (3) San Lucas, (4) Cosio Knob, (5) Espinosa Canyon, (6) Jolon, (7) Williams Hill, (8) Hames Valley, (9) Wunpost, (10) Valleton, (11) Tierra Redonda Mountain, (12) Bradley.

Santa Margarita Formation. Nomland (1917a, p. 304–305) described beds near Indian Valley that he assigned to the Santa Margarita and Etchegoin Formations. Waring and Bradley (1917, p. 598–599) mentioned commercial production of diatomaceous earth on the north side of Hames Valley. English (1918) summarized the stratigraphy, structure, and petroleum possibilities of a large part of the southern Salinas Valley, including the area within the Hames Valley, Wunpost, and Valleton quadrangles. Kew (1920, p. 83, 85, 86, 90, 104) reported localities containing *Astrodapsis* in Swain Valley, Indian Valley, Lynch Canyon, and Sargent (Powell) Canyon. Vander Leck (1921, p. 87, 89) recorded evidence for a large fault near the Salinas River, and he (p. 87) pictured the structure at Hames Valley as "a broad synclinal trough." He (p. 89) also mentioned a large anticline that trends southeast in the southwestern part of the Wunpost quadrangle. Reed (1925, p. 594–595, and fig. 2) described the upper contact of the Monterey Shale exposed in the west bank of the Salinas River opposite Wunpost. Taliaferro (1934, pl. 11) indicated that spheroids of rhythmically and concentrically banded chert and porcelanite occur in the Monterey Shale near Hames Valley, and he (pl. 24) illustrated an example from west of there. Later Taliaferro (1943) summarized the geology of the Bradley and San Miguel 15-minute quadrangles, which include the Hames Valley, Wunpost, and Valleton 7½-minute quadrangles. Bramlette and Daviess (1944), in their general study of the Salinas Valley area, mentioned diatomaceous beds in the Monterey Shale near Hames Valley, tar sands and associated strata southwest of San Ardo, and porcelaneous beds near Indian Valley that they considered at least partly equivalent to the Pancho Rico Formation. Kilkenny (1948, p. 2266) concluded that faults extend along the west side of the Salinas River as far south as Bradley. Woodring and Bramlette (1950, p. 67–68) reported the occurrence of *Dendraster* in the Pancho Rico Formation at a locality near Lynch Canyon. Woodford (1951, p. 833) mentioned the narrowness of the Salinas River at Wunpost. Kilkenny and others (1952) prepared a structure section across the map area through the San Ardo oil field. Baldwin (1963, p. 11, 15) stated that the course of the Salinas River in the southern part of the Wunpost quadrangle is across a former drainage divide.

Papers concerned primarily with the San Ardo oil field include ones by Thorup (1948), Campbell (1948), Baldwin (1949, 1950, 1953), Barger and Zulberti (1949), Baldwin and others (1951), Fackler (1953), Miller (1953), Bradford and Lawrence (1956), and Colvin (1963). Gribi (1963a) briefly described the Lynch Canyon oil field.

FIELDWORK AND ACKNOWLEDGMENTS

The Hames Valley quadrangle was mapped in 1962, with the assistance of D. C. Wiese. The Wunpost quadrangle was mapped in 1962 and 1963, and the Valleton quadrangle was mapped in 1963. Mapping was done on aerial photographs of approximately 1:20,000 scale, and the field data were compiled on topographic maps of 1:24,000 scale.

Many landowners in the map area kindly permitted access to their property. W. S. Harris, Texaco, Inc., and E. A. Gribi, consulting geologist, King City, generously provided information on some wells. W. O. Addicott identified fossil mollusks and echinoids from the

map area and visited and collected from several localities. J. W. Durham identified echinoids from localities M982, M1674, and M1935. Patsy J. Smith identified fossil Foraminifera. J. G. Vedder and C. A. Repenning made the collection from localities M982 and M983.

STRATIGRAPHY

GENERAL FEATURES

The marine Miocene Monterey Shale, which is the oldest stratigraphic unit exposed in the map area, crops out in the hills west of the Salinas River and locally in the upper reaches of the larger canyons farther east. Diatomaceous strata near the top of the Monterey form a conspicuous member. The Pliocene Pancho Rico Formation comprises the marine sandstone and associated beds that conformably overlie and probably intertongue with the Monterey. The nonmarine Paso Robles Formation of Pliocene and Pleistocene(?) age overlies the Pancho Rico with apparent conformity east of the Salinas River and northeast of Hames Valley, but strata assigned to the Paso Robles unconformably overlie the Monterey in the southwestern part of the Hames Valley quadrangle. Alluvium and older alluvium cover the valley bottoms.

Many wells drilled for oil in the map area reached the pre-Tertiary basement complex (table 2, remarks column). The Vaqueros Formation and the Sandholdt Member of the Monterey Shale were reported in some wells drilled west of the Salinas River (structure section *A–B*, pl. 1), and strata that are generally called "continental beds" or "nonmarine red beds" occur beneath the Monterey and Santa Margarita(?) Formations in several wells drilled east of the river (table 2, remarks column; structure section *B–C*, pl. 2; *C–D*, pl. 3). Some wells in the eastern part of the Valleton quadrangle penetrated beds that may belong to the marine upper Miocene Santa Margarita Formation (structure section *C–D*, pl. 3).

Plate 4 shows the succession, generalized lithologic character, and approximate maximum thickness of stratigraphic units exposed in the Hames Valley, Wunpost, and Valleton quadrangles.

DESCRIPTION OF EXPOSED FORMATIONS

TERTIARY SYSTEM

MIOCENE SERIES—MONTEREY SHALE

Blake (1855) named the Monterey Shale for exposures near the town of Monterey, which is on the coast about 65 miles northwest of the Hames Valley quadrangle. The Monterey Shale forms most of the high hills west of the Salinas River in the map area and crops out east of the river mainly in Indian Valley (fig. 2) and Sargent, Walker, and Powell Canyons. The Monterey exposed east of the river cor-

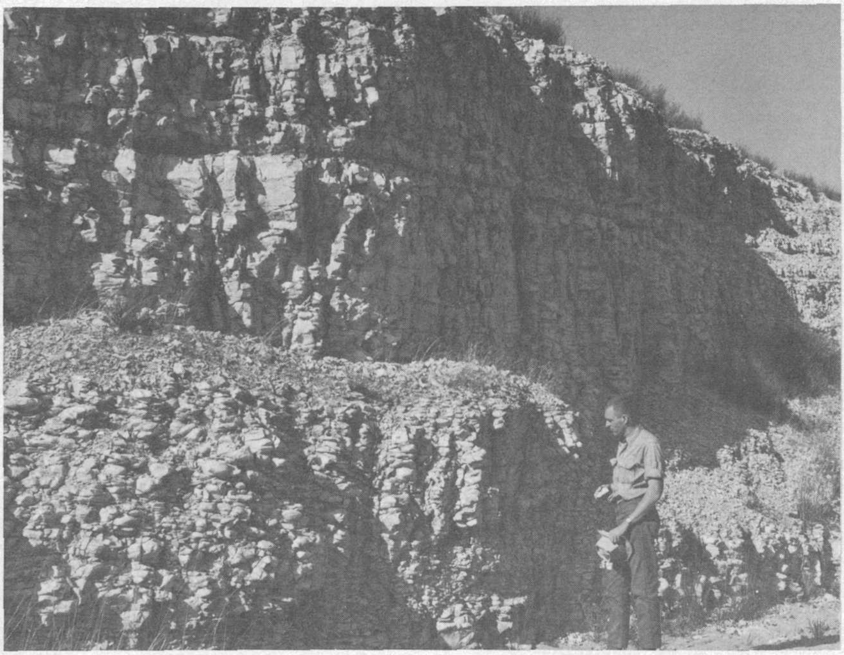

FIGURE 2.—Porcelaneous rocks of the Monterey Shale exposed along Big Sandy Creek where the stream enters Indian Valley. The beds are nearly flat lying. The thin dark bed about 3 feet below the top of the outcrop is bentonitic clay.

responds approximately to the unit that English (1918, p. 229) called "a shale member of the Santa Margarita" Formation, and that Taliaferro (1943, p. 460) designated the "upper Santa Margarita shale." However, the porcelaneous and diatomaceous beds that are exposed east of the river are identical in lithologic character and stratigraphic position with the Monterey Shale north of Hames Valley, and for that reason they are here assigned to the Monterey. The base of the Monterey is concealed in the map area.

DIATOMACEOUS MUDSTONE MEMBER

The sequence of diatomaceous mudstone beds in the upper part of the Monterey Shale at most places in the map area is here considered a member of the Monterey. The member is distinguished by the conspicuously diatomaceous character of its strata and by its stratigraphic position at the top of the Monterey.

Taliaferro (1943, p. 459) noted that the "highest member" of the Monterey Shale near Hames Valley is "a rather pure diatomite," and Bramlette and Daviess (1944) reported that "diatomaceous shale locally forms the upper part of the [Monterey] formation, as in part of Hames Valley * * *." Kilkenny and others (1952) showed an "upper diatomite member of Monterey Formation" on their structure section across Hames Valley. Mandra (1963, p. 104) gave the name "Buttle Diatomite" to diatomaceous beds in the upper part of the Monterey in Buttle Canyon, about 2 miles south of the Hames Valley quadrangle. The diatomaceous mudstone member of the Monterey shown on the geologic maps (pls. 1, 2, and 3) corresponds, at least approximately, to the diatomaceous units of these other investigators.

Diatomaceous mudstone beds that crop out in the map area east of the Salinas River are correlated on the basis of lithologic character and stratigraphic position with the diatomaceous mudstone member exposed north of Hames Valley (fig. 3). English (1918, p. 230) noted the occurrence of diatomaceous strata east of the river, but assigned them to a shale member of the Santa Margarita Formation. Kilkenny and others (1952) indicated that diatomaceous mudstone beds in Sargent Canyon belong to the Pancho Rico Formation, but the mudstone beds there, unlike the mudstone beds in the typical Pancho Rico, lack interjacent sandstone beds.

The contact of the diatomaceous mudstone member with the main body of the Monterey Shale is gradational and intertonguing. North

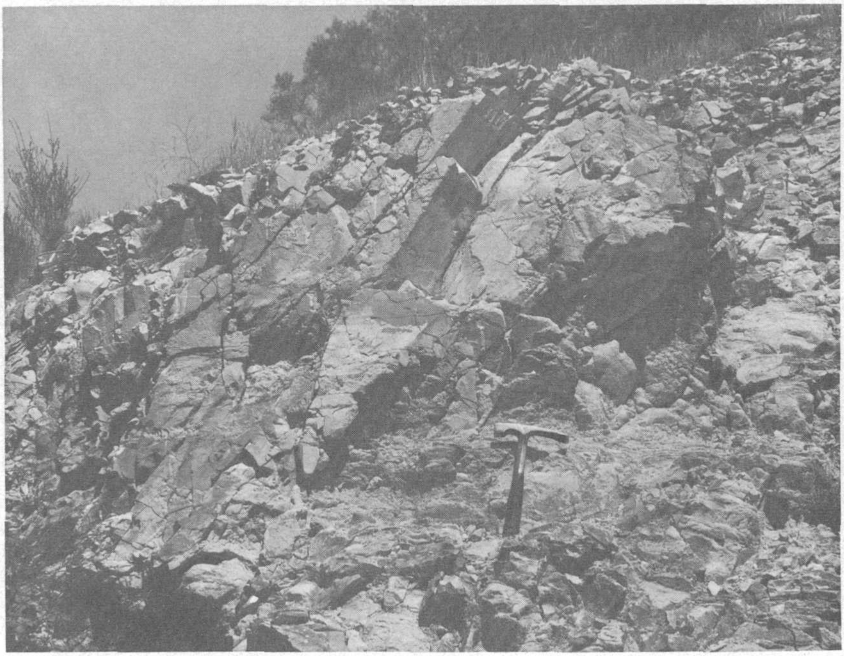

FIGURE 3.—Massive diatomaceous mudstone of the diatomaceous mudstone member of the Monterey Shale exposed at prospect hole in SW¼ sec. 23, T. 23 S., R. 10 E., Wunpost quadrangle. The faces on the outcrop are chiefly joint surfaces.

of Swain Valley (pl. 2) the lower contact of the member is at the base of the predominantly diatomaceous sequence of beds that overlies porcelaneous rocks typical of most of the Monterey (measured sections 1 and 2). In the member there and farther east porcelanite or porcelaneous mudstone beds are interstratified with diatomaceous mudstone units (measured sections 1 and 2). Near the NE. cor. sec. 26, T. 23 S., R. 10 E., the member thins and intertongues with porcelaneous rocks (measured section 1). Where the upper contact of the Monterey is exposed in the river bank opposite Wunpost, the Monterey consists entirely of porcelaneous rocks. The member is absent near the northeast corner of the Valleton quadrangle, but the reason for its absence is unclear. On structure sections *C–D* (pl. 3), the member is shown to thin by intertonguing with the overlying Pancho Rico Formation, but lateral change from diatomaceous to porcelaneous rock may also be involved. According to Bramlette (1946, p. 47, 48), lateral variation of this kind occurs in the Monterey in other areas.

LITHOLOGY

The part of the Monterey Shale exposed in the map area consists mainly of porcelanite and porcelaneous mudstone, but there is some mudstone, diatomaceous mudstone, dolomitic carbonate beds and concretions, chert, bentonitic clay, and rarely sandstone and tuff, in approximate decreasing order of abundance. At least three-fourths of the Monterey exposed southwest of Hames Valley is porcelanite, and the other rocks that crop out there are chiefly porcelaneous mudstone. Porcelanite and porcelaneous mudstone are about equally abundant between Hames Valley and the Salinas River. Mudstone is common in the Monterey in and near the western part of the San Ardo oil field, and diatomaceous mudstone is characteristic of the uppermost part of the formation near Swain Valley and east of the Salinas River. Dolomitic carbonate beds are conspicuous in the Monterey in a belt about 1 mile wide that parallels the edge of the hills southwest of the Salinas River. Carbonate beds are rare southwest of Hames Valley. Tuff beds are exposed in the hills just west of the Salinas River in the northern part of the Hames Valley quadrangle. A unit of sandstone at least 50 feet thick crops out along Big Sandy Creek (east of the center of sec. 2, T. 23 S., R. 12 E.). In the subsurface east of the Salinas River, the Monterey includes sandstone beds (structure sections *A–B*, pl. 1; *B–C*, pl. 2; *C–D*, pl. 3) that Kilkenny and others (1952) assigned to the Santa Margarita Formation, but that Hughes (1963, p. 95) placed mainly in the Monterey.

Porcelaneous rocks.—Porcelanite is a silica-cemented rock that has the dull luster of unglazed porcelain (Bramlette, 1946, p. 15). According to X-ray analysis, porcelanite consists chiefly of cristobalite, quartz, and opal. Porcelanite with the addition of clastic material grades into porcelaneous mudstone, which is intermediate in texture between porcelanite and clastic mudstone. Porcelaneous mudstone contains fine and very fine sand, silt, and clay bound in a porcelaneous matrix. Three thin sections of procelaneous mudstone from the map area contain 70–90 percent matrix, 10–20 percent silt particles larger than 0.02 mm, 1–15 percent sand, 1–10 percent mica flakes, and less than 1 percent fish scales, diatoms, and sponge spicules.[1] Nearly all the sand grains in the thin sections are quartz or feldspar. In the thin sections the grains generally appear to be angular and are ordinarily less than 0.12 mm in size, although the largest are 0.15–0.20 mm.

Porcelanite and porcelaneous mudstone (fig. 2) generally occur in beds 1–6 inches thick, although thicker or thinner beds are common. Porcelaneous rocks range from well bedded to irregularly bedded or massive. Ordinarily they are separated into angular fragments by joints spaced 0.25–4 inches apart, and locally they are crushed or brecciated. Beds or larger units of porcelanite are interstratified with porcelaneous mudstone or mudstone, and units of porcelaneous rock commonly include dolomitic carbonate beds or concretions. Some beds contain both porcelanite and porcelaneous mudstone in irregular layers or ill-defined masses. Thin beds or partings of shaly mudstone or bentonitic clay separate some beds of porcelaneous rock (fig. 2). Porcelaneous rocks at some localities contain fish scales and molds of mollusk shells, Foraminifera, or fish vertebrae. Porcelanite is generally pinkish gray, yellowish gray, or very light gray. Porcelaneous mudstone is mainly very pale orange and less commonly pinkish gray or yellowish gray.

Clastic rocks.—Mudstone in the Monterey Shale is similar to porcelaneous rocks of the Monterey in bedding characteristics and general appearance, but it lacks porcelaneous material in the matrix and is less well indurated. Unlike the porcelaneous rocks, the mudstone may be easily scratched by a fingernail. The mudstone is ordinarily massive or poorly bedded, but where beds are apparent they are generally 1–6 inches thick. Fossil diatoms, fish scales, molds or casts of Foraminifera, casts of fish vertebrae, and imprints of mollusk shells are more common in mudstone than they are in porcelaneous rocks. Mudstone is generally very pale orange or yellowish gray. A thin section of massive mudstone contains about 75 percent matrix, 20 per-

[1] The percentage of constituents in these and other thin sections were determined by the Chayes (1949) point-count method.

cent silt particles larger than 0.02 mm, 5 percent very fine sand, and less than 1 percent mica. The length of the largest sand grain in the section is 0.13 mm, and of the largest mica flake is 0.26 mm.

Diatomaceous mudstone (fig. 3) that forms the upper part of the Monterey Shale at most places in the map area is more massive, less well indurated, and less dense than other rock in the formation. It is white and has a hackly or conchoidal fracture. Discoidal fossil diatoms about 0.4 mm in diameter are conspicuous in the rock.

Sandstone that occurs in the Monterey Shale on the east side of Big Sandy Creek (sec. 2, T. 23 S., R. 12 E.) consists of angular and subangular fine and medium grains of quartz and feldspar, together with conspicuous but less abundant biotite. It is white, massive, friable, noncalcareous, and unfossiliferous.

Vitric tuff is interbedded with mudstone of the Monterey Shale in a fault block (secs. 29 and 32, T. 22 S., R. 10 E.) near the edge of the hills west of the Salinas River. It is pale brown or moderately yellowish brown and friable. The color is apparently caused by oil staining. The tuff beds are poorly exposed and their thickness and extent are uncertain. The larger shards in a thin section of the tuff are about 0.35 mm long.

Carbonate beds and concretions.—Carbonate beds in the Monterey Shale are commonly as thick as 2 or 3 feet. They are associated with both porcelaneous rocks and mudstone, but ordinarily they are absent from the diatomaceous mudstone member. The rock consists of clay and silt in a matrix of ferruginous dolomite. It is massive, dense, and generally more resistant to weathering than are porcelaneous rocks and mudstone. It has a wide range of color on freshly exposed surfaces, including grayish orange, pale yellowish orange, and yellowish gray.

Concretions of similar dolomitic carbonate rock in the Monterey Shale are ellipsoidal and as large as 5 or 6 feet in diameter and as thick as 2 or 3 feet. They occur at particular horizons, and their longer axes lie parallel to the bedding. In some places beds can be traced into and through concretions from the enclosing rock. These beds are thicker in the concretion than they are outside of it, suggesting differential compaction of the rock following formation of the concretions.

Chert.—Chert is uncommon in the Monterey Shale in the map area, but it is associated with porcelaneous rocks at a few places. It is generally dark colored and occurs in irregular beds or bands ⅛–6 inches thick.

THICKNESS

The Monterey Shale is only partly exposed in the map area. The thickness of the Monterey, including the Sandholdt Member, in the syncline in upper Hames Valley is probably at least 5,800 feet (measured on structure section *A–B*, pl. 1). The thickness of the Sandholdt Member is at least 800 feet nearby in the James M. Douglas Smith 1 (No. 14 on map). The thickness of the sequence of beds assigned to the Monterey in the San Ardo oil field, including sandstone units, is about 1,500 feet (measured on structure section *A–B*, pl. 1; *B–C* pl. 2). The thickness of the Monterey, including the diatomaceous mudstone member, may be about 2,000 feet near Powell Canyon, but it is only about 400 feet in the Barnsdall Oil Kelch 1 (No. 3 on map), near the east border of the Valleton quadrangle (measured on structure section *C–D*, pl. 3). This eastward thinning of the Monterey may be partly due to intertonguing of the unit in the subsurface with sandstone beds that are tentatively assigned to the Santa Margarita Formation, as suggested on structure section *C–D* (pl. 3). The thickness of the diatomaceous mudstone member of the Monterey is as much as 600–700 feet near Swain Valley (estimated from the geologic map, pl. 1), but it is only 112–120 feet about 2 miles farther east (measured sections 1 and 2). The thickness of the member is about 350 feet west of Indian Valley (sec. 33, T. 22 S., R. 12 E., measured on the geologic map, pl. 3). The member thins and disappears to the east.

AGE AND CONDITIONS OF DEPOSITION

The part of the Monterey Shale exposed in the map area is considered late Miocene in age. Fossils useful for age determination are scarce in the Monterey Shale in the map area. According to Kilkenny and others (1952), the foraminiferal faunas in the Monterey Shale exposed in and near the western part of the San Ardo oil field belong to the late Miocene Mohnian Stage of Kleinpell. Colvin (1963, p. 58) stated that microfossils are scarce in the field in the siltstone unit between the Aurignac and Lombardi sands, but that correlative beds to the west contain a microfauna indicative of the lower Mohnian Stage. Hughes (1963, p. 94) too assigned this siltstone unit to the lower Mohnian Stage and placed the superjacent Lombardi sand and overlying siltstone beds in the upper Mohnian Stage. Mandra (1963, p. 104) assigned the diatomaceous beds at the top of the Monterey on the southwest side of Hames Valley to the late Miocene Delmontian Stage of Kleinpell. A Miocene(?) age is suggested by *Tellina congesta* Conrad and an unidentified naticid (W. O. Addicott, written commun., 1964) from the Monterey at locality M1932 (table 4), west of the Salinas River in the San Ardo oil field. Some of the uppermost beds of the Monterey may be of Pliocene age if the Monterey and Pancho Rico Formation intertongue as suggested on structure sections *B–C* (pl. 2) and *C–D* (pl. 3), but evidence for the age of the upper part of the Monterey based on fossils from that part of the formation is inconclusive.

Fossils in the Monterey Shale show that the unit is marine. Baldwin (1950, p. 1987) considered the sandstone units in the Monterey along and east of the Salinas River as near-shore, and presumably shallow-water, facies of the finer grained, and presumably deeper water, beds farther west.

PLIOCENE SERIES—PANCHO RICO FORMATION

Reed (1925, p. 606) gave the name Poncho Rico Formation to marine beds exposed on the east side of the Salinas Valley, and although he presumably intended that strata along Pancho Rico Creek, 1½–4½ miles north of the Wunpost quadrangle, should be considered typical of the formation, he failed to define the unit adequately. The Pancho Rico Formation comprises sandy marine strata and interbedded finer grained rocks that generally overlie the Monterey Shale and underlie the nonmarine Paso Robles Formation in the Salinas Valley area of southern Monterey County (Durham and Addicott, 1964). Waring (1914, p. 423) and English (1918, p. 231) assigned beds in the Pancho Rico in the map area east of the Salinas River to the Jacalitos and Etchegoin Formations, and Nomland (1917b, p. 215), Taliaferro (1943, p. 457), and Baldwin (1950, p. 1988) placed them in the Etchegoin Formation. Kew (1920, p. 104) and Reed (1925, p. 593, 594) assigned beds in the Pancho Rico in the map area west of the river to the Santa Margarita Formation, and Taliaferro (1943, p. 457) considered part of these beds Santa Margarita and part Etchegoin.

The Pancho Rico Formation crops out along the north side of Hames and Swain Valleys, on both sides of the Salinas River in the southwest part of the Wunpost quadrangle, and in a structurally complex strip west of the river north of Wunpost. It also covers about 20 square miles east of the river in the northeastern part of the Wunpost and Valleton quadrangles.

The Pancho Rico Formation conformably overlies and probably intertongues with the Monterey Shale. The lower contact is at the base of the stratigraphically lowest sandstone unit above the thick sequence of diatomaceous or porcelaneous rocks typical of the Monterey. The contact is gradational in that diatomaceous mudstone occurs in some places above the sandstone beds that mark the base of the Pancho Rico.

LITHOLOGY

The Pancho Rico Formation in the map area is chiefly and characteristically sandstone, but the unit also contains mudstone, conglomerate, porcelaneous mudstone, and dolomitic carbonate beds, in approximate order of decreasing abundance. Very fine and fine-grained sandstone are most common in the Pancho Rico west of the Salinas River, and coarser grained sandstone and conglomerate are common in the upper part of the unit east of the river. Porcelaneous rocks and noncalcareous mudstone are interbedded with very fine and fine-grained sandstone in the Pancho Rico near the Salinas River in the northern part of the Hames Valley quadrangle. Diatomaceous mudstone is interbedded with sandstone in the lower part of the Pancho Rico near Swain Valley, west of the Salinas River, and locally at places east of the river. Dolomitic carbonate beds are conspicuous in the formation near the north edge of the Hames Valley quadrangle.

Very fine grained sandstone in the Pancho Rico Formation is massive or poorly bedded and is associated at many places with mudstone, porcelaneous rocks, and calcareous concretions. It is generally noncalcareous, moderately well indurated, and pale yellowish brown or yellowish gray. It appears to be oil stained at some localities. Molds and casts of clam shells are common.

Fine-grained sandstone in the Pancho Rico Formation is generally massive or in beds 2–3 feet thick. It is ordinarily noncalcareous and friable, but some beds are well cemented by calcite. It is yellowish gray, very pale orange, or white.

A thin section of very fine and fine-grained noncalcareous arkosic sandstone from the San Ardo oil field west of the Salinas River contains about 65 percent sand grains and 35 percent silt and clay matrix. The grains in the thin section are angular and are mainly 0.08–0.18 mm in greatest dimension, although the largest grain is 0.31 mm long. A thin section of similar-appearing rock from the Pancho Rico nearby contains only about 20 percent sand grains, including mica flakes, and 80 percent matrix. A thin section of very fine and fine-grained noncalcareous arkosic sandstone from south of Swain Valley contains about 30 percent sand grains and 70 percent silt and clay matrix. The grains in the thin section are angular and are generally 0.06–0.22 mm in greatest dimension, although two grains are as large as 0.8 mm. Diatom frustules and sponge spicules are abundant in the rock, which is from a bed that apparently intertongues with the diatomaceous mudstone member of the underlying Monterey Shale. A thin section of very fine and fine-grained noncalcareous arkosic sandstone from the Pancho Rico in Walker Canyon (measured section 4, unit 4) contains 45 percent sand grains and 55 percent silt and clay matrix. The

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grains in the section are mainly angular and subangular and 0.09–0.18 mm in greatest dimension. A few rounded grains are glauconite.

Medium- and coarse-grained sandstone in the Pancho Rico Formation is generally massive or thick bedded, but some is in beds less than 1 foot thick. It is arkosic and is commonly fossiliferous and conglomeratic. The rock at many places is well cemented with calcite; however, at some localities it is well indurated but noncalcareous, and at many other localities it is friable and noncalcareous. It has a wide range of color that is largely related to weathering, but most commonly it is yellowish gray.

A thin section of fine- to coarse-grained calcareous sandstone from the Pancho Rico Formation in the northeastern part of the Hames Valley quadrangle (NE¼ sec. 32, T. 22 S., R. 10 E.) contains about 15 percent quartz grains, 20 percent feldspar grains, and 65 percent calcite matrix, including some shell fragments. The grains in the thin section are angular or subangular and are generally 0.18–0.53 mm in greatest dimension, but some are as large as 1.55 mm. The rock is in beds 2–3 feet thick. A thin section of well-sorted medium-grained arkosic sandstone from the Pancho Rico in the southwestern part of the Wunpost quadrangle (near the south edge of sec. 23, T. 23 S., R. 10 E.) contains about 20 percent quartz, 35 percent feldspar, 45 percent calcite matrix, and less than 2 percent mica and dark minerals. The sand grains in the thin section are angular to rounded and are 0.25–0.35 mm in greatest dimension. The rock occurs in beds 6–10 inches thick. A thin section of very fine to medium-grained arkosic sandstone from Walker Canyon (measured section 4, unit 3) contains about 60 percent sand grains and 40 percent calcite matrix. The grains in the thin section are mainly angular or subangular and are 0.09–0.53 mm in greatest dimension. They are chiefly quartz and feldspar, but include biotite, hornblende, porcelaneous rock, and glauconite. The glauconite grains are well rounded. Thin sections of poorly sorted fine- to coarse-grained noncalcareous sandstone from beds about 60 and 80 feet higher stratigraphically (measured section 4, units 5 and 7) contain about 40 percent sand grains and 60 percent silt and clay matrix. The grains in the thin sections are 0.18–0.8 mm in greatest dimension. They are mainly quartz and feldspar, but some rounded grains are glauconite, phosphate pellets, and porcelaneous rock. A thin section of poorly sorted conglomeratic fossiliferous sandstone from the Pancho Rico in the northwestern part of the Valleton quadrangle (east of the center of sec. 1, T. 23 S., R. 11 E.) contains grains of quartz and feldspar cemented by rims composed of layers of opal. Fibrous chalcedony fills interstices between the rimmed grains, and calcareous shell material is replaced by silica. With respect to cementation and replacement of calcareous shell material, the rock is similar to a Miocene orthoquartzite from New Jersey described by Friedman (1954).

Mudstone and porcelaneous mudstone in the Pancho Rico Formation are similar to rocks in the Monterey Shale. Two thin sections of mudstone from the Pancho Rico just west of the Salinas River (SW¼ sec. 33, T. 22 S., R. 10 E.) contain about 20 percent sand grains and 80 percent silt and clay matrix. The sand grains in the thin section are angular and are mainly 0.13–0.18 mm in greatest dimension, although a few are as large as 0.4 mm. The rock is massive, noncalcareous, and contains mica flakes and small charcoallike clasts. A thin section of mudstone from the Pancho Rico in the southern part of the Wunpost quadrangle (measured section 3, unit 5), contains about 90 percent clay and silt matrix and 10 percent very fine sand.

Conglomerate in the Pancho Rico contains pebbles and cobbles in a sandy matrix. The larger clasts are generally rounded or subrounded and are mainly porcelaneous rock, chert, volcanic rock, quartzite, gneiss, and granitic rock. The relative abundance of the kinds of clasts changes from place to place. Fossils are common in many conglomerate beds. Shell material is preserved at some places; only molds and casts of shells remain at others; and in a few beds calcareous shell material is replaced by silica.

Dolomitic carbonate beds in the Pancho Rico Formation are identical with those in the Monterey Shale.

THICKNESS

The thickness of the Pancho Rico Formation is 100–200 feet northeast of Hames Valley (measured on the geologic map, pl. 1) and is greater than 375 feet 2–3½ miles farther east near the Salinas River (measured section 2). The thickness is about 500 feet in the San Ardo oil field (measured on structure sections *A–B*, pl. 1, and *B–C*, pl. 2), 450–500 feet near Sargent Canyon (measured on the geologic map, pl. 2) where both the upper and lower contacts are exposed, and about 650 feet east of Indian Valley (measured on the geologic map, pl. 3). As indicated on structure sections *B–C* (pl. 2) and *C–D* (pl. 3), changes in the thickness of the Pancho Rico may be at least partly due to probable intertonguing of the unit with the Monterey Shale and Paso Robles Formation.

AGE AND CONDITIONS OF DEPOSITION

The Pancho Rico Formation is considered Pliocene in age. Megafossils from the Pancho Rico Formation are listed on table 1. According to W. O. Addicott (written commun., 1963, 1964), the collections from localities M1675, M1676, M1934, M1967, and M1970 (see table 4) indicate Pliocene age, and those from localities M1930, M1935, and M1966 indicate early Pliocene age. The fossil echinoids from locality M1674 are probably of early Pliocene age (J. W. Durham and W. O. Addicott, written commun., 1964). Mudstone beds near the top of the Pancho Rico in the northwest part of the Valleton quadrangle at fossil locality Mf746 contain the following Foraminifera (identified by P. B. Smith):

Elphidium hughesi Cushman and Grant (abundant)
Ammonia beccarii (Linné) (common)
Buliminella elegantissima (d'Orbigny) (abundant)
Bolivina cf. *B. girardensis* Rankin (rare)
Bolivina cf. *B. malagensis* Kleinpell (rare)
Bolivina cf. *B. obliqua* Barbat and Johnson (rare)

The foraminifers are mainly species that indicate shallow water (less than 20 meters) and that range from at least early Miocene to Recent age (P. B. Smith, written commun., 1963).

Both the larger and smaller fossils in the Pancho Rico Formation in the map area indicate a shallow marine environment.

TABLE 1.—*Fossils from the Pancho Rico Formation*

[Identified by W. O. Addicott, except where otherwise noted. ×, present as identified; ?, doubtful identification; cf., similar form, specimen(s) incomplete or too poorly preserved for definite identification; aff., comparable but apparently different form; sp., species not determinable; ?sp, genus questionably identified]

	USGS locality											
	M982	M983	M1674	M1675	M1676	M1930	M1933	M1934	M1935	M1966	M1967	M1970
Gastropods:												
Bittium cf. *B. attenuatum multifilosum* Bartsch								×				
casmaliense Bartsch	cf.[1]	×						sp.	×			
casmaliense Bartsch, strongly sculptured form	×										×	
Calicantharus cf. *C. fortis* forma *angulata* (Arnold)	sp.								×			
humerosus (Gabb)									cf.	?		
kettlemanensis (Arnold)					×				×			?
?*Calicantharus* sp.						×					×	
Calliostoma coalingensis (Arnold)	sp.				cf.	×					×	
etchegoinense Nomland						×						
Calliostoma cf. *ligatum* (Gould)								×				
Calyptraea filosa (Gabb)	sp.				sp.	×		×		×		
Cancellaria cf. *C. fernandoensis* Arnold									×			
Crepidula cf. *C. nummaria* Gould									×			
princeps Conrad					cf.	?						
cf. *C. onyx* Sowerby								×	×			sp.
Crucibulum (*Dispotaea*) n. sp.						×			×			
Epitonium (*Cirsotrema*?) sp.					×							
Forreria belcheri (Hinds)								?	×			×
Kelletia kelleti (Forbes)								×				
Margarites aff. *M. pupillus* (Gould)									×			

See footnote at end of table.

TABLE 1.—*Fossils from the Pancho Rico Formation*—Continued

	USGS locality											
	M982	M983	M1674	M1675	M1676	M1930	M1933	M1934	M1935	M1966	M1967	M1970
Megasurcula n. sp. aff. *M. wynoocheensis* (Weaver)	×	×							×			
Mitrella gausapata (Gould)						sp.			sp.		×	
Nassarius aff. *N. californianus* (Conrad)	×								×			
Neverita recluziana (Deshayes)					sp.			×	cf.			
Ocenebra cf. *O. tethys* (Nomland)								×	×			
Sinum cf. *S. scopulosum* (Conrad)									×			
Turritella cooperi Carpenter		×[1]										×
cooperi forma nova Nomland					×							
gonostoma hemphilli Applin in Merriam	×											
vanvlecki Arnold						×		×	×			
n. sp. (*T. broderipiana* stock)								×				
Pelecypods:												
Amiantis n. sp.? aff. *A. stalderi* (Clark)												×
Anadara trilineata (Conrad)		×[1]								sp.	sp.	
Trilineata forma *canalis* (Conrad)	×											
Clinocardium sp									×			
Cryptomya californica Conrad?								×				
Cyclocardia californica (Dall)	×	?				sp.			×			
Diplodonta sp	×				×							
Florimetis biangulata (Carpenter)		×			×	×		×	×		×	×
Glans n. sp. aff. *G. radiata* (Sowerby)									×			
Glycymeris cf. *G. grewingki* Dall									×			
Lucinisca n. sp.? aff. *L. nuttalli* (Conrad)		?	sp.		×							
Lyropecten terminus Arnold	cf.			×	×			?sp.	×	×		?
Macoma affinis Nomland								×				
cf. *M. arnheimi* Dall								×				
cf. *M. indentata* Carpenter								×		×		
nasuta (Conrad)	?	×			×	?		×	×	×		?
secta (Conrad)								×	×			×
Modiolus rectus (Conrad)										×		
Mya arenaria Linné								×				
cf. *M. truncata* Linné								×				
Nuculana taphria (Dall)					×							
Ostrea atwoodi Gabb	×			sp.		×		sp.	×			sp.
Protothaca cf. *P. lacinata hannibali* Howe					×				×	?	×	
tenerrima (Carpenter)					×				?		×	
Sanguinolaria cf. *S. nuttalli* Conrad									×			
Saxidomus nuttalli Conrad					×							
Siliqua cf. *S. media* (Sowerby) of Woodring [and Bramlette] (1950)	×									×		
Solen perrini Clark								×	sp.	×	sp.	cf.
Spisula hemphilli (Dall)?					sp.				×	×		
cf. *S. mercedensis* Packard								×				
Tellina cf. *T. aragonia* Dall									×			
cf. *T. lutea* Wood			?						×			
Trachycardium quadragenarium (Conrad)	?				sp.				×	cf.		
Transenella tantilla (Gould)					sp.				×			
Tresus nuttalli (Conrad)?								×				
Barnacles:												
Balanus gregarius (Conrad)	×				cf.	sp.	sp.		×	sp.		×
sp. (Small)									×			
Echinoids:												
Astrodapsis aff. *A. cuyamanus* Kew			×[2]									
fernandoensis Pack	×[2]		cf.[2]									
salinasensis Richards	×[2]		cf.[2]									
spatiosus Kew									×[2]	cf.		
sp. (*A. whitneyi-A. jacalitosensis* group)									×[2]			
Dendraster sp									×			

[1] Identified by Ellen J. Moore.
[2] Identified by J. Wyatt Durham.

TERTIARY AND QUATERNARY(?) SYSTEMS

PLIOCENE AND PLEISTOCENE(?) SERIES—PASO ROBLES FORMATION

Fairbanks (1898, p. 565) gave the name Paso Robles Formation to nonmarine beds exposed about 17 miles south of the Valleton quadrangle near the town of Paso Robles. The Paso Robles Formation crops out in much of the map area east of the Salinas River, on the sides of Hames Valley, and near the southwest corner of the Hames Valley quadrangle. It is chiefly conglomerate, sandstone, and mudstone.

The Paso Robles Formation overlies the Pancho Rico Formation with apparent conformity east of the Salinas River and northeast of Hames Valley. The base of the Paso Robles in these areas is placed at the top of the stratigraphically highest lithologic unit that contains marine fossils. The Paso Robles apparently lies directly on the diatomaceous mudstone member of the Monterey Shale southwest of Hames Valley, but the beds there are poorly exposed and the contact relations are obscure. The Paso Robles lies with pronounced angular unconformity on porcelaneous rocks of the Monterey Shale near the southwest corner of the Hames Valley quadrangle. The beds assigned to the Paso Robles there are equivalent to those questionably assigned to the Paso Robles farther west in the Williams Hill quadrangle (Durham, 1965).

Ideally, the base of the Paso Robles Formation represents the beginning of nonmarine deposition following the last withdrawal of the Tertiary sea from the map area. Practically, the base east of the Salinas River is the lower contact of the first prominent lithologic unit above the stratigraphically highest occurrence of marine fossils. At many places the uppermost part of the underlying Pancho Rico Formation contains abundant fossil oyster shells, 1–2 inches long. In areas of nearly flat lying beds, the topographically highest occurrence of these shells marks the approximate base of the Paso Robles. The base west of the Salinas River is the lower contact of the stratigraphically lowest conglomerate unit above finer grained rocks of the Pancho Rico Formation or Monterey Shale. Obviously, the base of the Paso Robles does not necessarily represent the same stratigraphic horizon throughout the map area. As mapped, the Paso Robles could contain some marine beds that lack fossils, and if the basal contact of the Paso Robles is in a sequence of intertonguing marine and nonmarine beds, some nonmarine beds may be included in the Pancho Rico.

LITHOLOGY

The Paso Robles Formation in the map area consists mainly of conglomerate, sandstone, and mudstone units, whose cumulative thicknesses in the part of the Paso Robles exposed east of the Salinas River in the southern part of the Wunpost quadrangle (measured section 3) have the ratio of 6:5:2, respectively. In this sequence of beds, which typifies at least part of the Paso Robles, conglomerate forms 9 units that range from 5 to 45 feet in thickness (median thickness 13½ ft.), sandstone forms 51 units that range from 2 inches to 10 feet in thickness (median thickness 14 inches), and mudstone forms 42 units that range from 1 inch to 12 feet in thickness (median thickness 8 inches). Resistant beds of limestone (fig. 5) are conspicuous in the Paso Robles at some places, especially in the southwestern part of the Hames Valley quadrangle (secs. 27, 28, 33, and 34, T. 23 S., R. 9 E.), and in the southeast part of the Valleton quadrangle (secs. 34 and 35, T. 23 S., R. 12 E.). Beds of clay and woody lignite crop out in railroad cuts east of the Salinas River in the southern part of the Wunpost quadrangle (measured section 3, units 24–28 and 48).

Conglomerate beds in the Paso Robles Formation typically contain pebbles and small cobbles in a matrix of sand or sand and silt (fig. 4). The rock ranges from friable to well indurated and is generally noncalcareous, although some beds are well cemented by calcite. The larger clasts in the conglomerate include several kinds of rock. Pebbles collected from a roadcut near the south edge of the Wunpost quadrangle (sec. 1, T. 24 S., R. 10 E.) are about 75 percent basement and volcanic rocks, 23 percent rocks obviously derived from the Monterey Shale, and 2 percent sandstone. Pebbles collected north of the mouth of Sargent Canyon (near center of sec. 2, T. 23 S., R. 10 E.) are about 55 percent basement and volcanic rocks, 45 percent debris from the Monterey, and less than 1 percent sandstone. Pebbles collected in Sheep Canyon (near SE cor. sec. 5, T. 23 S., R. 11 E.) are about 98 percent debris from the Monterey and only about 2 percent basement and volcanic rocks. Pebbles collected in Indian Valley (near S¼ cor. sec. 29, T. 23 S., R. 12 E.) are about 65 percent basement and volcanic rocks, 30 percent debris from the Monterey, and 5 percent rock derived from Franciscan terrane. Basement and volcanic rocks include gneiss, schist, quartzite, quartz, porphyries, and granitic plutonic rocks. Debris from the Monterey includes porcelaneous rocks, brownish-gray or dusky yellow chert, and mudstone—including diatomaceous mudstone. The clasts obviously derived from Franciscan terrane are greenstone or grayish-red and pale yellowish-green chert.

Sandstone in the Paso Robles Formation is arkosic and ranges from fine to coarse grained and conglomeratic. Granules and pebbles are

FIGURE 4.—Conglomerate and poorly sorted sandstone beds of the Paso Robles Formation exposed in roadcut near the south edge of the Wunpost quadrangle. Cross-stratification nearby in the same exposure indicates a current direction to the left (south).

common in the sandstone (fig. 4), either scattered or in lenses. Much of the rock is massive or poorly bedded, but some is cross-stratified, laminated, or cross-laminated. Most of the sandstone is noncalcareous and friable, but beds that are well indurated and noncalcareous and others that are firmly cemented by calcite occur in the formation. Some sandstone beds are lenticular, and some fill channels in the underlying rock. The sandstone has a wide color range, but most commonly it is yellowish gray.

A thin section of sandy limestone from the Paso Robles Formation just east of the Salinas River (measured section 3, unit 60) contains about 15 percent sand grains and 85 percent calcite matrix. The size of the sand grains ranges from 0.06 to 0.7 mm. Another thin section of sandy rock (measured section 3, unit 37) contains about the same proportion of sand and matrix, but the matrix is only slightly calcareous and is chiefly silt and clay. The size of the sand grains in this thin section ranges from 0.06 to 0.18 mm. The rock contains small cavities lined with calcite.

Mudstone in the Paso Robles is generally massive, noncalcareous, and has a hackly fracture, but in some places it is laminated, and locally it is calcareous. Ordinarily it is grayish orange, very pale orange, or yellowish gray. Some units of mudstone contain lenses of irregular pods of sandstone and some others grade into sandstone. Secondary gypsum is commonly associated with mudstone along bedding and joint surfaces.

Limestone in the Paso Robles Formation is massive, occurs in units about 2–5 feet thick, and commonly forms bold outcrops (fig. 5). It is generally gray, pinkish gray, or very pale orange. Four thin sections of the limestone contain a few scattered sand grains, 0.06–0.18 mm long, in an aphanitic matrix. The limestone in two of the thin sections contains vugs and cracks that are lined or nearly filled with secondary calcite. A thin section of limestone from near the southwest corner of the Hames Valley quadrangle (sec. 28, T. 23 S., R. 9 E.) contains former cavities and cracks that are lined with opal and filled with fibrous chalcedony.

THICKNESS

The thickness of the Paso Robles Formation may be greater than 1,000 feet east of the San Ardo oil field (structure section *B–C*, pl. 2).

FIGURE 5.—Massive limestone beds in the Paso Robles Formation one-quarter of a mile west of the center of sec. 34, T. 23 S., R. 9 E., near the southwest corner of the Hames Valley quadrangle.

Where the base of the formation is exposed east of the Salinas River in the southwestern part of the Wunpost quadrangle, the thickness is greater than 500 feet (measured on the geologic map, pl. 2). The top of the Paso Robles is absent or unrecognized in the map area, so that probably even where the unit is thickest, only part of the original thickness remains.

AGE AND CONDITIONS OF DEPOSITION

Fossils are scarce or absent in the Paso Robles Formation. Plant material is preserved in woody lignite beds exposed along the railroad in the southwestern part of the Wunpost quadrangle (measured section 3, units 24 and 27). Samples from these and associated beds were prepared for pollen analysis, but only a few gymnosperm pollen grains, too weathered for identification, were obtained (Estella B. Leopold, written commun., 1964). The Paso Robles is considered to be of Pliocene and possibly Pleistocene age because it overlies and probably intertongues with the Pancho Rico Formation of Pliocene age, and unconformably underlies older alluvium.

The Paso Robles Formation lacks marine fossils and has the poor sorting and rude stratification commonly attributed to nonmarine rocks. Much of the formation closely resembles older alluvium in the area and is presumably of fluviatile origin, but other depositional environments are suggested by the limestone and lignite beds in the formation.

QUATERNARY SYSTEM

PLEISTOCENE AND RECENT(?) SERIES—OLDER ALLUVIUM

Older alluvium includes fluviatile sediments that unconformably overlie the Paso Robles and other formations and that are older than Recent alluvium in modern streams. It covers or borders valleys in the map area and occurs high on valley sides as isolated remnants of formerly more extensive alluvial deposits.

Older alluvium is chiefly poorly sorted and consists of semiconsolidated conglomerate, sandstone, and mudstone. It resembles parts of the Paso Robles Formation and in places it is difficult to distinguish between the two units. Southwest of Hames Valley, for example, in an area of ploughed fields and poor exposures, the contact between the older alluvium and Paso Robles is arbitrarily placed at the base of the hills that border the valley.

Bluffs of older alluvium along the Salinas River are as high as 80 feet, and hills mapped as older alluvium in Hames Valley are about the same height. The maximum thickness of older alluvium in the map area is unknown because where the unit is thickest, the base is concealed. However, the maximum thickness may be as little as 100 feet.

Older alluvium is younger than the Paso Robles Formation of Pliocene and Pleistocene(?) age and is older than Recent alluvium. It is thus limited to Pleistocene and possibly Recent age.

RECENT SERIES—ALLUVIUM

Alluvium occurs in the beds of all streams in the map area, but it is most extensive along the Salinas River and Big Sandy Creek and is shown on the geologic maps only along those streams. It is mainly sand and sandy gravel. The gravel is composed of pebbles and cobbles similar to those in the Paso Robles Formation. Clasts as large as boulders are rare in the alluvium.

STRUCTURE

GENERAL FEATURES

The major structural divisions of the Hames Valley, Wunpost, and Valleton quadrangles are (a) the area west of Hames Valley, where a moderately thick sequence of faulted and folded strata overlies the basement complex, (b) the belt between Hames Valley and the Salinas River, where a thick sequence of slightly folded to tightly folded and faulted beds overlies the basement complex, and (c) the area east of the Salinas River, where a comparatively thin sequence of nearly undeformed strata covers the basement complex. Systems of northwest-trending faults west of Hames Valley and west of the Salinas River mark the boundaries of the divisions.

Monterey Shale exposed in the southwestern part of the Hames Valley quadrangle is deformed into closely spaced north- to northwest-trending folds and is cut by large northwest-trending faults. The Paso Robles Formation, which there unconformably overlies the Monterey, is warped into broad folds and is apparently unfaulted. The Texaco Hall 1 (No. 62 on map), the only exploratory well drilled in this part of the map area, reportedly reached weathered granitic rock at a depth of about 3,000 feet or less, but was drilled alternately in basement and sedimentary rocks to much greater depths. The trace of a large fault is about 500 feet southwest of the well site, and the well may have penetrated slivers of basement complex associated with that fault. But even discounting fault slivers of basement rock in the well, the depth to the surface of the basement complex in this part of the map area must be considerably less than it is farther northeast near Hames Valley.

Monterey Shale and younger strata are exposed in a belt about 5 miles wide that extends northwest across the map area west of the

Salinas River. The southwest border of the belt is the system of en echelon faults between sec. 6, T. 24 S., R. 10 E., at the south edge of the Hames Valley quadrangle, and sec. 4, T. 23 S., R. 9 E., at the west edge of the same quadrangle. The Monterey and younger rocks exposed in most of the belt form broad folds and lack large faults, but near the Salinas River the beds are tightly folded, locally overturned, and cut by large faults. The Monterey Shale in this belt, except possibly southwest of Hames Valley, is overlain conformably by the Pancho Rico Formation, which is in turn overlain conformably by the Paso Robles Formation. The Pancho Rico Formation is apparently absent southwest of Hames Valley and the Paso Robles there appears to lie directly on the Monterey Shale, as it does in the southwest part of the Hames Valley quadrangle, but the relations may be complicated by faulting.

The surface of the basement complex is much deeper near Hames Valley than it is elsewhere in the map area. The Shell Oil Labarere 27–X (No. 42 on map, sec. 21, T. 23 S., R. 10 E.), on the ridge between Hames and Swain Valleys, penetrated sedimentary rocks for nearly 11,000 feet, although it was probably not above the deepest depression on the basement surface. Gribi (1963b, p. 26) showed the top of the basement complex to be deeper than 14,000 feet below sea level near Hames Valley. The surface of the basement complex slopes upward to the northeast away from Hames Valley (pl. 5). The average slope of the basement-complex surface between the Shell Oil Labarere 27–X and the Texaco Labarere 3–1 (No. 67 on map, sec. 15, T. 23 S., R. 10 E.), drilled 2½ miles farther northeast near the Salinas River, is about 2,880 feet per mile, or about 28°. The average slope between the Texaco Labarere 3–1 and the Socony Mobil Oil Ferrini 73 (well A, pl. 5, sec. 11, T. 23 S., R. 10 E.), drilled about 1½ miles farther northeast near the center of the San Ardo oil field, is about 600 feet per mile, or about 7°. The average slope farther north between the Texaco Aurignac 1–29 (No. 57 on map, sec. 5, T. 23 S., R. 10 E.) and the Texaco Aurignac 1–30 (No. 58 on map, sec. 33, T. 22 S., R. 10 E.), drilled less than half a mile northeast, measured oblique to the strike of the basement-complex surface, is about 4,300 feet per mile, or about 38°. Information from wells shows that the sloping surface of the basement complex trends southeastward in the subsurface across the northeast quarter of the Hames Valley quadrangle, approximately parallel to the front of the hills west of the Salinas River. Near the east edge of the quadrangle, the trend of the surface turns more toward the east across the southern part of the Wunpost quadrangle (pl. 5).

Strata of the Monterey Shale and younger units exposed east of the Salinas River are tilted and deformed into broad folds and are cut by few, if any, faults. The exposed strata are apparently conformable, although Baldwin (1950, p. 1987) reported a "slight localized unconformity" in the San Ardo oil field at the base of the diatomaceous mudstone unit that he assigned to the Pancho Rico Formation and that is here considered a diatomaceous mudstone member of the Monterey Shale. Colvin (1963, p. 57) reported a disconformity at the same horizon. The basement complex in most of the map area east of the river has a platformlike surface of low relief (pl. 5). The surface is shallowest in the northwestern part of the Wunpost quadrangle and near the San Ardo oil field, where it is generally 2,000 feet or less below sea level and is overlain by strata of late Miocene age. Farther east the basement complex surface is generally deeper and is overlain by beds of pre-late Miocene age.

Structure sections *A–B*, *B–C*, and *C–D* (pls. 1, 2, and 3) illustrate the geologic structure of the map area as interpreted from surface and well data. The parts of section *A–B* between the Texaco Aurignac 3 and Rosenberg 1–10, and the part of sections *B–C* and *C–D* between the Bishop Oil and Cuyama Oil O'Reilly 1 and Jergins Oil U.S.L. South 1 are adapted partly from Kilkenny and others (1952).

FAULTS

Faults in the Monterey Shale are rarely well exposed, but they are commonly marked by a linear zone of crushed rock and steeply dipping or contorted beds against which nearby structural features terminate abruptly. Generally their exact location, and in some places their very existence, is questionable. Faults that separate the Monterey from other units are more obvious, but because they ordinarily are poorly exposed, their location is seldom precise.

The northwest-trending faults in the southwestern part of the Hames Valley quadrangle belong to a fault system that extends at least 7½ miles northwest of the map area across the Williams Hill quadrangle into the Espinosa Canyon quadrangle and continues at least 5 miles southeast of the map area into the Tierra Redonda Mountain quadrangle. Wells drilled in and just southwest of this fault system in the map area reach the basement complex at much shallower depths than do wells drilled 1–3 miles northeast of it. This apparent offset of the basement-complex surface suggests that the fault system in the Monterey is the effect in the sedimentary cover of displacement along one or more faults in the basement complex below.

The zone of faults and tight folds near the edge of the hills west of the Salinas River in the northern part of the map area is markedly dissimilar to the area of nearly undeformed rocks ¼–2 miles farther east across the river. The contrast in the structure was attributed by

Diller and others (1915, p. 119) to a large fault along the river, by English (1918, p. 245) to a syncline or a faulted syncline under the valley, and by Vander Leck (1921, p. 87, 89) to a fault that extends along the west side of the valley to about 3–5 miles south of San Ardo. Reed (1925, p. 590) gave the name "King City fault" to the structural feature that forms the boundary between the structurally contrasting east and west sides of the Salinas Valley, and he (1933, p. 44) noted "fair evidence" for existence of the fault through the Hames Valley and Wunpost quadrangles. Kilkenny (1948, p. 2265) considered the King City fault as primarily a subsurface feature (p. 2266) that formed a west-facing escarpment by normal faulting in Eocene time. He further concluded that the escarpment was periodically renewed in Miocene time and was the locus of thrust faulting in Pliocene and Pleistocene time.

Drilling near the west edge of the San Ardo oil field demonstrated that rocks exposed there lie above a thrust fault, the Los Lobos thrust fault of Kilkenny and others (1952). On structure section A–B (pl. 1), this thrust fault intersects the Texaco Rosenberg 1–10, Aurignac 1, and Garrissere 1. Faults near the edge of the hills west of the river are apparently related to this thrust fault, which is distinct from any fault beneath the river along which the basement complex to the east might have been uplifted. The thrust fault may be the probable subsurface fault shown on plate 5, as suggested on structure section A–B (pl. 1). The trace of the thrust fault may be concealed by alluvium and older alluvium along the river, or perhaps the displacement near the surface is distributed among several faults, as suggested on structure section A–B (pl. 1). Surficial evidence of faulting along the west side of the river is lacking south of about the latitude of Wunpost. North of there the zone of faults and tightly folded rocks west of the Salinas River is presumably caused by crumpling, crushing, and thrusting of the thick sequence of strata west of the river against the structurally high and comparatively rigid mass of basement rock east of the river. Farther southeast the basement complex is at greater depth (pl. 5), and the beds along and west of the river are much less severely deformed, possibly because the basement complex there is more remote. The thrust fault involves the Pancho Rico and Paso Robles Formations, so that the latest movement at least is thus no older than Pliocene in age.

FOLDS

Beds in the map area near large faults are generally deformed into closely spaced, steep-limbed folds, and those in areas that lack large faults are ordinarily warped into broad folds. The folds west of the Salinas River trend north to northwest, subparallel to the major faults. The genetic relationship of these folds and faults seems obvious. The broad poorly defined folds in the northern part of the map area east of the river trend southwestward, nearly perpendicular to the trend of the regional structure farther west.

The Monterey Shale near the faults in the southwestern part of the Hames Valley quadrangle is tightly folded, but the Paso Robles Formation there is much less severely deformed, suggesting at least two periods, or one long continuing period of deformation. The Monterey Shale and younger formations in the central part of the Hames Valley quadrangle are warped into broad folds, and dips greater than 40° are rare in that part of the map area. The Monterey Shale and Pancho Rico Formation near the edge of the hills west of the Salinas River are distorted into closely spaced and locally overturned folds in fault blocks. The beds east of the Salinas River are generally so little deformed, and in many places so poorly exposed, that determination of the structure of beds at the surface is difficult. The configuration of the basal contacts of the Pancho Rico and Paso Robles Formations suggests a series of broad southwest-trending and plunging folds in the northern part of the Wunpost and the northeastern part of the Valleton quadrangles. The folds in the Wunpost quadrangle, at least, appear unrelated to relief on the surface of the basement complex, for the anticline near Deadman Gulch is above a structural high, and the anticline near Sargent Canyon is above a structural low on that surface (pl. 5).

ECONOMIC GEOLOGY

Petroleum is the dominant mineral resource in the map area. The San Ardo oil field covers about 4,200 acres in the Hames Valley and Wunpost quadrangles, and the smaller Lynch Canyon oil fields extends into part of the Wunpost quadrangle. Table 2 lists 80 exploratory and outpost wells drilled for oil in the map area outside oil fields.

Prospectors have shown some interest in the diatomaceous mudstone member of the Monterey Shale as a source of diatomite. An adit in the Wunpost quadrangle (near center of SW¼ sec. 23, T. 23 S., R. 10 E.) was dug horizontally more than 50 feet into diatomaceous rock before being abandoned. The remains of smaller pits and tunnels are evident at several places. Waring and Bradley (1917, p. 598–599) reported that diatomaceous earth from sec. 20, T. 23 S., R. 10 E., had been on the market since 1905 and was adapted for use as building blocks for interior fireproof walls.

A small abandoned sand quarry is on the east side of Big Sandy Creek in the Valleton quadrangle (near center of NE¼ sec. 2, T. 23 S., R. 12 E.) It is in a unit of friable sandstone in the Monterey Shale.

TABLE 2.—*Exploratory and outpost wells outside oil fields in the Hames Valley, Wunpost, and Valleton quadrangles, drilled before 1964*

[Locations were supplied by the operators and verified in the field where possible. Stratigraphic nomenclature used in remarks column is that of the operator or of the authority cited, and is not necessarily the same as that used elsewhere in this report. Elevation: from topographic map, t; kelly bushing, kb; ground, gr; derrick floor, df]

No. on map (pl. 5)	Operator	Well	Location				Year(s) drilled	Elevation (feet)	Total depth (feet)	Remarks (depths in feet)
			Quadrangle	Sec.	Township south	Range east				
1	Adelanto Development Corp.	McCool 1	Wunpost	35	22	10	1956	525 t	2,650	Top Santa Margarita Formation, 1,624; top Lombardi sand, 2,390; top basement complex, 2,559 (California Oil Fields, 1956, v. 42, no. 2, p. 124).
2	Ash, Fred, and Sons.	Wood 1	do	27	23	11	1963	960 t	3,300	
3	Barnsdall Oil Co.	Kelch 1	Valleton	23	23	12	1948	1,900 gr	2,407	Reported basement complex(?) (Oakeshott and others, 1952, p. 29) or red beds at bottom. Also called Sunray Oil Kelch 1. On structure section C–D, pl. 3.
4	do	P. W. and P. 1.	Wunpost	29	23	11	1948	851 kb	4,151	Reported: top Campbell [Aurignac] zone, 2,900; top basement complex, 4,088; top unweathered basement complex, 4,139.
5	do	R. and W. 1	Valleton	21	23	12	1948	1,050 gr	4,100	Basement complex(?) at bottom (Oakeshott and others, 1952, p. 29); reported: oil-stained shale in core, 4,055; top red beds, 3,010.
6	Bishop Oil Co.	Alexander B-1	Wunpost	8	23	11	1953	751 gr	2,468	Top Lombardi sand, 1,924; top Aurignac sand, 2,344; top basement complex, 2,462–2,468 (California Oil Fields, 1953, v. 39, no. 2, p. 103).
7	Bishop Oil Co. and Cuyama Oil Co.	O'Reilly 1	do	32	22	11	1948	769 kb	2,483	Basement complex at bottom (Oakeshott and others, 1952, p. 28). On structure section B–C, pl. 2.
8	Chanslor-Canfield Midway Oil Co.	San Ardo 6-G-1.	Hames Valley.	6	23	10	1946–47	1,009 gr	8,062	According to Kilkenny (1948, p. 2266), this well "encountered 8,000 ft of Monterey cherty shales on 170 ft or more of granodiorite breccia * * * believed to be a recemented talus deposit at the base of the old scarp. The age of the talus is pre-Monterey and probably pre-Vaqueros."
9 [1]	Continental Oil Co.	Alexander 88-5	Wunpost	5	23	11	1955	980 t	2,986	Top Lombardi sand, 2,418; top Aurignac sand, 2,810; top basement complex, 2,935 (California Oil Fields, 1955, v. 41, no. 2, p. 117).
10	Creagmile, J. C., and Stewart, J. T.	Detoy 2	Valleton	28	23	12	1935(?)–38	1,340 t	2,582	Monterey Shale at bottom; oil and gas shows, 1,778–1,824 (Bramlette and Daviess, 1944). Also called McDonald Detoy 2.
11	Cuyama Oil Co.	O'Reilly 2	Wunpost	28	22	11	1948	855 t	2,962	Reported top basement complex, 2,923. On structure section B–C, pl. 2.

12 [2]	Doheney	1(?)	Hames Valley.	20	22	10	1908–09	600(?)	1,000	Only traces of oil (Waring, 1914, p. 435).
13 [2]	do	2(?)	do	20	22	10	1908–09	(?)	1,135	Do.
14	Douglas, James M.	Smith 1	do	36	22	9	1933(?)–34	1,380 t	4,158	Monterey Shale, 0–3,200; Sandholdt Shale, 3,200–4,158; tar, 1,070; gas show, 2,008 (Bramlette and Daviess, 1944); Vaqueros Formation at bottom (Oakeshott and others, 1952, p. 28). Also called San Ardo 1(?). On structure section A–B, pl. 1.
15	General Petroleum Corp.	Garrissere 67X–30.	do	30	22	10	1953	835 t	3,367	Basement complex at bottom (Jennings and Hart, 1956, p. 56).
16	do	Hambey 248–18	Wunpost	18	23	11	1954	1,038 kb	3,051	Top Monterey Shale, 1,470; top Lombardi sand, 2,440; top Aurignac sand, 2,669 (California Oil Fields, 1954, v. 40, no. 2, p. 119); basement complex at bottom(?) (Colvin, 1963, pl. 4).
17	Hames Valley Development Co.	Peri 1	Hames Valley.	30	23	10	1953	904 df	800	Reported Monterey Shale at bottom.
18	Hamilton Dome Oil Co.	Benjamin 1	Valleton	9	23	12	1958	1,128 kb	2,448	Basement complex at bottom (Popenoe, 1959, p. 1400). On structure section C–D, pl. 3.
19 [1]	Humble Oil and Refining Co.	A. Orradre 1	Wunpost	25	22	10	1956	660 t	2,072	Top Santa Margarita Formation, 1,362; basement complex at bottom (California Oil Fields, 1956, v. 42, no. 2, p. 121).
20 [1]	do	Louise McCool Core Hole 1.	do	26	22	10	1956	925 t	2,465(?)	Top C-sand, 1,650; basement complex at bottom (California Oil Fields, 1956, v. 42, no. 2, p. 121); top Lanigan sand, 1,185 below sea level (Gribi, 1963a, p. 72).
21	Jergins Oil Co	Aurignac 1	Hames Valley.	9	23	10	1951	837 kb	4,321	Reported: plugged, 3,510; on March 20, pumped 18 bbl per day, 14.0° API gravity oil, 18 percent cut; on March 28, pumped 14 bbl per day, 14.4° API gravity oil, 16 percent cut; on March 30, pumped 16 bbl per day, 14.0° API gravity oil, 16 percent cut. Later abandoned.
22 [1]	do	Aurignac 2	do	9	23	10	1951	852 kb	3,961	Reported no oil or gas shows.
23 [1]	do	Jergins USL 25–9.	do	9	23	10	1951	1,386(?)kb	6,470	Do.
24 [1]	do	Lanigan 249–35	Wunpost	35	22	10	1951	620 t	2,804	Top Lombardi sand, 2,340; top Aurignac sand, 2,735; basement complex at bottom (California Oil Fields, 1952, v. 38, no. 2, p. 100). On structure section B–C, pl. 2.
25 [1]	do	Lanigan 251–35	do	35	22	10	1951	688 kb	2,873	Basement complex at bottom (Colvin, 1963, fig. 1); reported no oil or gas shows.
26 [1]	do	McCool 1	do	26	22	10	1951	760 t	2,478(?)	Bottom in basement complex (Barger and Zulberti, 1949, pl. 2).
27	do	San Ardo 23–35	do	35	22	10	1947	540 t	2,567	Lombardi sand wet (Barger and Zulberti, 1949, p. 20). Reported basement complex at bottom. Also called North American Oil Consolidated and Jergins Oil McCool 1.
28 [1]	do	USL South 1	Valleton	26	22	11	1949	1,200 t	3,302	Top Santa Margarita Formation, 1,550; top Lombardi sand, 1,930; top nonmarine red beds, 2,200; top basement complex, 3,293 (Oakeshott and others, 1952, p. 63). Also called Jergins Oil and North American Oil Consolidated South 1. On structure section C–D, pl. 3.

See footnotes at end of table.

TABLE 2.—*Exploratory and outpost wells outside oil fields in the Hames Valley, Wunpost, and Valleton quadrangles, drilled before 1964*—Continued

No. on map (pl. 5)	Operator	Well	Location: Quadrangle	Location: Sec.	Location: Township south	Location: Range east	Year(s) drilled	Elevation (feet)	Total depth (feet)	Remarks (depths in feet)
29 [1]	Jergens Oil Co.	USL South 2	Valleton	30	22	12	1949	1,530 t	2,366	Reported: top, Lombardi sand, 1,855; top red beds, 2,170. Also called Jergins Oil and North American Oil Consolidated USL South 2. On structure section C–D, pl. 3.
30	Jergins Oil Co. and North American Oil Consolidated.	Garrissere 1	Hames Valley.	28	22	10	1949	520 t	3,171	Reported top conglomerate, 3,088.
31	do	McCool 1	Wunpost	27	22	10	1948	480 t	2,110	Reported: top of oil sand, about 1,940; basement complex at bottom Lombardi sand wet and 78 ft structurally higher than in discovery well of field; located about 3,000 ft to the southwest (Barger and Zulberti, 1949, p. 17, 20).
32	Kern Oil Co.	Alexander 35–16.	do	16	23	11	1956	1,068 kb	3,250	Top Lombardi sand, 2,475; Miocene rocks at bottom (California Oil Fields, 1956, v. 42, no. 2, p. 121).
33	Mohawk Petroleum Corp.	Alexander 37X–28.	do	28	23	11	1957	898 kb	4,270	Top Pancho Rico Formation, 448; top Aurignac sand, 3,058; Miocene rocks at bottom (California Oil Fields, 1957, v. 43, no. 2, p. 124).
34	Newton Drilling Co.	Burden 1	Valleton	35	22	12	1959	1,250 kb	1,543	Top Santa Margarita Formation, 233; top Aurignac sand, 835; Miocene rocks at bottom (California Oil Fields, 1959, v. 45, no. 2, p. 118). Reported no oil or gas shows.
35	North American Oil Consolidated, Jergins Oil Co., and The Texas Co.	Rosenberg 1	Wunpost	[3] 34	22	10	1947	495 t	2,500	Reported: top basement complex, 2,462; formation test of tarry oil zone, 2,195–2,228, recovered 260 ft muddy water with spots of oil.
36	Northern Oil Co.	Sinclair 1	do	26	22	10	1962	704 kb	2,234	Reported: top C–sand, 1,420; top D–sand, 1,770; top Lombardi sand, 2,135; top nonmarine beds, 2,187; top basement complex, 2,224. Also called C. A. Luckey Sinclair 1.
37	do	Sinclair B2–1	do	35	22	10	1962	535 t	2,334	Top Lombardi sand, 1,890; bottom in Miocene rocks (California Oil Fields, 1962, v. 48, no. 2, p. 172).
38	Osage Oil and Gas Corp.	Osage-Alexander 1.	do	8	23	11	1956	759(?)kb	2,432	Reported: October 19, pumped 70–100 bbl per day net, rate, 13° API gravity oil, from 2,330–2,428, sanded up; November 8, pumped 20 bbl per day, 12.7° API gravity oil, 70 percent cut; abandoned.
39	Porter, B. F., Estate.	Porter 1	do	36	23	10	1949	509 gr	3,354	"Occasional tarry horizons" (Oakeshott and others, 1952, p. 63). Basement complex at bottom (Moody, 1950, p. 1025).

40 [2]	San Antonio Oil Co.	(?)	Hames Valley.	20	22	10	1901(?)	(?)	700(?)	River gravel at bottom (Waring, 1914, p. 435). California Div. Mines (1943, p. 650) listed three wells belonging to this company in secs. 20, 29, and 30, but Waring (1914, p. 435) mentioned only one.
41	Shell Oil Co.	Dudley-Grimes-Jorgensen unit 1.	do	19	22	10	1948–49	705 t	2,721	Top conglomerate, 2,453; top basement complex, 2,571 (Oakeshott and others, 1952, p. 63).
42 [1]	do	Labarere 27-	do	21	23	10	1959	1,088 df	10,957	Basement complex (Popenoe, 1960, p. 913), or lower Miocene(?) sandstone (Gribi, 1963b, pl. 2) at bottom.
43 [1]	Standard Oil Co.	Alexander 57	Wunpost	8	23	11	1950	1,069 gr	2,902	Reported: top Lombardi sand, 2,347; top Orradre (Aurignac) sand, 2,711; top basement complex, 2,898.
44	do	Alexander 85-9	do	9	23	11	1951	932 df	2,812	Reported: Lombardi sand, 2,230–2,557; Orradre (Aurignac) sand, 2,618–2,774; conglomerate, 2,774–2,811; top basement complex, 2,811.
45 [1]	do	Alexander B6-5	do	5	23	11	1951	1,096 df	3,050	Top Lombardi sand, 2,605; top Aurignac sand, 3,019; top basement complex, 3,043 (Jennings and Hart, 1956, p. 56).
46 [1]	do	Alexander D6-3	do	3	23	11	1952	1,206 df	2,938	Reported: top Lombardi sand, 2,670; Aurignac sand absent; top basement complex, 2,928.
47	do	Alexander Maher 75-21.	do	21	23	11	1952	965 t	3,527	Top Lombardi sand, 2,620; top Aurignac sand, 2,962; top nonmarine beds, 3,488 (Jennings and Hart, 1956, p. 57). Joint test with Ohio Oil Co.
48	do	Powell 1	Valleton	1	23	11	pre-1914	1,190 t	875	
49 [1]	Sunray Oil Corp.	Alexander 33-15	Wunpost	15	23	11	1954–55	1,440 t	3,437	Top Lombardi Sand, 2,832; top Aurignac sand, 3,214; bottom in Miocene rocks (California Oil Fields, 1955, v. 41, no. 2, p. 114).
50	Superior Oil Co.	Davis Core Hole 14.	Valleton	1	23	11	1949	1,180 t	3,440	Bottom in basement complex (Moody, 1950, p. 1025).
51	Tache Petroleum Co.	Lanigan 1	Wunpost	24	22	10	1962	691 kb	1,810	Top Miocene rocks, 1,244 (California Oil Fields, 1962, v. 48, no. 2, p. 171); basement complex at bottom (Gribi, 1963a, p. 72); also called Moriqui Exploration and Rancho Oil Lanigan 1.
52	Terminal Drilling Co.	Teddy 1	Valleton	26	23	12	1952	1,530 t	4,143	Miocene rocks at bottom (California Oil Fields, 1952, v. 38, no. 2, p. 97).
53	Texaco, Inc.	Adrian Orradre 1.	Wunpost	19	22	11	1955	813 kb	2,225	Top Lombardi sand, 2,006; top basement complex, 2,147± (California Oil Fields, 1955, v. 41, no. 2, p. 114).
54	do	Aurignac 1	Hames valley.	4	23	10	1946	1,020 t	4,201	Aurignac sand wet; very heavy oil, 3,025; top granitic breccia, 3,765; top basement complex, 4,200 (Barger and Zulberti, 1949, p. 15, 20). On structure section A–B, pl. 1.
55	do	Aurignac 3	do	31	22	10	1948	1,320 gr	4,765	Top basement complex, about 4,550 (Kilkenny and others, 1952). On structure section A–B, pl. 1.
56	do	Aurignac 1-28	do	5	23	10	1957	758 gr	6,723	Bottom in basement complex (Popenoe, 1958, p. 1406).
57	do	Aurignac 1-29	do	5	23	10	1957	655 gr	6,083	Bottom in basement complex (Popenoe, 1958, p. 1406); plugged at 3,700, redrilled to 5,445.
58	do	Aurignac 1-30	do	33	22	10	1957	720 t	4,018	Top Aurignac sand, 2,967; top basement complex, 4,004 (California Oil Fields, 1958, v. 44, no. 2, p. 141).

See footnotes at end of table.

TABLE 2.—*Exploratory and outpost wells outside oil fields in the Hames Valley, Wunpost, and Valleton quadrangles, drilled before 1964*—Continued

No. on map (pl. 5)	Operator	Well	Location: Quadrangle	Location: Sec.	Location: Township south	Location: Range east	Year(s) drilled	Elevation (feet)	Total depth (feet)	Remarks (depths in feet)
59	Texaco, Inc.	Aurignac B-1	Hames Valley.	9	23	10	1952	730 gr	3,821	Bottom in basement complex (Moody, 1953, p. 1224).
60	do	Aurignac C-1	do	33	22	10	1961	580 t	3,321	Top Aurignac sand, 2,752; bottom in basement complex (California Oil Fields, 1961, v. 47, no. 2, p. 148).
61 [1]	do	Garrissere 1	do	32	22	10	1950	733 gr	4,532	Top basal Monterey sand, 4,350; bottom in sandstone (Oakeshott and others, 1952, p. 63). On structure section A–B, pl. 1.
62	do	Hall 1	do	26	23	9	1955	1,259 kb	5,940	Weathered basement complex, 3,010; bottom in unweathered basement complex (California Oil Fields, 1955, v. 41, no. 2, p. 114).
63	do	Kock 1	do	20	22	10	1960–61	616 kb	3,451	Bottom in basement complex (Popenoe, 1962, p. 1008).
64	do	M. Garrissere 2	do	29	22	10	1960	533 kb	2,998	Bottom in basement complex (Popenoe, 1961, p. 970).
65	do	M. Garrissere 3	do	29	22	10	1962	810 kb	4,534	Reported: April 17, pumped 31 bbl per day, 12.4° API gravity oil, 32 percent cut, from 4,240–4,273; April 22, pumped 21 bbl per day, 14.6° API gravity oil 32 percent cut; April 23, pumped 7 bbl per day, 14.6° API gravity oil, 70 percent cut; April 25, pumped 6 bbl per day, 14.6° API gravity oil, 72 percent cut. Abandoned.
66	do	Labarere One 1	Wunpost	25	23	10	1948	605 kb	3,771	Bottom in upper Miocene(?) rocks (Oakeshott and others, 1952, p. 28).
67 [1]	do	Labarere 3-1	do	15	23	10	1952	591 gr	3,402	Top Aurignac sand, 2,252; top basement complex 3,266 (California Oil Fields 1952, v. 38, no. 2, p. 97).
68	do	Lombardi 2	do	27	22	10	1948	487 gr	2,470	Lombardi sand wet; bottom in basement complex (Barger and Zulberti, 1949, p. 20, pl. 2).
69	do	Nichols 1	Valleton	13	23	11	1952	1,300 t	3,404	Top Lombardi sand, 2,903; bottom in basement complex (California Oil Fields, 1952, v. 38, no. 2, p. 97).
70	do	Orradre 1	Wunpost	31	23	11	1947	575 gr	3,795	Bottom in upper Miocene rocks (Oakeshott and others, 1952, p. 28).
71	do	Rosenberg 1-95	Hames Valley.	[3] 34	22	10	1952	448 kb	2,596	Top Lombardi sand, 2,247; top Aurignac sand, 2,542; bottom in basement complex (California Oil Fields, 1952, v. 38, no. 2, p. 100).
72	do	Rosenberg 1-173	do	[3] 33	22	10	1958	430 t	2,888	Bottom in basement complex (Colvin, 1963, pl. 4).
73	do	Rosenberg 1-174	do	[3] 28	22	10	1958	425 t	2,781	Top Aurignac sand, 2,543; top basement complex, 2,765 (California Oil Fields, 1958, v. 44, no. 2, p. 141).
74	do	Rosenberg 1-180	do	[3] 27	22	10	1959	440 t	2,575	Bottom in basement complex (Popenoe, 1960, p. 913).
75	do	Sesnon 1	Wunpost	3	24	11	1956	772 gr	3,761	Top Monterey Shale, 1,335; top Aurignac sand, 2,910; bottom in basement complex (California Oil Fields, 1956, v. 42, no. 2, p. 121).

76	do	Wood 1	Valleton	25	23	11	1954	1,140 t	3,824	Top Monterey Shale, 1,700; top unweathered basement complex, 3,780 (California Oil Fields, 1954, v. 40, no. 2, p. 117).
77	do	Wood-Maher 1	Wunpost	23	23	11	1949	1,159 gr	3,178	Top Monterey Shale, 1,315; top Lombardi sand, 2,704; top Aurignac sand, 3,023; top basement complex, 3,114 (Oakeshott and others, 1952, p. 64).
78 [2]	Tomboy Oil and Improvement Co.	2	Hames Valley.	19	22	10	1901	(?)	1,325	"Some oil struck" (Waring, 1914, p. 435).
79	Tresaden, D. P., and Reynolds, H. G.	Tres-Rey and Associates 1.	Valleton	31	22	12	1959	1,280 t	3,001	Bottom in basement complex (California Oil Fields, 1959, v. 45, no. 2, p. 118).
80 [1]	Wilshire Oil Co	Hunter-Dryden 71-26.	Wunpost	26	23	10	1951	775 gr	5,052	Bottom in basement complex (Jennings and Hart, 1956, p. 56).

[1] Location verified in field. [2] Not shown on geologic maps, pls. 1, 2, and 3. [3] Projected section.

SAN ARDO OIL FIELD

DEVELOPMENT

Discovery of commercial quantities of oil in the Salinas Valley came in 1947 after nearly half a century of seemingly futile exploration. Promising oil sand was found west of the Salinas River in the Texaco Aurignac 1 (No. 54 on map, sec. 4, T. 23 S., R. 10 E.) and Aurignac 2A (drilled in sec. 4 about 1,040 ft east of Aurignac 1, within the later boundary of the San Ardo field), both begun in 1946, but conventional liners and gun perforations used in completing the wells allowed large amounts of sand to enter the holes along with heavy, tarry oil (Barger and Zulberti, 1949, p. 16–17; Baldwin, 1953, p. 9). The failure of these wells demonstrated the need for special completion practices to control the sand (Miller, 1953, p. 11).

The encouraging indications of oil in the two Aurignac wells led to the drilling in 1947 of a third well, the North American Oil Consolidated, Jergins Oil, and The Texas Co. Rosenberg 1 (No. 35 on map, projected sec. 34, T. 22 S., R. 10 E.), east of the Salinas River (Kilkenny, 1948, p. 2268). This well, the first in which oil sands were found east of the river (Campbell, 1948), penetrated sandstone for about 240 feet, but only the upper 30 feet of the sandstone was saturated with oil and the well failed to produce oil (Kilkenny, 1948, p. 2268; Barger and Zulberti, 1949, p. 17).

This additional encouraging indication of oil resulted in the drilling of another well, the Texaco Lombardi 1 (sec. 27, T. 22 S., R. 10 E.), east of the Salinas River. This well penetrated oil sand at a depth of 2,133–2,158 feet and was completed with a gravel-packed liner on November 4, 1947, initially pumping 155 barrels per day of 10° API gravity oil (Barger and Zulberti, 1949, p. 17). Although the well produced oil for only a short time before water entered the hole, and although it is in an isolated part of the field, the Lombardi area, it is generally regarded as the discovery well (Campbell, 1948).

The main part of the San Ardo oil field was discovered by the Jergins (Socony Mobil) Oil Orradre 1–12 (sec. 12, T. 23 S., R. 10 E.). This well was completed in 1948 with a gravel-packed liner and yielded 4,074 Mcf of gas per day (through a $^{32}/_{64}$-inch bean with 680 psi tubing pressure and 770 psi casing pressure) from a depth of 2,119–2,224 feet (Colvin, 1963, p. 57). Although only about 20 feet of gas sand was open to the well above about 70 feet of oil sand, the difference in viscosity of the oil and gas allowed only gas to enter the hole (Miller, 1953, p. 11). The first well to produce oil in the main part of the field was the Jergins (Socony Mobil) Oil Orradre 15–12 (sec. 12, T. 23 S., R. 10 E.), which had initial production of 125 barrels per day of

11.5° API gravity oil cutting 10 percent water (Barger and Zulberti, 1949, p. 17).

The first producing well in the field west of the Salinas River was the Texaco Aurignac (NCT–1) 4 (sec. 4, T. 23 S., R. 10 E.). It initially produced 110 barrels per day of 13° API gravity oil from a depth of 2,642–2,748 feet (Barger and Zulberti, 1949, p. 18).

Early development of the San Ardo field was hampered by want of a market for the crude oil. At first the crude oil was carried by truck nearly 60 miles to a pumping station near Santa Margarita (Miller, 1953, p. 11). An 8-inch pipeline 39.8 miles long was completed in 1951 between the field and the coast at Estero Bay, where the crude oil was loaded aboard tankers at an existing marine terminal (Colvin, 1963, p. 57). The viscous San Ardo crude oil is blended with about 25 percent higher gravity oil to aid its flow through the pipeline. The blend is 14.0°–14.8° API gravity and has a viscosity of 175 seconds furol at 180° F. (Miller, 1953, p. 5). The higher gravity oil added to the San Ardo crude oil is removed and recycled to the field through a 4-inch pipeline laid beside the main pipeline. Four pumping stations that have oil-heating facilities are spaced along the pipeline, which can handle 32,000 barrels of oil per day (Colvin, 1963, p. 57). Other pipelines deliver gas from the field to the nearby towns of King City and Paso Robles.

All of the more than 800 producing wells in the field have electric pumps. Oil is collected in tank batteries that have heating facilities for defrothing and dewatering the oil, and waste water is disposed of in wells maintained for the purpose (Colvin, 1963, p. 58, 59).

STRATIGRAPHY

According to Kilkenny and others (1962), the basement complex east of the Salinas River in the San Ardo oil field is overlain by the Santa Margarita Formation, which includes in ascending order the Aurignac sand, Aurignac siltstone, Lombardi sand, Lombardi siltstone, and an upper sand member, followed by the San Ardo Group, which contains the Pancho Rico mudstone and the Paso Robles Formation and Pancho Rico sands undifferentiated. They also indicated that their Aurignac and Lombardi sands intertongue with or grade into the Monterey Formation to the west, where the sedimentary cover on the basement complex is much thicker. Hughes (1963, p. 94, 95) considered the Aurignac sand, Aurignac siltstone, Lombardi sand, and Lombardi siltstone, of Kilkenny and others, as part of the Monterey Shale, overlain in sequence by the Santa Margarita, Pancho Rico, and Paso Robles Formations. The Aurignac and Lombardi sands are here also considered to be sandstone units within the Monterey Shale, but the Pancho Rico mudstone of Kilkenny and others (1952) is correlated with the diatomaceous mudstone member of the Monterey Shale that is exposed in the map area both east and west of the Salinas River.

Baldwin and others (1951, p. 2633) proposed the name "Aurignac sand" for the lower of the two productive units in the San Ardo oil field. The name "Orradre sand" was applied to the Aurignac sand west of the Salinas River during early stages in the development of the field (Barger and Zulberti, 1949, p. 18), but information from wells drilled later demonstrated the identity of the Aurignac and Orradre sands (Baldwin and others, 1951, p. 2633), and the term "Orradre sand" was discontinued. The Aurignac sand west of the Salinas River is about 120 feet thick and consists of coarse-grained friable sandstone (Bradford and Lawrence, 1956, p. 30). The thickness of the unit varies east of the river, where the Aurignac lies on the basement complex, but the average thickness is about 100 feet. The unit consists of very fine grained firm silty sandstone (Barger and Zulberti, 1949, p. 18).

The Lombardi sand, named for its discovery in the Texaco Lombardi 1, is generally separated from the stratigraphically lower Aurignac sand by a siltstone unit 35–70 feet thick (Colvin, 1963, p. 58). The Lombardi sand is about 250 feet thick and consists of fine- to medium-grained well-sorted unconsolidated sandstone (Bradford and Lawrence, 1956, p. 30).

STRUCTURE AND ACCUMULATION OF OIL

Beneath most of the San Ardo oil field the surface of the basement complex forms an irregular platformlike structural feature that lies 1,800–2,100 feet below sea level, but near the southwest edge of the field the surface slopes steeply southwestward to 3,000 feet or more below sea level (pl. 5). Information from wells drilled to the basement complex suggests that a broad, flat ridge of basement complex trends southeastward under the field from the southern part of sec. 34, T. 22 S., R. 10 E., to the northern part of sec. 12, T. 23 S., R. 10 E., and thence more eastward toward sec. 9, T. 23 S., R. 11 E. (pl. 5).

The sequence of beds, including the oil-bearing Aurignac and Lombardi sands, that overlies this ridge on the basement complex is the stratigraphic equivalent of the upper part of the much thicker sequence of beds southwest of the Salinas River. The oil-bearing and associated beds form a broad, flat-topped irregular anticline (Baldwin, 1950, p. 1983), but this subsurface structural feature is not apparent in beds exposed in the field.

The oil at the San Ardo oil field accumulated in sandstone beds of near-shore facies on a broad eastward-plunging anticline (Baldwin, 1953, p. 10). Later downwarping superimposed a broad syncline on the original anticlinal structure of the field, and apparently caused warping of the oil-water interfaces in both the Aurignac and the Lombardi sands (Colvin, 1963, p. 58). According to Colvin (1963, figs. 3 and 4), the axis of the synclinal trough on the oil-water interface in the Lombardi sand trends and plunges northwestward from about sec. 18, T. 23 S., R. 11 E., toward sec. 34, T. 22 S., R. 10 E.; the axis of the synclinal trough on the interface in the Aurignac sand trends more northward through sec. 4, T. 23 S., R. 10 E., and sec. 33, T. 22 S., R. 10 E., and plunges nearly due north. Colvin (1963, p. 58) attributed the lack of correspondence of the axes to permeability changes and to deformation related to faulting near the Salinas River.

The productive limits of the field are controlled mainly by the tilted oil-water interface and by permeability barriers (Colvin, 1963, p. 58). Oil in both the Aurignac and Lombardi sands is trapped where these units grade westward into finer grained and less permeable beds (Gribi, 1963b, p. 24). The limits of production from the Aurignac sand are determined by pinching out of the unit to the north and by decreasing permeability of the sandstone to the south (Colvin, 1963, p. 59). The limits of production from the Lombardi sand are determined by the tilted oil-water interface on the northeast and southeast sides and by a decrease in the grain size and permeability of the unit to the northwest and southwest (Bradford and Lawrence, 1956, p. 30).

DRILLING PRACTICE

Wells in the San Ardo oil field are drilled with portable rotary equipment (Bradford and Lawrence, 1956, p. 30). The general procedure is to cement 100–500 feet of surface casing (Miller, 1953, p. 12), drill an 11-inch hole to the top of the oil sand, reduce the hole size to 8½ inches, and continue drilling until the desired depth is reached. An electric log is then run, and an 8⅝-inch casing is cemented at the top of the productive sand to obtain a water shutoff. The cement is drilled out of the casing to within about 5 feet of the shoe, and a combination gun-perforator and tester is run into the hole to perforate and test the effectiveness of the water shutoff. The hole is then cleaned out and the clay-base drilling fluid used until this stage in the drilling operation is replaced with an oil-base or similar drilling fluid. After the hole below the casing shoe is underreamed to 13½ inches, a 6⅝-inch preperforated 60- or 80-mesh liner is landed and flow packed with $\frac{3}{16}$-inch gravel. Wells are drilled and completed in about 6 days (Bradford and Lawrence, 1956, p. 30).

Water production tends to replace oil production in wells drilled in the Lombardi area of the San Ardo oil field. As oil is pumped, the oil-water interface rises or cones vertically 30–50 feet around the holes of the wells that are drilled deep enough to reach or nearly reach the interface. This condition is controlled by bottoming the holes well above the oil-water contact. Similar conditions were found in the main part of the field in the early stages of development (Miller, 1953, p. 11).

Wells in which casing was set just below the gas-oil interface in the main part of the field produced with high gas-oil ratios soon after completion because of depression or coning of the gas-oil interface near the hole. This coning was controlled, and more normal gas-oil ratios were obtained in later wells by setting the casing 20 feet below the gas-oil contact (Miller, 1953, p. 11).

The steepness of the hills west of the Salinas River made road and well-site preparations expensive; directional drilling was impractical there because of the shallow depth to the productive oil sand (Miller, 1953, p. 11). Drilling costs west of the river were also increased because the crushed and fractured rock there led to lost circulation of drilling fluid and necessitated setting about 500 feet of surface casing (Miller, 1953, p. 12).

Wells just east of the main channel of the Salinas River are protected from high water by a levee about 1½ miles long. Wells drilled from the levee are whipstocked under the riverbed (Miller, 1953, p. 12).

PRODUCTION

According to Colvin (1963, p. 59), 86 million barrels of oil and 18 billion cubic feet of gas were produced before 1963 from 581 wells completed in the Lombardi zone, and 39 million barrels of oil and 25 billion cubic feet of gas were produced before 1963 from 274 wells completed in the Aurignac zone. Table 3 summarizes the annual production statistics for the field.

TABLE 3.—*Production statistics, San Ardo oil field*

Year	Average number of wells actually producing oil	Production of oil (bbl)	Net gas withdrawn (Mcf)	California Oil Fields (1947–62)		
				Volume	No.	Page
1947	1	737		33	2	25
1948	13	119,572	7,517	34	1, 2	19; 17, 32
1949	46	480,765	5,255	35	1, 2	23, 38; 25, 40
1950	22	188,068	3,710	36	1, 2	27, 45; 25, 43
1951	153	2,744,896	172,817	37	1, 2	28, 46; 18, 25
1952	333	8,280,661	614,649	38	1, 2	24, 31; 30, 37
1953	413	11,283,710	1,734,501	39	1, 2	30, 36; 40, 47
1954	455	11,172,184	5,045,917	40	1, 2	52, 58; 64, 71
1955	516	10,972,221	6,135,603	41	1, 2	71, 78; 59, 67
1956	612	11,732,789	5,577,331	42	1, 2	69, 76; 62, 70
1957	675	11,844,658	4,229,296	43	1, 2	78, 88; 68, 77
1958	648	10,864,509	3,314,562	44	2	82, 92
1959	668	10,983,153	3,073,803	45	2	56, 68
1960	717	11,517,752	3,537,548	46	2	112, 124
1961	756	11,741,432	4,536,065	47	2	87, 97
1962	811	11,099,568	5,646,530	48	2	110, 121
Total		125,026,675	43,635,104			

LYNCH CANYON OIL FIELD

The Lynch Canyon oil field is at the north edge of the Wunpost quadrangle in sec. 24, T. 22 S., R. 10 E. It was discovered in 1962 by the Moriqui Exploration Lanigan 172, which, when completed, pumped 41 barrels per day of 11.8° API gravity oil from 1,706 and 1,744 feet depth (Barton, 1962, p. 150). According to Gribi (1963a, p. 73), the oil is in a sandstone unit (Lanigan sand) in the Monterey Shale on the west flank of a broad south-plunging structural high on the basement complex (pl. 5). The sandstone unit terminates against the basement complex to the east and grades into finer grained rocks to the west. It is apparently equivalent to a sandstone unit in the San Ardo oil field that is about 150 feet stratigraphically above the Lombardi sand (Barton, 1962, p. 150). Nine wells were completed in the field by April 1964, when the drilling of wells intended for steamflood operations was begun (Rintoul, 1964, p. 4).

TABLE 4.—*Fossil localities*

USGS No.	Location				Formation	Types of fossils				
	Quadrangle	Sec.	Township south	Range east		Foraminifera	Gastropods	Pelecypods	Barnacles	Echinoids
Mf746	Valleton	25	22	11	Pancho Rico	×	-----	-----	-----	-----
M982	Wunpost	25	23	10	do	-----	×	×	-----	-----
M983	do	25	23	10	do	-----	×	×	-----	-----
M1674	do	36	23	10	do	-----	-----	×	-----	×
M1675	do	25	23	10	do	-----	-----	×	-----	-----
M1676	Hames Valley	29	22	10	do	-----	×	×	×	-----
M1930	Valleton	9	23	12	do	-----	×	×	×	-----
M1932	Hames Valley	4	23	10	Monterey	-----	×	×	-----	-----
M1933	Valleton	15	23	12	Pancho Rico	-----	-----	-----	×	-----
M1934	Wunpost	25	23	10	do	-----	×	×	-----	-----
M1935	do	28	22	11	do	-----	×	×	×	×
M1966	Valleton	36	22	11	do	-----	×	×	×	-----
M1967	do	1	23	11	do	-----	×	×	-----	-----
M1970	Wunpost	25	23	10	do	-----	×	×	×	-----

MEASURED SECTIONS

SECTION 1.—*North of Swain Valley on southwest flank of anticline in sec. 26, T. 23 S., R. 10 E., Wunpost quadrangle*

	Thickness	
	Feet	Inches
Paso Robles Formation (lower part only):		
60. Conglomerate, pebbles and small cobbles of chert, porcelaneous rock, basement rock, and volcanic rock; matrix and interbeds of sandstone that is arkosic, grayish orange (10*YR* 7/4), fine and medium grained, noncalcareous, friable; beds as thick as 6 in	30+	0
Total (part measured), Paso Robles Formation	30+	0
Contact gradational.		
Pancho Rico Formation:		
59. Sandstone, arkosic, yellowish-gray (5*Y* 8/1), fine- and medium-grained, noncalcareous, friable; lenses of coarse grains	16	0
58. Covered	8	0
57. Sandstone, arkosic, yellowish-gray (5*Y* 8/1), fine- and medium-grained, noncalcareous, friable, massive; granules and small pebbles of porcelaneous rock in lenses near top; scattered calcareous nodules	20	0
56. Sandstone, arkosic, yellowish-gray (5*Y* 8/1), very fine grained, locally calcareous; more firmly indurated than unit 57	92	0
55. Covered	33	6
54. Sandstone, arkosic, yellowish-gray (5*Y* 8/1), fine-grained, noncalcareous, friable, massive; partly covered	5	0
53. Sandstone, arkosic, yellowish-gray (5*Y* 8/1), very fine grained, scattered coarser grains; more firmly indurated than unit 54	1	0
Total, Pancho Rico Formation	175	6
Contact conformable.		
Monterey Shale (upper part only):		
Monterey Shale above diatomaceous mudstone member:		
52. Porcelanite and porcelaneous mudstone, yellowish-gray (5*Y* 8/1) and white (*N*9), poorly bedded	8	0
Total, Monterey Shale above diatomaceous mudstone member	8	0
Diatomaceous mudstone member:		
51. Mudstone, diatomaceous, white (*N*9), massive; grades into underlying unit	6	0
50. Conglomerate, pebbles of chert, basement rock, porcelaneous rock, and volcanic rock; matrix of diatomaceous mudstone like unit 51		6
49. Mudstone, diatomaceous, like unit 51	1	6

SECTION 1.—*North of Swain Valley on southwest flank of anticline in sec. 26, T. 23 S., R. 10 E., Wunpost quadrangle*—Continued

	Thickness	
Diatomaceous mudstone member—Continued	Feet	Inches
48. Porcelanite, yellowish-gray (5*Y* 8/1)		6
47. Mudstone, diatomaceous, like unit 51	1	0
46. Porcelanite, like unit 48		2
45. Mudstone, diatomaceous, like unit 51	4	0
44. Porcelanite, like unit 48		3
43. Mudstone, diatomaceous, like unit 51	22	0
42. Porcelanite, light-olive-gray (5*Y* 6/1)	1	6
41. Mudstone, diatomaceous, like unit 51	19	6
40. Porcelanite, like unit 42		4
39. Mudstone, diatomaceous, like unit 51	11	8
38. Porcelanite, like unit 42		2
37. Mudstone, diatomaceous, like unit 51	1	3
36. Porcelanite, like unit 42		3
35. Mudstone, diatomaceous, like unit 51		2
34. Porcelanite, like unit 42		6
33. Mudstone, diatomaceous, like unit 51	1	0
32. Porcelanite, like unit 42		6
31. Mudstone, diatomaceous, like unit 51	1	6
30. Porcelanite, like unit 42	1	6
29. Mudstone, diatomaceous, like unit 51	8	0
28. Porcelanite, like unit 42	1	0
27. Mudstone, diatomaceous, like unit 51	3	6
26. Porcelanite, like unit 42		4
25. Mudstone, diatomaceous, like unit 51	1	0
24. Porcelanite, like unit 42	4	0
23. Mudstone, diatomaceous, like unit 51	1	0
22. Porcelanite, like unit 42	1	0
21. Mudstone, diatomaceous, like unit 51	4	0
20. Porcelanite, like unit 42		5
19. Mudstone, diatomaceous, like unit 51		6
18. Porcelanite, like unit 42	1	0
17. Mudstone, diatomaceous, like unit 51	1	4
16. Porcelanite, like unit 42		6
15. Mudstone, diatomaceous, like unit 51		8
14. Porcelanite, like unit 42		6
13. Mudstone, diatomaceous, like unit 51		2
12. Porcelanite, like unit 42	1	0
11. Mudstone, diatomaceous, like unit 51	2	0
10. Porcelanite, like unit 42		6
9. Mudstone, diatomaceous, like unit 51		8
8. Porcelanite, like unit 42		8
7. Mudstone, diatomaceous, like unit 51	9	0
6. Porcelanite, like unit 42	1	0
5. Mudstone, diatomaceous, like unit 51		6
Total, diatomaceous mudstone member	120	0

SECTION 1.—*North of Swain Valley on southwest flank of anticline in sec. 26, T. 23 S., R. 10 E., Wunpost quadrangle*—Continued

	Thickness Feet	Thickness Inches
Monterey Shale below diatomaceous mudstone member:		
4. Porcelanite, yellowish-gray (5Y 8/1); beds 1–6 in. thick, poorly bedded	23	0
3. Covered	44	0
2. Mudstone, very pale orange (10YR 8/2), massive, hackly fracture	10	0
1. Porcelanite, pale-yellowish-brown (10YR 6/2), massive, hackly fracture; contains poorly preserved Foraminifera	57	0
Total, Monterey Shale below diatomaceous mudstone member (part measured)	134	0
Total, Monterey Shale, including diatomaceous mudstone member (part measured)	262	0
Base of exposed section.		

SECTION 2.—*North of Swain Valley on northeast flank of anticline in secs. 23, 24, and 26, T. 23 S., R. 10 E., Wunpost quadrangle*

	Thickness Feet	Thickness Inches
Pancho Rico Formation (part only):		
30. Sandstone, arkosic, yellowish-gray (5*Y* 8/1) and white (*N*9), fine-grained, noncalcareous, friable; partly covered	376	0
Total, Pancho Rico Formation (part measured)	376	0
Contact concealed, apparently conformable.		
Monterey Shale (upper part only).		
Monterey Shale above diatomaceous mudstone member:		
29. Covered	10	0
28. Porcelanite and porcellaneous mudstone, very pale orange (10*YR* 8/2); beds 6–24 in. thick, poorly bedded, hackly fracture	85	6
27. Mudstone, very pale orange (10*YR* 8/2), massive; contains fossils Foraminifera, diatoms, and fish fragments	3	0
26. Porcelanite, very pale orange (10*YR* 8/2), poorly bedded, hackly fracture	14	0
Total, Monterey Shale above diatomaceous mudstone member	112	6
Diatomaceous mudstone member:		
25. Mudstone, diatomaceous, very pale orange (10*YR* 8/2) massive	3	0
24. Porcelanite, like unit 26	2	0
23. Mudstone, diatomaceous, like unit 25	12	0
22. Porcelanite, like unit 26	9	0
21. Mudstone, pale-yellowish-brown (10*YR* 6/2), poorly bedded hackly fracture, noncalcareous	1	3
20. Porcelanite, like unit 26	1	2
19. Mudstone, like unit 21	8	0
18. Porcelanite, like unit 26		7

SECTION 2.—*North of Swain Valley on northeast flank of anticline in secs. 23, 24, and 26, T. 23 S., R. 10 E., Wunpost quadrangle*—Continued

Diatomaceous mudstone member—Continued	Thickness Feet	Thickness Inches
17. Mudstone, diatomaceous, like unit 25	1	0
16. Porcelanite, like unit 26		3
15. Mudstone, diatomaceous, like unit 25		2
14. Porcelanite, like unit 26		4
13. Mudstone, diatomaceous, like unit 25		1
12. Porcelanite, like unit 26		3
11. Mudstone, diatomaceous, like unit 25	9	0
10. Porcelanite, like unit 26		9
9. Mudstone, diatomaceous, like unit 25		6
8. Porcelanite, like unit 26		7
7. Mudstone, diatomaceous, like unit 25		8
6. Porcelanite, like unit 26		4
5. Mudstone, diatomaceous, like unit 25		11
Total, diatomaceous mudstone member	51	10
Monterey Shale below diatomaceous mudstone member:		
4. Porcelanite, very pale orange (10*YR* 8/2) and pale-yellowish-brown (10*YR* 6/2); beds 2–12 in. thick; hackly fracture; interbeds of mudstone 1–2 in. thick	119	6
3. Covered	19	0
2. Mudstone, very pale orange (10*YR* 8/2), massive, hackly fracture	3	0
1. Porcelanite, pale-yellowish-brown (10*YR* 6/2), massive, hackly fracture; contains poorly preserved Foraminifera	25	0
Total, Monterey Shale below diatomaceous mudstone member (part measured)	166	6
Total, Monterey Shale, including diatomaceous mudstone member (part measured)	330	10
Base of exposed section.		

SECTION 3.—*East of Salinas River along railroad north of mouth of Sarah Canyon, sec. 25, T. 23 S., R. 10 E., Wunpost quadrangle*

	Thickness Feet	Thickness Inches
Paso Robles Formation (part only):		
119. Conglomerate, rounded pebbles of basement rock, porcelaneous rock, and chert; massive; matrix mainly of sandstone that is arkosic, yellowish gray (5*Y* 7/2), noncalcareous, friable; top covered	30	0
118. Mudstone, grayish-orange (10*YR* 7/4), massive, hackly fracture		3
117. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), fine- and medium-grained, noncalcareous, friable; contains lenses of coarser grains and small pebbles	1	0

SECTION 3.—*East of Salinas River along railroad north of mouth of Sarah Canyon, sec. 25, T. 23 S., R. 10 E., Wunpost quadrangle*—Continued

Paso Robles Formation (part only)—Continued

	Thickness Feet	Thickness Inches
116. Mudstone, like unit 118		3
115. Sandstone, like unit 117	2	0
114. Mudstone, like unit 118	1	0
113. Sandstone, like unit 117	5	0
112. Mudstone, like unit 118	1	0
111. Sandstone, arkosic, pale-greenish-yellow (10Y 8/2), fine-grained, noncalcareous, friable, massive	1	0
110. Mudstone, like unit 118	1	0
109. Sandstone, like unit 117	8	0
108. Mudstone, like unit 118	2	0
107. Conglomerate, like unit 119	15	0
106. Mudstone, like unit 118	2	2
105. Sandstone, like unit 111	1	2
104. Mudstone, like unit 118		8
103. Sandstone, like unit 111		4
102. Mudstone, like unit 118		9
101. Sandstone, like unit 111		5
100. Mudstone, like unit 118		10
99. Sandstone, arkosic, yellowish-gray (5Y 7/2) and dusky-yellow (5Y 6/4), fine-grained, noncalcareous, well-indurated; bedding indistinct; moderately porous	7	6
98. Conglomerate, like unit 119	5	0
97. Sandstone, like unit 111		5
96. Mudstone, like unit 118		8
95. Sandstone, like unit 111		3
94. Mudstone, like unit 118		5
93. Sandstone, like unit 117	2	8
92. Mudstone, like unit 118		1
91. Sandstone, like unit 111		5
90. Mudstone, like unit 118		1
89. Sandstone, like unit 111		2
88. Mudstone, like unit 118		1
87. Sandstone, like unit 111		7
86. Mudstone, like unit 118	2	6
85. Sandstone, like unit 111		8
84. Mudstone, like unit 118		7
83. Sandstone, like unit 111	2	6
82. Sandstone, like unit 117	4	0
81. Conglomerate, like unit 119	20	0
80. Sandstone, like unit 111	1	4
79. Mudstone, like unit 118		3
78. Sandstone, like unit 111		5
77. Mudstone, like unit 118		3
76. Sandstone, like unit 111		3
75. Mudstone, like unit 118		2
74. Sandstone, like unit 111		3
73. Mudstone, like unit 118		2
72. Sandstone, like unit 111	1	2
71. Mudstone, like unit 118; lower contact gradational		4

SECTION 3.—*East of Salinas River along railroad north of mouth of Sarah Canyon, sec. 25, T. 23 S., R. 10 E., Wunpost quadrangle*—Continued

Paso Robles Formation (part only)—Continued

	Thickness Feet	Thickness Inches
70. Sandstone, like unit 111; thickens and thins along strike; lower contact distinct, but irregular	1	6
69. Mudstone, like unit 118; pinches out along strike		1
68. Sandstone, like unit 111; thins along strike; lower contact distinct, but irregular	2	8
67. Mudstone, like unit 118; lower contact distinct, but irregular		6
66. Sandstone, like unit 111; lower contact gradational		10
65. Mudstone, like unit 118; lower contact gradational		11
64. Sandstone, like unit 111; thickens and thins along strike; lower contact distinct		10
63. Mudstone, like unit 118; lower contact distinct		9
62. Mudstone, yellowish-gray (5*Y* 7/2), massive, hackly fracture, noncalcareous, moderately porous; lower contact gradational		8
61. Sandstone, like unit 111; lower contact irregular		9
60. Sandy limestone, yellowish-gray (5Y 7/2); fine and scattered medium grains of quartz and feldspar; lower contact irregular		7
59. Sandstone, like unit 111	2	0
58. Mudstone, like unit 62		6
57. Sandstone, like unit 111	2	6
56. Mudstone, like unit 62		6
55. Sandstone, like unit 111	5	6
54. Mudstone, like unit 62		6
53. Sandstone, like unit 111; lower contact gradational	3	6
52. Mudstone, like unit 62		6
51. Sandstone, like unit 111; scattered pebbles; lower contact gradational	6	0
50. Mudstone, like unit 62; lower contact gradational	1	0
49. Sandstone, like unit 111; lower contact irregular	3	6
48. Clay, moderate-yellowish-brown (10*YR* 4/6) and light-olive-gray (5*Y* 5/2), massive, hackly fracture; lower contact distinct	1	3
47. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), fine-grained, calcareous, well-cemented; contains nodules and thin interbeds of mudstone; lower contact irregular	1	0
46. Mudstone, like unit 62; lower contact gradational	2	0
45. Sandstone, like unit 111; lower contact gradational	6	0
44. Conglomerate, like unit 119; sandstone lenses near top; scattered clasts of dusky-yellow (5*Y* 6/4) mudstone about 6 ft below top are rounded and are as long as 15 in	45	0
43. Covered	10	0
42. Conglomeratic sandstone, arkosic, yellowish-gray (5*Y* 7/2), fine- to coarse-grained, noncalcareous, friable; lenses and irregular beds of pebbles, mainly of porcelaneous rock and chert; lower contact gradational	7	0
41. Sandstone, arkosic, pale-reddish-brown (10*R* 5/4), very fine grained, noncalcareous, massive; a few scattered pebbles; lower contact gradational		8

SECTION 3.—*East of Salinas River along railroad north of mouth of Sarah Canyon, sec. 25, T. 23 S., R. 10 E., Wunpost quadrangle*—Continued

Paso Robles Formation (part only)—Continued	Thickness Feet	Thickness Inches
40. Sandstone, like unit 111; lower contact gradational	2	9
39. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), fine-grained, noncalcareous, massive; lower contact gradational	1	2
38. Sandstone, arkosic, pale-yellowish-brown (10YR 6/2), very fine grained; a few scattered coarser grains and granules; noncalcareous; massive; lower contact gradational		6
37. Sandstone, yellowish-gray (5*Y* 7/2), fine grained (except near top where some graded beds have medium and coarse grains; lower contacts of graded beds are irregular and gradational), locally slightly calcareous, well-indurated, massive; calcareous nodules near top of unit; lower contact of unit gradational	10	0
36. Conglomerate, rounded pebbles and cobbles of basement rock and porcelaneous rock, massive; matrix of sandstone is arkosic, yellowish gray (5*Y* 7/2), noncalcareous, friable; lower contact distinct, channels as much as 4 ft into underlying units	6	0
35. Sandstone, moderate-yellowish-brown (10*YR* 5/4), fine-grained, noncalcareous, porous, laminated and cross-laminated; lower contact distinct		8
34. Mudstone, olive-gray (5*Y* 4/1), massive, noncalcareous, clayey; includes layers of gypsum; lower contact distinct	1	0
33. Sandstone, grayish-orange (10*YR* 7/4), fine-grained, noncalcareous, massive, porous; lower contact distinct		8
32. Mudstone, yellowish-gray (5*Y* 7/2), noncalcareous, generally massive but locally laminated, porous; lower contact gradational	2	0
31. Sandstone, yellowish-gray (5*Y* 7/2), fine-grained, noncalcareous, friable, massive; lower contact gradational		8
30. Mudstone, like unit 32; lower contact gradational	3	0
29. Mudstone, pinkish-gray (5*YR* 8/1), noncalcareous, massive, hackly fracture; gypsum along bedding and joint surfaces; lower contact irregular and gradational	1	0
28. Clay, dusky-yellowish-brown (10*YR* 2/2), massive; contains gypsum and jarosite(?); lower contact gradational		1
27. Woody lignite, brownish-gray (5*YR* 4/1), flaky; lower contact irregular		2
26. Mudstone, like unit 29; lower contact irregular	4	6
25. Clay, like unit 28; lower contact distinct		10
24. Woody lignite, like unit 27; lower contact distinct		4
23. Conglomerate, like unit 36; sandstone lenses in upper part, larger clasts most common in lower part; channels as much as 3 ft into underlying unit	13	6
22. Sandstone, yellowish-gray (5*Y* 7/2), fine-grained, noncalcareous, massive, porous; lower contact irregular	6	0

SECTION 3.—*East of Salinas River along railroad north of mouth of Sarah Canyon, sec. 25. T. 23 S., R. 10 E., Wunpost quadrangle*—Continued

Paso Robles Formation (part only)—Continued	Thickness Feet	Thickness Inches
21. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), fine- to coarse-grained, noncalcareous, friable, cross-stratified, pebbly; lower contact irregular	1	4
20. Sandstone, yellowish-gray (5*Y* 7/2), fine-grained, noncalcareous, friable, laminated; lower contact distinct		7
19. Mudstone, pale-olive (10*YR* 6/2), noncalcareous, massive; gypsum along bedding and joint surfaces; includes one gypsum layer 1 in. thick; lower contact gradational		6
18. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), fine- and medium-grained (lenses of coarser grains), locally calcareous, friable, massive; thins along strike; lower contact irregular	5	0
17. Sandstone, arkosic, yellowish-gray (5*Y* 8/1), medium-grained (lenses of coarse grains and scattered coarse grains and pebbles), noncalcareous, friable, massive; lower contact gradational	1	8
16. Conglomerate; rounded pebbles of basement rock and porcelaneous rock; massive; matrix of sandstone is arkosic, yellowish gray (5*Y* 8/1) and moderate brown (5*YR* 3/4), noncalcareous, friable; lenses of sandstone; lower contact distinct	8	0
15. Mudstone, pale-greenish-yellow (10*Y* 8/2), noncalcareous, massive, hackly fracture; lower contact distinct		1
14. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), medium-grained, noncalcareous, friable, laminated; lower contact distinct	2	4
13. Mudstone, like unit 15; lower contact gradational	3	0
12. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), fine- to coarse-grained and pebbly, noncalcareous, friable; gypsum on joint surfaces; lower contact covered	10	0
11. Covered	5	0
10. Mudstone, very pale orange (10*YR* 8/2), noncalcareous, massive, hackly fracture, moderately porous; locally contains irregular masses of fine-grained sandstone; lower contact distinct	12	0
Total, Paso Robles Formation (part measured)	340	4

Contact conformable.

Pancho Rico Formation (part only):		
9. Sandstone, grayish-orange (10*YR* 7/4), fine-grained, generally noncalcareous and friable but locally well cemented and calcareous; fossil mollusk shells abundant in upper part and in calcareous beds (loc. M1934); lower contact irregular	7	6
8. Sandstone, arkosic, yellowish-gray (5Y 7/2), generally fine grained (scattered coarser grains and pebbles), noncalcareous, cross-stratified (indicating northerly current); lower contact distinct	1	6

SECTION 3.—*East of Salinas River along railroad north of mouth of Sarah Canyon, sec. 25, T. 23 S., R. 10 E., Wunpost quadrangle*—Continued

Pancho Rico Formation (part only)—Continued	Thickness	
	Feet	*Inches*
7. Sandstone, yellowish-gray (5Y 7/2), fine-grained, noncalcareous, friable; beds 10–16 in. thick; scattered charcoallike clasts $\frac{1}{4}$–$\frac{1}{2}$ in. long; gypsum on joint surfaces; lower contact distinct	6	6
6. Claystone, pale-greenish-yellow (10Y 8/2), noncalcareous, massive, moderately porous; gypsum abundant on bedding and joint surfaces; gypsum layer 1 in. thick at top of unit; lower contact distinct	10	0
5. Mudstone, very pale orange (10YR 8/2), noncalcareous, moderately porous, poorly bedded; beds 6–24 in. thick; gypsum on joint surfaces; contains lenses and irregular podlike masses of pebbly sandstone as thick as 4 in.; lower contact irregular	14	0
4. Sandstone, arkosic, yellowish-gray (5Y 7/2), generally fine grained (scattered coarser grains and pebbles), noncalcareous, well-indurated, porous; contains fossil mollusk shells; lower contact gradational	0	4
3. Conglomerate, pebbles and cobbles mainly of basement rock, but also of porcelaneous rock; larger clasts in lower part mainly pebbles less than one-half in. long; cobbles 2–5 in. long are common in upper part; matrix of sandstone is arkosic, yellowish gray (5Y 7/2), fine and medium grained, noncalcareous, friable, porous; lower contact gradational	6	6
2. Siltstone, yellowish-gray (5Y 7/2) and very light gray (*N*8), noncalcareous, porous, laminated; local sandy streaks; veins of gypsum; lower contact distinct	1	8
1. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), generally fine grained (scattered coarser grains and pebbles), noncalcareous, locally well indurated; contains fossil mollusk shells (loc. M1970); upper part conglomeratic, contains scattered pebbles and small cobbles of basement rock and porcelaneous rock; lower contact concealed	4	0
Total, Pancho Rico Formation (part measured)	52	0

SECTION 4.—*North of Walker Canyon, secs. 22 and 27, T. 22 S., R. 11 E., Wunpost quadrangle*

	Thickness (Feet)
Pancho Rico Formation (part only):	
17. Conglomerate, pebbles and cobbles of chert and basement rock; matrix of sandstone is yellowish gray (5*Y* 7/2), mainly noncalcareous, locally well indurated; contains mollusk shells	5
16. Sandstone, arkosic, yellowish-gray (5*Y* 8/1), fine- and medium-grained (scattered coarser grains), locally calcareous, massive; poorly exposed	36
15. Conglomerate, rounded pebbles of chert; matrix of sandstone is yellowish gray (5*Y* 7/2), noncalcareous, well indurated; molds of clam shells; poorly exposed, partly covered	12
14. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), generally fine grained (scattered medium grains), noncalcareous, moderately friable, massive; poorly exposed	10
13. Conglomerate, like unit 15; locally calcareous; contains sponge spicules (?) and silicified mollusk shells	17
12. Mudstone, yellowish-gray (5*Y* 8/1), noncalcareous, massive, hackly fracture; partly covered	58
11. Conglomerate, like unit 15; poorly exposed	4
10. Covered	8
9. Conglomerate, like unit 15; poorly exposed	12
8. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), generally fine grained (scattered coarser grains and granules of porcelaneous rock), noncalcareous, massive	58
7. Sandstone, arkosic, light-brown (5*YR* 5/6), fine- to coarse-grained and granulitic, noncalcareous, well-indurated, poorly bedded; beds 6–24 in. thick; contains glauconite grains, phosphate pellets, scattered chips of mudstone, and mollusk shells; forms ledges	17
6. Conglomerate, rounded pebbles of chert, and some of porcelaneous rock; matrix of sandstone is yellowish gray (5*Y* 7/2), calcareous, well cemented; contains clam shells	1
5. Sandstone, arkosic, yellowish-gray (5*Y* 7/2), fine-grained, scattered coarser grains), noncalcareous, friable, massive; molds of clam shells	25
4. Mudstone, very pale orange (10*YR* 8/2), calcareous, massive, hackly fracture, poorly exposed; includes some beds of very fine and fine grained noncalcareous arkosic sandstone that contains rounded grains of glauconite	45
3. Sandstone, arkosic, pale-yellowish-brown (10*YR* 6/2), fine- and medium-grained, calcareous well-cemented; beds 6–12 in. thick; molds of clam shells; contains grains of glauconite; locally forms cliffs, but generally poorly exposed	7
2. Sandstone, arkosic, yellowish-gray (5*Y* 8/1), fine-grained, noncalcareous, friable, micaceous, massive; locally forms cliffs, but generally poorly exposed	37
Total, Pancho Rico Formation (part measured)	352

SECTION 4.—*North of Walker Canyon, secs. 22 and 27, T. 22 S., R. 11 E., Wunpost quadrangle*—Continued

Contact conformable.

Monterey Shale:

Diatomaceous mudstone member (part only):	*Thickness (Feet)*
1. Mudstone, diatomaceous, white (*N*9) and very pale orange (10*YR* 8/2), massive; conchoidal fracture; poorly exposed, base covered.	75
Total, Monterey Shale, diatomaceous mudstone member (part measured)	75

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