Lithologic Characteristics of Upper Oligocene and Miocene Rocks Drilled at Elk Hills, Kern County, California

GEOLOGICAL SURVEY BULLETIN 1375

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By W. L. ADKISON

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A detailed description of a reference section for the Temblor Formation, Monterey Shale, and Reef Ridge Shale based on well cuttings and cores, foraminiferal determinations, and electrical-log correlations in the western part of the Elk Hills oil field, Naval Petroleum Reserve No. 1

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By W. L. ADKISON

ABSTRACT

Rocks of late Oligocene and Miocene ages are described in detail for two wells in the western part of the Elk Hills oil field, Naval Petroleum Reserve No. 1, Kern County, Calif. The wells are identified as Unit Operation, Naval Petroleum Reserve No. 1 wells 526–30R and 555–30R, both in sec. 30, T. 30 S., R. 23 E. A reference section for upper Oligocene and Miocene rocks at Elk Hills is established from the detailed descriptions of cuttings and cores, foraminiferal determinations, and electrical-log correlations. The rocks are divided, in upward order, into the Temblor Formation, Monterey Shale, and Reef Ridge Shale. Moderate to steeply dipping strata were encountered in both wells, which were stopped in the Temblor.

Rocks of the Temblor Formation have a drilled thickness of 3,801 feet in well 555–30R and are divided, in upward order, into the Santos Shale, Carneros Sandstone, and Media Shale Members. The Santos Shale Member has a drilled thickness of 3,295 feet in this well and consists of shale, siltstone, and some sandstone. The lower 236 feet is Zemorrian in age and is assigned to the late Oligocene. The upper 220 feet of the Santos in well 555–30R is stratigraphically equivalent to the lower part of the Carneros Sandstone Member in well 526–30R. The Carneros in well 526–30R consists of three bodies of sandstone separated by two beds of shale. The lower sandstone probably grades laterally into siltstone that is included in the upper part of the Santos in well 555–30R. The Media Shale Member at the top of the Temblor is hard shale in well 555–30R, where it has a drilled thickness of 205 feet. In well 526–30R the Media apparently is missing; the Carneros Sandstone Member is unconformably overlain by the Gould Shale Member of the Monterey Shale.

Rocks of the Monterey Shale have a drilled thickness of 4,108 feet in well 526–30R. The members include, in upward order, the Gould, Devilwater(?), McDonald of local usage, and Elk Hills Shale Members. Identification of the members is based largely on the contained Foraminifera. The Gould Shale Member consists of 185 feet of shale. The Devilwater(?) Shale Member, 161 feet thick, is composed of shale, sandstone, and siltstone. The McDonald Shale Member of local usage is 257 feet thick and is almost entirely shale. The Elk Hills Shale Member is a new name proposed herein for strata called Antelope Shale Member in some previous reports on the Elk Hills oil field. The type section for this new member is in well 526–30R, between drilled depths of 6,035 and 9,540 feet, where the rocks are siliceous shale, diatomaceous(?) siltstone, and some sandstone.

The Reef Ridge Shale consists largely of shale; it has a drilled thickness of 578 feet in well 526–30R. The boundary of the Reef Ridge and the overlying Etchegoin Formation, of Pliocene age, is difficult to determine; the contact may be gradational.

The post-Miocene rocks include, in upward order, the Etchegoin, San Joaquin, and Tulare Formations; these rocks are 5,457 feet in total drilled thickness.

INTRODUCTION

The Elk Hills oil field lies about 20 miles southwest of the city of Bakersfield in the southern part of the San Joaquin Valley (fig. 1). This giant field constitutes most of Naval Petroleum Reserve No. 1 and extends over much of a large anticline that is expressed on the surface by a line of hills about 17 miles long and 7 miles wide. The field has produced more than 275 million barrels of oil and has ultimate recoverable reserves estimated to exceed 1 billion barrels. The U.S. Government, through the U.S. Navy, owns about 80 percent of the reserves, Standard Oil Company of California the remainder.

This report is part of a comprehensive geologic study of Naval Petroleum Reserve No. 1 made by the U.S. Geological Survey at the request of the Naval Petroleum and Oil Shale Reserves Office of the U.S. Navy. The purpose of the report is to establish and document a reference section for subsurface upper Oligocene and Miocene rocks in the Elk Hills oil field in particular and in the southwestern San Joaquin Valley in general by relating detailed lithologic composition and fossil content to electrical-log characteristics. This detailed study should prove useful not only in the stratigraphic analysis of the Elk Hills oil field but also in the continuing search for oil and gas in the southwestern San Joaquin Valley.

Subsurface reference sections for the Temblor Formation, Monterey Shale, and Reef Ridge Shale are here established in parts of two wells drilled with rotary tools in the western part of the Elk Hills oil field. These wells are identified as Unit Operation Naval Petroleum Reserve No. 1 wells 526–30R and 555–30R, both located in sec. 30, T. 30 S., R. 23 E. (fig. 2). Well 555–30R, completed in 1952, is designated a reference section for the Temblor Formation because it contains the most complete section of these rocks and many cores were taken. Well 526–30R, completed in 1968, is designated a reference section for the Monterey Shale and Reef Ridge Shale because the rotary samples of these rocks, taken at 10-foot intervals in this well, are more representative than the samples from well 555–30R. Samples and cores for wells 526–30R and 555–30R are stored in the Navy facilities at Elk Hills.

DRILLING DATA

Well 555–30R is located 2,381 feet north and 2,239 feet west of the southeast corner of sec. 30, T. 30 S., R. 23 E., Kern County. Drilling

started on August 26, 1950. Total depth of 12,856 feet was reached on November 21, 1951, and the well was shut in on January 14, 1952. Elevation of the derrick floor, from which depth measurements were made, was 1,341 feet above mean sea level. Dipmeter surveys indicated dips as steep as 60° in parts of the Temblor Formation. The greatest well-bore deviation, 10°, was found at the total depth. The well was plugged back to 9,385 feet and completed through perforations between 9,309 and 9,350 feet in the First Carneros sand in the upper part of the Temblor Formation. The well flowed 183 barrels of 50.2°

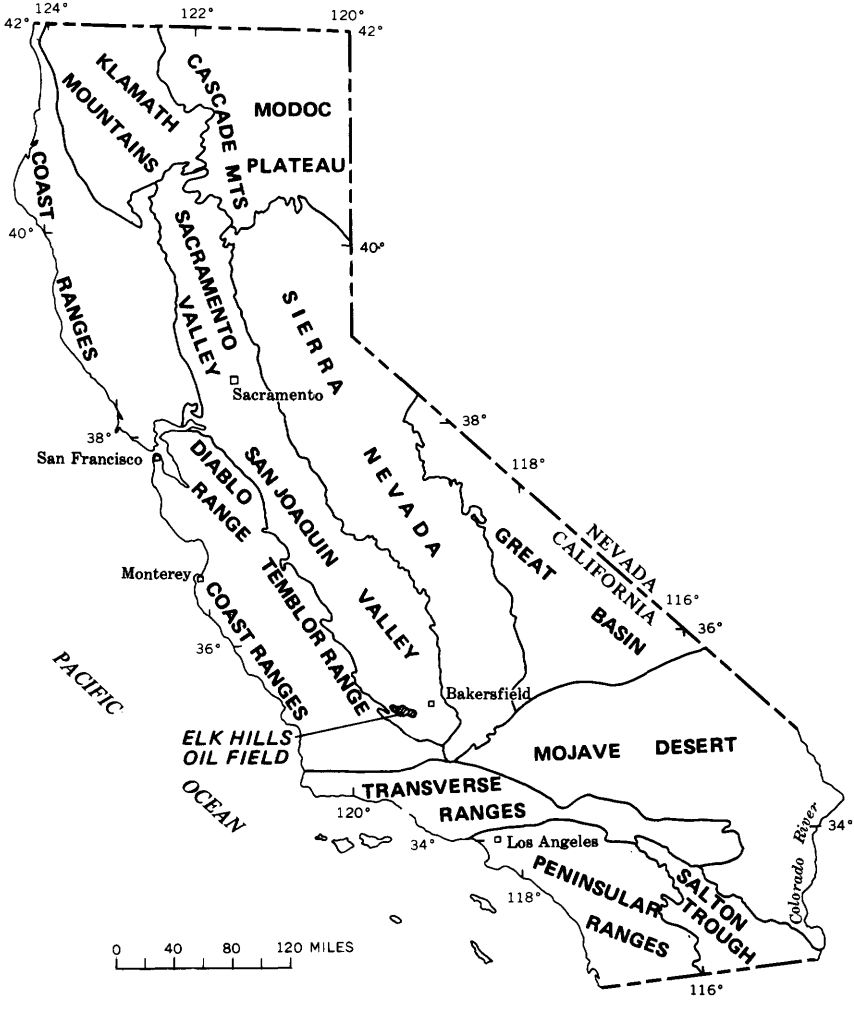

FIGURE 1.—Map of California showing location of Elk Hills oil field.

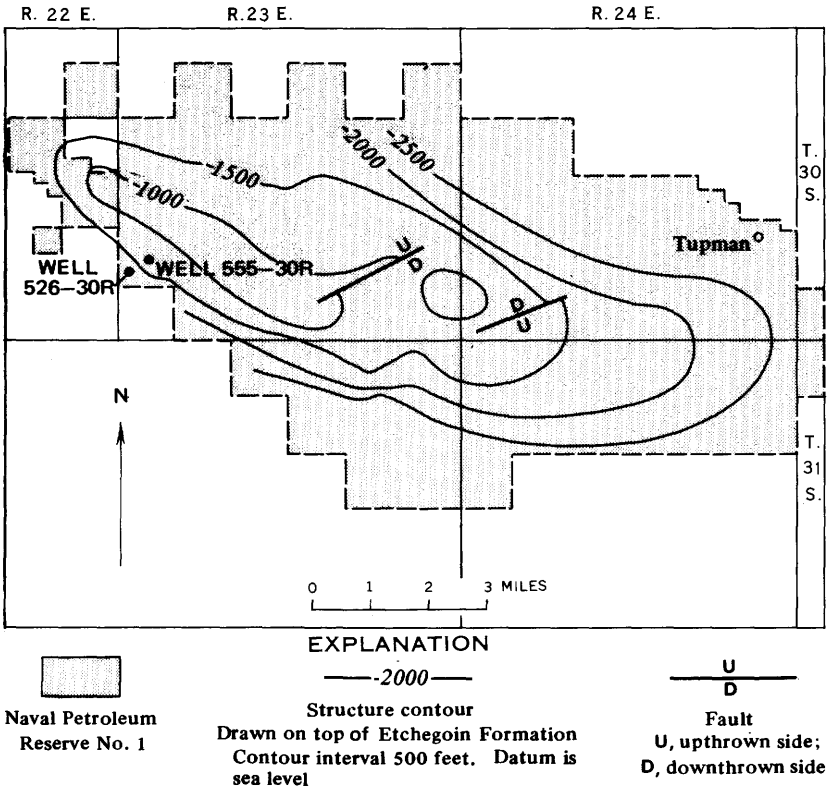

FIGURE 2.—Location of wells 526–30R and 555–30R, Elk Hills oil field, Kern County, Calif., in relation to structure of the Etchegoin Formation.

gravity (A.P.I.) oil and 1.7 million cubic feet of gas per day through an 11/64-inch choke. An earlier drill-stem test indicated gas in commercial volumes in the Olig sand near the base of the Pliocene Etchegoin Formation.

Well 526–30R is located 1,650 feet north and 990 feet east of the southwest corner of sec. 30, T. 30 S., R. 23 E. Drilling commenced on February 29, 1968, and terminated on May 23, 1968, after reaching a total depth of 10,700 feet. Elevation of the derrick floor, the datum for depth measurements, was 1,261 feet above mean sea level; ground level is 1,245 feet. Dips exceeding 50° are found in the lower part of the well. Deviation of the well bore reached 25° in the middle part of the Monterey Shale. Well 526–30R was plugged as a suspended well after an unsuccessful drill-stem test of the Carneros Sandstone Member of the Temblor Formation. An oil-saturated sand is present near the base of the Tulare Formation of Pliocene and Pleistocene age; a production test was not made.

METHODS OF INVESTIGATION

Rotary samples and sidewall cores from well 526–30R were examined under a binocular microscope with concurrent reference to the electrical log, using the procedure described by Maher (1959). In addition, the drilling-time log, the driller's daily reports, and the log prepared by the mud loggers were consulted. As the samples were studied, an interpretive sample log was plotted on a paper log strip. Colored pencils were used to designate different rock types, details of lithology were indicated by inked symbols, and rock descriptions were lettered along the side of the log at appropriate depths. The colored strip log was plotted at a scale of 1 inch equals 100 feet; a scale used which permits the showing of beds as thin as 1–2 feet. Conversion to single-color lithologic symbols (pl. 1) required some exaggeration of bed thicknesses or generalization of lithology. For example, many carbonate beds are probably no more than a foot thick, although they are shown considerably thicker.

Rotary samples and conventional cores from well 555–30R (pl. 2) were described by E. E. Glick; he used techniques similar to those used by the writer. Some of the lithologic terminology used by Glick was slightly modified so that it would be consistent with the lithologic terminology used for well 526–30R. Before the sample examination for well 555–30R was started, some cores were sawed parallel to the long axes in order to study bedding features. Half of each sawed core was preserved. The remaining halves of the cores and the cores that could not be sawed were then put through a jaw-type rock crusher to facilitate examination with a binocular microscope. The crushing produced rock fragments slightly larger than average rotary cuttings.

Magnifications of 6.3× and 10.5× were used by the writer to examine the gross features of the samples; magnifications as much as 45× were used to see the minute features. Bedding, except for laminations, is generally not determinable from rotary samples. The Rock Color Chart (Goddard and others, 1948) was used to describe the rock colors. The grain-size terminology is mainly in accordance with the Wentworth grade scale. The term "shale" is used for clastic rocks composed chiefly of clay and fine-silt particles without regard to bedding because clay and fine silt cannot be differentiated with the techniques used in this study. The term "siltstone" is used for clastic rocks composed of coarse-silt particles and also for rocks that probably are composed mainly of medium silt-size diatom fragments and called diatomite by some writers. Limestone was differentiated from dolomite by the speed of reaction in 6*N* hydrochloric acid at room temperature. Dolomite shows no immediate reaction in the acid and dissolves very slowly compared with limestone. All carbonate rocks that were examined contain appreciable but unmeasured amounts of

silt and clay; this insoluble material may exceed 50 percent of the rock in some beds. The term "dense" is used to describe carbonates and chert composed of particles too small to be seen under 6.3× magnification. The dense rocks commonly break with a conchoidal fracture. Dark-gray or black rounded grains, probably phosphatic, are generally called by the acronym "sporbo" by local petroleum geologists, and this term is used in some lithologic descriptions.

ACKNOWLEDGMENTS

Samples and crushed cores from well 555–30R were studied by E. E. Glick, and sawed cores were examined for bedding features by W. A. McCracken. Microfossil determinations were made by R. S. Beck and James Burrow. Core descriptions and other information from the Unit Operator, Standard Oil Company of California, were used where necessary. Stratigraphic correlations are adapted from work by J. C. Maher, R. J. Lantz, and R. D. Carter, of the U.S. Geological Survey, who are conducting a study of the subsurface rocks of the Elk Hills for the U.S. Navy.

STRATIGRAPHY

Rocks of Cenozoic age are exposed at many places on the flanks of the San Joaquin Valley, where they have been uplifted by major structural movements. Rocks cropping out along the west side of the southern San Joaquin Valley are mostly marine in origin and range in age from Eocene to Pleistocene. Their areal distribution and general structural attitude are shown on geologic maps of the Temblor Range that were compiled by Dibblee (1968; 1973). The Cenozoic rocks dip eastward from the Temblor Range, extend under the valley, and reappear 50 miles to the east on the flanks of the Sierra Nevada and Tehachapi Mountains. Church and others (1957) have illustrated the regional stratigraphic relations of the Cenozoic rocks by a correlation section that extends from the San Andreas fault on the west side of the Temblor Range, eastward through the Elk Hills oil field, and from there northeastward to the Sierra Nevada foothills northeast of Bakersfield.

The oldest rocks drilled in the western part of Elk Hills at the time of this report (1971) are Eocene and Oligocene in age (J. C. Maher, R. D. Carter, and R. J. Lantz, written commun., 1969). These strata were reached in well 532–25Z, located about a mile west-northwest of well 526–30R and outside the boundary of Naval Petroleum Reserve No. 1. The oldest rocks drilled within the Reserve, found in well 555–30R, are assigned an Oligocene age in accordance with Dibblee's (1973) study of equivalent rocks that are exposed in the Temblor Range to the west. Most petroleum geologists have considered these

rocks to be early Miocene in age. The Oligocene strata are overlain by rocks of Miocene, Pliocene, and Pleistocene age.

OLIGOCENE AND MIOCENE ROCKS

Rocks of Oligocene and Miocene age crop out in the foothills and mountains west of the San Joaquin Valley and extend eastward beneath younger rocks in the valley. Because these rocks have great economic importance, many geologists have studied them at exposures and in the subsurface for several decades. As a result, the geologic literature contains an abundance of papers that describe or interpret parts of the geologic record in the valley and adjacent areas. Numerous controversies regarding age and correlation have arisen because of rapid and pronounced changes in the lithology, thickness, and faunal content of these rocks. Early workers relied extensively on paleontology in their stratigraphic studies, and later workers found that micropaleontology was very useful, especially in the study of subsurface rocks. These strata are commonly divided by micropaleontologists into stages and zones based on foraminiferal assemblages.

The Oligocene and Miocene rocks in the western part of Elk Hills are divided, in upward order, into the Temblor Formation, Monterey Shale, and Reef Ridge Shale. The Temblor and Monterey are subdivided into members.

TEMBLOR FORMATION

The name "Temblor Beds" was suggested by Anderson in 1905 (p. 169, 170) for a sequence of sandstone and shale, about 1,500 feet thick, below the Monterey Shale at Canara [Carneros] Springs and at Temblor [Ranch] in western Kern County (fig. 3). During the preceding year Hamlin (1904, p. 14) coined the term "Vaquero Sandstone" for exposures in Los Vaqueros Valley in the western part of Salinas Valley, and in the years following several geologists applied the name "Vaqueros" to Anderson's (1905) Temblor Beds in the San Joaquin Valley and adjacent areas. Anderson (1908, p. 16–20, 38, 39) further described the Temblor Beds, corrected misidentifications of these and other rocks in the area north of Coalinga, and criticized usage of the name "Vaqueros" in the valley and adjacent areas. According to Anderson (1908, p. 38, 39), the original description of the Vaqueros was inadequate both stratigraphically and paleontologically, although he noted that "most of the strata that have been described under the name 'Vaquero Sandstone' *** are without doubt to be correlated with the Temblor beds of the Mount Diablo range."

Arnold (1909, p. 19) correlated Anderson's (1905) Temblor Beds in the Coalinga area with his Vaqueros Formation on the basis of paleontologic evidence; he used the name "Vaqueros" and assigned these strata to the lower Miocene. For the next 20 years or more the term "Vaqueros Sandstone" or "Vaqueros Formation" was used in

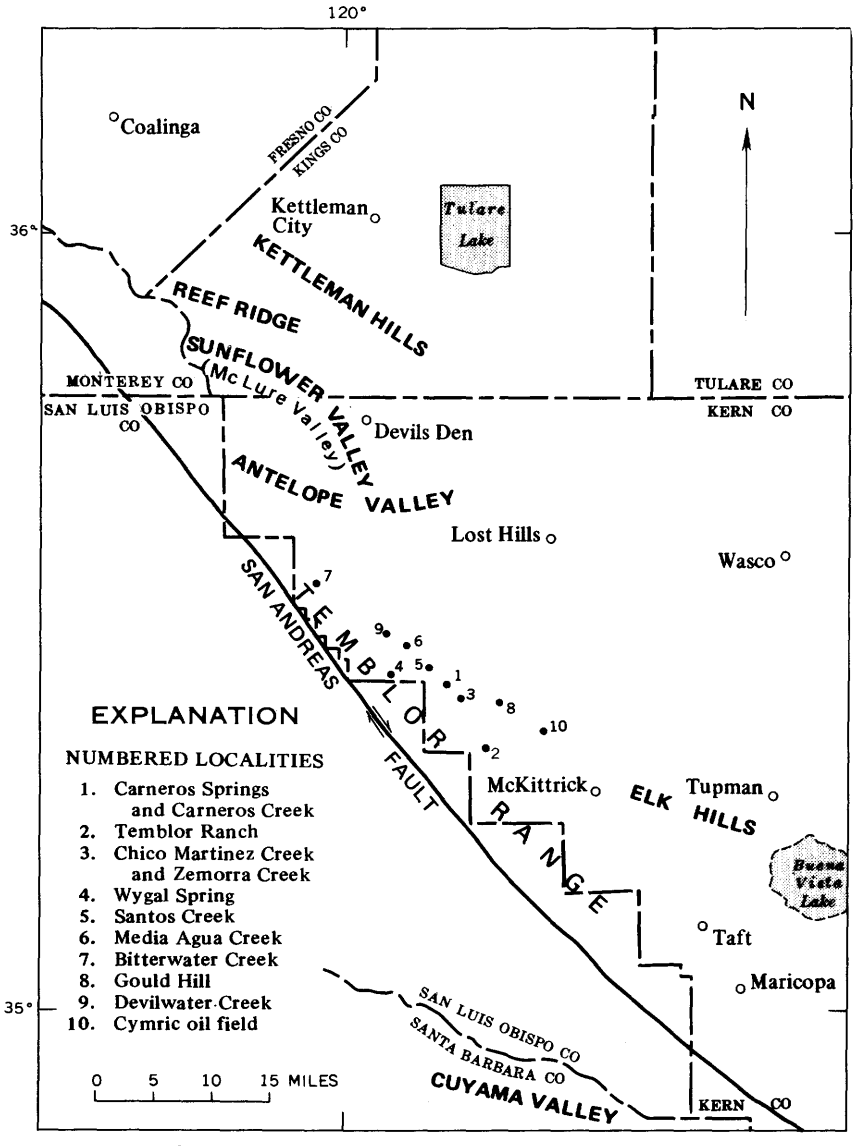

FIGURE 3.—Location of Elk Hills in relation to most localities of Oligocene and Miocene rocks discussed.

reports of the U.S. Geological Survey for the San Joaquin Valley and adjacent areas. During most of this period, writers continued to discuss the stratigraphic and chronologic relations between the Vaqueros Sandstone and Temblor Formation, and historical summaries of the controversy are included in articles by Louderback (1913), Wiedey (1928), and Loel and Corey (1932). Wiedey (1928,

p. 106) believed that the Vaqueros was older than the Temblor and stratigraphically below it. The term "Temblor" has been widely used in the San Joaquin Valley for about 40 years, although some geologists have assigned a Vaqueros age to the lower part of the Temblor Formation. For example, at Kettleman Hills Goudkoff (1934, p. 460) provisionally identified the Vaqueros Sandstone beneath the Temblor, although he had no direct paleontologic data to support this identification. The next year Schenck (1935, p. 523) wrote "widely realized to-day is the fact that the lower part of the Temblor formation *** at its type area, is the age equivalent of the upper part of the Vaqueros at its type locality." Woodring, Stewart, and Richards (1940, fig. 14) indicated that the lower part of the Temblor in the Chico Martinez Creek area is equivalent to rocks assigned to the Vaqueros in the south end of the San Joaquin Valley.

The age of the Temblor Formation was first determined as lower (early) Miocene by Anderson (1905, p. 172). Arnold and Anderson (1910, p. 87, 88) also assigned the Temblor (Vaqueros) in the Coalinga area to the lower Miocene. According to Merriam (1915, fig. 2, p. 26), a vertebrate fossil zone at the top of the Temblor north of Coalinga, the *Merychippus* zone, is not older than middle Miocene. The *Merychippus* zone was correlated with part of the *Valvulineria californica* zone (stratigraphically above the uppermost Temblor in the type area) by Bode (1935, p. 84), who concluded that the *Merychippus* zone cannot be older than late middle Miocene. Schenck (1935, p. 521–536) questioned the assignment of a Miocene age to the Vaqueros Sandstone, the upper part of which is generally considered the age equivalent of the lower part of the Temblor and he concluded that the Vaqueros is probably Oligocene in age. The Temblor Formation was assigned to the lower Miocene and lowermost middle Miocene Series by Kleinpell (1938, fig. 14), who indicated that the lower Miocene of California was supposedly equivalent to part of the Oligocene Series in Europe. According to Foss and Blaisdell (1968, p. 33, 38–41), most geologists assign a Miocene age to the Temblor Formation on the west side of the San Joaquin Valley. The lower part of the Temblor (Zemorrian Stage of Kleinpell, 1938) was considered as mostly or entirely Oligocene in age by Bandy and Arnal (1969, p. 793, 794). This age designation was used by Dibblee (1973) and it is used in the present report.

The original description of the Temblor Beds by F. M. Anderson (1905, p. 169, 170) was very generalized, and a type section was not clearly designated. A few years later, Anderson used the term "type locality" in referring to his earlier description (Anderson, 1908, p. 18), but whether he meant Carneros (Canara) Springs or Temblor Ranch is uncertain. Dibblee (1973) designated (1) the type section of the

Temblor Formation as that exposed at Carneros Creek, (2) the type area as the exposures from Carneros Creek to Zemorra Creek, and (3) a reference section of the Temblor and all its members as the section exposed at Zemorra Creek (sec. 9, T. 29 S., R. 20 E.) (fig. 3). The lower part of the Temblor Formation on Zemorra Creek, 380 feet thick, was designated the type section of the Zemorrian Stage by Kleinpell (1938, p. 103–108).

The Temblor Formation is commonly divided into members on the northeast flank of the central Temblor Range and in many oil fields to the east. This subdivision resulted from work by petroleum geologists, mainly during the late twenties and early thirties, but by present-day standards, the members were not properly named and defined.

Early descriptions of the Temblor Formation in the vicinity of Carneros and Chico Martinez Creeks were mostly very generalized. More detailed descriptions were published by Kleinpell (1938, p. 105–106), Woodring, Stewart, and Richards (1940, p. 130), Curran (1943, p. 1367–1370), and the San Joaquin Geological Society (1959, p. 13). Foss and Blaisdell (1968, p. 38–41) briefly discussed the lithology, fauna, age, and stratigraphic relations of the members of the Temblor along the west side of the San Joaquin Valley and in the subsurface to the east.

The subdivisions of the Temblor as defined by Dibblee (1973) are used in the present report. The members include, in upward order, the Cymric Shale, Wygal Sandstone, Santos Shale, Agua Sandstone, Carneros Sandstone, Media Shale, and Buttonbed Sandstone. The nomenclature used above, with the exception of two new names, the Cymric and Wygal, closely parallels that of Foss and Blaisdell (1968, p. 38–41).

In the Elk Hills oil field, the Temblor Formation has a drilled thickness of 3,801 feet in well 555–30R. The true thickness is considerably less, but difficult to calculate, because dipmeter surveys show that the rocks dip 22°–60° and the well-bore deviation reaches 10° at the bottom of the well. The true thickness is probably of the order of 2,400–2,700 feet.

CYMRIC SHALE AND WYGAL SANDSTONE MEMBERS, UNDIFFERENTIATED

The lowermost part of the Temblor Formation, for many years called the Salt Creek Shale Member by petroleum geologists, was renamed the Cymric Shale Member by Dibblee (1973). The new name, taken from the Cymric oil field located mainly in T. 29 S., R. 21 E., (fig. 3) is necessary because the name "Salt Creek" is preoccupied. As early as 1936 the term "Salt Creek Shale" was in common usage in the North Belridge oil field (Williams, 1936, p. 12). The lowermost part of the Temblor on Zemorra Creek was called the Lower Temblor Shale Member by Kleinpell (1938, p. 106) and considered as

the basal unit of the type Zemorrian Stage. These strata were termed the barren shale member of local usage by Woodring, Stewart, and Richards (1940, p. 130). According to Dibblee (1973), the Cymric Shale Member on Zemorra Creek consists of dark-gray clayey to silty shale about 74 feet thick.

The lower sandstone member of the Temblor Formation has been informally called the Phacoides sand or Phacoides reef for many years. This unit was renamed the Wygal Sandstone Member by Dibblee (1973) because the term "Phacoides," the name of a fossil, may not be used as a stratigraphic term. The new name is taken from Wygal Spring, located in the northeast quarter of sec. 33, T. 28 S., R. 19 E. (fig. 3). As early as 1933, the term "Phacoides reef" was shown on a correlation chart by Gester and Galloway (1933, fig. 3) but was not mentioned elsewhere in their report. Other writers have applied the names "Lower Temblor Sandstone Member" (Kleinpell, 1938, p. 106–108) or "*'Phacoides'* reef member of local usage" (Woodring and others, 1940, p. 130) to strata now called Wygal Sandstone Member. This member on Zemorra Creek (fig. 3), about 75 feet thick, consists of gray sandstone that is glauconitic in the upper part and locally fossiliferous and calcareous in the basal part (Dibblee, 1973).

The Cymric Shale and Wygal Sandstone Members were not reached in wells 526–30R and 555–30R but were drilled in well 532–25Z, about a mile to the west-northwest (J. C. Maher, R. D. Carter, and R. J. Lantz, written commun., 1969). Well samples were not available for well 532–25Z, but lithologic interpretation of the electrical log for this well suggests that these members are composed of shale, siltstone, and thin beds of sandstone and have a total thickness of 257 feet (J. C. Maher, R. D. Carter, and R. J. Lantz, written commun., 1969).

SANTOS SHALE MEMBER

The stratigraphic position of the Santos Shale Member was first indicated in a report on Kettleman Hills by Gester and Galloway (1933, fig. 3), but these writers made no further reference to the Santos. The member presumably was named for exposures on Santos Creek (fig. 3), although this was never formally stated (Heikkila and MacLeod, 1951, p. 8). Sandstone in the upper part of the Santos in the area northwestward from Carneros Creek was called the Agua Sandstone Member, presumably from Media Agua Creek, by Clark and Clark (1935) but they did not adequately define the unit nor specify a type locality. On Zemorra Creek, Kleinpell (1938, p. 106) used the name "Middle Temblor Shale Member," indicated its equivalency to the Santos, and placed the upper limit of the type Zemorrian Stage at the top of a 30-foot sandstone bed that lies 50 feet below the Carneros Sandstone Member. The terms "Lower Santos" and "Upper Santos" were used by Goudkoff (1941, p. 251) for beds below

and above the Agua Sandstone Member, respectively, and this usage has been widely adopted by petroleum geologists.

The Santos Shale Member, as described by Dibblee (1973), consists of medium- to dark-gray clayey to silty shale that is locally somewhat siliceous in the upper part. The member is 275 feet thick at the reference section on Zemorra Creek, where it is divided into a lower and an upper part, 180 and 60 feet thick respectively, by the Agua Sandstone Member. On the northeast flank of the Temblor Range, the Agua crops out locally as discontinuous lenses of light-gray rarely fossiliferous sandstone, 130 feet thick, within the Santos Shale Member (Dibblee, 1973).

At Elk Hills the Santos Shale Member was reached in both wells described in this report. Well 555–30R (pl. 2) made the greatest penetration into the member, 3,295 feet, but did not reach the base. The Santos in this well is informally divided into six lithologic zones for the purpose of description. The Agua Sandstone Member cannot be identified in well 555–30R. The uppermost (sixth) zone of the Santos in well 555–30R is stratigraphically equivalent to the lower part of the Carneros Sandstone Member in well 526–30R.

The true thickness of the Santos drilled in well 555–30R is considerably less than the drilled thickness of 3,295 feet. Dipmeter surveys made at numerous points in the member suggest dips of 22°–60°, and the direction of dip seemingly varies rather widely. The accuracy of the dipmeter data is unknown. Apparent dips in many cores from the Santos were measured by the Unit Operator. The apparent dips range from 20° to 80° and average about 45°. The deviation of the well bore is about 2°–5° through most of the member, but in the lower part the deviation increases to 10° at the bottom of the hole. The true thickness of the Santos cannot be determined accurately but probably is about 2,000–2,300 feet. The thicknesses given in this paper for the lithologic zones of the Santos in well 555–30R are drilled thicknesses and are not corrected for dip.

The first or lowermost zone of the Santos consists of medium dark-gray to brown shale 236 feet thick. Some beds are limy, silty, or phosphatic, and slickenside surfaces are fairly common in the rotary samples. A thin bed of very silty gray dolomite lies near the middle of the zone. The rotary samples of the rocks were mostly unwashed and dirty and thus difficult to study.

The microfauna in two cores from the lowermost zone of the Santos was studied by R. S. Beck (written commun., 1952). In the upper core (pl. 2) Beck found a few foraminifers that he considered diagnostic of the Zemorrian Stage. These were identified as *Siphogenerina nodifera* and *Siphogenerina* cf. *S. mayi*. Other Foraminifera in the upper core are given in table 1. The lower core contained undiagnostic

TABLE 1.—*Foraminifera in cores from the Temblor Formation in well 555–30R*
[Identifications by R. S. Beck]

Species	Santos Shale Member						Carneros Sandstone Member			
	Lithologic zones						Second Carneros sand	Upper shale	First Carneros sand	Media Shale Member
	1	2	3	4	5	6				
Ammodiscus sp				×	×					
Anomalina californiensis	×			×	×	×				
sp			×							
Bathysiphon sp		×	×	×	×	×	×			
Bolivina marginata					cf.	×	×			
marginata adelaidana						×	×	×		
sp					×	×				
Bulimina carnerosensis		×								
inflata alligata							?	×		
ovata		×								
Buliminella subfusiformis		×				×		×		
Cassidulina carinata						×	×			
Cibicides americanus		×			×	×	×	×	×	×
floridanus					×	×	×	×	cf.	cf.
hodgei					cf.	cf.	cf.			
pseudouvigerianus evolutus		×	cf.		×					
sp					?		×			
Clavulina communis					cf.					
patens			cf.	cf.	cf.					
sp		×	×	×	×					
Cyclammina cancellata obesa			×	×	×	×	×			
incisa					×	×	×	×		
sp	×	×		×	×	×[1]	×	×		×[1]
Dentalina multilineata						cf.				
pauperata		×			×	×	×	×		×
quadrulata		×			×			cf.		
sp		×[1]	×[1]		×	×				
Discorbis sp							×			
Elphidium sp							×			
Eponides umbonatus					cf.		cf.?			
Glandulina(?) sp		×								
Globigerina sp		×								
Globobulimina pacifica		×								
Gyroidina soldanii		×		×	×	×	×	×		
sp		×	×							
Haplophragmoides trullissata		×	×	×	×	×	×	×		cf.
Karreriella(?) sp			×							
Lagena sp		×								
Nodogenerina advena								×		×
sp		×								
Nodosaria anomala		cf.			cf.					
arundinea		cf.	cf.							cf.[1]
pyrula				cf.						
sp		×			?[1]					
Nonion affinis		cf.		cf.						
Plectofrondicularia californica				×						
miocenica										cf.[1]

TABLE 1.—*Foraminifera in cores from the Temblor Formation in well 555–30R*—Continued

Species	Santos Shale Member						Carneros Sandstone Member			Media Shale Member
	Lithologic zones						Second Carneros sand	Upper shale	First Carneros sand	
	1	2	3	4	5	6				
Pseudoglandulina conica		cf.								
Quinqueloculina sp							×			
Robulus simplex					×	×	×	×		cf.
warmani				cf.[1]	×		×	×		×
sp	×	×[1]	?[1]	×[1]	×	×	×	×		
Sigmoilina sp			×	×	×					
Siphogenerina mayi	cf.[1]									
nodifera	×									
tenua		×								
transversa	×				×	×	×	×	cf.[1]	×
sp				?[1]	×	×				
Sphaeroidina variabilis		×	×	×	?					
Textularia sp					×					
Uvigerina(?) *gesteri*		cf.								
mexicana		cf.	cf.							
Uvigerinella obesa								×		×
obesa impolita		×			×	×	×	×		
californica parva						×				
sp					×[1]	×	×		×	
Valvulineria nuttalli		cf.								
Verneuilina(?) sp				×						
Virgulina(?) sp		×								

[1] Identified from fragments.

arenaceous Foraminifera, pyritized Radiolaria, and fragments of fish bones. Both cores contained plant fragments, according to the core description by the Unit Operator. The lowermost zone of the Santos in well 555–30R is Zemorrian in age, on the basis of a relatively sparse microfauna, and the zone is assigned a late Oligocene age following Dibblee (1973).

The upper contact of the lowermost zone is marked by an upward change from gray shale to dark-brown siliceous shale. The change in lithology is poorly defined by the electrical properties of the rocks (pl. 2), and the contact may be gradational. This contact probably marks the top of Oligocene strata because, as described below, rocks about 20 feet above the contact contain a sparse microfauna of early Saucesian (early Miocene) age.

The second zone of the Santos, 577 feet thick, is light- to medium-gray siltstone and interbedded medium- to dark-gray silty shale. Some siltstone in the upper part is pale yellowish brown, and some shale in the middle part is dark brownish gray. The siltstone beds are

partly limy or sandy, and a few are slightly phosphatic. Several shale beds in the lower part contain phosphatic grains in small concentrations. Shale at the base is dark brown, silty, siliceous, hard, and partly fractured. Glauconite is found chiefly in shale in the upper-middle part. A crushed core sample from a depth of about 12,175 feet included some medium-light-gray soft flaky material questionably identified as bentonite. Volcanic glass was identified at a depth of about 12,192 feet.

Fossils in the second zone consist of plant fragments, mainly in the upper part, and scarce microfossils, chiefly Foraminifera. A core near the base of the second zone (pl. 2) contained the foraminifers *Siphogenerina tenua* and *Bulimina carnerosensis*, species that R. S. Beck (written commun., 1952) considers diagnostic of the lower Saucesian Stage of early Miocene age.

The upper contact of the second zone is placed at the top of the dominantly siltstone sequence. The contact is probably gradational. The electrical log (pl. 2) indicates no significant differences in electrical properties of the rocks adjacent to the contact.

The third zone, 436 feet thick, is mainly dark-gray shale, but medium-light-gray siltstone and sandstone are interbedded with the shale to a considerable extent in much of the upper half. Grain size of the sandstone varies from very fine to coarse, and the relative abundance of dark-colored grains gives the sandstone a "salt and pepper" appearance. Some shale is silty and slightly phosphatic. Slickenside surfaces were noted in the lower part of the zone, and contorted laminae are present in some siltstone beds in the upper part.

The rocks of the third zone are largely unfossiliferous except for scarce Foraminifera, given in table 1. A small amount of coalified plant debris was seen in siltstone in the upper part.

The contact with the overlying fourth zone may be an erosional disconformity, for it is marked by an upward change from shale to partly coarse-grained sandstone. This lithologic change apparently coincides with a relatively pronounced change in the electrical resistivity (pl. 2), but the spontaneous-potential curve gives almost no indication of the change in lithology.

The fourth zone of the Santos, 884 feet thick, consists mainly of sandstone in the lower and upper parts and interbedded shale, siltstone, and sandstone in the middle part. Sandstone in the lower 255 feet is medium light gray, very fine to coarse grained, limy, silty, and clayey. The grain size generally decreases upward. Glauconite, phosphatic grains, and mica are found in much of the sandstone, and a "salt and pepper" appearance is fairly common. Sandstone in the rest of the fourth zone resembles that in the lower part except that much of it in the upper part is cemented by dolomite. The generally

poor sorting of much of the sandstone, indicated by the large variety in grain size and the abundance of silt and clay, suggests low porosity. Siltstone in the fourth zone closely resembles that in the underlying zones. Much of it is sandy, and some in the upper part is very dolomitic. The shale also is very similar to that in underlying zones. Dark shades of gray predominate, but some shale is brownish gray to brownish black. Almost all the shale is silty. The upper half of this zone contains a few beds of light-gray to brownish-gray dense silty dolomite, possibly only a few inches thick. Slickenside surfaces were noted on shale fragments in parts of the interval between 10,956 and about 11,143 feet, and some contorted bedding was seen in core samples taken between 11,143 and 11,151 feet.

Twenty-one core samples from the fourth zone were tested for permeability; the maximum permeability, 1 millidarcy, was at a depth of 11,219.5 feet. The porosity of these samples was not determined. Slight oil stains in two cores were noted by the Unit Operator (pl. 2).

Plant fossils are present in some beds in the middle and upper parts of the fourth zone, and fish scales are in a few beds, mainly near the top. Foraminifera are generally rare; the species identified are given in table 1. In several cores the foraminifers were fragmented and (or) arenaceous and could not be identified.

Rocks of the fourth zone include much sandstone and seem to lie in the stratigraphic position of the Agua Sandstone Member; this member forms the uppermost part of the Zemorrian Stage at exposures on Zemorra Creek (Dibblee, 1973, fig. 11). This correlation is not supported by foraminiferal identifications. According to R. S. Beck (written communs., 1952, 1969), cores from the fourth zone contained no Foraminifera definitely indicative of a Zemorrian age, whereas the core near the base of the older second zone contained *Siphogenerina tenua* and *Bulimina carnerosensis*, species diagnostic of an early Saucesian age.

The contact with the overlying fifth zone appears to be marked by an upward change from sandstone to dolomite. The contact could not be identified on the electrical log.

The fifth zone of the Santos Shale Member consists mainly of silty shale 942 feet thick. The shale is commonly medium dark gray, but some in the lower part is dark brownish gray. Much of the shale is hard and at least slightly limy. The zone includes many thin beds and laminae of gray siltstone and, in the lower and middle parts, a few beds of medium-light-gray silty glauconitic fine-grained sandstone. Most rocks include at least some phosphatic material, especially in the lower part and also near the top. The lower and middle parts contain a few beds of impure dolomite; fractures are present in the two lower beds. Some shale fragments from the lower part have slickenside

surfaces. Contorted bedding in siltstone and shale was noted in a few samples about 290 feet above the base and also near the top of the zone.

A core sample of sandstone from a depth of 10,229.5 feet had a porosity of 4.2 percent and no permeability. Fractures in the sandstone and the underlying thin shale contained oil, according to the Unit Operator.

Generally, rocks of the fifth zone become increasingly fossiliferous upward. Fossils consist mainly of Foraminifera, given in table 1, and fish scales and bone fragments. Near the top a few beds contain scarce pelecypods informally termed "mud pectens." Plant fragments are conspicuously absent. Many of the rocks may be diatomaceous, but diatoms were not definitely recognized. These rocks rather closely resemble some of the diatomaceous rocks of the upper Miocene.

The upper contact of the fifth zone of the Santos in well 555–30R lies in an interval of missing well samples. Electrical properties of the strata in this interval suggest an upward change from shale to siltstone at the contact (pl. 2). The siltstone probably grades westward into sandstone that, in well 526–30R (pl. 1), was called the Third Carneros sand of the Carneros Sandstone Member (R. D. Carter, J. C. Maher, and R. J. Lantz, written commun., 1969). Because rocks in the stratigraphic position of the Third Carneros sand seemingly include no sandstone in well 555–30R, the top of the Santos Shale Member is placed stratigraphically higher at the base of sandstone locally called the Second Carneros sand (pl. 2).

The sixth (uppermost) zone of the Santos Shale Member in well 555–30R is composed of silty shale and interbedded siltstone. These rocks, 220 feet thick, are stratigraphically equivalent to the lower part of the Carneros Sandstone Member, but they are assigned to the Santos because of the almost total absence of sandstone. The shale is mostly medium dark gray to brownish black, limy, phosphatic, and relatively hard. Siliceous shale is present in the upper part. The medium-light-gray siltstone closely resembles that in the underlying zones of the Santos. Most of the siltstone probably occurs as very thin beds and laminae that grade upward into shale beds of similar thickness. Two thin beds of medium-light-gray silty bentonite are present about 35 feet below the top of the zone. Slickenside surfaces were noted in the bentonite.

Numerous beds in the sixth zone contain Foraminifera, given in table 1, and fish scales and bone fragments. Diatoms were questionably identified in a few beds, and some beds may be composed largely of diatom fragments.

The top of the sixth zone is marked by a sharp upward change from shale to sandstone. This lithologic change is clearly indicated by the

spontaneous-potential curve of the electrical log (pl. 2), although the depth to the contact, if determined from this curve, is several feet less than the depth recorded by the driller. At a depth of 9,672 feet, the driller measured and corrected the depth to 9,663 feet. Driller's depths were used in the preparation of plate 2, and the depth correction was not distributed upward from the point of measurement.

Well 526–30R was drilled 256 feet into the Santos Shale Member, and two sidewall cores were taken (pl. 1). The strata are equivalent to the upper part of the fifth zone of the member in well 555–30R. According to dipmeter surveys, the Santos in well 526–30R probably dips about 30°–60° toward the northeast, and the well bore through this member deviates 4°–5° toward the west-southwest.

The Santos in well 526–30R consists of shale, a few thin beds of dolomite, and two thin beds of sandstone. The shale is dark shades of gray and brownish gray, silty or limy, and slightly to moderately siliceous in parts. A thin bed of light-gray flaky shale seemingly lies 100 feet above the bottom of the hole, but this material in the samples may have caved from above. The dolomite is dark brownish gray, very fine grained, hard, and very silty; one bed is finely sandy. White crystalline dolomite or calcite fills fractures in the dolomite. The thickness of the dolomite beds is difficult to determine. The sandstone is light to medium gray, very fine to fine grained, silty, and slightly limy and glauconitic. The upper bed is siliceous, and both beds appear to have little porosity.

Foraminifera are the principal fossils found in the Santos in well 526–30R, but a few fragments of fish bones in some samples from the lower 100 feet were noted by R. S. Beck (written commun., 1969). The Foraminifera are given in table 2 and some are shown with the log on plate 1. The stratigraphic positions of the microfossils indicated on plate 1 are approximate because only rotary samples were used. Portions of samples from three consecutively drilled 10-foot intervals were combined to make one paleontologic sample representing a 30-foot interval. The microfauna suggests an early Saucesian (early Miocene) age, according to R. S. Beck (written commun., 1969).

The upper contact of the Santos Member in well 526–30R is defined by an upward change from shale to sandstone. This contact is probably sharp. It is readily recognizable on the spontaneous-potential curve of the electrical log but is less well defined on the short-normal resistivity curve (pl. 1).

CARNEROS SANDSTONE MEMBER

The term "Carneros Sandstone" was shown as a subdivision of the Temblor Formation by Goudkoff (1931, table 1). Cushman and Barbat (1932, footnote on p. 31) state that Carneros Sandstone Member was a name used by H. G. Schenck "*** for the prominent

TABLE 2.—*Foraminifera in rotary samples from Miocene rocks in well 526-30R*
[Identifications by R. S. Beck]

Species	Temblor Formation		Monterey Shale											
						Elk Hills Shale Member								
						Electrical-log zones								
	Santos Shale Member	Carneros Sandstone Member	Gould Shale Member	Devilwater (?) Shale Member	McDonald Shale Member (of local usage)	E	DD	D	C	B	A	N	Reef Ridge Shale
Ammobaculites sp												×	
Anomalina californiensis	×												
Bathysiphon sp									[1]×	[1]×	[1]×		
Bolivina parva					×								
salinasensis			cf.										
vaughani (?)											cf.		
sp							?						
Bulimina inflata alligata		cf.											
ovata		×	×	×									
sp	×	?[1]	×										
Buliminella subfusiformis			×	×									
Cassidulina crassa			cf.	×									
margareta	cf.												
monicana					cf.[1]								
Cibicides floridanus	×	×											
pseudoungerianus evolutus	×												
Cyclammina cancellata obesa	×	×											
sp		×										×	
Dentalina obliqua			×										
pauperata	×	×											
sp				×									
Eponides keenani			×										
Globigerina bulloides					×		?	×	×	×			
Gyroidina rotundimargo										×			
soldanii	×												
Haplophragmoides trullissata	×	×											
sp					?	?		×	×	×	×	×	×
Hemicristellaria beali			×										
Lagena sp	?												
Nodosaria soluta	cf.												
Pullenia miocenica			cf.										
Robulus simplex		×											
warmani	×	×											
Siphogenerina branneri			×										
transversa	×	×											
Sphaeroidina variabilis	×	×											
Uvigerina hootsi					×								
sp										?			
Uvigerinella obesa	×	×											
Valvulineria depressa			×										
robusta			×										

[1]Identified from fragments.

sandstone containing *Pecten miguelensis* Arnold near the middle of the Type Temblor section." This member on Zemorra Creek (fig. 3) consists of medium- to coarse-grained sandstone, 215 feet thick, that contains many zones of hard limy concretions; a thin foraminiferal shale lies 80 feet below the top (Woodring and others, 1940, p. 130). Heikkila and MacLeod (1951, p. 9) described facies changes in the Bitterwater Creek area, northwestern Kern County, where sandstone of the Carneros grades laterally into shale assigned to the upper part of the Santos Shale Member and the Media Shale Member.

The Carneros Sandstone Member in the western part of the Elk Hills oil field and adjacent areas includes a considerable amount of

shale that, for the most part, lies in two laterally persistent unnamed zones. Although these shale zones commonly include some interbedded sandstone and siltstone, they provide the basis for locally differentiating three bodies of sandstone, informally named, in downward order, the First, Second, and Third Carneros sands (R. J. Lantz and R. D. Carter, written commun., 1969). As described, the Third Carneros sand probably grades into siltstone between wells 526–30R and 555–30R. The siltstone equivalent of the Third Carneros sand and the overlying shale zone in well 555–30R are included in the Santos Shale Member.

The Carneros Sandstone Member in well 526–30R has a drilled thickness of 301 feet. Dipmeter surveys indicate that, in general, the rocks dip 25°–40° toward the northeast, and the deviation of the well bore through the member is 3°–5°, mostly westward. The true thickness may approximate 250 feet. Drilled thicknesses are used in the following description.

The Third Carneros sand of the Carneros Sandstone Member is 14 feet thick in well 526–30R, where it consists of light-gray sandstone (pl. 1). The sandstone is very fine to medium grained, silty, partly limy, and glauconitic. Coarse grains are scattered in the lower part; the grain size of the sandstone probably decreases upward. A bed of medium-gray shale, about a foot thick, lies near the middle of the Third Carneros sand.

Microfossils may be present in the Third Carneros sand, but none were seen when the samples were examined. Foraminifera from the Carneros Sandstone Member are given in table 2. The occurrence of Foraminifera in the different parts of the member is not shown in table 2, mainly because caving and contamination of samples is possible in rotary drilling.

The Third Carneros sand is overlain by the lower shale of the Carneros Sandstone Member in well 526–30R. The curves of the electrical log (pl. 1) suggest a relatively sharp contact.

The lower shale of the Carneros Sandstone Member, 187 feet thick, consists mostly of medium- to dark-gray and dark-brownish-gray shale. Some shale beds are silty, slightly limy, or siliceous. Two thin beds of bentonitic(?) shale are found in the middle and upper parts respectively. The bed in the middle part has a conspicuous light-gray color and a waxy luster. The positions of these two beds are apparently marked on the electrical log by uncommonly low resistivity at depths of 10,285 and 10,340 feet (pl. 1). These beds probably are useful local stratigraphic markers in the western part of the Elk Hills oil field and adjacent areas, as suggested by electrical-log correlations from well 555–30R northwestward to the Railroad Gap oil field (R. J. Lantz and R. D. Carter, written commun., 1969). Another thin bed

of bentonitic(?) shale may lie near the base of the lower shale at a depth of 10,410 feet, but this is uncertain. The lower shale of the Carneros also includes, in the lower-middle part, a 4-foot bed of fine-grained gray siliceous sandstone and an overlying bed of dark-brownish-gray hard impure dolomite.

Fossils in the lower shale of the Carneros consist of Foraminifera, and these are included in table 2. The microfaunal assemblage is indicative of a Saucesian age (R. S. Beck, written commun., 1969).

The upper contact of the lower shale is defined by an upward change from very siliceous shale to sandstone. The contact is probably sharp, though on the spontaneous-potential curve of the electrical log it is only moderately well defined (pl. 1).

The description of the rest of the Carneros Sandstone Member is chiefly for well 555–30R, because the member was cored almost completely in that well. Core recovery was poor to fair for many intervals, but for the member as a whole, recovery was nearly 72 percent.

The Carneros Sandstone Member in well 555–30R includes, in upward order, the Second Carneros sand, the upper shale, and the First Carneros sand (pl. 2). The drilled thickness, 301 feet, considerably exceeds the true thickness, for three dipmeter surveys indicate dips of 25°–48° in the member. Many apparent dips measured in cores and reported by the Unit Operator range from 30° to 60° and average about 43°. Wellbore deviation was 3°–4° through the member. The true thickness may be as little as 220 feet or as much as 260 feet. Drilled thicknesses are given in the following description.

The Second Carneros sand of the Carneros Sandstone Member, 158 feet thick in well 555–30R, consists of sandstone in the lower half and interbedded sandstone and shale in the upper half. The sandstone is medium light gray to brownish gray, mostly very fine to medium grained, limy or dolomitic, silty, and clayey. Some sandstone contains coarse or very coarse grains. Glauconite is found as scattered grains mainly in the lower part. Laminae of shale and siltstone are common in most of the sandstone. Shale in the Second Carneros is medium dark gray to brownish black, silty, and slightly limy and phosphatic. The color is generally darker in the upper part. Because contorted bedding is a common feature, sediment flowage in a relatively plastic state may have occurred shortly after deposition of much of the strata.

Porosity and permeability of the sandstone in the Second Carneros sand were determined in 1951 during the drilling of the well. Core sampling was done at 1-foot intervals for the most part. The porosity ranges from 6.9 percent to 19.9 percent, as shown in table 3, and generally exceeds 10 percent. Permeability of the sandstone ranges from 0 to 17 millidarcys, but only a few samples had permeability greater

TABLE 3.—*Porosity and permeability of cores from the Carneros Sandstone Member of the Temblor Formation in well 555–30R*

[Determinations by Core Laboratories, Inc.]

Depth (feet)	Permeability (millidarcys)	Porosity (percent)	Depth (feet)	Permeability (millidarcys)	Porosity (percent)	Depth (feet)	Permeability (millidarcys)	Porosity (percent)
First Carneros sand								
9279.5	35	14.2	9307.5	.0	7.7	9325.5	4.5	11.3
9280.5	7.3	15.7	9308.5	3.7	9.2	9326.5	7.1	14.8
9281.5	8.4	16.6	9309.5	2.9	12.2	9334.5	.0	7.3
9289.5	11	16.8	9310.5	.0	9.4	9335.5	.0	7.6
9290.5	19	16.2	9311.5	2.4	13.9	9336.5	.0	14.7
9291.5	25	16.8	9312.5	.0	8.0	9337.5	4.1	15.4
9292.5	6.8	10.7	9313.5	2.9	11.0	9338.5	2.5	12.9
9293.5	8.0	19.5	9315.5	.0	11.9	9339.5	2.4	10.9
9294.5	5.1	18.1	9316.5	.0	8.8	9340.5	.0	8.1
9295.5	.0	4.3	9317.5	.0	12.4	9342.5	4.4	14.8
9296.5	.0	14.0	9318.5	1.8	7.5	9343.5	3.6	15.2
9297.5	5.9	15.8	9319.5	.0	13.7	9344.5	1.9	11.1
9298.5	1.9	10.0	9320.5	.0	11.1	9350.5	.0	.....
9299.5	2.5	12.3	9321.5	5.2	12.6	9352.5	.0	.....
9303.5	2.9	8.9	9322.5	4.2	12.1	9390.5	.0	.....
9305.5	.0	10.2	9323.5	6.3	14.3			
9306.5	.0	10.6	9324.5	4.7	14.7			
Second Carneros sand								
9408.5	.0	.....	9489.5	.0	.....	9517.5	1.1	15.0
9412.5	.0	9.9	9490.5	1.0	12.8	9529.5	.0	11.6
9413.5	.0	9.5	9491.5	6.7	16.8	9530.5	.0	13.7
9414.5	.0	14.1	9492.5	6.2	17.3	9531.5	.0	13.7
9415.5	.0	14.0	9493.5	5.3	19.9	9532.5	.0	.....
9416.5	.0	8.9	9494.5	1.5	16.5	9533.5	.0	13.7
9417.5	.0	9.4	9495.5	2.0	14.2	9534.5	.0	11.7
9428.5	.4	11.0	9496.5	1.3	17.1	9540.5	.0	13.1
9430.5	.1	7.5	9497.5	3.0	16.7	9541.5	8.4	15.6
9434.5	1.0	10.2	9498.5	1.9	14.8	9542.5	5.8	19.2
9435.5	1.3	12.7	9499.5	7.1	19.6	9543.5	6.7	19.2
9436.5	6.3	11.3	9500.5	.5	9.0	9544.5	7.2	16.3
9440.5	.2	6.9	9501.5	.0	.....	9545.5	10	15.5
9442.5	.0	11.7	9502.5	1.6	13.2	9546.5	6.1	15.9
9453.5	4.3	12.4	9503.5	4.0	13.6	9547.5	.0	.....
9454.5	2.2	10.8	9504.5	3.8	14.3	9548.5	.0	.....
9455.5	2.5	10.7	9505.5	2.9	13.7	9549.5	11	16.5
9461.5	3.4	11.9	9506.5	1.6	13.6	9550.5	11	17.2
9462.5	.0	.....	9507.5	1.9	11.8	9551.5	11	18.5
9476.5	.0	7.2	9508.5	1.6	13.1	9552.5	13	17.0
9477.5	17	18.3	9509.5	1.6	14.8	9553.5	.0	6.9
9478.5	3.7	18.3	9510.5	1.0	13.7	9554.5	2.8	17.5
9479.5	7.1	18.2	9511.5	1.7	12.4	9555.5	1.8	15.0
9484.5	2.5	17.4	9512.5	2.5	13.0	9557.5	.0	9.8
9485.5	8.0	19.1	9513.5	3.1	14.4	9559.5	.0	.....
9486.5	.0	.....	9514.5	2.2	15.0	9560.5	.0	.....
9487.5	.0	.....	9515.5	1.1	11.5			
9488.5	.0	.....	9516.5	1.5	12.0			

than 10 millidarcys. Numerous samples with no measureable permeability had as much as 14.1 percent porosity. Oil staining was noted by the Unit Operator in several beds of sandstone in the upper and middle parts of the Second Carneros sand.

Fossils in the Second Carneros sand consist mainly of Foraminifera (table 1). Some forms were poorly preserved, and other forms in some cores were questionably identified from internal molds. Scarce sponge spicules were found in a few cores from the middle part of the Second Carneros (R. S. Beck, written commun., 1969). Brownish-black shale in the upper part contained "mud pectens."

The top of the Second Carneros sand is defined by an upward change in dominant lithology from sandstone to shale. Because these rock types are interbedded to a considerable extent, both above and

below the contact, determination of the contact from crushed-core samples is difficult. The spontaneous-potential curve of the electrical log suggests a fairly sharp contact (pl. 2).

The Second Carneros sand of the Carneros Sandstone Member in well 526–30R is mostly sandstone, 47 feet thick, that is siliceous in the basal bed and in the uppermost part. This sandstone is, for the most part, similar to that in the lower part of the Second Carneros sand in well 555–30R. The upper part of the Second Carneros of well 555–30R, interbedded sandstone and shale, is apparently missing in well 526–30R. The absence of these beds might indicate a period of either nondeposition or erosion prior to deposition of the upper shale of the Carneros Sandstone Member. Another interpretation explaining the absence of these beds was proposed by R. J. Lantz and R. D. Carter (written commun., 1969). They suggest that an unconformity lies at the top of the Second Carneros sand in well 526–30R and that the overlying rocks (upper shale and First Carneros sand) should be assigned to the Gould Shale Member of the Monterey Shale. Later work by J. C. Maher, R. J. Lantz, and R. D. Carter (written commun., 1969) and by the writer has resulted in the interpretation used in the present report.

The upper shale of the Carneros Sandstone Member is 55 feet thick in well 555–30R, where it is composed chiefly of shale and some sandstone and siltstone. The color of the shale is dark gray to brownish black in the lower part and medium dark gray in the upper part. Some shale is silty, phosphatic, and slightly limy; shale at the top is finely sandy. Laminae, lenses, and thin beds of siltstone and very fine to medium-grained sandstone are common in the upper shale of the member. Sandstone dikes are present in the lower part. Contorted bedding in the upper part probably indicates soft-sediment deformation.

Analyses of three cores of sandstone from the upper shale showed no measurable permeability (table 3); the porosity was not determined. The Unit Operator reported no oil stains in the cores.

Foraminifera were found in all cores of the upper shale, and these are given in table 1. The number of species identified is somewhat less than for the Second Carneros sand but considerably more than for the overlying First Carneros sand. In addition to the Foraminifera, shale near the base contained fish scales and "mud pectens," and a bed near the middle contained fish scales and plant fragments.

The upper shale of the Carneros Sandstone Member may grade upward into the First Carneros sand in well 555–30R. A gradational contact is suggested by the very silty and finely sandy shale at the top of the upper shale and by the slope of the spontaneous-potential curve of the electrical log (pl. 2). Core recovery in the basal part of the First Carneros was incomplete; the contact may lie slightly higher

than indicated in the detailed sample log and within an interval of lost core.

The upper shale of the Carneros Sandstone Member is 45 feet thick in well 526–30R. The shale is predominantly medium dark to dark gray, silty, and mostly siliceous, but the uppermost part is medium gray, slightly limy, and not siliceous. These rocks seem to differ notably from those in the upper shale of the Carneros in well 555–30R. The difference might be ascribed to erroneous logging of caving siliceous shale from the Gould Shale Member of the Monterey Shale in well 526–30R. Assignment of the upper shale to the Carneros in this well is based primarily on its stratigraphic position. In addition, a few Foraminifera *(Haplophragmoides trullissata* and *Uvigerinella* cf. *U. obesa)* which are suggestive of a Carneros or Media age were found by R. S. Beck in the rotary samples from a depth of 10,200–10,230 feet. Although this fossil collection is assigned a depth 4–34 feet below the top of the Second Carneros sand (pl. 1), there is a good possibility that the fossils actually came from strata above the Second Carneros and did not appear in the higher samples because of rotary-sample lag.

The type of contact between the upper shale and the First Carneros sand in well 526–30R is unknown because of the lack of cores. The electrical log suggests only minor differences in the electrical properties of the rocks below and above the contact (pl. 1).

The First Carneros sand of the Carneros Sandstone Member is 88 feet thick and consists almost entirely of medium-light-gray limy silty sandstone. Grain size ranges from very fine to very coarse and sorting is commonly poor. Phosphatic grains are found mainly in the upper part. Dark-gray shale laminae are fairly common in some beds. Contorted bedding is apparently absent, providing a notable contrast with the underlying units. A few samples exhibited graded bedding; others showed pinch-and-swell features and load casts. A very thin bed of phosphatic siliceous shale lies in the upper part.

The porosity and permeability of the sandstone in the First Carneros sand were determined mostly at 1-foot intervals (table 3). The porosity ranges from 4.3 percent to 19.5 percent and averages about 12 percent. The permeability ranges from 0 to 35 millidarcys and is generally higher in the upper part. Sixteen core samples had no measurable permeability but had porosity as high as 14.7 percent. Most cores of sandstone showed some oil staining according to the Unit Operator.

Foraminifera are present in parts of the First Carneros sand in well 555–30R (not listed on pl. 2). Although the microfaunal assemblage is very small (table 1), a few species indicate a Saucesian age (R. S. Beck, written commun., 1952). Sandstone near the middle of

the First Carneros includes pebble-sized shell fragments. The very thin siliceous shale bed in the upper part is very fossiliferous; Foraminifera are abundant.

The contact between the First Carneros sand and the overlying Media Shale Member in well 555–30R probably lies about 10 feet above the depth at which coring was started. The top of the Carneros is interpreted from the electrical log because there is a missing-sample interval above the uppermost core (pl. 2). A gradational contact seems likely, from the evidence of the electrical log.

The First Carneros sand is 8 feet thick in well 526–30R, where it consists of light-gray very fine to fine-grained very silty sandstone in which medium grains are scattered. The sandstone is clayey and slightly limy and glauconitic. Some hard sandstone appears to be tightly cemented. The sandstone is assigned to the Carneros Sandstone Member because it more closely resembles the sandstone in the Second Carneros sand than the thin sandstone in the overlying Gould Shale Member of the Monterey Shale. The First Carneros sand in well 526–30R is also lithologically similar to part of the First Carneros in well 555–30R, except for the absence of glauconite in well 555–30R.

Fossils seem to be absent in the First Carneros sand in well 526–30R. The First Carneros lies within the depth interval (10,140–10,170 feet) doubtfully assigned to a paleontologic sample that yielded a few Foraminifera *(Siphogenerina branneri* and *Pullenia miocenica)* of post-Carneros age. These microfossils probably came from the Gould Shale Member and indicate caving or lagging of the rotary samples.

The Carneros Sandstone Member is generally overlain by the Media Shale Member. In well 526–30R the Media is apparently missing and the Carneros is overlain unconformably by the Gould Shale Member of the Monterey Shale. This interpretation is based largely on the absence in the rotary samples of Foraminifera diagnostic of the Media and the presence of two species *(Siphogenerina branneri* and *Pullenia miocenica)* characteristic of the Gould in samples assigned by the driller to the depth 10,140–10,170 feet, an interval extending 27 feet below the top of the Carneros. The thickness of the First Carneros sand in well 526–30R is considerably reduced compared with the thickness in well 555–30R; this difference in thickness may indicate erosion of part of the First Carneros sand before deposition of the overlying beds.

MEDIA SHALE MEMBER

The term "Media Shale" was first published by Cunningham and Barbat (1932, table 1). A type locality for the Media was not formally designated but was presumed by Heikkila and MacLeod (1951, p. 8)

to be on Media Agua Creek. Exposures of the Media on Zemorra Creek were designated the type section by Dibblee (1973). The Media Shale Member on Zemorra Creek, described by Woodring, Stewart, and Richards (1940, p. 130), consists of dark silty partly foraminiferal shale, 920 feet thick, which includes a few zones of calcareous concretions, a hard 5-foot sandstone bed 160 feet below the top, and a 50-foot cherty shale 40 feet below the sandstone. Farther northwest, in the Bitterwater Creek area, shale of the Media becomes increasingly siliceous upward, and the middle part of the member includes numerous hard limestone beds averaging about 3 feet in thickness (Heikkila and MacLeod, 1951, p. 9, 10).

The Media Shale Member has a drilled thickness of 205 feet in well 555–30R (pl. 2). A dip of 24° was indicated in one dipmeter survey made in the upper part, and the Unit Operator reported apparent dips of 40°–46° in two cores. The true thickness may be about 150 feet.

The Media consists almost entirely of medium dark-gray partly limy hard shale. The lower part is slightly phosphatic; the middle and upper parts are mostly siliceous. Slickenside surfaces are found in both core samples of the shale, and fractures in the upper core are filled with dolomite, calcite, and pyrite. Tarry oil on some fractures in the lower core was noted by the Unit Operator.

Fossils in the Media Shale Member include Foraminifera (table 1), fragments of fish bones, and "mud pectens". The foraminiferal assemblage in the two cores is diagnostic of the upper Saucesian Stage (R. S. Beck, written commun., 1952).

The top of the Media Shale Member is difficult to determine in well 555–30R because the Buttonbed Sandstone Member, uppermost division of the Temblor Formation in the Temblor Range, is absent in the western part of the Elk Hills oil field and adjacent areas. In well 555–30R the Media is overlain by rocks assigned to the Gould Shale Member of the Monterey Shale (not shown on pl. 2). A study of the Foraminifera in two cores from depths of 9,094–9,100 feet and 8,986–8,996 feet indicates that the contact lies between these cores. According to R. S. Beck (written commun., 1952), the deeper of these cores contains two species of Foraminifera, *Siphogenerina transversa* and *Cibicides americanus*, not found in beds above the basal part of the Media in the Chico Martinez Creek area. In the shallower of these cores, Beck found a few poorly preserved specimens of *Siphogenerina* cf. *S. branneri*, a fossil that he considers restricted stratigraphically to the Gould Shale Member of the Monterey and to the underlying Buttonbed Sandstone Member of the Temblor. In well 555–30R the position of the contact between the Media and the Gould is determined primarily by slight changes in electrical-log character and in accordance with the available paleontologic data.

MIOCENE ROCKS

MONTEREY SHALE

For more than a century the name "Monterey" has been applied in various ways to rocks of Miocene age in California. The term "Monterey Formation" was first used by Blake (1855, p. 331) in describing Tertiary strata on a hill about 2 miles southeast of the town of Monterey (fig. 1). According to Louderback (1913, p. 194, 195), the context of Blake's report indicates that he did not intend to name or define a stratigraphic unit but rather used the term in a locality sense for the type of material at Monterey. Regardless of Blake's intentions, most writers have applied the name Monterey to a stratigraphic unit of formation rank. A critical review of the early literature concerning the Monterey and the underlying Vaqueros was included in the report by Louderback (1913, p. 193–232).

The Monterey Shale at the type locality near Monterey was described by Martin (1912), who estimated the thickness at 2,000 feet and listed the molluscan fossils. Hanna (1928) also described the Monterey at the type locality and summarized the fauna and flora.

The Monterey Shale was recognized by early workers along the west side of the San Joaquin Valley about the turn of the century. Eldridge (1903, p. 306–310) briefly described the formation near Coalinga, McKittrick, and Sunset. Many other writers have used the term "Monterey Shale" or "Formation" for the siliceous and diatomaceous shales of Miocene age along the west side of the Valley. Geologists have differed considerably regarding the stratigraphic position of the upper contact and, to a lesser extent, the lower contact of the formation.

The name "Monterey" has also been used as a group name to include the Vaqueros Sandstone and the overlying siliceous and diatomaceous shaly rocks generally called Monterey Shale or Formation. Usage of the name "Monterey" in a group sense was apparently intended by Lawson (1893, p. 24), who applied the term "Monterey series" to Miocene rocks near Carmel, about 3 miles south of the town of Monterey. Other early writers, notably Louderback (1913, p. 232), also used the term "Monterey series" in a group sense. Usage of the term "Monterey" as a group name made necessary a new formation name for the rocks formerly designated Monterey Shale. These rocks were called Maricopa Shale by English (1916, p. 198) in a report on the Cuyama Valley (fig. 3), about 25 miles south-southwest of Elk Hills, but he did not specify or describe a type section for the formation. Pack (1920, p. 38) described the type section of the Maricopa Shale in secs. 13 and 24, T. 11 N., R. 24 W., S.B.B. and M., about a mile south of Maricopa (fig. 3) where the thickness is 4,800 feet.

English (1918, p. 228), in a report on the Salinas Valley, stated that the Maricopa Shale in the vicinity of its type section included beds equivalent not only to the Monterey Shale of former usage but also beds equivalent to part of the overlying Santa Margarita Formation. Because of this relation, the term "Salinas Shale" was proposed by English (1918, p. 228) to replace the term "Monterey Shale" in the Salinas Valley. The name Salinas Shale, was applied to exposures of diatomaceous shale overlying the Vaqueros Sandstone on the west side of Salinas Valley, about 70 miles northwest of Elk Hills, but a type section was not designated.

According to Woodring, Stewart, and Richards (1940, p. 122), "The raising of Monterey to group rank was based on the view *** that the Vaqueros sandstone and Monterey shale together constitute a stratigraphic unit of varying lithologic facies separated from the overlying Santa Margarita sandstone by a widespread unconformity ***." This unconformity was described as early as 1904 by Fairbanks (1904, p. 4, 8, 10), who also named and described the Santa Margarita Formation from exposures near Santa Margarita in the Salinas Valley. Later more detailed work, mainly during the twenties, showed that the contact between the Monterey and Santa Margarita was not an unconformity of great regional extent (Reed, 1933, p. 206, 207). Hanna (1928, p. 974) mentioned the possibility that the Santa Margarita is a sandy phase of all or part of the Monterey, and later workers in the Coast Ranges generally agreed that sandstones of the Santa Margarita interfinger laterally with the upper part of the Monterey Shale (Woodring and others, 1940, p. 122, 123). A proposal to abandon the terms "Monterey Group," "Maricopa Shale," and "Salinas Shale" was made by Woodring, Stewart, and Richards (1940, p. 123). These writers recommended application of the term "Monterey Shale" to "*** Miocene strata in the Coast Ranges characterized by hard siliceous shale and soft shale containing microscopic siliceous fossils, regardless of varying chronologic relations of these strata within the Miocene, in accordance with the principle that a formation need not be of the same age from place to place."

The Monterey Shale on the west side of the San Joaquin Valley was divided into members many years ago. Most of the members were informally named, and some were more accurately considered biostratigraphic zones because their identification depended largely on the contained microfauna. The members identified by petroleum geologists in the vicinity of Chico Martinez Creek, listed and briefly described in a guidebook by the San Joaquin Geological Society (1959, p. 13), include, in upward order, the Gould Shale, Devilwater Silt, McDonald Shale, Antelope Shale, Chico Martinez Chert, and Chico Martinez (Belridge) Diatomite. According to the San Joaquin

Geological Society (1959, p. 13), the McDonald Shale, Antelope Shale, and Chico Martinez Chert Members are equivalent to the McLure Shale Member, a stratigraphic unit first defined as a formation (Henny, 1930) in the area bordering McLure Valley (now known as Sunflower Valley) south of Reef Ridge (fig. 3).

The exposed rocks of the Monterey Shale in the Temblor Range and adjacent foothills to the northeast were studied and mapped on a regional basis by Dibblee (1973), who briefly reviewed the nomenclature and longstanding correlation problems. He designated the exposures along Chico Martinez Creek (fig. 3) on the northeast flank of the Temblor Range as a reference section for the Monterey Shale and its members. The members of the Monterey adopted by Dibblee (1973) northeast of the San Andreas fault include, in upward order, the Gould Shale, Devilwater Shale, McLure Shale, and Belridge Diatomite Members. Where exposed, these units are separable on the bases of lithologic composition and weathering characteristics. According to Dibblee (1973) the McLure Shale Member consists of siliceous shale that, in outcrops outside the Chico Martinez Creek area, cannot be separated with certainty into the McDonald Shale, Antelope Shale, and Chico Martinez Chert Members of local usage.

In the Elk Hills oil field, the Monterey Shale in well 526–30R has a drilled thickness of 4,108 feet. The true thickness is considerably less, but difficult to calculate, because dipmeter surveys indicate that the rocks generally dip about 20°–45° toward the northeast, east, and southeast. The well-bore deviates as much as 25° through the formation, mostly toward the southwest. The true thickness is probably of the order of 3,500–3,600 feet.

The subdivision of the Monterey Shale found most useful in the subsurface of the Elk Hills oil field differs in part from that adopted for the Temblor Range by Dibblee (1973). The Gould Shale Member, and in some wells the overlying Devilwater Shale Member, are identified in the oil field. The Devilwater is overlain by the McDonald Shale Member of local usage. Rocks of the Monterey Shale above the McDonald in the Elk Hills oil field are here named the Elk Hills Shale Member, and a type section is established in well 526–30R. The McDonald Shale Member of local usage and the Elk Hills Shale Member are stratigraphically equivalent to the McLure Shale Member and possibly the Belridge Diatomite Member, as present at Chico Martinez Creek. If strata equivalent to the Belridge are present in the Elk Hills oil field, they cannot be distinguished from the underlying rocks.

GOULD SHALE MEMBER

The Gould Shale Member was first mentioned by Cunningham and Barbat (1932, table 1), who considered this a member of the Temblor Formation but, through an oversight, omitted in the left-hand column

of their correlation chart a line separating the Temblor from the Monterey. This incidental mention of the term "Gould" was inadequate for the purpose of establishing a stratigraphic unit, and accordingly Barbat (1932, p. 611, 612) defined the Gould as the 220–230 feet of beds overlying their Button bed member of the Temblor and underlying the *Valvulineria californica* zone of the Monterey Shale. The member was named for Gould Hill (fig. 3) which is near the type locality in sec. 14, T. 29 S., R. 20 E., (Mount Diablo base line and meridian), Kern County. Because of faunal affinities between the Gould and the upper part of the Temblor, Cunningham and Barbat (1932, p. 420) thought the Gould to be probably Temblor in age. Goudkoff (1934, p. 468), on the other hand, wrote "the foraminiferal assemblage of the Gould shale *** is much more closely related to that of the [overlying] *Valvulineria californica* zone than to that of the type Temblor." For many years the Gould has been considered the basal shale member of the Monterey Shale along the west side of the San Joaquin Valley.

Exposures of the Gould Shale Member on Chico Martinez Creek (fig. 3) consist of hard shale, about 550 feet thick, that is light brown, brittle, laminated, siliceous, and partly limy (San Joaquin Geol. Soc., 1959, p. 13). In the Temblor Range, Dibblee (1973) applied the name "Gould Shale Member" to siliceous shale in the Monterey Shale that conformably overlies the Temblor Formation and underlies the Devilwater Shale Member. As thus defined and mapped, the Gould presumably includes strata equivalent in age to the Devilwater Shale Member in the southeastern part of the range (Dibblee, 1973). Many geologists have combined the Gould and Devilwater Members because of the difficulty in separating these units lithologically in areas away from the vicinity of Chico Martinez Creek.

The Gould Shale Member in well 526–30R has a drilled thickness of 185 feet, but the upper contact is approximate because it is difficult to determine. The rocks dip about 20°–30° northeast, according to a dipmeter survey, and the well bore deviates 5°–9° southwest. The true thickness of the member probably approximates 170 feet.

The Gould consists of medium- to dark-gray and brownish-gray shale, and, in the upper half, a few thin beds of limestone and sandstone (pl. 1). The lower half of the member is almost entirely siliceous shale; the shale in the upper half is partly siliceous and partly limy. Some siliceous shale in the upper part has calcite-filled fractures. The limestone is chiefly brownish gray, dense to very fine grained, and argillaceous. The sandstone is medium light to medium dark gray, very fine to fine grained, silty, and slightly dolomitic.

Much of the shale and the limestone of the Gould contain microfossils, mainly Foraminifera (table 2). The upper part contains the

foraminifers *Siphogenerina branneri, Valvulineria robusta,* and *Hemicristellaria beali.* According to R. S. Beck, (written commun., 1969) these fossils, among others, characterize the Gould Shale Member and, where present, the underlying Buttonbed Sandstone Member of the Temblor Formation.

The upper contact of the Gould Shale Member is placed at the top of the shale that contains *Siphogenerina branneri.* The position of the contact is approximate because the upper part of the Gould and the lower part of the overlying shale are lithologically similar. The assignment of the overlying unit for an interval of about 160 feet is questionable; it is called the Devilwater(?) Shale Member of the Monterey.

DEVILWATER(?) SHALE MEMBER

The identification of the rocks above the Gould Shale Member is uncertain in well 526–30R. The presence of the Devilwater Shale Member in this well is suggested by electrical-log correlations with nearby wells where the member is identified by the contained microfauna. These correlations are not supported by the microfossil determinations made for well 526–30R, as discussed below. Therefore, the rocks above the Gould are called Devilwater(?) Shale Member.

The Devilwater Shale Member was originally called the Devilwater Silt, presumably for exposures in Devilwater Creek (fig. 3). The name was first used, but not defined, by Bailey (1939, p. 67, pls. 1, 3) in a brief description of the Wasco oil field. Dibblee (1973) modified the name to Devilwater Shale Member and specified the type section at Chico Martinez Creek. Prior to the usage of the term "Devilwater," these strata were generally called the *Valvulineria californica* zone. This foraminiferal zone, which lies at the base of the Monterey Shale in its type area (Goudkoff, 1931, p. 840), has been well known and widely used for faunal correlation by micropaleontologists for many years.

The Devilwater Shale Member is 1,190 feet thick at the type section on Chico Martinez Creek where it consists of soft foraminiferal clayey shale and silty mudstone overlying the siliceous shale of the Gould Shale Member and underlying the siliceous McLure Shale Member (Dibblee, 1973). In the general area of Chico Martinez Creek, the Devilwater consists of gray, buff, and brown silty shale and siltstone, and these rocks are massive, nodular, clayey, and locally siliceous and calcareous (San Joaquin Geol. Soc., 1959, p. 13).

In well 526–30R rocks assigned to the Devilwater(?) Shale Member have a drilled thickness of 161 feet, but the upper contact is approximate. A dipmeter survey indicates that the rocks dip about 30°–40° northeast and the well bore deviates 9°–15° southwest. The true thickness is probably about 150 feet.

Shale, sandstone, and siltstone compose the Devilwater(?) Shale Member in well 526–30R. The shale is chiefly medium dark to dark gray, but shale at the top of the member is brownish gray, finely banded with dark gray or dark brownish gray, and very siliceous. The sandstone, found in the middle and upper parts, is mostly medium gray, very fine to medium grained, silty, siliceous, and slightly dolomitic. Porosity of the sandstone appears to be very low. The siltstone is medium gray, sandy, and siliceous.

Microfossils are present in a few beds of medium-gray slightly limy shale in the lower part of the Devilwater(?) Shale Member. In his study of the Foraminifera from this part of the Monterey (table 2), R. S. Beck (written commun., 1969) did not find a faunal assemblage (*Valvulineria californica* zone) diagnostic of the Devilwater Shale Member. In rotary samples from the interval 9,900–9,960 feet, Beck identified *Bulimina ovata, Uvigerina hootsi, Cassidulina crassa,* and *Buliminella subfusiformis.* These species, especially *Uvigerina hootsi,* suggest that the Devilwater may be absent in this well and the strata in the interval 9,900–9,960 feet may be the lower part of the McDonald Shale Member of local usage. On the other hand, the daily drilling reports for well 526–30R indicate considerable difficulties in drilling the rocks from 9,700–9,960 feet. The Foraminifera listed above may have come from fragments of the overlying McDonald which were knocked or scraped from the wall of the hole during drilling operations.

The contact with the overlying McDonald Shale Member of local usage is rather arbitrarily placed at the top of the brownish-gray very siliceous shale. The contact coincides with a fairly abrupt upward decrease in electrical resistivity, but the spontaneous-potential curve gives no indication of the change in lithology (pl. 1).

M'DONALD SHALE MEMBER OF LOCAL USAGE

The McDonald Shale Member of local usage was probably named informally by petroleum geologists from exposures southwest of the McDonald oil field (Foss and Blaisdell, 1968, p. 37), which lies about 21 miles northwest of Elk Hills. The first published mention of the term apparently was by Cushman and Goudkoff (1938, p. 1), but they did not describe the member. They noted that the foraminifer *Pulvinulinella gyroidinaformis* characterized a very widespread stratigraphic zone, commonly called the McDonald Shale, along the west side of the San Joaquin Valley. Cushman and Goudkoff also mentioned that the basal beds of the McLure Shale along Reef Ridge are stratigraphically equivalent to the *Pulvinulinella gyroidinaformis* zone. The McDonald was described and mapped in the Temblor Range southwest of McKittrick by Simonson and Krueger (1942, p. 1616, 1617, fig. 8), who wrote that this member was more silty and massive and darker colored than the underlying Devilwater and

Gould Members, undifferentiated. They also noted a diagnostic foraminiferal fauna in the McDonald.

According to the San Jcaquin Geological Society (1959, p. 13), the McDonald Shale Member on Chico Martinez Creek (fig. 3) is about 2,300 feet thick and consists of light-buff to reddish-brown silty punky to siliceous laminated shale and a few beds of limestone. The McDonald was delineated on a map of the Chico Martinez Creek area (San Joaquin Geol. Soc., 1959, p. 6, 7), and it has been identified in numerous reports on subsurface rocks in western Kern County. The name "McDonald" was not adopted by Dibblee (1973) in his regional study mainly because these rocks and the overlying rocks are mostly siliceous shale that are difficult to distinguish in field mapping outside the Chico Martinez Creek area.

In the Elk Hills oil field, the McDonald Shale Member of local usage is a distinct lithologic unit, as determined from extensive stratigraphic work by J. C. Maher, R. J. Lantz, and R. D. Carter. The lower contact is difficult to determine in well 526–30R as described above.

The McDonald Shale Member of local usage in well 526–30R has a drilled thickness of 257 feet. Dipmeter surveys indicate the rocks dip about 25°–45° toward the northeast, east, and in the uppermost part, the southeast. The well bore deviates 11°–15° toward the southwest. The true thickness is probably about 240 feet.

The McDonald consists almost entirely of shale that is medium to dark gray, dark brownish gray, and, in the upper part, brownish black. Siliceous partly cherty shale dominates the upper third of the member. The lower half includes a few thin beds of medium-gray fairly soft limy shale and gray very fine to fine-grained silty sandstone. Two beds of light-gray to pale olive flaky shale, possibly bentonitic, are questionably logged in the McDonald. The upper bed contains scattered sand grains. The positions of these two beds seem to be indicated by low resistivity values at 24 feet above the base and 36 feet below the top of the member (pl. 1), and the resistivity curve suggests a third, similar bed near the middle.

Fossils are generally scarce in the McDonald, but R. S. Beck (written commun., 1969) found some Foraminifera in parts of the member (table 2). These include *Uvigerina hootsi, Bolivina parva,* and a fragment of *Cassidulina* cf. *C. monicana,* fossils which Beck considers characteristic of the McDonald. The diagnostic foraminifer *Pulvinulinella gyroidinaformis* was not found in well 526–30R, although it is present (but rare) in one or two nearby wells (R. S. Beck, written communs., 1967).

The upper contact of the McDonald Shale Member of local usage in well 526–30R is placed at the top of the dark-colored siliceous cherty shale. The relative coarseness of the overlying sandstone sug-

gests that this contact might be a disconformity of at least local importance. The lithologic change at the top of the McDonald coincides with changes in both the spontaneous-potential and the resistivity curves of the electrical log (pl. 1).

ELK HILLS SHALE MEMBER

In the Elk Hills oil field, the rocks of the Monterey Shale above the McDonald Shale Member of local usage make up a thick extensive stratigraphic unit that contains major oil reserves. A varied and confusing stratigraphic nomenclature has been applied to these rocks. The name "Antelope Shale" probably has been most used, but in at least four ways, since Noble (1940, fig. 1) first used the name in a brief discussion of the Rio Bravo oil field. That discussion included neither a type locality nor an adequate description for the Antelope. In the eastern part of Elk Hills, the term "Antelope" was applied by Park and Land (1955, pl. 6) to the uppermost part of the Monterey Shale (above the N horizon, pl. 1); the underlying strata, downward to the McDonald, were called Stevens. The term "Stevens sand" is commonly used in an economic sense for any sandstone in the Monterey above the McDonald Shale Member of local usage. In the Elk Hills oil field, Church and others (1957) used the term "Antelope Shale" for rocks above the McDonald and below the N horizon (pl. 1), and they called the overlying Miocene rocks the McLure Shale and Reef Ridge Shale, undifferentiated. Lorshbough (1967, p. 36, pls. 4, 6) used the term "Antelope Shale" for all rocks of the Monterey above the McDonald in the Elk Hills oil field. The Unit Operator for this field called the lower part of these strata the Antelope Shale and used the name "Brown shale" for the upper part. The top of the Antelope Shale of the Unit Operator is identified on plate 1. Because of these differing usages, the name "Antelope" is not used in this report. The new name "Elk Hills Shale Member" is here given to the rocks of the Monterey Shale lying above the McDonald Shale Member of local usage and below the Reef Ridge Shale.

The type section for the Elk Hills Shale Member of the Monterey Shale is in well 526–30R between drilled depths of 6,035 and 9,540 feet (pl. 1). According to a dipmeter survey, the rocks in the upper half dip generally 15°–35°. In the lower half, the dip seems to increase considerably, and below a depth of 7,860 feet, many dips exceeding 60° are indicated. In general, the direction of dip varies from northeast to southeast. Many pronounced changes in amount and direction of dip within closely spaced vertical intervals cause considerable doubt about the usefulness of much of the dipmeter data. Some of these striking variations in dip and strike probably measure fractures in the rocks rather than bedding. The deviation of the well bore through the Elk Hills Shale Member ranges from 4° to 25°, and the direction

of deviation is southwest to west. The thickness of the member is about 3,000–3,100 feet, but uncertainties regarding dip and strike of the rocks preclude an accurate calculation of the thickness.

The Elk Hills Shale Member is divided, in upward order, into the E, DD, D, C, B, A, and N zones (pl. 1), following recommendations by J. C. Maher, R. D. Carter, and R. J. Lantz (written commun., 1970). This subdivision, based chiefly on electrical-log characteristics, is modified in part from one used by the Elk Hills Engineering Committee (1957, p. 7, fig. 1) for reservoir-engineering purposes. The Committee divided the rocks of the Monterey Shale above the Devilwater Shale Member into seven units called, in upward order, the PG, DD, D, C, B, A, and N intervals; these intervals, together with the overlying Reef Ridge Shale, constitute the Stevens zone according to the Unit Plan Contract between the U.S. Navy and Standard Oil Company of California. In an earlier report on the Elk Hills oil field, Wells (1952, p. 244) used the same letter designations for a similar subdivision of the rocks below the N-point electrical-log marker (N horizon, pl. 1). The PG interval of the Elk Hills Engineering Committee included the McDonald Shale Member of local usage and the lower part of the overlying member herein named the Elk Hills Shale Member. In this report the McDonald is identified, and the lower part of the Elk Hills Shale Member is called the E zone. The seven zones are useful in making correlations within the Elk Hills oil field, and they are described below using drilled thicknesses.

The E zone of the Elk Hills Shale Member is 825 feet thick in well 526–30R. The rocks consist mainly of shale, siltstone, and sandstone. The shale is mostly medium dark to dark gray, but in the lower part, much of it is brownish gray. Siliceous and cherty shale is abundant in the lower part above the basal sandstone. The siltstone, found mainly in the middle and upper parts, is medium light to dark gray and partly sandy. Sandstone occurs at the base of the zone and in several beds near the middle and in the upper part. The basal sandstone, 23 feet thick, is medium light gray, very fine to medium grained, silty, slightly dolomitic, and siliceous in the upper few feet. The grain size increases downward, and the lower part includes some coarse and very coarse grains. Feldspar grains and mica are the principal accessory minerals. Sandstone in the middle and upper parts of the zone is generally similar to the basal sandstone. Most sandstone beds in the middle part are probably no more than three feet thick. Several sandstone beds apparently are fairly porous, and one bed near the top appears oil stained. Two thin beds of limestone lie in the lower-middle part of the zone. The limestone is pale yellowish brown, very fine grained to dense, dolomitic, and argillaceous. A thin bed of light-gray to yellowish-brown flaky shale, possibly bentonitic, lies

about 140 feet above the base of the zone. This shale contains scattered sand grains and mica.

Fossils seem to be rare in the E zone of the Elk Hills Shale Member. Some beds of sandstone and siltstone in the upper and middle parts contain carbonaceous or coaly fragments. A bed of siltstone near the base may contain diatom fragments. R. S. Beck (written commun., 1969) found a few specimens of *Haplophragmoides*(?) sp. and a few other indeterminate fossil fragments in several samples from the E zone (table 2).

The contact between the E zone and the overlying DD zone is marked by an upward change from sandy siltstone to shale. The contact is indicated on the resistivity curve of the electrical log by a sharp upward decrease in the resistivity; the spontaneous-potential curve gives almost no indication of the lithologic change (pl. 1). In the Elk Hills oil field, the top of the E zone is readily identified on most resistivity logs of wells that reached the zone.

The DD zone, 248 feet thick in well 526–30R, consists of dusky yellowish-brown to dark-gray silty shale, medium-dark-gray siltstone, and, in the lower half, some light- to medium-gray silty sandstone. Many of the beds are siliceous. A few beds near the top may contain dark-brownish-gray to brownish-black dense chert, although this chert may have caved from higher strata. The sandstone is mostly very fine to fine grained, and the porosity appears to be low. Shale at the base of the zone is light to medium gray, silty to sandy, flaky to splintery, and possibly bentonitic. Electrical resistivity of this shale is very low (pl. 1). The lower part of the zone includes a thin bed of pale yellowish-brown limestone, and the middle part includes a thin bed of dusky yellowish-brown to brownish-black dolomite. Both carbonate beds are very fine grained and argillaceous.

Fossils are rare in the DD zone. Scattered carbonaceous fragments are present in some of the sandstone. Finely color banded siltstone and shale in the upper half of the zone may contain diatom fragments. From a sample of the upper part, R. S. Beck (written commun., 1969) questionably identified two foraminifers, *Bolivina* sp. and *Globigerina bulloides* (table 2). He noted the presence of the diatom *Coscinodiscus* sp. near the middle of the zone.

The top of the DD zone is marked by an upward change from dark-gray and grayish-black shale to brownish-gray sandy siliceous siltstone. The change in lithology is indicated on both the spontaneous-potential and resistivity curves of the electrical log (pl. 1).

The D zone of the Elk Hills Shale Member is 661 feet thick in well 526–30R, where it is chiefly siltstone and silty shale. Most of the siltstone probably consists largely of diatom fragments, although few diatom fossils or molds were recognized during the sample study. The

grain size of this siltstone, slightly smaller than coarse silt, is strikingly uniform for the most part. For this rock type, the term "diatomaceous siltstone" is used here; some writers use the term "diatomite." This siltstone is pale yellowish brown to brownish gray, and finely color banded dark gray; it is siliceous and in part slightly dolomitic. Much of the siltstone apparently has considerable porosity, as indicated by water-absorption tests made during the sample examination. Most of the shale is brownish gray to dark gray; some is pale yellowish brown or grayish black. Nearly all the shale is siliceous, and some probably is composed largely of diatom fragments. Chert occurs in much of the D zone, either in thin beds or as nodules in other rock types. The chert is dusky brown to brownish black and dark gray, dense, and partly color banded. The D zone includes several thin beds of sandstone and dolomite. The sandstone, found in the lower half of the zone, is light to medium dark gray, very fine to medium grained, silty, and partly siliceous. The dolomite is pale yellowish brown to brownish gray, dense to very fine grained, argillaceous, and hard.

Microfossils are present in much of the D zone, but many of them are too broken to identify. In a few samples R. S. Beck (written commun., 1969) identified *Haplophragmoides* sp., *Globigerina bulloides* (table 2), Radiolaria, and some echinoid spines. Carbonaceous material seems to be absent.

The upper contact of the D zone is marked by an upward change from siltstone to shale. The contact is readily identified on the spontaneous-potential curve of the electrical log, but it is poorly defined by the resistivity curve (pl. 1).

The C zone, 367 feet thick in well 526–30R, consists predominantly of brownish-gray to dark-gray shale. The shale is silty and partly siliceous. The zone includes some interbedded diatomaceous siltstone and several thin beds of sandstone and dolomite. The siltstone closely resembles that in the D zone. The sandstone is light to medium gray, very fine to fine grained, silty, and partly siliceous and dolomitic. Dolomite, found chiefly in the lower half of the C zone, is very similar to that in the D zone.

Fossils are generally rare in the C zone. R. S. Beck (written commun., 1969) identified *Haplophragmoides* sp. and *Globigerina bulloides* in a few samples and, in the upper part, fragments of *Bathysiphon* sp. (table 2).

An upward change from shale to sandstone marks the top of the C zone. This contact is readily identified on the electrical log (pl. 1).

The B zone, 379 feet thick, consists of interbedded siltstone, shale, and sandstone. The pale-yellowish-brown to brownish-gray siliceous diatomaceous siltstone closely resembles siltstone in the D zone.

Dark-gray very thin streaks and stringers are common. Siltstone at the top may contain dusky-brown dense vitreous chert. In the lower part of the B zone, some siltstone is medium light to dark gray, sandy, and siliceous. The shale is medium dark to dark gray and dusky brown to brownish gray, silty, and mostly siliceous; a few beds are olive gray or yellowish gray. The sandstone occurs in beds less than 10 feet thick. The sandstone is light gray for the most part, very fine to fine grained, and silty, but some is medium dark gray or greenish gray. Dark-gray to black grains, commonly called sporbo, are found in a few sandstone beds near the base of the zone. Some of the sandstone appears to be fairly porous; one bed, 140 feet below the top, may be partly oil stained. The B zone apparently includes a few thin beds of brownish-gray very fine grained argillaceous dolomite; these beds may be logged from caved or recirculated samples.

A few microfossils were found in several samples from the B zone by R. S. Beck (written commun., 1969). He identified the foraminifers *Haplophragmoides* sp., *Bathysiphon* sp., *Globigerina bulloides*, *Uvigerina*(?) sp., *Gyroidina rotundimargo* (table 2), diatoms including *Coscinodiscus* sp., and spherical Radiolaria.

The upper contact of the B zone is defined by an upward lithologic change from siltstone to fairly soft gray shale. Changes in the character of the electrical log at the contact are less pronounced than for some of the other contacts; the lithologic change is suggested mainly by the spontaneous-potential curve (pl. 1).

The A zone is 315 feet thick in well 526–30R, where it consists of diatomaceous siltstone interbedded with shale and small amounts of sandstone and dolomite. Rocks of this zone are very similar to those in the B zone. The siltstone is partly dolomitic in the lower half and partly sandy in the upper half. The very fine grained sandstone is found in a few beds about 1–4 feet thick. Except for the uppermost bed, the porosity of the sandstone appears to be low.

Microfossils are fairly common in some beds in the lower half of the A zone but rare in the upper half. From this zone, R. S. Beck (written commun., 1969) identified the foraminifers *Haplophragmoides* sp., *Bolivina* cf. *B. vaughani*(?), *Bathysiphon* sp. (table 2), the diatom *Coscinodiscus* sp., and spherical Radiolaria.

The top of the A zone lies within a sequence of interbedded diatomaceous siltstone and shale. The contact with the overlying rocks is defined primarily by the character of the spontaneous-potential curve of the electrical log (pl. 1). The top of the Antelope Shale of the Unit Operator lies about 78 feet below the top of the A zone (R. D. Carter, J. C. Maher, and R. J. Lantz, written commun., 1969).

The N zone, 710 feet thick, forms the uppermost subdivision of the Elk Hills Shale Member. This zone consists predominantly of diato-

maceous siltstone and lesser amounts of shale and sandstone. Although these rocks are very similar to those in underlying zones, siliceous rocks are somewhat less common. The siltstone generally varies in color from pale yellowish brown to brownish gray; it may also be light to dark gray, yellowish gray, and very pale orange. Very thin dark-gray streaks are abundant in many beds. Diatomaceous siltstone units 20 feet or more thick are more common in the N zone than in the other zones. The shale is brownish gray, dusky brown, dark gray, silty, and partly siliceous. The sandstone is medium light to medium dark gray or partly greenish gray, very fine to medium grained, and silty or clayey. Accessory minerals found in some of the sandstone include mica, feldspar, pyrite, and black rounded grains. Most sandstone beds are about 3 feet thick; the greatest thickness is 8 feet. The sandstone in several beds appears to be fairly porous, and three beds are partly oil stained. The N zone includes a few thin beds of pale-yellowish-brown to brownish-gray argillaceous or siliceous dolomite and, in the lower-middle part, some dusky-brown to brownish-black dense chert. The chert probably occurs in a bed, about 3 feet thick, that overlies very siliceous diatomaceous siltstone.

Pelecypod fragments were found in several sandstone beds in the N zone, and one sandstone bed in the upper part contained gastropods. Fragments of fish bones also occur in the zone. Microfossils identified by R. S. Beck (written commun., 1969) include *Haplophragmoides* sp., *Ammobaculites* sp., *Cyclammina* sp. (table 2), *Coscinodiscus* sp., sponge spicules, and spherical Radiolaria. In most samples studied by Beck, *Haplophragmoides* sp. was common, but the other microfossils were scarce.

Two electrical-log markers, called the Q and N points by the Unit Operator, lie within the N zone. These markers are called horizons in this report (pl. 1). In the lower part of the zone the Q horizon is persistent only in the western part of the Elk Hills oil field (J. C. Maher, R. D. Carter, and R. J. Lantz, written commun., 1970); near the top of the zone the N horizon extends through most of the field. The N horizon has for many years been used extensively as a datum in studies of oil fields east of Elk Hills.

The upper contact of the N zone marks the top of the Elk Hills Shale Member; it also separates the Monterey Shale from the overlying Reef Ridge Shale. This contact in well 526–30R is defined by an upward lithologic change from brown siliceous shale to gray partly sandy shale that is not siliceous. The microfauna in the upper part of the Monterey and the lower part of the Reef Ridge provide no assistance in determining the position of the contact. The lithologic change at the contact is suggested by a change in the resistivity of the strata (pl. 1).

REEF RIDGE SHALE

The name Reef Ridge Shale was proposed by Barbat and Johnson (1933, p. 239; 1934, p. 3–5) for a distinctive soft blue (brown weathering) clay shale poorly exposed on the northeast side of Reef Ridge, stratigraphically above the brown siliceous shale of the McLure Shale Member. These workers noted that the distinctive character of the strata was first recognized by Arnold and Anderson (1910, p. 92), who included the rocks as an upper division of the Santa Margarita(?) Formation near the southeast end of Reef Ridge but mapped equivalent rocks along the northwest end of Reef Ridge as a transition zone assigned to the overlying Jacalitos Formation. Barbat and Johnson (1934, p. 4) believed that their Reef Ridge Shale was not included in the McLure Shale by Henny (1930, p. 403–410), who applied the term "McLure" to the brown, mostly siliceous shale in the Coalinga region. As originally defined, the Reef Ridge Shale included, in the lower part, brown clayey and silty shale that Henny (1930) had included in the McLure; for this reason, Siegfus (1939, p. 31, 32, 43) restricted the Reef Ridge to the gray shale overlying the brown shale of the McLure.

In a study of the Coalinga region, Adegoke (1969, p. 19–21) ranked the Reef Ridge and underlying McLure as members of the Monterey Shale and suggested that distinction based on color alone is likely to be erroneous because the color of the Reef Ridge differs from place to place. He described the shale of the Reef Ridge as brownish at the base where it grades downward into the McLure, light blue to purplish gray in most of the overlying beds, and rusty brown and sandy in the upper part which grades into brown sandstone of the overlying Etchegoin Formation (Adegoke, 1969, p. 21).

The age of the upper part of the Reef Ridge Shale in the type area has been controversial for many years. Barbat and Johnson (1934, p. 11) regarded the Reef Ridge as latest Miocene in age on the basis of stratigraphic relations and faunal content and correlated the formation with the upper part of the Monterey Shale. On the basis of stratigraphic position, they suggested (1934, p. 9) a correlation between the Reef Ridge and the upper diatomite member (Belridge Diatomite of Siegfus, (1939)) of the Monterey ("Maricopa") on Chico Martinez Creek and credited P. P. Goudkoff with finding Foraminifera of Reef Ridge affinities in the diatomite. Dibblee (1973) believes the Belridge Diatomite Member is older than the Reef Ridge Shale.

In a study of the Kettleman Hills oil field, Goudkoff (1934, p. 439, 473) considered the microfauna in the upper part of the Reef Ridge to be closely related to that in the overlying Jacalitos Formation of Pliocene age. Siegfus (1939, p. 37, 44) questioned the chronologic

significance of the shallow-water Foraminifera in the Jacalitos, although he assumed the age of the upper part of the Reef Ridge is generally transitional between the Miocene and Pliocene. Woodring, Stewart, and Richards (1940, p. 121) considered the age of the Reef Ridge Shale to be late Miocene; they based their conclusion on R. M. Kleinpell's opinion that the Foraminifera from this formation have Miocene affinities.

In areas far from the type area, the age of the upper part of the Reef Ridge Shale is even more controversial. Difficulties in correlation arise from lateral changes in lithology, thickness, and faunal content. As pointed out by Foss and Blaisdell (1968, p. 34), geologists are not in general agreement on rocks assignable to the formation.

The Reef Ridge Shale in well 526–30R has a drilled thickness of 578 feet. A dipmeter survey indicates that the rocks generally dip about 15°–45° and the direction of dip is mostly northeast to east. However, the amount and direction of dip, as recorded by the dipmeter, varies so widely within closely spaced vertical intervals that the accuracy of much of the data seems uncertain. The deviation of the well bore through the Reef Ridge is about 2°–4°; the direction of deviation is west to northwest. The true thickness is about 530 feet.

The Reef Ridge Shale consists almost entirely of shale in well 526–30R, but the formation includes a few thin beds of siltstone, sandstone, and dolomite. The shale is mostly dark gray and olive gray; some shale in the lower third is grayish black. The shale is silty or partly sandy and some of it contains thin stringers or lenses of sandstone. A few beds of siliceous shale are found mainly in the middle and lower parts. The siltstone is mostly olive gray to brownish gray and sandy. The sandstone, in beds as much as 3 feet thick, is medium to dark gray, very fine to fine grained, and mostly very silty or clayey. One sandstone bed near the middle of the formation may be oil stained in part. The dolomite is mostly pale to moderate yellowish brown, very fine grained to dense, very argillaceous, and hard. Coal or lignite probably occurs in one or more very thin beds or lenses near the middle of the formation. The stratigraphic position of the coal is uncertain because well samples from the formation contained only a few coal fragments at most. These fragments might have caved from a thin undetected coal bed in the overlying Pliocene rocks.

Fossils are generally rare in the Reef Ridge Shale in well 526–30R, and no diagnostic microfossils were found by R. S. Beck (written commun., 1969). The only foraminifer he identified is *Haplophragmoides* sp. (table 2), which occurs, at least rarely, throughout the formation. In some samples Beck found a few diatoms, Radiolaria, and fragments of mollusks and fish bones. A sample near the base contained a few specimens of *Coscinodiscus* sp.

An electrical-log marker, called the F horizon (F point of Unit Operator), lies near the middle of the Reef Ridge Shale (pl. 1). This marker is recognized in the western part of the Elk Hills oil field, but its eastward extent is uncertain.

The contact between the Reef Ridge Shale and the overlying Etchegoin Formation is difficult to determine in many wells in the Elk Hills field. In several wells about 2 miles west of well 526–30R, the Reef Ridge is overlain by a sandstone unit, several hundred feet thick, called the Olig sand zone (J. C. Maher, R. D. Carter, and R. J. Lantz, written commun., 1969). This zone includes some interbedded shale, especially in the lower part. Eastward the shale becomes the dominant lithology; the individual sandstone beds pinch out or grade into shale. The contact between the Reef Ridge and the Etchegoin in well 526–30R was determined by J. C. Maher, R. D. Carter, and R. J. Lantz (written commun., 1969), who made detailed electrical-log correlations between this well and those to the west, where the Olig sand zone is very thick and is predominantly sandstone.

In well 526–30R the contact between the Reef Ridge Shale and the Etchegoin Formation is placed at the base of a thin fine-grained sandstone (pl. 1) that is approximately equivalent to the lowermost sandstone in the Olig sand zone to the west. Rocks above the contact constitute a shale unit 157 feet thick that is overlain by a thick sandstone called the Olig sand. This sandstone is approximately equivalent to the upper part of the Olig sand zone in wells to the west (J. C. Maher, R. D. Carter, and R. J. Lantz, written commun., 1969). Rocks of the shale unit generally resemble the strata in the upper part of the Reef Ridge except that siliceous shale and brownish-gray shale are more common above the formation contact. The general similarity of the rocks suggests that the contact may be gradational in well 526–30R. Some geologists would include the shale unit in the Reef Ridge and place the upper contact at the base of the Olig sand.

POST-MIOCENE ROCKS

A reference section for subsurface Pliocene rocks at Elk Hills was described by Berryman (1973) for well 324–19R, located about a mile north of well 526–30R. The Pliocene and Pleistocene rocks in well 526–30R are described briefly below and in detail in the following section.

The Pliocene Etchegoin Formation, 2,637 feet thick in well 526–30R, is divided into the Tupman Shale Member and the overlying Carman Sandstone Member (pl. 1), named and described by Berryman (1973) following unpublished work by J. C. Maher, R. D. Carter, and R. J. Lantz (written commun., 1970). The Tupman Shale Member is 1,347 feet thick in well 526–30R, where it consists of shale and

some interbedded siltstone and sandstone. The member is divided into the informal Olig sand zone and the overlying Buliminella silt zone. The Olig sand zone, 224 feet thick, includes the Olig sand in the upper part. The Olig sand consists of fine- to coarse-grained feldspathic sandstone 67 feet thick. A mile north, the Olig sand is absent in well 324–19R, the type section for the Tupman. Some geologists place the boundary between Miocene and Pliocene rocks at the base of the Olig sand; others consider the Olig as the upper part of the Miocene (Foss and Blaisdell, 1968, p. 34, 37). The middle part of the Tupman includes several sandstone beds, and the top of one of these, as delineated by the electrical log, is called the O horizon (pl. 1). This electrical-log marker is readily identified in much of the Elk Hills field.

The Carman Sandstone Member is 1,290 feet thick in well 526–30R, where it is divided into four informally named zones; in upward order, they are the Calitroleum, Gusher, Wilhelm, and Mulina sand zones (pl. 1). Each zone includes several sandstone beds separated by shale or siltstone. The numerous infomally named "oil sands" within these zones are not identified in well 526–30R because detailed correlation of many electrical logs for wells in the western part of the Elk Hills oil field strongly suggests most "oil sands" are lenses of limited extent (R. D. Carter, J. C. Maher, and R. J. Lantz, written commun., 1969). The top of the Etchegoin Formation is difficult to recognize in well 526–30R; it was determined by correlation of the Mulinia electrical-log horizon from other wells (R. D. Carter, J. C. Maher, and R. J. Lantz, written commun., 1969).

The San Joaquin Formation, of Pliocene age, is 1,540 feet thick in well 526–30R, where it is divided into the informal Scalez sand zone and the overlying Mya sand zone. In this well the Scalez sand zone, 255 feet thick, consists predominantly of shale and includes, in the lower part, the Scalez electrical-log horizon. The Mya sand zone, 1,285 feet thick, also consists largely of shale. Sandstone and siltstone, in beds as much as 15 feet thick, make up a small part of the zone. In well 324–19R, about a mile to the north, the middle and upper parts of the San Joaquin include somewhat more sandstone and siltstone (Berryman, 1973). The upper contact of the formation is marked by a pronounced lithologic change from shale to poorly sorted feldspathic sandstone, and this contact is readily identified on the electrical log (pl. 1).

The Tulare Formation, of Pliocene and Pleistocene age, is chiefly sand and poorly consolidated sandstone. This formation, 1,280 feet thick in well 526–30R, is divided into a lower sand and gravel member, a clay member, and an upper sand and gravel member in accordance with the classification of R. D. Carter, R. J. Lantz, and J. C. Maher (written commun., 1969).

The lower sand and gravel member of the Tulare Formation, 567 feet thick in well 526–30R, consists of sand and sandstone interbedded with siltstone and shale. Grain size of the sand and sandstone varies from very fine to very coarse; some sand in the upper part contains granules. Some sandstone and siltstone in the lower part of the member was abundantly oil stained (pl. 1).

The clay member, in the middle of the Tulare, is 91 feet thick and consists chiefly of silty to sandy shale and some fine to coarse sand. This member is rather well delimited by electrical-log characteristics (pl. 1).

The upper sand and gravel member of the Tulare, 622 feet thick, is predominantly feldspathic sand; samples are missing for the upper 117 feet. Grain size of the sand varies from fine to very coarse, and much of the sand contains granules. A small part of the upper member consists of sandy siltstone and partly sandy shale, that may be more accurately described as poorly consolidated clay, claystone, or mudstone.

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DETAILED DESCRIPTION OF LITHOLOGY
WELL 526–30R

[1,650 ft north, 990 ft east of SW. cor. sec. 30, T. 30 S., R. 23 E.]

Altitude (drill floor) 1,261 feet

	Depth (ft)
Quaternary and Tertiary Systems:	
Pleistocene and Pliocene Series:	
Tulare Formation:	
Upper sand and gravel member:	
No samples	0–117
One sample. Sand, medium to very coarse, subangular; scattered chert and magnetite grains. Much lost-circulation material	117–150
Sand, fine to very coarse, subangular to angular; scattered granules and fragments of white chert, feldspar, and light-gray very fine grained limestone	150–160
Sand, as above; scattered fragments of granite, quartzite, and other hard rocks	160–180
Sand, fine to very coarse, mostly coarse to very coarse, subangular to angular; some fragments of white to gray chert, feldspar, and dark-gray to green rock	180–190
Sand, as above; more fine to medium grains than unit above	190–200
Sand, medium to very coarse, subangular to angular; more granules than unit above; fragments of feldspar, chert, and igneous rocks	200–210
Shale, moderate-yellowish-brown	210–212
Sandstone, light-gray, very fine grained, limy, micaceous	212–216
Sand, medium to very coarse, subangular; feldspar fragments	216–221
Shale, as above	221–223
Sand, as above; few granules, scattered white chert fragments	223–306
Siltstone, light-greenish-gray, very finely sandy, micaceous	306–314
Sand, medium to very coarse, subangular; granules common, feldspar grains; scattered grains of green, purple, and dark-gray rock and white chert	314–330
Shale, light-olive-gray to moderate-yellowish-brown, slightly limy; 2-ft sand bed in middle	330–340
Sand, as above	340–362
Shale, moderate yellowish-brown (indicated by mud balls in sample)	362–365
Estimated sample lag—20 ft.	
Sand, as above	365–375

	Depth (ft)
Quaternary and Tertiary Systems—Continued	
Pleistocene and Pliocene Series—Continued	
Tulare Formation—Continued	
Upper sand and gravel member—Continued	
Sand, medium to very coarse; abundant granules and small pebbles of many rock types; feldspar fragments	375–395
Sand, as above; probably no pebbles	395–406
Shale, light-olive-gray. Probably contains scattered grains of fine to medium sand	406–410
Sand, medium to very coarse; scattered pebbles	410–435
Sand, medium to very coarse, subangular; scattered granules, feldspar grains	435–460
Sand, fine to very coarse, subangular; scattered granules, feldspar grains. Upper half probably includes beds of light-olive-gray sandy siltstone	460–480
Sand, fine to very coarse, subangular; feldspar grains and other rock fragments; greenish-gray to olive-gray clay and silt matrix	480–515
Sand, medium to very coarse; some granules; olive-gray silty matrix in part; fragments of white chert, feldspar, and other rocks in part; tightly cemented with calcite in part (in 530–545 sample)	515–550
Siltstone, light-olive-gray, very finely to finely sandy. Near middle a 3-ft bed of fine to coarse subangular feldspathic silty sand	550–564
Sand, medium to very coarse, subangular; few granules, feldspar fragments; trace of pyrite	564–580
Sand, as above; probably much greenish-gray silty clay matrix	580–593
Sand, medium to very coarse, subangular; feldspar fragments	593–604
Sand, as above; probably much gray to greenish-gray silty clay matrix	604–610
Sand, fine to coarse, scattered very coarse grains, subangular; feldspar fragments	610–622
Clay member:	
Shale, light-olive-gray, silty, slightly dolomitic, finely to medium sandy in part; stringers of fine to medium very argillaceous sand	622–645
Sand, as above	645–647
Shale, as above. Trace of light-gray very fine grained argillaceous limestone (found in 670–685 sample)	647–665
Sand, as above	665–668
Shale, light-olive-gray, slightly dolomitic, sandy in part. One small gastropod (found in 685–700 sample)	668–685
Shale, light-olive-gray to greenish-gray, limy in small part, silty	685–713
Lower sand and gravel member:	
Sand, fine to coarse, some very coarse grains and granules; few fragments of feldspar and white chert. Probably includes a thin bed of fine- to medium-grained pyritic sandstone	713–730
Estimated sample lag—10 ft.	

	Depth (ft)
Quaternary and Tertiary Systems—Continued	
Pleistocene and Pliocene Series—Continued	
Tulare Formation—Continued	
Lower sand and gravel member—Continued	
Shale, light-olive-gray, silty	730–733
Sand, as above	733–739
Shale, light-olive-gray, silty, slightly limy. Gastropods abundant in part	739–750
Siltstone, light-olive-gray to medium-light-gray, very finely to finely sandy, limy in part	750–760
Shale, medium-gray, silty	760–768
Sand fine to coarse, some very coarse grains and few granules; few grains of feldspar and white chert	768–785
Sand, fine to coarse, subangular, limy in part	785–790
Siltstone, medium-light-gray, very finely to finely sandy, slightly limy, fairly soft	790–799
Sandstone, medium-light-gray, very fine to medium-grained, silty, soft, "dirty". A 4-ft bed of light-olive-gray silty shale in middle	799–810
Shale, light-olive-gray to medium-gray, silty	810–818
Sandstone, medium-light-gray, very fine to medium-grained, scattered coarse grains; some feldspar; trace of mica. Probably good porosity	818–848
Shale, light-olive-gray, silty	848–856
Sandstone, as above	856–865
Sandstone, light-gray, very fine to medium-grained, some coarse grains; includes pyrite, feldspar, and biotite. Clean, free drilling	865–875
Shale, as above	875–880
Sandstone, as above; probably very silty in part; includes several thin shale beds as above	880–914
Shale, as above	914–917
Sandstone, light-olive-gray, very fine to medium-grained, probably very silty	917–921
Sand, light-gray, very fine to medium, scattered coarse grains; fragments of feldspar and some biotite and pyrite	921–930
Shale, light-olive-gray, silty; interbedded with sandstone as above	930–937
Sandstone, as above	937–949
Shale, as above	949–954
Sandstone, as above	954–966
Shale, light-olive-gray, silty; interbedded with some sandstone as above	966–983
Sandstone, as above	983–990
Siltstone, light-olive-gray, finely sandy	990–1,007
Shale, medium-gray	1,007–1,015
Sandstone, light-gray to light-olive-gray, very fine to medium-grained	1,015–1,020
Siltstone, as above	1,020–1,027
Sandstone, as above; fairly common biotite	1,027–1,035
Siltstone, as above; interbedded with some sandstone as above	1,035–1,070

	Depth (ft)
Quaternary and Tertiary Systems—Continued	
Pleistocene and Pliocene Series—Continued	
Tulare Formation—Continued	
Lower sand and gravel member—Continued	
Shale, light-olive-gray; interbedded with sandstone as above	1,070–1,083
Sandstone, light-gray, fine- to medium-grained, some coarse grains, subangular; some mica, feldspar, and pyrite. Free drilling	1,083–1,089
Shale, as above; interbedded with sandstone as above	1,089–1,095
Shale, medium-gray to greenish-gray, silty	1,095–1,107
Sandstone, as above; interbedded with olive-gray silty shale	1,107–1,120
Sandstone, light-gray, fine- to medium-grained, some coarse grains, subangular; few fragments of mica, feldspar, and pyrite. Free drilling	1,120–1,125
Shale, pale-yellowish-brown	1,125–1,127
Sandstone, light-olive-gray, very fine to fine-grained, very silty; some biotite; trace of fossil fragments	1,127–1,130
Sandstone, as above; many dark-gray ostracods; probably some fine- to medium-grained sandstone	1,130–1,138
Siltstone, light-olive-gray, very sandy, slightly limy to limy. A 3-ft bed of light-olive-gray very fine to fine-grained sandstone at 1,145–1,148	1,138–1,159
Shale, light-olive-gray, silty	1,159–1,164
Sandstone, light-olive-gray, very fine to medium-grained, some coarse grains, slightly limy, very silty in part. Sidewall cored at 1,166 and 1,169	1,164–1,170
Siltstone, greenish-gray, micaceous, slightly limy	1,166
Sandstone, greenish-gray, very fine to medium-grained, scattered coarse grains, micaceous, silty	1,169
Siltstone, greenish-gray to light-olive-gray, micaceous. Sidewall cored at 1,173	1,170–1,174
Siltstone, greenish-gray, micaceous; interbedded with oil-stained very fine to fine-grained silty sandstone including scattered medium and coarse grains. Sidewall cored at 1,176	1,174–1,177
Sandstone, brownish-gray (oil-stained), very fine to medium-grained, some coarse grains and granules. Free drilling. Sidewall cored at 1,179, 1,183, and 1,188	1,177–1,192
Sandstone, brownish-gray (oil-stained), silty, very fine to very coarse grained; trace of granules; oil odor	1,179
Sandstone, brownish-gray (oil-stained), fine- to very coarse grained; good porosity; oil odor	1,183
Sandstone, brownish-gray (oil-stained), fine-grained, well sorted; fair porosity; oil odor	1,188
Siltstone, greenish-gray to light-olive-gray, clayey; few thin-shelled pelecypods and ostracods. Poor samples. Sidewall cored at 1,193, 1,197, 1,201, 1,209	1,192–1,210
Siltstone, light-olive-gray, oil stained, micaceous	1,193
Siltstone, light-olive-gray, limy, micaceous; pelecypod fragments	1,197
Siltstone, as above. No fossils	1,201

	Depth (ft)
Quaternary and Tertiary Systems—Continued	
Pleistocene and Pliocene Series—Continued	
Tulare Formation—Continued	
Lower sand and gravel member—Continued	
Siltstone, as above; some dark-greenish-gray slightly limy silty shale	1,209
Sandstone, slightly oil-stained, very fine to coarse-grained, very few coarse grains; free drilling. Sidewall cored at 1,213 and 1,217	1,210–1,220
Sandstone, oil-stained, very fine to fine-grained. Good porosity	1,213
Sandstone, as above	1,217
Siltstone, brownish-gray to slightly oil-stained, very finely sandy, clayey, laminated. Sidewall cored at 1,221	1,220–1,223
Shale, medium-gray to light-olive-gray. A 2-ft bed of light-olive-gray very fine to medium-grained sandstone near the top and another near the middle	1,223–1,248
Sandstone, fine- to coarse-grained, subangular, silty and clayey. Free drilling	1,248–1,252
Shale, light-olive-gray, silty	1,252–1,257
Sandstone, fine- to coarse-grained, some very coarse grains, subangular; some gray feldspar grains; trace of pyrite. Free drilling	1,257–1,270
Sandstone, as above, fewer coarse and very coarse grains. Probably interbedded with light-olive-gray very finely to finely sandy micaceous siltstone	1,270–1,280
Tertiary System:	
Pliocene Series:	
San Joaquin Formation:	
Mya sand zone:	
Shale, light-olive-gray, silty; few thin-shelled pelecypods	1,280–1,307
Siltstone, light-olive-gray, very finely to medium sandy, limy; upper half interbedded with shale as above	1,307–1,316
Shale, light-olive-gray to greenish-gray and medium-dark-gray in lower part	1,316–1,335
Shale, light-olive-gray, silty, micaceous	1,335–1,345
Shale, greenish-gray to light-olive-gray, silty to finely sandy	1,345–1,358
Sandstone, fine- to coarse-grained, subangular, free drilling	1,358–1,361
Shale, greenish-gray to light-olive-gray; few ostracods and Foraminifera	1,361–1,370
Sandstone, as above	1,370–1,372
Shale, as above; silty in part	1,372–1,400
Shale, light-olive-gray to greenish-gray; few thin-shelled pelecypods; pelecypods abundant in lower 7 ft	1,400–1,427
Siltstone, light-olive-gray, micaceous; interbedded with shale as above	1,427–1,437
Shale, as above; many pelecypod fragments may be	

	Depth (ft)
Tertiary System—Continued	
Pliocene Series—Continued	
San Joaquin Formation—Continued	
Mya sand zone—Continued	
result of caving.	1,437–1,462
Siltstone, light-olive-gray, very micaceous; scattered very fine to fine sand	1,462–1,476
Shale, as above; pelecypod fragments may be result of caving.	1,476–1,495
Siltstone, light-olive-gray, micaceous	1,495–1,503
Shale, as above; silty in part	1,503–1,525
Dolomite, pale-yellowish-brown to light-olive-gray, very fine grained, clayey, hard, almost dense	1,525–1,526
Shale, light-olive-gray, silty in lower part	1,526–1,545
Siltstone, light-olive-gray, micaceous	1,545–7,550
Shale, light-olive-gray to greenish-gray, silty in part	1,550–1,605
Dolomite, pale to moderate-yellowish-brown with dark-gray streaks, very fine grained, clayey, hard, almost dense, little pyrite	1,605–1,606
Shale, greenish-gray, silty in part	1,606–1,650
Siltstone, light-olive-gray, micaceous, probably clayey	1,650–1,657
Shale, as above	1,657–1,670
Dolomite, greenish-gray, very fine grained, clayey	1,670–1,671
Shale, greenish-gray to dark-gray	1,671–1,680
Siltstone, light-olive-gray, micaceous	1,680–1,684
Shale, greenish-gray, silty in part	1,684–1,727
Sandstone, light-gray, very fine to fine-grained, some medium and coarse grains, silty; some gray feldspar and biotite. Free drilling. Sidewall cored at 1,734	1,727–1,738
Estimated sample lag—10 ft.	
Shale, greenish-gray, silty, micaceous	1,738–1,750
Shale, greenish-gray, silty in part. May include thin beds of micaceous siltstone. Mostly lost-circulation material in 1,810–1,820 sample	1,750–1,846
Siltstone, light-olive-gray, micaceous	1,846–1,850
Shale, as above; middle part includes a 4-ft siltstone bed as above	1,850–1,870
Siltstone, light-olive-gray, very limy, micaceous, scattered fine to medium grains of sand, hard	1,870–1,876
Shale, greenish-gray, silty in part; may include thin siltstone beds	1,876–1,935
Shale, greenish-gray. Dark-gray to brown plant like fragments at about 1,950	1,935–1,967
Siltstone, light-olive-gray, micaceous, slightly limy; scattered very fine to medium sand grains may be result of caving	1,967–1,970
Shale, greenish-gray, silty	1,970–1,990
Sandstone, light-gray, very fine to medium-grained, silty, not limy	1,990–1,993
Siltstone, medium-light-gray, very finely sandy,	

	Depth (ft)
Tertiary System—Continued	
Pliocene Series—Continued	
San Joaquin Formation—Continued	
Mya sand zone—Continued	
micaceous	1,993–2,000
Shale, greenish-gray, silty in part; pelecypod fragments in lower part; a 3-ft bed of light-olive-gray micaceous siltstone 5 ft below top	2,000–2,034
Shale, light-olive-gray, medium-gray and brownish-gray, silty in part, very dolomitic in lower 4 ft; fish fragments, abundant ostracods in part	2,034–2,044
Siltstone, light-olive-gray, micaceous, very sandy in part	2,044–2,050
Shale, olive-gray to brownish-gray, silty in part; very finely to finely sandy stringers. Lower part contains abundant ostracods, fish fragments, pelecypods	2,050–2,078
Shale, greenish-gray, silty, very finely to finely sandy	2,078–2,081
Shale, brownish-gray to olive-gray; abundant ostracods	2,081–2,087
Shale, light-olive-gray to olive-gray, silty in part; few fish fragments may be result of caving	2,087–2,115
Shale, as above; slickensides	2,115–2,133
Shale, brownish-gray, silty; abundant finely divided plant fragments	2,133–2,140
Shale, light-olive-gray to olive-gray, silty	2,140–2,150
Shale, greenish-gray to olive-gray; pelecypods, fish fragments	2,150–2,160
Shale, as above; gastropods, ostracods, and fish fragments in upper part	2,160–2,180
Shale, olive-gray; ostracods. Contains one subrounded granule of gray feldspar	2,180–2,190
Shale, as above; abundant ostracods, few fish fragments, and questionable pelecypods	2,190–2,210
Shale, light-olive-gray to olive-gray	2,210–2,220
Shale, light-olive-gray, silty, very finely to finely sandy; ostracods	2,220–2,224
Siltstone, light-olive-gray, very finely to finely sandy, micaceous; abundant fine carbonaceous fragments; may include scattered medium and coarse quartz and feldspar grains	2,224–2,230
Shale, olive-gray; ostracods, questionable pelecypods	2,230–2,250
Shale, medium-gray, slight green tint; abundant pelecypod fragments, few fish fragments	2,250–2,260
Shale, greenish-gray to olive-gray, silty in part; fossil fragments (probably result of caving)	2,260–2,286
Siltstone, light-olive-gray, micaceous	2,286–2,290
Shale, greenish-gray to olive-gray, silty in part. A 3-ft siltstone bed near middle	2,290–2,372
Siltstone, light-gray to light-greenish-gray, micaceous, probably laminated to very thin bedded	2,372–2,374
Shale, greenish-gray, silty in part. Probably includes	

	Depth (ft)
Tertiary System—Continued	
Pliocene Series—Continued	
San Joaquin Formation—Continued	
Mya sand zone—Continued	
siltstone beds as above	2,374–2,417
Siltstone, light-olive-gray to light-gray, very finely sandy in part, micaceous	2,417–2,426
Shale, as above	2,426–2,437
Dolomite, olive-gray, very fine grained, clayey, almost dense	2,437–2,439
Shale, olive-gray to greenish-gray. Probably includes thin beds of siltstone in middle part. Fossils (gastropods, pelecypods and fish fragments) in shale which may have caved from above	2,439–2,477
Sandstone, light-olive-gray, very fine to fine-grained, very silty, limy, micaceous; low porosity	2,477–2,480
Siltstone, light-olive-gray to greenish-gray, micaceous	2,480–2,487
Shale, light-olive-gray, silty stringers; pelecypods, fish fragments in lower part may be the result of caving	2,487–2,518
Siltstone, light-olive-gray, micaceous	2,518–2,520
Shale, light-olive-gray to greenish-gray, silty in part	2,520–2,540
Shale, medium-gray, slight greenish tint; abundant pelecypods, ostracods	2,540–2,545
Shale, greenish-gray to light-olive-gray; abundant Foraminifera	2,545–2,555
Shale, olive-gray, silty in part	2,555–2,567
Scalez sand zone:	
Shale, greenish-gray to medium-gray; abundant pelecypods	2,567–2,575
Shale, olive-gray to greenish-gray, silty in part	2,575–2,590
Shale, light-olive-gray, slightly dolomitic in part	2,590–2,600
Shale, light-olive-gray, very silty; few fine to coarse sand grains	2,600–2,604
Shale, medium-gray, slight greenish tint; abundant pelecypods; ostracods (may be result of caving)	2,604–2,614
Shale, light-olive-gray to greenish-gray, silty in part. Fossils, as above, may have caved	2,614–2,656
Siltstone, medium-light-gray, micaceous	2,656–2,660
Shale, as above; pelecypods	2,660–2,680
Shale, olive-gray; questionable pelecypods	2,680–2,688
Siltstone, medium-light-gray to light-olive-gray, very finely sandy in part, micaceous; pyrite	2,688–2,693
Shale, light-olive-gray, silty in part	2,693–2,705
Shale, as above; pelecypods, very small gastropods, few Foraminifera	2,705–2,720
Shale, as above; pelecypods, ostracods	2,720–2,755
Shale, light-olive-gray to greenish-gray, silty in part. Fossils, as above, may have caved	2,755–2,800
Shale, as above; ostracods, pelecypods, Foraminifera (may have caved)	2,800–2,820

	Depth (ft)
Tertiary System—Continued	
Pliocene Series—Continued	
Etchegoin Formation:	
Carman Sandstone Member:	
Mulinia sand zone:	
Shale, as above	2,820–2,830
Shale, light-olive-gray; few gray high-spired gastropods, pelecypods	2,830–2,845
Shale, as above, silty; pelecypods, ostracods, few gastropods. Probably interbedded with light-olive-gray siltstone	2,845–2,877
Sandstone, light-olive-gray, very fine to fine-grained, scattered medium grains, subangular, silty, slightly limy, friable; many black subrounded grains; many pelecypod fragments. Sidewall cored at 2,879	2,877–2,882
Shale, light-olive-gray, silty in part; pelecypods, gastropods, few Foraminifera. Samples include much fine to coarse loose sand	2,882–2,900
Shale, greenish-gray; abundant ostracods in part, pelecypods, few Foraminifera	2,900–2,910
Shale, greenish-gray to light-olive-gray; interbedded with greenish-gray to medium-light-gray siltstone in middle part	2,910–2,950
Sandstone, light-olive-gray, very fine grained, very clayey and silty; many black grains; oil odor. Sidewall cored at 2,951	2,950–2,952
Shale, greenish-gray; abundant pelecypods in part; few thin beds of very fine to fine-grained sandstone. Sidewall cored at 2,958	2,952–2,958
Siltstone, oil-stained, very finely sandy, clayey in part; few pelecypod fragments	2,958–2,962
Shale, greenish-gray, very finely to medium sandy; abundant pelecypods	2,962–2,972
Siltstone, greenish-gray to medium-light-gray	2,972–2,975
Shale, greenish-gray, silty in part; abundant pelecypod fragments (may have caved)	2,975–3,014
Wilhelm sand zone:	
Siltstone, greenish-gray, very finely sandy in part	3,014–3,030
Sandstone, light-olive-gray, fine- to medium-grained, very clayey and silty; low porosity. Sidewall cored at 3,031	3,030–3,034
Siltstone, light-olive-gray; interbedded with greenish-gray to light-olive-gray silty shale. Probably includes thin beds of light-olive-gray very fine to fine-grained silty limy sandstone with low porosity	3,034–3,080
Siltstone, medium-light-gray to light-olive-gray, very finely sandy, micaceous	3,080–3,084
Shale, greenish-gray to light-olive-gray, silty in part; few gastropods, pelecypods (may have caved)	3,084–3,109
Siltstone, light-olive-gray, very finely sandy in part; interbedded with light-olive-gray very fine grained	

	Depth (ft)
Tertiary System—Continued	
Pliocene Series—Continued	
Etchegoin Formation—Continued	
Carman Sandstone Member—Continued	
Wilhelm sand zone—Continued	
silty sandstone	3,109–3,132
Shale, greenish-gray, silty in part	3,132–3,145
Sandstone, fine- to medium-grained. Free drilling	3,145–3,148
Shale, as above	3,148–3,150
Sandstone, light-olive-gray, fine- to medium-grained, green "clay" grains common, fairly clayey; fairly good porosity; some oil odor. Sidewall cored at 3,155	3,150–3,160
Shale, light-olive-gray to greenish-gray, silty in part. Probably includes thin siltstone beds. Samples are mostly loose very fine to medium sand	3,160–3,206
Siltstone, medium-light-gray to light-olive-gray, very finely sandy in part	3,206–3,212
Shale, as above	3,212–3,220
Siltstone, as above	3,220–3,227
Shale, as above	3,227–3,233
Siltstone, as above	3,233–3,237
Shale, as above	3,237–3,248
Siltstone, as above	3,248–3,253
Shale, olive-gray	3,253–3,267
Siltstone, as above	3,267–3,270
Sandstone, light-olive-gray, very fine to fine-grained, silty, free drilling	3,270–3,277
Siltstone, light-olive-gray, very finely sandy	3,277–3,289
Shale, light-olive-gray, silty	3,289–3,310
Shale, light-olive-gray to greenish-gray, partly silty in lower half	3,310–3,356
Gusher sand zone:	
Shale, as above, silty	3,356–3,367
Siltstone, medium-light-gray, very finely sandy	3,367–3,370
Shale, as above	3,370–3,422
Siltstone, light-olive-gray, very finely to finely sandy	3,422–3,430
Shale, as above	3,430–3,436
Siltstone, as above	3,436–3,460
Shale, as above	3,460–3,464
Siltstone, light-olive-gray, very finely to medium sandy, about 50 percent sand; scattered dark-green "clay" grains. Sidewall cored at 3,467	3,464–3,468
Sandstone, light-gray, very fine to medium-grained, very silty; low porosity. Sidewall cored at 3,469	3,468–3,470
Electrical-log interpretation. No samples from 3,500 to 3,585. Bottom of 9⅝″ casing at 3,495	3,470–3,565
Estimated sample lag—about 20–30 ft.	
Sandstone, as above	3,470–3,472
Siltstone, as above	3,472–3,477
Shale, as above; thin siltstone bed near top	3,477–3,494
Siltstone, as above	3,494–3,503
Shale, as above	3,503–3,517
Siltstone, as above	3,517–3,522

Tertiary System—Continued
Pliocene Series—Continued
Etchegoin Formation—Continued
Carman Sandstone Member—Continued
Gusher sand zone—Continued

	Depth (ft)
Shale, as above	3,522–3,530
Siltstone, as above	3,530–3,540
Shale, as above	3,540–3,565
Siltstone, light-olive-gray, very finely sandy, micaceous	3,565–3,568
Sandstone, light-olive-gray, very fine to fine-grained, very silty, limy, micaceous	3,568–3,570
Siltstone, as above	3,570–3,580
Shale, light-olive-gray, silty	3,580–3,596
Siltstone, as above	3,596–3,599
Sandstone, fine- to coarse-grained, subangular, probably very silty and soft, micaceous, feldspar fragments; free drilling	3,599–3,607
Siltstone, light-olive-gray, very finely to medium sandy	3,607–3,610
Shale, light-olive-gray, silty; few very fine to medium sand grains	3,610–3,617
Siltstone, as above	3,617–3,620
Shale, light-olive-gray, silty	3,620–3,649
Dolomite, yellowish-gray to light-olive-gray, very fine grained, silty, clayey, hard	3,649–3,650
Shale, as above	3,650–3,657
Siltstone, light-olive-gray, very finely to finely sandy	3,657–3,660
Sandstone, light-olive-gray, very fine to medium-grained, very silty; pelecypod fragments	3,660–3,663
Shale, light-olive-gray to greenish-gray, silty	3,663–3,675
Siltstone, light-olive-gray, very finely to finely sandy	3,675–3,694
Sandstone, fine- to medium-grained, probably very silty and soft; abundant dark-gray to black grains, feldspar, mica. A 2-ft siltstone bed in middle. Free drilling	3,694–3,705
Shale, olive-gray, silty to finely sandy	3,705–3,715
Sandstone, very fine to medium-grained, probably very silty and soft; feldspar, mica. Free drilling	3,715–3,724
Shale, olive-gray, silty to finely sandy	3,724–3,735
Sandstone, fine- to medium-grained, some coarse grains, subangular, probably very silty in part; some feldspar and mica. Free drilling	3,735–3,757
Shale, olive-gray, silty	3,757–3,763
Siltstone, light-olive-gray, very finely to medium sandy	3,763–3,770
Shale, light-olive-gray, silty to finely sandy	3,770–3,797
Sandstone, light-gray, fine-grained, clayey, limy to dolomitic	3,797–3,800
Shale, as above	3,800–3,832
Siltstone, light-olive-gray, very finely to finely sandy	3,832–3,840
Shale, light-olive-gray, silty to finely sandy	3,840–3,873

	Depth (ft)
Tertiary System—Continued	
Pliocene Series—Continued	
Etchegoin Formation—Continued	
Carman Sandstone Member—Continued	
Calitroleum sand zone:	
Sandstone, fine- to medium-grained, scattered coarse grains, probably silty to clayey; few tight limy to dolomitic beds; pelecypod fragments. Mostly free drilling	3,873–3,886
Siltstone, light-olive-gray, very finely to finely sandy	3,886–3,893
Shale, light-olive-gray, silty	3,893–3,896
Sandstone, as above	3,896–3,900
Siltstone, as above; pelecypod fragments	3,900–3,906
Sandstone, as above; pelecypod fragments	3,906–3,910
Siltstone, light-olive-gray, very finely to finely sandy; pelecypod fragments	3,910–3,925
Sandstone, as above; pelecypod fragments	3,925–3,940
Sandstone, medium-light-gray to light-olive-gray, very fine to fine-grained, silty, dolomitic, tight	3,940–3,944
Siltstone, light-olive-gray, very finely to finely sandy in part, dolomitic in part	3,944–3,953
Sandstone, light-olive-gray, very fine to fine-grained, very silty; interbedded with light-olive-gray sandy siltstone. Mostly free drilling	3,953–3,966
Siltstone and sandstone, as above; pelecypod fragments	3,966–4,003
Shale, olive-gray to medium-gray, silty	4,003–4,035
Sandstone, light-olive-gray, very fine to fine-grained, very silty. Dolomitic to limy and hard and tight in lower 4 ft; many pelecypod fragments. Mostly free drilling.	4,035–4,048
Siltstone, light-olive-gray, very finely to finely sandy in part	4,048–4,066
Sandstone, medium-light-gray, very fine to fine-grained, silty, limy, tight	4,066–4,070
Siltstone, as above	4,070–4,074
Sandstone, light-olive-gray, very fine to fine-grained, very silty	4,074–4,078
Siltstone, as above	4,078–4,085
Sandstone, light-olive-gray, very fine to fine-grained, silty, limy; pelecypod fragments; low porosity	4,085–4,088
Siltstone, as above	4,088–4,097
Sandstone, as above	4,097–4,100
Shale, light-olive-gray, silty; pelecypods	4,100–4,106
Siltstone, light-olive-gray, dolomitic	4,106–4,110
Tupman Shale Member:	
Buliminella silt zone:	
Shale, light-olive-gray to medium-gray, silty in part; pelecypods, few Foraminifera, and ostracods	4,110–4,130
Dolomite, yellowish-gray to light-olive-gray, very fine grained, very silty	4,130–4,131
Shale, as above; Foraminifera	4,131–4,155
Siltstone, medium-light-gray, very finely to finely	

	Depth (ft)
Tertiary System—Continued	
Pliocene Series—Continued	
Etchegoin Formation—Continued	
Tupman Shale Member—Continued	
Buliminella silt zone—Continued	
sandy in part, dolomitic in part. Probably includes thin beds of very fine to fine-grained silty friable sandstone with many black rounded grains	4,155–4,172
Shale, medium-gray, slight greenish tint, silty in part	4,172–4,192
Siltstone, medium-light-gray	4,192–4,198
Dolomite, medium-light-gray, very fine grained, clayey to silty	4,198–4,200
Shale, greenish-gray, silty	4,200–4,227
Shale, medium-gray to greenish-gray, silty in part; few pelecypods	4,227–4,257
Siltstone, yellowish-gray, very finely sandy, dolomitic	4,257–4,260
Shale, greenish-gray	4,260–4,264
Siltstone, light-olive-gray, very finely sandy	4,264–4,268
Shale, greenish-gray to medium-gray, silty	4,268–4,280
Sandstone, medium-light-gray, very fine to fine-grained, silty, limy; pelecypods	4,280–4,283
Shale, greenish-gray, silty; pelecypods, few Foraminifera	4,283–4,290
Dolomite, pale-yellowish-brown, very fine grained, silty to clayey, hard, tight	4,290–4,292
Shale, medium-gray	4,292–4,300
Shale, greenish-gray to medium-gray, silty	4,300–4,327
Sandstone, light-olive-gray to medium-light-gray, very fine to fine-grained, silty, limy, micaceous; low porosity	4,327–4,330
Shale, greenish-gray, silty in part	4,330–4,357
Siltstone, light-olive-gray, very finely to finely sandy; pelecypods. Interbedded with shale as above	4,357–4,375
Siltstone, as above; interbedded with medium-gray silty shale. Samples include loose sand and black grains that may be sporbo	4,375–4,397
Siltstone, light-olive-gray, very finely to finely sandy	4,397–4,408
Shale, medium-gray, silty	4,408–4,420
Siltstone, light-olive-gray, very finely to finely sandy; black rounded grains as above	4,420–4,430
Shale, greenish-gray, silty	4,430–4,439
Dolomite, medium-light-gray, very fine grained, silty to clayey; common black phosphatic-looking grains that may be sporbo	4,439–4,440
Sandstone, medium-gray, very fine grained, silty; abundant black grains	4,440–4,443
Shale, olive-gray, silty	4,443–4,454
Siltstone, light-olive-gray, very finely to finely sandy	4,454–4,467
Shale, olive-gray, silty	4,467–4,472
Siltstone, medium-gray to olive-gray, very finely to finely sandy; some black rounded grains	4,472–4,480

Tertiary System—Continued
Pliocene Series—Continued
Etchegoin Formation—Continued
Tupman Shale Member—Continued
Buliminella silt zone—Continued

	Depth (ft)
Shale, olive-gray to dark-greenish-gray, silty to sandy	4,480–4,499
Sandstone, very fine to fine-grained, probably silty and clayey. Free drilling. May be caving	4,999–4,502
Shale, olive-gray, silty	4,502–4,508
Dolomite, pale-yellowish-brown, very fine grained, silty to clayey, hard, siliceous-looking in part	4,508–4,510
Shale, olive-gray, silty to finely sandy	4,510–4,527
Shale, olive-gray to medium-dark-gray, silty; probably interbedded with olive-gray sandy siltstone	4,527–4,556
Siltstone, light-olive-gray, very finely to finely sandy in part	4,556–4,564
Shale, greenish-gray	4,564–4,567
Siltstone, medium-gray, very finely to finely sandy	4,567–4,572
Shale, medium-gray, slight greenish tint, silty	4,572–4,584
Shale, olive-gray, silty to finely sandy	4,584–4,610
Siltstone, medium-gray, very finely to finely sandy	4,610–4,614
Shale, as above	4,614–4,630
Siltstone, light-olive-gray to medium-gray, very finely sandy, limy in part; questionable pelecypods	4,630–4,634
Dolomite, medium-light-gray, very fine grained, very clayey, silty, hard, tight	4,634–4,636
Shale, olive-gray, silty to sandy	4,636–4,661
Sandstone, olive-gray, very fine to fine-grained, silty, probably siliceous cement, hard, tight; scattered dark grains	4,661–4,663
Shale, medium-dark-gray, slight greenish tint, silty	4,663–4,670
Sandstone, medium-light-gray, very fine to medium-grained, probably very silty; many black rounded grains. Free drilling	4,670–4,673
Shale, olive-gray, silty to sandy. A 1-ft sandstone bed as above at 4,689	4,673–4,724
Sandstone, medium-gray, fine- to medium-grained, silty, clayey; many dark-gray to black rounded phosphatic-like grains; low porosity	4,724–4,730
Shale, olive-gray, silty, sandy	4,730–4,738
Dolomite, medium-light-gray to yellowish-gray, very fine grained, clayey, partly sandy; abundant black phosphaticlike grains in part	4,738–4,741
Shale, medium-dark-gray	4,741–4,752
Sandstone, medium-gray, very fine to fine-grained, silty, clayey; abundant black rounded phosphatic-like grains	4,752–4,762
Shale, olive-gray, silty to sandy	4,762–4,770
Dolomite, pale-yellowish-brown, very fine grained, clayey; abundant black fine to medium rounded	

	Depth (ft)
Tertiary System—Continued	
Pliocene Series—Continued	
Etchegoin Formation—Continued	
Tupman Shale Member—Continued	
Buliminella silt zone—Continued	
phosphaticlike grains. May be caving	4,770–4,772
Shale, olive-gray, silty	4,772–4,780
Electrical-log interpretation; no samples from 4,805 to 4,895	4,780–4,870
Estimated sample lag—25 ft.	
Shale, as above	4,780–4,810
Sandstone, as above	4,810–4,814
Shale, as above	4,814–4,870
Shale, medium-dark-gray, slight olive-gray tint, silty in part; abundant black rounded phosphaticlike grains in part	4,870–4,890
Shale, olive-gray, silty	4,890–4,900
Electrical-log interpretation; no samples from 4,925 to 4,965	4,900–4,940
Estimated sample lag—25 ft.	
Shale, as above	4,900–4,940
Shale, medium-dark-gray to olive-gray, slight brownish tint in part, silty in part, finely sandy with sporbo in part	4,940–4,960
Shale, medium-dark-gray, slight green and brown tints in part, silty in part	4,960–5,015
Shale, olive-gray to greenish-gray, silty in part	5,015–5,040
Shale, medium-gray to medium-dark gray and olive-gray, silty in part	5,040–5,070
Dolomite, pale-yellowish-brown, very fine grained, very clayey, hard, dense; subconchoidal fracture May be caving	5,070–5,072
Shale, greenish-gray, silty. May be caving	5,072–5,080
Shale, medium-dark-gray to olive-gray, silty	5,080–5,135
Shale, olive-gray, brownish tint, harder than above, probably siliceous	5,135–5,180
Shale, olive-gray, slight brownish tint, silty; thin beds and lenses of olive-gray sandy siltstone and silty very fine to fine-grained sandstone	5,180–5,200
Shale, olive-gray, brownish tint, probably siliceous	5,200–5,210
Siltstone, olive-gray, very finely to finely sandy, tight	5,210–5,212
Shale, olive-gray; thin beds and lenses of olive-gray siltstone	5,212–5,228
Sandstone, light-olive-gray to medium-gray, very fine to fine-grained, silty, tight, probably siliceous	5,228–5,230
Shale, medium-dark-gray	5,230–5,233
Olig sand zone:	
Olig sand 5,233–5,300:	
Sandstone, medium-light-gray to light-olive-gray, very fine to fine-grained, silty, probably siliceous	5,233–5,235
Shale, olive-gray	5,235–5,237
Sandstone, light-gray to yellowish-gray, fine- to	

	Depth (ft)
Tertiary System—Continued	
Pliocene Series—Continued	
Etchegoin Formation—Continued	
Tupman Shale Member—Continued	
Olig sand zone—Continued	
Olig sand—Continued	
coarse-grained, some very coarse grains and granules, micaceous, dolomitic, some gray subrounded feldspar grains; little visible porosity	5,237–5,244
Estimated sample lag—20 ft.	
Shale, olive-gray	5,244–5,247
Sandstone, as above; somewhat coarser, more free drilling; probably better porosity than above	5,247–5,260
Sandstone, light-gray to yellowish-gray, fine- to coarse-grained, some very coarse grains and granules of quartz and feldspar, silty, white clay cement, not dolomitic, fair porosity	5,260–5,280
Shale, olive-gray, silty to finely sandy	5,280–5,286
Sandstone, light- to medium-gray, fine- to coarse-grained, very coarse grains and granules as above, dolomitic in part; little visible porosity	5,286–5,300
Shale, olive-gray, greenish tint in party, silty; sporbo in part	5,300–5,310
Shale, olive-gray to brownish-gray, siliceous, hard	5,310–5,339
Dolomite, pale-yellowish-brown to light-olive-gray, very fine grained, dense, clayey, probably siliceous to cherty in part	5,339–5,340
Siltstone, light-olive-gray, clayey	5,340–5,342
Shale, olive-gray, silty	5,342–5,353
Shale, olive-gray, brownish tint, probably siliceous	5,353–5,364
Siltstone, olive-gray, very finely to finely sandy, clayey, tight; interbedded with shale as above	5,364–5,374
Shale, olive-gray, brown tint in part, silty to finely sandy. Probably includes stringers of sandy clayey siltstone	5,374–5,400
Shale, medium-dark-gray, silty	5,400–5,408
Shale, olive-gray, brownish tint, probably siliceous	5,408–5,416
Shale, brownish-gray, silty	5,416–5,429
Sandstone, medium-gray to olive-gray, very fine to fine-grained, silty, clayey, tight	5,429–5,431
Siltstone, medium-gray to olive-gray, very finely sandy, clayey, tight	5,431–5,437
Shale, dark-gray, slight brownish tint, silty to finely sandy, siliceous in part	5,437–5,450
Dolomite, brownish-gray, dense, very clayey	5,450–5,452
Shale, as above	5,452–5,454
Sandstone, medium-dark-gray, very fine to fine-grained, silty, clayey, tight	5,454–5,457
Miocene Series:	
Reef Ridge Shale:	
Shale, dark-gray, silty	5,457–5,464
Siltstone, olive-gray, scattered very fine to fine	

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Reef Ridge Shale—Continued	
sand grains	5,464–5,468
Shale, olive-gray, silty	5,468–5,505
Shale, medium-dark- to dark-gray, silty to finely sandy	5,505–5,520
Dolomite, pale- to moderate yellowish-brown, very fine grained, argillaceous	5,520–5,521
Shale, dark-gray, slight brownish tint, silty, probably siliceous	5,521–5,530
Sandstone, medium-gray, very fine to fine grained, silty, clayey, tight	5,530–5,531
Shale, olive-gray to medium-dark-gray, silty	5,531–5,570
Sandstone, medium-gray, very fine to fine-grained, silty, clayey, tight	5,570–5,572
Shale, olive-gray, silty	5,572–5,590
Shale, dark-gray, silty, very finely sandy in upper part. May have sandstone stringers in upper part	5,590–5,635
Shale, olive-gray, silty	5,635–5,650
Shale, medium-gray to olive-gray, siliceous	5,650–5,660
Shale, medium-gray, silty to finely sandy; trace of coal. Probably includes thin beds or laminae of very fine to fine-grained clayey sandstone	5,660–5,670
Shale, medium-dark- to dark-gray, slight brownish tint, silty to finely sandy; trace of coal (may be caving)	5,670–5,688
Sandstone, medium-dark-gray, very fine to fine-grained, very silty and clayey	5,688–5,690
Shale, as above	5,690–5,693
Dolomite, pale-yellowish-brown to light-olive-gray, very fine grained, very argillaceous, hard (may be caving)	5,693–5,694
Shale, olive-gray, silty	5,694–5,710
Shale, olive-gray, dark-gray streaks, may be siliceous	5,710–5,714
Shale, medium-gray, siliceous; dark-gray silty to finely sandy shale	5,714–5,718
Sandstone, olive-gray to medium-dark-gray, very fine to fine-grained, very silty, clayey; probably oil-stained in part; may be caving	5,718–5,721
Shale, medium-dark- to dark-gray, slight brownish tint, silty, very finely micaceous in lower 10 feet	5,721–5,750
Shale, medium- to medium-dark-gray, siliceous	5,750–5,770
Shale, medium-dark- to dark-gray, silty; trace of fish scales	5,770–5,780
Dolomite, moderate-yellowish-brown, very fine grained to dense, very argillaceous; may be caving	5,780–5,781
Shale, olive-gray, silty, slightly to moderately siliceous	5,781–5,805
Siltstone, olive-gray to medium-gray, very finely to finely sandy, clayey; may be caving	5,805–5,808
Shale, medium-dark-gray to olive-gray and greenish-gray, silty to very finely sandy in part	5,808–5,820
Shale, dark-gray, silty	5,820–5,830
Shale, olive-gray, silty	5,830–5,838
Shale, dark-gray, silty to finely sandy	5,838–5,847
Sandstone, medium- to dark-gray, very fine to fine-	

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Reef Ridge Shale—Continued	
grained, very clayey	5,847–5,850
Shale, dark-gray, silty. Some grayish-black shale in upper 10 feet	5,850–5,874
Dolomite, pale- to moderate-yellowish-brown, very fine grained, dense, very argillaceous; may be caving	5,874–5,875
Shale, olive-gray to medium-dark-gray, silty	5,875–5,910
Dolomite, dusky-brown to dark-gray, very fine grained, very argillaceous, hard, tight; some round microfossils	5,910–5,911
Shale, dark-gray to grayish-black and olive-gray, silty	5,911–5,925
Shale, dark-gray; trace of coal	5,925–5,930
Shale, olive-gray, slight brownish tint, silty, siliceous in part. Probably interbedded with dark-gray shale as above	5,930–5,952
Shale, medium-gray, silty, streaked with dark-gray, probably slightly to moderately siliceous	5,952–5,965
Shale, olive-gray, silty	5,965–5,970
Dolomite, pale- to moderate-yellowish-brown, very fine grained to dense, very argillaceous, hard, siliceous	5,970–5,972
Shale, olive-gray to medium-dark-gray, slight brownish tint, silty	5,972–5,982
Siltstone, brownish-gray, olive-gray tint	5,982–5,985
Shale, dark-gray to grayish-black, silty; some very finely sandy streaks in lower 25 ft.	5,985–6,035
Monterey Shale:	
Elk Hills Shale Member:	
N zone:	
Shale, dark- to dusky-yellowish-brown, silty, dark-gray siliceous streaks	6,035–6,045
Estimated sample lag—25 ft.	
Siltstone, medium-gray, abundant dark-gray streaks, siliceous, hard	6,045–6,050
Siltstone, diatomaceous(?), pale to moderate-yellowish-brown, fairly soft; dark-gray streaks of organic material, very finely micaceous; fish fragments	6,050–6,055
Shale, olive-gray, silty	6,055–6,060
Siltstone, as above	6,060–6,065
Shale, brownish-gray, dark-gray streaks, silty	6,065–6,070
Siltstone, diatomaceous(?), medium-light-gray to pale-yellowish-brown, dark-gray streaks, fairly soft, very finely micaceous	6,070–6,080
Siltstone, as above, but light-gray to yellowish-gray; probably interbedded with shale as above	6,080–6,105
Siltstone, light-gray to light-olive-gray, micaceous; sporbo in part; very finely sandy in part	6,105–6,109
Sandstone, light-gray, very fine to fine-grained, silty, clayey, micaceous; pelecypods, gastropods; fair porosity	6,109–6,112
Siltstone, as above	6,112–6,115
Shale, medium-gray to greenish-gray, silty, very	

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
N zone—Continued	
finely micaceous	6,115–6,120
Sandstone, medium-light-gray, very fine to fine-grained, silty, clayey, micaceous; green clay (?) grains; pelecypods	6,120–6,124
Shale, medium-light-gray, slight purplish tint, dark-gray streaks; siliceous	6,124–6,130
Siltstone, diatomaceous (?), brownish-gray to yellowish-brown, mottled in part, dark-gray streaks, moderately siliceous	6,130–6,136
Shale, diatomaceous (?), brownish-gray, silty, siliceous	6,136–6,142
Siltstone, as above	6,142–6,150
Siltstone, diatomaceous (?), very pale orange to pale-yellowish-brown, dark-gray streaks	6,150–6,154
Shale, brownish-gray to dusky-brown, dark-gray streaks, silty, siliceous; fish fragments	6,154–6,164
Siltstone, as above	6,164–6,175
Siltstone, brownish-gray, gray streaks, siliceous	6,175–6,182
Shale, brownish-gray to dusky-brown and dark-gray, silty	6,182–6,198
Siltstone, diatomaceous (?), pale-yellowish-brown, few dark-gray streaks	6,198–6,208
Shale, brownish-gray to dusky-brown and dark-gray, silty	6,208–6,215
Dolomite, brownish-gray, very fine grained to dense, hard, siliceous; much silt-size silica	6,215–6,216
Siltstone, as above	6,216–6,225
Siltstone, diatomaceous (?), brownish-gray, mottled and streaked with dark-gray, moderately siliceous	6,225–6,235
Dolomite, as above. May be caving	6,235–6,237
Siltstone, as above	6,237–6,245
Siltstone, diatomaceous (?), brownish-gray, siliceous	6,245–6,250
Siltstone, diatomaceous (?), pale-yellowish-brown	6,250–6,258
Dolomite, pale-yellowish-brown, very fine grained, argillaceous	6,258–6,262
Siltstone, diatomaceous (?), brownish-gray to dark-gray, moderately siliceous	6,262–6,272
Siltstone, diatomaceous (?), pale-yellowish-brown	6,272–6,288
Shale, dark-gray to dark-brownish-gray, silty, moderate siliceous	6,288–6,300
Siltstone, diatomaceous (?), pale-yellowish-brown	6,300–6,307
Sandstone, medium-gray to greenish-gray, very fine to fine-grained, clayey, silty, micaceous; pelecypod fragments. May be caving	6,307–6,311
Siltstone, diatomaceous (?), brownish-gray, siliceous	6,311-6,320
Siltstone, diatomaceous (?), pale-yellowish-brown	6,320-6,330
Siltstone, diatomaceous (?), brownish-gray, siliceous	6,330–6,340

Tertiary System—Continued
Miocene Series—Continued
Monterey Shale—Continued
Elk Hills Shale Member—Continued
N zone—Continued

	Depth (ft)
Shale, dusky-yellowish-brown, silty	6,340–6,345
Sandstone, medium-dark-gray, very fine to medium-grained, clayey, very micaceous; may be oil-stained	6,345–6,350
Sandstone, medium-light-gray, very fine to medium-grained, scattered coarse and very coarse grains, subangular, micaceous, dolomitic, silty; feldspar grains, scattered black grains; little visible porosity	6,350–6,352
Siltstone, diatomaceous(?), brownish-gray, siliceous	6,352–6,359
Shale, medium-dark-gray to brownish-gray, silty, moderately siliceous	6,359–6,366
Sandstone, medium-light-gray, very fine to fine-grained, scattered medium grains, silty; fair porosity	6,366–6,370
Sandstone, greenish-gray, very fine to fine-grained, silty; pelecypod fragments	6,370–6,374
Siltstone, diatomaceous(?), brownish-gray to pale-yellowish-brown, moderately siliceous	6,374–6,390
Siltstone, medium-dark-gray, slight brownish tint, very hard, siliceous, dolomitic; "grainy" fracture	6,390–6,392
Siltstone, diatomaceous(?), brownish-gray, moderately siliceous	6,392–6,403
Shale, brownish-gray to medium-dark-gray, silty, moderately siliceous in part; interbedded with brownish-gray moderately siliceous diatomaceous(?) siltstone	6,403–6,447
Siltstone, diatomaceous(?), pale-to-moderate-yellowish-brown	6,447–6,456
Shale, brownish-gray to dusky-brown, silty	6,456–6,462
Siltstone, diatomaceous(?), brownish-gray, moderately siliceous	6,462–6,469
Shale, as above	6,469–6,473
Siltstone, as above	6,473–6,480
Shale, medium-dark-gray, silty to very finely sandy	6,480–6,485
Siltstone, diatomaceous(?), brownish-gray, moderately siliceous	6,485–6,493
Sandstone, medium- to medium-dark-gray, fine- to medium-grained, subangular, micaceous; siliceous cement, mostly hard and tight; oil-stained in part	6,493–6,496
Shale, medium-dark-gray, silty, siliceous	6,496–6,500
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, moderately siliceous	6,500–6,508
Sandstone, medium-light-gray, very fine grained, silty, clayey; pelecypod fragments. May be caving	6,508–6,510
Siltstone, medium-dark-gray, dolomitic, hard, tight; few pelecypod fragments	6,510–6,512
Shale, medium-dark-gray, silty, siliceous	6,512–6,517
Siltstone, diatomaceous(?), pale-yellowish-brown; gilsonite(?) vein	6,517–6,523

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
N zone—Continued	
Siltstone, diatomaceous(?), brownish-gray, siliceous	6,523–6,530
Chert, dusky-brown to brownish-black, dense	6,530–6,533
Siltstone, diatomaceous(?), dark-gray to dusky-brown, very siliceous, finely sandy in lower part	6,533–6,544
Siltstone, diatomaceous(?), brownish-gray, dark-gray streaks and films, siliceous	6,544–6,554
Shale, dark-gray, silty, siliceous	6,544–6,560
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, abundant dark-gray streaks and films in part, very finely to finely sandy in upper half, very siliceous in part	6,560–6,580
Siltstone, diatomaceous(?), pale-yellowish-brown, moderately siliceous in part	6,580–6,607
Siltstone, diatomaceous(?), brownish-gray to dark-gray, very siliceous	6,607–6,612
Siltstone, diatomaceous(?), pale-yellowish-brown, dark-gray streaks and films, siliceous and tight in part	6,612–6,628
Dolomite, pale-yellowish-brown to brownish-gray, very fine grained to dense, argillaceous in part, siliceous in part; scattered pinpoint porosity	6,628–6,630
Shale, dark-gray, silty	6,630–6,637
Sandstone, medium-gray, very fine to fine-grained, silty, clayey, micaceous; scattered dark-gray to black rounded grains	6,637–6,641
Shale, dark-gray, silty, sandy in part	6,641–6,650
Shale, dusky-brown, silty	6,650–6,660
Shale, olive-gray, dark-gray, and dusky-brown, silty	6,660–6,680
Sandstone, medium-dark-gray to brownish-gray, very fine to medium-grained, siliceous, hard; low porosity; may be oil-stained; (may have caved from 6,495)	6,680–6,683
Shale, dark-gray, silty	6,683–6,688
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray. May be caving. A 2-ft. shale bed 4 ft. below top	6,688–6,701
Shale, dark-gray to dusky-brown, silty to finely sandy in part	6,701–6,708
Sandstone, gray, very fine to fine-grained, clayey	6,708–6,711
Shale, medium-dark-gray, silty	6,711–6,718
Siltstone, diatomaceous(?), brownish-gray to dusky-brown	6,718-6,724
Shale, as above	6,724–6,727
Sandstone, medium-gray, fine- to medium-grained, subangular; abundant pyrite; hard, tight	6,727–6,730
Siltstone, diatomaceous(?), brownish-gray, moderately siliceous; probably interbedded with medium-dark-gray moderately siliceous shale	6,730–6,745

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
A zone:	
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, moderately siliceous; interbedded with medium-dark-gray to brownish-gray moderately siliceous silty shale	6,745–6,766
Sandstone, light-gray, very fine to fine-grained, silty, slightly dolomitic; fairly porous	6,766–6,770
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous	6,770–6,774
Shale, medium-dark- to dark-gray	6,774–6,778
Dolomite, pale-yellowish-brown, dense, argillaceous to siliceous; some pyrite	6,778–6,780
Siltstone, diatomaceous(?), brownish-gray to dusky-brown and dark-gray, siliceous; dusky-brown chert	6,780–6,787
Shale, dark-gray, siliceous, silty	6,787–6,790
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous	6,790–6,796
Shale, dark-gray, siliceous	6,796–6,802
Siltstone, as above; chert as above (may be caving)	6,802–6,810
Shale, medium-dark-gray to brownish-gray, silty	6,810–6,818
Dolomite, pale-yellowish-brown to brownish-gray, dense, argillaceous to very siliceous; trace of pinpoint porosity; quartz fracture fillings	6,818–6,820
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous, sandy in lower 5 ft. A 3-ft. gray shale bed 3 ft. below top	6,820–6,840
Shale, diatomaceous(?), dusky-brown and dark-gray, laminated, siliceous, silty	6,840–6,847
Sandstone, light-gray, very fine grained, diatomaceous(?) in part, slightly micaceous; low porosity	6,847–6,850
Siltstone, diatomaceous(?), brownish-gray, dusky-brown, and medium-dark-gray, siliceous. Probably includes stringers of light-gray very fine grained sandstone	6,850–6,865
Shale, dark-gray, silty, siliceous	6,865–6,873
Siltstone, as above	6,873–6,880
Shale, as above	6,880–6,883
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous	6,883–6,893
Shale, dark-gray, silty	6,893–6,896
Siltstone, as above	6,896–6,905
Shale, brownish-gray to dark-gray, siliceous, silty	6,905–6,913
Siltstone, as above; fracture fillings of calcite and pyrite	6,913–6,917
Shale, as above; may contain a few microfossils	6,917–6,930
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, siliceous	6,930–6,940
Sandstone, brownish-gray, very fine grained, silty,	

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
A zone—Continued	
siliceous, micaceous, tight	6,940–6,941
Shale, medium-dark-gray, silty	6,941–6,945
Dolomite, pale-yellowish-brown to brownish-gray, dense to very fine grained, argillaceous, hard, tight	6,945–6,947
Shale, brownish-gray to dark-gray, silty, siliceous	6,947–6,955
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray in lower part, siliceous, slightly dolomitic in part	6,955–6,982
Shale, brownish-gray, silty, siliceous	6,982–6,988
Dolomite, as above	6,988–6,989
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous, dolomitic in part	6,989–7,000
Shale, diatomaceous(?), medium-dark to dark-gray and dusky-brown, silty, siliceous	7,000–7,010
Siltstone, as above	7,010–7,020
Shale, medium-dark-gray, silty	7,020–7,026
Siltstone, diatomaceous(?), pale-yellowish-brown, moderately siliceous	7,026–7,030
Shale, medium-gray, silty, fairly soft	7,030–7,038
Siltstone, as above	7,038–7,044
Shale, as above	7,044–7,050
Sandstone, medium-light-gray, very fine grained, silty; low porosity	7,050–7,052
Shale, as above	7,052–7,060
B zone:	
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous; includes dusky-brown dense vitreous chert (may be caving)	7,060–7,074
Shale, brownish-gray to dusky-brown, silty, siliceous to very siliceous	7,074–7,086
Siltstone, as above. May include some medium-light-gray very fine grained silty sandstone (probably caved from 7,050)	7,086–7,095
Shale, brownish-gray, olive-gray, and medium-dark-gray, silty, siliceous in part	7,095–7,110
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, dark-gray films, siliceous, slightly dolomitic in part; microfossils	7,110–7,123
Sandstone, light-gray, very fine to fine-grained, subangular, silty, very micaceous, slightly dolomitic; fair porosity	7,123–7,132
Estimated sample lag—40 ft.	
Shale, medium-dark- to dark-gray, silty, moderately siliceous	7,132–7,140
Siltstone, as above; interbedded with shale as above	7,140–7,155
Shale, yellowish-gray to brownish-gray, siliceous, slightly dolomitic	7,155–7,160
Siltstone, diatomaceous(?), pale-yellowish-brown	

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
B zone—Continued	
to brownish-gray, dark-gray films, siliceous. Probably interbedded with dark-gray to brownish-gray siliceous silty shale	7,160–7,175
Dolomite, pale-yellowish-brown to brownish-gray, dense to very fine grained, argillaceous to siliceous; may be caving	7,175–7,177
Shale, medium-dark-gray, silty	7,177–7,182
Siltstone, as above	7,182–7,190
Shale, as above. May include near the top a 1-ft bed of brownish-gray very fine grained argillaceous dolomite	7,190–7,200
Sandstone, medium-dark-gray, very fine to fine-grained, silty, slightly dolomitic; low porosity	7,200–7,204
Sandstone, light- to medium-gray, very fine to fine-grained, silty, micaceous; fair porosity; may have some oil-stain	7,204–7,209
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, siliceous	7,209–7,222
Shale, medium-dark- to dark-gray and dusky-brown, silty, partly siliceous	7,222–7,236
Siltstone, diatomaceaus(?), medium-light-gray to brownish-gray, siliceous; includes white clay grains and stringers	7,236–7,243
Shale, as above	7,243–7,260
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, siliceous; interbedded with shale as above	7,260–7,277
Sandstone, light-gray, very fine to fine-grained, silty, micaceous, slightly dolomitic. May be caving	7,277–7,279
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, some dark-gray films and stringers, siliceous. A 2-ft brownish-gray silty shale bed near top	7,279–7,295
Shale, dark-gray, silty, moderately siliceous	7,295–7,298
Siltstone, as above	7,298–7,305
Shale, medium-dark- to dark-gray and olive-gray, silty to sandy, micaceous, siliceous	7,305–7,314
Sandstone, medium-dark-gray, very fine to fine-grained, silty to very clayey; some light-gray very fine grained silty micaceous sandstone	7,314–7,318
Shale, medium-dark-gray, slight brownish tint, silty, siliceous	7,318–7,328
Siltstone, medium-dark- to dark-gray, very finely to finely sandy, siliceous, hard, tight	7,328–7,336
Shale, as above	7,336–7,342
Siltstone, diatomaceous(?), brownish-gray, siliceous	7,342–7,346
Shale, as above	7,346–7,349
Dolomite, brownish-gray, very fine grained, very	

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
B zone—Continued	
argillaceous, hard, tight. May be caving	7,349–7,351
Shale, as above	7,351–7,356
Siltstone, medium-light- to medium-gray, very finely sandy, siliceous, hard, tight	7,356–7,360
Shale, brownish-gray, silty, siliceous	7,360–7,367
Siltstone, as above	7,367–7,373
Shale, medium-dark- to dark-gray, silty, moderately siliceous	7,373–7,386
Sandstone, light-gray, very fine to fine-grained, silty; some mica and dark grains; fair porosity. Some greenish-gray very fine to fine-grained clayey sandstone	7,386–7,390
Siltstone, greenish-gray, very finely to finely sandy, micaceous	7,390–7,394
Shale, as above	7,394–7,400
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous; few very fine and fine sand grains	7,400–7,407
Sandstone, greenish-gray to medium-gray, very fine to fine-grained, very clayey; common black phosphaticlike grains (probably sporbo)	7,407–7,409
Shale, medium-dark- to dark-gray, silty	7,409–7,417
Shale, diatomaceous(?), brownish-gray, silty. Probably includes stringers of pale-yellowish-brown diatomaceous(?) siltstone	7,417–7,429
Siltstone, brownish-gray to medium-dark-gray, very finely to finely sandy, siliceous	7,429–7,432
Sandstone, light-gray, very fine grained, silty; scattered dark-gray grains; fairly good porosity	7,432–7,436
Sandstone, medium-gray, very fine grained, silty, siliceous, tight	7,436–7,439
C zone:	
Shale, medium-dark- to dark-gray and brownish-gray, silty	7,439–7,448
Dolomite, brownish-gray to dusky-brown, light-gray streaks in part, very fine grained, argillaceous, hard, tight; crystalline fillings in fractures or vugs	7,448–7,450
Shale, as above	7,450–7,460
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish- gray, siliceous, slightly dolomitic in part	7,460–7,467
Shale, dark-gray, silty, siliceous	7,467–7,473
Siltstone, diatomaceous(?), brownish-gray, siliceous	7,473–7,480
Shale, dark-brownish-gray, silty, siliceous	7,480–7,493
Shale, dark-gray to grayish-black, silty, very micaceous, siliceous	7,493–7,500
Shale, dark-brownish-gray to dark-gray, silty, siliceous in part	7,500–7,510
Sandstone, medium-light-gray, very fine grained, silty; low porosity	7,510–7,511

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
C zone—Continued	
Shale, dark-brownish-gray to dark-gray, silty, partly siliceous in lower 10 ft	7,511–7,540
Sandstone, as above. May be caving	7,540–7,542
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, siliceous; some very fine and fine sand grains	7,542–7,547
Shale, dusky-brown to dark-gray in lower part, silty, siliceous	7,547–7,560
Sandstone, medium-gray, very fine grained, silty, siliceous, slightly dolomitic, tight; may be caving	7,560–7,562
Siltstone, diatomaceous(?), brownish-gray, siliceous	7,562–7,567
Shale, as above	7,567–7,570
Sandstone, as above	7,570–7,572
Shale, medium-dark- to dark-gray, silty	7,572–7,588
Sandstone, as above; may be caving	7,588–7,590
Siltstone, diatomaceous(?), brownish-gray, siliceous	7,590–7,594
Shale, dark-brownish-gray to dark-gray in lower part, silty, moderately siliceous in part	7,594–7,613
Shale, dark-brownish-gray to medium-dark-gray in lower part, silty, siliceous in part. Probably includes a few thin brownish-gray siliceous diatomaceous(?) siltstone beds	7,613–7,662
Dolomite, dusky-brown to pale-yellowish-brown, dense to very fine grained, argillaceous, hard; white crystalline dolomite fillings in fractures and vugs	7,662–7,665
Shale, dark-brownish-gray to dark-gray, silty, moderately siliceous in part	7,665–7,676
Dolomite, dusky-brown to brownish-black, very fine grained, very argillaceous, hard, tight	7,676–7,678
Shale, dark-gray, silty, micaceous	7,678–7,683
Siltstone, diatomaceous(?), brownish-gray, moderately siliceous	7,683–7,686
Shale, brownish-gray to pale-yellowish-brown, silty, moderately siliceous	7,686–7,706
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, moderately siliceous	7,706–7,710
Shale, as above; interbedded with siltstone as above	7,710–7,723
Shale, dark-gray to grayish-black, silty; few light-gray clay fragments; questionable microfossils	7,723–7,740
Shale, medium-dark-gray, slight brownish tint, silty; questionable microfossils	7,740–7,757
Shale, as above, moderately siliceous	7,757–7,770
Dolomite, brownish-gray, dense to very fine grained, argillaceous, hard, tight. May be caving	7,770–7,772
Shale, brownish-gray, silty, moderately siliceous	7,772–7,783
Shale, medium-dark- to dark-gray, silty	7,783–7,788
Siltstone, diatomaceous(?), pale-yellowish-brown to	

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
C zone—Continued	
brownish-gray, siliceous, slightly dolomitic; microfossils	7,788–7,792
Shale, as above	7,792–7,798
Shale, brownish-gray, silty, siliceous	7,798–7,806
D zone:	
Siltstone, diatomaceous(?), pale-yellowish-brown, moderately siliceous	7,806–7,810
Shale, diatomaceous(?), pale-yellowish-brown to medium-dark-gray, siliceous	7,810–7,814
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous, slightly dolomitic in part	7,814–7,818
Shale, medium-dark-gray, silty, siliceous	7,818–7,821
Siltstone, as above	7,821–7,825
Shale, as above	7,825–7,827
Siltstone, dark-gray, very finely sandy, siliceous, micaceous, tight	7,827–7,830
Shale, as above	7,830–7,832
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous; interbedded with dusky-brown dense chert and very siliceous shale	7,832–7,845
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous, slightly dolomitic. Sidewall cored at 7,850 (no recovery)	7,845–7,853
Shale, dark-gray to brownish-gray, very siliceous; some dusky-brown to brownish-black dense chert	7,853–7,860
Siltstone, diatomaceous(?), pale-yellowish-brown, finely banded with dark-gray, siliceous. Sidewall cored at 7,865	7,860–7,870
Siltstone, diatomaceous(?), dark-brownish-gray, siliceous, slightly dolomitic; scattered very fine and fine sand grains	7,870–7,875
Shale, dark-gray, silty, siliceous	7,875–7,878
Dolomite, pale-yellowish-brown to brownish-gray, very fine grained, argillaceous, hard; some pinpoint porosity	7,878–7,880
Siltstone, diatomaceous(?), brownish-gray to dark-brownish-gray, siliceous	7,880–7,894
Shale, diatomaceous(?), dark-brownish-gray, silty, siliceous	7,894–7,900
Shale, pale-yellowish-brown, brownish-gray and dark-gray laminae, silty, siliceous	7,900–7,918
Dolomite, pale-yellowish-brown, very fine grained, argillaceous, hard; few small vugs and some pinpoint porosity. May be caving	7,918–7,920
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous, slightly dolomitic in part; white calcite in fractures. Sidewall cored at 7,924 and 7,929 (no recovery at 7,929)	7,920–7,933

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
D zone—Continued	
Shale, brownish-gray to dark-gray, silty, siliceous; questionable microfossils; some brownish-black to dark-gray dense chert	7,933–7,945
Siltstone, as above	7,945–7,950
Shale, as above; some dusky-brown to brownish-black dense chert and banded chert	7,950–7,970
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, siliceous, slightly dolomitic, may be fractured; microfossils; chert as above	7,970–7,990
Shale, dark-gray; questionable gilsonite in fractures	7,990–7,992
Dolomite, pale-yellowish-brown, very fine grained; abundant very fine silica	7,992–7,993
Siltstone, diatomaceous(?), very pale-orange to pale-yellowish-brown, siliceous, slightly dolomitic in upper part; brownish-gray to dusky-brown dense and banded chert; thin beds of dark-gray silty siliceous shale near middle. Sidewall cored at 8,004, 8,015, and 8,028 (no recovery at 8,028)	7,993–8,034
Shale, pale-yellowish-brown, with brownish-gray, dusky-brown, and dark-gray bands, siliceous, silty; questionable microfossils in part; dark-brownish-gray to dark-gray banded chert	8,034–8,060
Shale, pale-yellowish-brown to medium-light-gray, silty, siliceous	8,060–8,079
Siltstone, as above	8,079–8,085
Siltstone, brownish-gray to dark-gray, micaceous, siliceous, tight; scattered very fine and fine sand grains	8,085–8,093
Shale, olive-gray, brownish-gray, and dark-gray, silty, siliceous, micaceous; scattered very fine and fine sand grains	8,093–8,110
Siltstone, diatomaceous(?), brownish-gray to pale-yellowish-brown, siliceous	8,110–8,114
Shale, brownish-gray to dark-gray, silty, siliceous; interbedded with siltstone as above	8,114–8,128
Siltstone, diatomaceous(?), pale-yellowish-brown, siliceous	8,128–8,142
Shale, medium-dark-gray, slight brownish tint, very siliceous, silty; dark-brownish-gray to dark-gray dense chert and banded rough chert	8,142–8,149
Siltstone, as above	8,149–8,152
Shale, dark-brownish-gray, fine dark-gray bands, siliceous; chert as above	8,152–8,165
Siltstone, diatomaceous(?), pale-yellowish-brown, dark-gray bands, siliceous; brownish-gray dense banded chert	8,165–8,170
Siltstone, dark-gray, very finely to finely sandy, siliceous, tight	8,170–8,180

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
D zone—Continued	
Sandstone, medium-dark-gray, very fine to medium-grained, very siliceous, hard, tight; dark-gray sandy chert	8,180–8,182
Shale, medium-dark- to dark-gray, silty, siliceous; few white round questionable microfossils; dark-brownish-gray dense chert and banded chert	8,182–8,195
Shale, as above; dark-brownish-gray in part	8,195–8,205
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, siliceous; interbedded and interlaminated with dark-brownish-gray siliceous cherty shale as above. Siltstone and shale probably fractured. Sidewall cored at 8,214	8,205–8,215
Sandstone, light-gray, very fine to medium-grained, scattered coarse grains, very silty, some feldspar grains, slightly dolomitic and glauconitic, soft. Sidewall cored at 8,216	8,215–8,217
Siltstone, as above; interbedded with shale as above. Sidewall cored at 8,219 (no recovery)	8,217–8,230
Shale, diatomaceous(?), brownish-gray to dark-brownish-gray, silty, siliceous; few white siliceous questionable microfossils	8,230–8,265
Shale, medium-dark- to dark-gray, silty, siliceous, very finely to finely sandy in upper part; few microfossils	8,265–8,280
Shale, brownish-black, silty, siliceous	8,280–8,290
Siltstone, brownish-gray, siliceous; dark-brownish-gray dense chert	8,290–8,293
Shale, dark-brownish-gray, silty, siliceous; dark-brownish-gray dense chert	8,293–8,305
Dolomite, pale-yellowish-brown to brownish-gray, very fine grained, hard, tight; abundant very finely divided silica; white crystalline calcite in fractures	8,305–8,306
Shale, as above	8,306–8,314
Siltstone, diatomaceous(?), pale-yellowish-brown to brownish-gray, finely banded, siliceous; probably interbedded with shale as above	8,314–8,334
Shale, as above	8,334–8,347
Sandstone, medium-dark-gray, very fine to fine-grained, scattered medium grains, very silty, siliceous, micaceous, tight	8,347–8,350
Shale, dark-gray to grayish-black, silty, siliceous	8,350–8,360
Sandstone, medium-light- to medium-gray, very fine to fine-grained, silty, micaceous, tight; may be caving	8,360–8,362
Shale, brownish-gray to dark-brownish-gray, silty, siliceous, dolomitic in part	8,362–8,373
Dolomite, pale-yellowish-brown, dense, argillaceous, hard; may be caving	8,373–8,375

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
D zone—Continued	
Shale, medium-dark-gray to dark-brownish-gray, silty, siliceous in part; questionable Foraminifera in part	8,375–8,398
Sandstone, medium-dark-gray, very fine grained, silty, siliceous, some pyrite, tight	8,398–8,400
Shale, dark-gray, silty, micaceous, siliceous	8,400–8,405
Shale, dark-brownish-gray to medium-dark-gray, silty, siliceous in part, finely banded; dark-brownish-gray to brownish-black dense chert	8,405–8,420
Shale, as above; interbedded with pale-yellowish-brown to dark-brownish-gray siliceous diatomaceous(?) siltstone; chert as above	8,420–8,440
Siltstone, medium-gray, very finely to finely sandy, micaceous	8,440–8,444
Shale, dark-gray to grayish-black, silty, very micaceous	8,444–8,450
Siltstone, light-gray, tight	8,450–8,454
Sandstone, medium-light-gray, very fine to medium-grained, subangular, silty, micaceous; low porosity	8,454–8,457
Siltstone, diatomaceous(?), brownish-gray, very finely to finely sandy, siliceous	8,457–8,467
DD zone:	
Shale, dark-gray to grayish-black, silty to very finely sandy	8,467–8,480
Siltstone, diatomaceous(?), brownish-gray, finely banded, siliceous; calcite-filled fractures; dark-brownish-gray to brownish-black dense chert (may be caving)	8,480–8,484
Shale, dark-gray, silty	8,484–8,489
Siltstone, as above; chert as above	8,489–8,492
Shale, dark-brownish-gray to dark-gray, silty, siliceous; chert as above	8,492–8,500
Siltstone, medium- to dark-gray, very finely to finely sandy in part, siliceous, abundant mica in part	8,500–8,509
Shale, medium-dark- to dark-gray, silty, siliceous, partly micaceous	8,509–8,517
Shale, dark-brownish-gray to dark-gray, silty; probably interbedded with medium-dark-gray micaceous siltstone	8,517–8,535
Shale, diatomaceous(?), dusky-yellowish-brown to dark-brownish-gray, finely banded, siliceous	8,535–8,566
Siltstone, medium-dark-gray, very finely sandy, siliceous	8,566–8,570
Shale, dark-gray, silty	8,570–8,573
Dolomite, dusky-yellowish-brown to brownish-black, very fine grained, very argillaceous, hard, tight; trace of pinpoint porosity and small vugs	8,573–8,576
Shale, dark-gray, slight brownish tint, silty, siliceous	8,576–8,587

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
DD zone—Continued	
Siltstone, medium-dark-gray, micaceous	8,587–8,590
Sandstone, medium-gray, very fine grained, silty, micaceous, siliceous, tight; calcite in fractures	8,590–8,594
Shale, medium-dark- to dark-gray, silty, slightly to moderately siliceous; interbedded with medium-dark-gray micaceous siltstone	8,594–8,610
Sandstone, medium-gray to light-olive-gray, very fine to fine-grained, very siliceous	8,610–8,612
Shale, as above	8,612–8,618
Sandstone, light-gray, very fine to medium-grained, scattered coarse grains, subangular, silty, slightly dolomitic and micaceous; scattered dark-gray shale grains, some yellowish-brown clay grains, fair porosity	8,618–8,622
Sandstone, as above, clayey; scattered carbonaceous films; less porous than sandstone above	8,622–8,627
Siltstone, medium-dark-gray, micaceous; interbedded with dark-gray silty shale. Some shale shows slickensides	8,627–8,650
Sandstone, light-gray, very fine to fine-grained, silty, slightly micaceous; scattered carbonaceous fragments; low porosity	8,650–8,657
Limestone, pale-yellowish-brown, very fine grained, moderately to very argillaceous	8,657–8,660
Shale, medium-dark-gray, silty	8,660–8,663
Sandstone, medium- to dark-gray, very fine to medium-grained, very silty; scattered mica and carbonaceous fragments; tight	8,663–8,666
Shale, dark-gray to dark-brownish-gray, silty, siliceous	8,666–8,672
Sandstone, medium-light-gray, very fine grained, silty, micaceous	8,672–8,674
Shale, dark-brownish-gray, silty, siliceous	8,674–8,685
Shale, medium-dark-gray, very silty and micaceous	8,685–8,700
Shale, light-gray, silty to finely sandy, slightly micaceous, may be bentonitic, flaky in part; scattered dark-gray fragments. Probably includes thin stringers of light-gray clayey very fine to fine-grained sandstone	8,700–8,710
Shale, medium-gray, silty, slightly micaceous, may be bentonitic, splintery	8,710–8,715
E zone:	
Siltstone, medium-light- to medium-dark-gray, very finely to finely sandy, micaceous	8,715–8,725
Sandstone, medium-light- to medium-dark-gray, mottled, very fine to medium-grained, very silty, micaceous; scattered carbonaceous material; very "dirty"	8,725–8,730

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
E zone—Continued	
Sandstone, as above, except very fine to coarse-grained; some yellowish-brown clay grains, some questionable oil-stain; low porosity	8,730–8,735
Siltstone, as above	8,735–8,740
Sandstone, as above	8,740–8,741
Shale, dark-gray, micaceous	8,741–8,746
Sandstone, as above, many very coarse grains, some feldspar grains. A 2-foot gray shale bed in middle	8,746–8,756
Shale, medium-dark- to dark-gray, slight brownish tint. Probably includes a 1-foot bed of medium-gray very fine to medium-grained very silty tight sandstone at 8,769 (may be caving)	8,756–8,786
Siltstone, medium-dark-gray, micaceous, sandy in part; scattered carbonaceous material. Probably interbedded with shale as above	8,786–8,794
Shale, dark-gray to grayish-black	8,794–8,804
Siltstone, medium-light-gray, sandy, micaceous, tight, hard; questionable coal films and stringers in small part	8,804–8,812
Shale, dark-gray	8,812–8,820
Shale, dark-brownish-gray to dark-gray, finely banded, siliceous; calcite in fractures. Probably includes a 2-foot bed of gray hard tight siltstone 6 ft below top	8,820–8,836
Shale, dark-gray, micaceous, silty	8,836–8,843
Sandstone, medium-light- to medium-gray, very fine grained, silty, micaceous; many yellowish-brown clay grains; low porosity	8,843–8,846
Shale, as above; interbedded with medium-dark-gray micaceous hard siltstone	8,846–8,860
Sandstone, medium-light-gray, very fine to medium-grained, scattered coarse grains, some feldspar and clay grains, silty, slightly dolomitic; scattered carbonaceous material; fairly good porosity	8,860–8,866
Shale, gray	8,866–8,867
Sandstone, as above, somewhat coarser; some well-sorted fine-grained dolomitic sandstone with fairly good porosity	8,867–8,876
Shale, dark-greenish-gray; may be caving	8,876–8,880
Shale, dark-gray, micaceous, silty	8,880–8,887
Sandstone, light- to medium-gray, very fine to coarse-grained, scattered very coarse grains, some feldspar and clay grains as above, silty, slightly micaceous and dolomitic, clayey in part; scattered coaly fragments; fair to poor porosity. A 1-ft gray shale bed 6 ft below top	8,887–8,905
Sandstone, yellowish-gray, very fine to coarse-grained, very limy; probably fair porosity	8,905–8,910

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
E zone—Continued	
Sandstone, light-gray, fine- to coarse-grained, silty; probably low porosity	8,910–8,915
Sandstone, medium-light-gray to yellowish-gray, very fine to fine-grained, scattered medium and coarse grains in part, silty, very siliceous; very fine pyrite in part; tight	8,915–8,929
Shale, medium-dark- to dark-gray, silty, micaceous	8,929–8,940
Shale, as above; interbedded with some medium-light-gray siliceous siltstone	8,940–8,970
Siltstone, medium-dark- to dark-gray, micaceous; probably interbedded with shale as above and some siliceous shale	8,970–8,987
Siltstone, medium-dark- to dark-gray, micaceous, siliceous	8,987–8,997
Shale, medium-dark- to dark-gray, silty in part, micaceous in lower half	8,997–9,054
Siltstone, medium- to dark-gray, micaceous, hard; abundant very fine pyrite in small part; tight; probably interbedded with shale as above	9,054–9,060
Shale, as above	9,060–9,067
Siltstone, as above	9,067–9,070
Shale, as above	9,070–9,084
Sandstone, medium-light-gray, very fine to fine-grained, silty, micaceous; low porosity	9,084–9,086
Shale, dark-gray, siliceous; dark-gray dense chert with trace of pyrite	9,086–9,100
Shale, dark-gray, micaceous, silty	9,100–9,110
Sandstone, light-gray, very fine to medium-grained, some coarse grains, silty, dolomitic to limy, some feldspar grains, slightly micaceous; fair porosity	9,110–9,120
Siltstone, medium-dark-gray, very finely to medium sandy	9,120–9,125
Sandstone, light-gray, very fine to fine-grained, scattered medium grains, silty, dolomitic, slightly micaceous; some carbonaceous material	9,125–9,128
Shale, dark-gray to grayish-black, silty, micaceous	9,128–9,134
Sandstone, as above	9,134–9,137
Shale, medium-dark- to dark-gray, silty in part, micaceous; interbedded with medium-dark-gray micaceous siltstone	9,137–9,170
Sandstone, medium-light-gray, very fine to fine-grained, scattered medium grains, silty; low porosity	9,170–9,172
Shale, as above	9,172–9,182
Sandstone, medium-light- to medium-dark-gray, very fine to fine-grained, some medium grains, silty, clayey, dolomitic in part, micaceous; some carbonaceous fragments; "dirty;" low porosity.	

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
E zone—Continued	
Interbedded with much shale as above	9,182–9,198
Limestone, pale- to dark-yellowish-brown, dense, argillaceous, dolomitic, very finely to medium sandy in part, hard	9,198–9,200
Shale, medium-dark- to dark-gray, silty	9,200–9,204
Sandstone, medium-gray, very fine to medium-grained, silty, siliceous, hard, tight	9,204–9,207
Shale, medium-dark- to dark-gray, micaceous, silty in upper half; may include trace of coal at about 9,220	9,207–9,225
Shale, dark-gray to dark-brownish-gray, siliceous. May be caving	9,225–9,230
Siltstone, medium-gray, very finely sandy, siliceous, slightly micaceous, hard, tight	9,230–9,233
Shale, dark-gray, very siliceous; some dark-gray dense chert with slight brownish tint in part	9,233–9,244
Limestone, pale-yellowish-brown, very fine grained, very dolomitic, argillaceous	9,244–9,246
Shale, dark-gray, silty, slickensides	9,246–9,258
Siltstone, medium-dark-gray, clayey to very finely sandy	9,258–9,261
Shale, dark-brownish-gray to dark-gray, finely banded, very siliceous; some dark-brownish-gray to dark-gray dense chert and banded chert	9,261–9,289
Siltstone, medium- to medium-dark-gray, very finely to finely sandy, micaceous	9,289–9,294
Shale, medium-dark- to dark-gray	9,294–9,305
Shale, medium-dark- to dark-gray and dark-brownish-gray, siliceous; some dark-gray to brownish-black dense chert and rough chert	9,305–9,340
Shale, similar to above; probably less siliceous and cherty	9,340–9,365
Shale, brownish-gray, fairly soft	9,365–9,370
Shale, dark-brownish-gray to dark-gray, siliceous	9,370–9,380
Shale, as above; much dark-gray and dark-brownish-gray to brownish-black dense chert	9,380–9,400
Shale, light-gray to pale-yellowish-brown, flaky, may be bentonitic; scattered mica and fine to medium sand grains	9,400–9,403
Shale, dark-gray, siliceous; much chert as above, calcite in fractures	9,403–9,420
Shale, dark-brownish-gray, very siliceous; some chert as above	9,420–9,435
Shale, medium-dark-gray, siliceous, silty, micaceous; some chert as above	9,435–9,445
Chert, dark-gray to dark-brownish-gray, dense to very finely grained; calcite in fractures; some brownish-gray silty siliceous finely banded shale	9,445–9,465

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Elk Hills Shale Member—Continued	
E zone—Continued	
Shale, medium-dark-gray, siliceous, silty; some chert as above	9,465–9,470
Shale, dark-gray to dark-brownish-gray, very siliceous; fine bands and lenses of yellowish-gray limy shale; some chert as above	9,470–9,478
Sandstone, light- to medium-gray, very fine to medium-grained, silty, slightly dolomitic; abundant pyrite in part; tight; may be caving	9,478–9,482
Siltstone, diatomaceous(?), pale-yellowish-brown, very finely to medium sandy, finely banded	9,482–9,487
Shale, dark-gray to dark-brownish-gray, very siliceous, finely banded; dark-gray to brownish-black dense to banded chert with white calcite in fractures	9,487–9,517
Sandstone, medium-light-gray, very fine to fine-grained, silty, siliceous, micaceous, slightly dolomitic; tight	9,517–9,525
Sandstone, medium-light-gray, very fine to medium-grained, scattered coarse grains, few feldspar grains, silty, micaceous, slightly dolomitic; low porosity	9,525–9,533
Sandstone, as above; yellowish-gray in part; a few very coarse grains; trace of questionable glauconite	9,533–9,540
McDonald Shale Member of local usage:	
Shale, dark-gray to brownish-black, very siliceous; some dark-gray to brownish-black dense chert	9,540–9,576
Shale, pale-olive, light-olive-gray, and light-gray, flaky; may be bentonitic; scattered very fine to fine sand grains and dark-gray grains. May be caving	9,576–9,580
Shale, dark-gray, siliceous. Probably interbedded with medium-dark- to dark-gray micaceous shale	9,580–9,625
Shale, medium-dark- to dark-gray and dark-brownish-gray	9,625–9,650
Shale, as above; probably siliceous	9,650–9,660
Shale, medium-dark- to dark-gray, fairly fissile, not siliceous. Probably interbedded with light- to medium-gray very fine to fine-grained silty micaceous sandstone in middle part	9,660–9,690
Shale, as above; slightly dolomitic in part	9,690–9,704
Sandstone, medium-gray, very fine to fine-grained, silty; may be caving	9,704–9,705
Shale, medium-dark- to dark-gray; some medium-gray fairly soft limy shale with slight brownish tint	9,705–9,717
Sandstone, medium-light-gray, very fine to fine-grained, silty; may be caving	9,717–9,722
Shale, medium-dark- to dark-gray, siliceous in part. A 2-ft bed of medium-dark-gray siltstone 7 ft above base	9,722–9,757

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
McDonald Shale Member—Continued	
Sandstone, medium-light-gray, very fine to fine-grained, few medium grains, silty, micaceous, slightly dolomitic; few carbonaceous fragments; low porosity	9,757–9,761
Shale, medium-dark- to dark-gray, siliceous in part	9,761–9,770
Shale, light-gray, flaky, may be bentonitic; may be caving	9,770–9,773
Shale, medium-dark- to dark-gray	9,773–9,780
Shale, medium-gray, limy, fairly soft	9,780–9,788
Siltstone, medium-light- to medium-dark-gray, very siliceous in part, some carbonaceous material, mica, and pyrite	9,788–9,791
Shale, as above	9,791–9,797
Devilwater Shale(?) Member:	
Shale, brownish-gray, fine dark-brownish-gray and dark-gray bands, very siliceous; dusky-brown dense chert	9,797–9,810
Electrical-log interpretation; no samples from 9,820 to 9,846	9,810–9,826
Estimated sample lag—10 ft.	
Shale, as above; chert as above	9,810–9,815
Sandstone, probably silty and siliceous as below	9,815–9,820
Siltstone, probably sandy and siliceous	9,820–9,826
Sandstone, medium-light- to medium-gray, very fine to fine-grained, scattered medium grains, silty, siliceous, slightly dolomitic and micaceous in part; some carbonaceous material; tight. (Described from first sample below 9,846.)	9,826–9,830
Siltstone, medium-gray, sandy, siliceous, tight	9,830–9,837
Shale, medium-dark- to dark-gray	9,837–9,858
Sandstone, as above	9,858–9,860
Shale, medium-dark- to dark-gray, moderately siliceous and brittle	9,860–9,870
Sandstone, medium-gray, very fine to medium-grained, silty, siliceous, slightly dolomitic, some pyrite and mica in parts; tight	9,870–9,890
Shale, dark-gray, siliceous; dark-gray chert	9,890–9,898
Sandstone, medium-light-gray, very fine to medium-grained, silty, slightly dolomitic; fair porosity	9,898–9,900
Shale, medium-dark- to dark-gray, slight brownish tint in part	9,900–9,916
Shale, medium-gray, slightly limy; fairly common Foraminifera	9,916–9,920
Shale, medium-dark- to dark-gray	9,920–9,937
Shale, medium-gray, slightly limy; few Foraminifera	9,937–9,940
Shale, medium-dark- to dark-gray	9,940–9,955
Shale, medium-gray, slightly limy; microfossils	9,955–9,958
Gould Shale Member:	
Shale, medium-dark- to dark-gray	9,958–9,965
Shale, medium-gray, slightly limy; microfossils	9,965–9,968

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Monterey Shale—Continued	
Gould Shale Member—Continued	
Limestone, medium-dark-gray to dark-brownish-gray, very fine grained, very argillaceous; few microfossils	9,968–9,970
Shale, medium-dark- to dark-gray, slightly limy; few microfossils	9,970–9,980
Shale, dark-gray, limy, fairly hard; abundant microfossils. Resembles "dirty" limestone	9,980–9,990
Shale, brownish-gray to dark-gray, limy, very siliceous; abundant microfossils	9,990–9,994
Limestone, brownish-gray to dusky-yellowish-brown, dense, hard, very argillaceous; few microfossils (probably Foraminifera)	9,994–9,996
Shale, as above; crystalline calcite in fractures	9,996–10,010
Limestone, brownish-gray, dense, dolomitic, argillaceous; few microfossils; some pinpoint porosity	10,010–10,012
Shale, dark-gray, siliceous in part	10,012–10,021
Sandstone, medium-light-gray, very fine to fine-grained, scattered medium grains, silty, dolomitic, slightly micaceous; low porosity	10,021–10,024
Shale, medium-dark- to dark-gray, slight brownish tint in part, siliceous in lower part	10,024–10,046
Sandstone, medium-light- to medium-dark-gray, very fine to fine-grained, silty, siliceous, slightly micaceous and dolomitic; tight	10,046–10,049
Shale, dark-gray, siliceous in part	10,049–10,060
Shale, medium-dark-gray to brownish-gray, very siliceous; sparse to abundant microfossils (mostly Foraminifera)	10,060–10,094
Shale, brownish-gray, less siliceous and softer than shale above; some microfossils (Foraminifera)	10,094–10,110
Shale, medium-dark-gray to dark-brownish-gray, very siliceous; abundant microfossils as above	10,110–10,135
Shale, medium-gray, slight greenish tint in part, slightly limy	10,135–10,143
Temblor Formation:	
Carneros Sandstone Member:	
First Carneros sand 10,143–10,151:	
Sandstone, light-gray, very fine to fine-grained, scattered medium grains, very silty, clayey, slightly limy and micaceous, slightly glauconitic; probably low porosity; includes some hard tight sandstone. Sidewall cored at 10,149	10,143–10,151
Shale, as above	10,151–10,160
Shale, medium-dark- to dark-gray, silty, mostly siliceous	10,160–10,196
Second Carneros sand 10,196–10,243:	
Sandstone, light- to medium-gray, fine- to medium-grained, some coarse grains, subangular, silty, slightly limy to limy, very siliceous in uppermost	

Tertiary System—Continued Miocene Series—Continued Temblor Formation—Continued Carneros Sandstone Member—Continued Second Carneros sand—Continued	*Depth (ft)*
part, many dark-gray grains, some pyrite and glauconite; low porosity	10,196–10,204
Sandstone, as above; probably fair porosity. Sidewall cored at 10,206 and 10,210 (no recovery at 10,210)	10,204–10,210
Sandstone, medium-light-gray, very fine to fine-grained, scattered medium grains, subangular, limy, silty, many dark-gray grains, slightly glauconitic. Sidewall cored at 10,216	10,210–10,221
Shale, dark-brownish-gray, silty, slightly dolomitic and glauconitic; some very finely to coarsely sandy stringers. Sidewall cored at 10,222	10,221–10,224
Sandstone, as above; fine- to coarse-grained. Sidewall cored at 10,228 (no recovery)	10,224–10,231
Dolomite, dark-brownish-gray to dark-gray, very fine grained, dense, argillaceous, siliceous, limy, hard. Sidewall cored at 10,232	10,231–10,232
Sandstone, as above	10,232–10,235
Shale, dark-gray, silty	10,235–10,240
Sandstone, as above; siliceous; tight	10,240–10,243
Shale, dark-gray, brownish tint in part, very siliceous	10,243–10,260
Shale, medium-dark-gray to dark-brownish-gray, slightly limy to limy, siliceous in upper part, silty in lower half; some microfossils	10,260–10,285
Shale, medium-gray, silty, may be bentonitic, slightly micaceous, few dark specks; very fine "grainy" fracture	10,285–10,290
Shale, medium-dark- to dark-gray, slightly limy; few microfossils	10,290–10,300
Shale, as above; silty in part	10,300–10,320
Shale, medium-dark- to dark-gray, slightly limy in part; fairly common Foraminifera, probably other microfossils. Some shale altered to grayish-black color in bag	10,320–10,340
Shale, very light- to light-gray, may be bentonitic; dark specks and waxy luster in part	10,340–10,344
Shale, medium-dark- to dark-gray, very silty	10,344–10,350
Shale, medium-dark- to dark-gray, silty in part, moderately siliceous	10,350–10,358
Dolomite, dark-brownish-gray, very fine grained, argillaceous, hard	10,358–10,362
Sandstone, medium- to medium-dark-gray, very fine to fine-grained, many dark grains, silty, siliceous, slightly dolomitic, some pyrite, trace of glauconite; tight	10,362–10,366
Shale, as above; siliceous in upper and lower parts	10,366–10,395
Shale, brownish-gray, slightly limy; microfossils	10,395–10,410
Shale, medium-gray, silty, may be bentonitic,	

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Temblor Formation—Continued	
Carneros Sandstone Member—Continued	
Second Carneros sand—Continued	
slightly micaceous; may be caving	10,410–10,413
Shale, dark-brownish-gray, slightly limy, silty in part; few Foraminifera	10,413–10,430
Third Carneros sand:	
Sandstone, light-gray, very fine to fine-grained, scattered medium grains, very silty, slightly limy, common glauconite; probably fair porosity. Sidewall cored at 10,432 and 10,434 (no recovery at 10,434)	10,430–10,435
Shale, medium-gray	10,435–10,436
Sandstone, as above, limy. Sidewall cored at 10,437	10,436–10,440
Sandstone, light-gray, very fine to medium-grained, scattered coarse grains, subangular, many dark grains, very silty, trace of glauconite; fairly good porosity. Sidewall cored at 10,441	10,440–10,444
Santos Shale Member:	
Shale, medium-dark- to dark-gray, slight brownish tint in part, mostly silty, slightly to moderately siliceous; some Foraminifera in part	10,444–10,480
Shale, dark-brownish-gray, slightly limy; common Foraminifera. Probably interbedded with shale as above	10,480–10,507
Dolomite, dark-brownish-gray, very fine grained, argillaceous, hard; few microfossils (probably Foraminifera); white crystalline dolomite in fractures	10,507–10,510
Shale, as above	10,510–10,515
Sandstone, light- to medium-light-gray, very fine to fine-grained, some medium grains, silty, siliceous, slightly limy and glauconitic; probably low porosity	10,515–10,521
Shale, dark-brownish-gray to medium-dark-gray, probably siliceous in part, slightly limy in part; microfossils	10,521–10,545
Shale, as above. May include beds of dolomite similar to that at 10,507 to 10,510	10,545–10,565
Siltstone, medium-dark-gray, very finely sandy, slightly limy	10,565–10,568
Sandstone, medium-gray, very fine to fine-grained, silty, slightly limy and glauconitic; tight	10,568–10,570
Shale, medium-dark- to dark-gray, slight brownish tint in part, silty, slightly to moderately siliceous, slightly dolomitic; sparse to abundant microfossils	10,570–10,592
Dolomite, medium-dark-gray, slight brownish tint, very fine grained, very argillaceous, few to abundant very fine and fine sand grains, hard; tight; white calcite in fractures	10,592–10,597
Shale, light-gray, flaky, may be bentonitic; may be caving	10,597–10,600
Shale, medium-dark- to dark-gray, slightly to	

	Depth (ft)
Tertiary System—Continued	
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
moderately siliceous, slightly limy, silty and sandy at top; scattered to abundant microfossils	10,600–10,620
Shale, dark-gray to dark-brownish-gray, slightly limy and siliceous; fairly common microfossils, Foraminifera. Sidewall cored at 10,620	10,620–10,635
Shale, dark-gray, silty, siliceous, slightly limy	10,635–10,642
Dolomite, dark-brownish-gray, very fine grained, very argillaceous, hard, trace of glauconite in part; white calcite in fractures and vugs	10,642–10,647
Shale, medium-gray, silty, slightly micaceous; calcite in fractures	10,647–10,657
Dolomite, as above	10,657–10,662
Shale, medium-dark-gray, silty, slightly siliceous; few microfossils	10,662–10,670
Shale, medium-dark- to dark-gray, silty, slightly siliceous and micaceous; few microfossils. Sidewall cored at 10,670	10,670–10,684
Shale, medium-dark-gray, slight brownish tint, slightly limy; microfossils	10,684–10,690
Electrical-log interpretation; no circulation samples at total depth	10,690–10,700
Estimated sample lag—10 ft.	
Shale, as above	10,690–10,700
Total depth	10,700

WELL 555–30R

[2,381 ft north, 2,239 ft west of SE. cor. sec. 30, T. 30 S., R. 23 E.]
(Modified from log by E. E. Glick)

	Altitude (drill floor) 1341 feet
No samples	0–5,990
Omitted	5,990–9,055
Miocene Series:	
Temblor Formation:	
Media Shale Member:	
Well cuttings. Shale, medium-dark-gray, siliceous, massive, hard; little or no banding	9,055–9,062
Well cuttings. Shale, as above; calcite crystals	9,062–9,094
Cored 6 ft, recovered 5 ft (2 trays)	9,094–9,100
Shale, medium-dark-gray, siliceous, massive, hard; little or no banding; Foraminifera and "mud pectens"; slickensides, fracture fillings of dolomite, calcite, and pyrite; (reported dip 40°–45°)	Tray 1
Shale, similar to above	Tray 2
Well cuttings. Shale, dull medium-dark-gray, siliceous, very slightly limy, hard; trace of diatomaceous siltstone laminae; Foraminifera (especially in lower part)	9,100–9,196
Cored 8 ft, recovered 5 ft (2 trays)	9,196–9,204
Shale, medium-dark-gray, slightly phosphatic, slightly	

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Media Shale Member—Continued	
limy to limy, hard; 1-in. bed of light-olive-gray siltstone in upper 1 ft of core; Foraminifera, fish debris; (reported dip 42°–46°)	Tray 1
Shale, similar to above; some slickensides	Tray 2
Well cuttings. Shale, medium-dark-gray, slightly limy and phosphatic, hard; trace of Foraminifera	9,204–9,260
Carneros Sandstone Member:	
First Carneros sand 9,260–9,348:	
Drilled. No samples (probably sandstone)	9,260–9,270
Cored 7 ft, recovered 2 ft (1 tray)	9,270–9,277
Sandstone, medium-light-gray, very fine to fine-grained, silty, slightly limy; medium-gray clayey micaceous silty layers, micro-graded bedding; (reported dip 35°–40°)	Tray 1
Cored 12 ft, recovered 4 ft (2 trays)	9,277–9,289
Sandstone, medium-light-gray, fine-grained, scattered medium grains, very silty, micaceous, slightly limy; 30 percent medium-gray limy very fossiliferous phosphatic silty siliceous shale; abundant "pellets" and Foraminifera in hard silty clay matrix; fracture fillings of light-brown silica and dolomite; (reported dip 30°–60°)	Tray 1
Sandstone, medium-light-gray, medium-grained, some coarse grains, very silty, micaceous, slightly limy, phosphatic; 10 percent dark-gray shale, partly laminated with fine-grained sandstone	Tray 2
Cored 14 ft, recovered 10½ ft (4 trays)	9,289–9,303
Sandstone, medium-light-gray, very fine to medium-grained, scattered coarse grains, very silty, micaceous, slightly limy and phosphatic; 20 percent dark-gray shale in laminae showing pinch and swell features and some load casts; (reported average dip about 35°)	Tray 1
Sandstone, similar to above; 5 percent shale as above	Tray 2
Sandstone, similar to above; somewhat banded with each sand layer different in grain size; shale laminae more closely spaced than above	Tray 3
Sandstone, medium-light-gray, very fine to coarse-grained, poorly sorted, limy; silt and carbonate matrix; trace of shale in "banded" pieces	Tray 4
Cored 2 ft, recovered 1 ft (1 tray)	9,303–9,305
Sandstone, light-gray, very fine to fine-grained, silty, limy, slightly phosphatic	Tray 1
Cored 10 ft, recovered 8 ft (3 trays)	9,305–9,315
Sandstone, as above: medium-grained in part; (reported dip 30°–40°)	Tray 1
Sandstone, similar to above; some very coarse grains and small pebble-sized shell fragments near base; good evidence of graded bedding associatd with a few shale laminae	Tray 2

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Carneros Sandstone Member—Continued	
First Carneros Sand—Continued	
Sandstone, medium-light-gray, very fine to fine-grained, trace of medium and coarse grains, very silty, poorly sorted, limy	Tray 3
Cored 19 ft, recovered 11 ft (4 trays)	9,315–9,334
Sandstone, medium-light-gray, fine- to medium-grained, scattered coarse and very coarse grains, silty, limy; trace of dark-gray micaceous shale laminae; (reported dip 30°–45°)	Tray 1
Sandstone, medium-light-gray to medium-gray, very fine to medium-grained, scattered coarse grains, silty, limy (especially in darker part), micaceous; trace of shale laminae	Tray 2
Sandstone, similar to above; more coarse grains	Tray 3
Sandstone, similar to above; no shale laminae	Tray 4
Cored 14 ft, recovered 10 ft (4 trays)	9,334–9,348
Sandstone, light-brownish-gray, very fine to medium-grained, trace of coarse grains, silty, limy, clayey; partings of dark-gray micaceous slightly phosphatic silty shale; (reported dip 50°–60°)	Tray 1
Sandstone, similar to above; no shale	Tray 2
Sandstone, similar to above; shale laminae showing pinch and swell features and some load casts	Tray 3
Sandstone, light-brownish-gray, very fine to medium-grained, scattered coarse grains, silty, very clayey, slightly limy, friable; trace of dark-gray shale partings	Tray 4
Cored 6 ft, recovered 6 ft (2 trays)	9,348–9,354
Shale, medium-dark-gray, very silty, finely sandy, slightly limy, phosphatic, hard; lenses and laminae of clayey fine-grained sandstone; (reported dip 45°–50°)	Tray 1
Shale, similar to above; probably more sandstone than above	Tray 2
Cored 5 ft, recovered 5 ft (2 trays)	9,354–9,359
Shale, medium-dark-gray, slightly limy, phosphatic; 30 percent contorted laminae or beds of siltstone and sandstone; each bed has a different grain size (very fine to medium). Distortion of laminae indicates soft-sediment deformation	Tray 1
Shale, similar to above	Tray 2
Cored 4 ft, recovered 2 ft (1 tray)	9,359–9,363
Shale, as above; some dark-gray shale with conchoidal fracture; Foraminifera; (reported dip 50°–55°)	Tray 1
Drilled, no samples	9,363–9,366
Cored 8 ft, recovered 2 ft (1 tray)	9,366–9,374
Shale and sandstone, as above; plant fragments, fish scales, Foraminifera; (reported dip 40°–45°)	Tray 1

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Carneros Sandstone Member—Continued	
First Carneros sand—Continued	
Cored 1 ft, recovered 1 ft (1 tray)	9,374–9,375
Shale, medium-dark-gray to brownish-black, limy, phosphatic; laminae and fine bands; trace of siltstone and very fine to medium-grained sandstone laminae; (reported dip 40°)	Tray 1
Drilled, no samples	9,375–9,385
Cored 21 ft, recovered 13 ft (5 trays)	9,385–9,406
Second Carneros sand 9,403–9,561:	
Shale, as above; interbedded with and grading into 40 percent limy slightly phosphatic very fine to medium-grained sandstone; sandstone dikes; (reported dip 30°–40°)	Tray 1
Shale and sandstone, similar to above	Tray 2
Shale and sandstone, similar to above; at least 50 percent sandstone; sandstone dike cuts about 5 in. of core	Tray 3
Shale, dark-gray to brownish-black, silty, slightly limy and phosphatic; 20 percent sandstone as above	Tray 4
Shale, similar to above; trace of fish scales, Foraminifera, and "mud pectens"	Tray 5
Cored 16 ft, recovered 15 ft (5 trays)	9,406–9,422
Shale, dark-gray to brownish-black, silty, slightly limy and phosphatic; Foraminifera; interbedded with 60 percent medium-light-gray limy clayey silty very fine to medium-grained sandstone	Tray 1
Shale, similar to above; about 10 percent sandstone as above; (reported dip 40°–45°)	Tray 2
Sandstone, similar to above; about 10 percent shale as above	Tray 3
Sandstone, similar to above; about 30 percent shale as above	Tray 4
Shale, brownish-black, silty, slightly limy and phosphatic; Foraminifera, "mud pectens"	Tray 5
Cored 30 ft, recovered 21 ft (7 trays)	9,422–9,452
Shale, as above; contorted interbeds of siltstone and very fine grained sandstone (40 percent); Foraminifera; (reported dip 40°–45°)	Tray 1
Sandstone, medium-gray, very fine to fine-grained, clayey, micaceous, slightly limy; laminae and beds of dark-gray shale (50 percent); hint of graded bedding	Tray 2
Sandstone, medium-light-gray, very fine to medium-grained, some coarse grains, silty, limy, very clayey; trace of dark-gray shale laminae, contorted beds	Tray 3
Shale, medium-dark-gray, silty; trace of siltstone and sandstone laminae. Contortion of beds includes boudinage structures and associated pull-apart	

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Carneros Sandstone Member—Continued	
Second Carneros sand—Continued	
structures, load casts, plastic flowage, and mixing ..	Tray 4
Sandstone, medium-light-gray, very fine to medium-grained, silty, limy, clayey	Tray 5
Shale, as above; 30 percent sandstone and siltstone as above; contorted beds as above	Tray 6
Shale, as above; 50 percent siltstone and limy sandstone as above	Tray 7
Cored 24 ft, recovered 12 ft (4 trays)	9,452–9,476
Sandstone, medium-light-gray, very fine to medium-grained, silty, limy, slightly glauconitic, micaceous, clayey; 30 percent medium-dark-gray shale. Chaotic structure suggests sediment flow—mixing shale "blocks" into sandstone matrix; (reported dip 35°–50°)	Tray 1
Siltstone, medium-gray, sandy, clayey, slightly limy; beds of clayey fine- to medium-grained sandstone; pull-apart, boudinage, and flow structures	Tray 2
Sandstone, medium-light-gray, very fine to fine-grained, trace of medium grains, poorly sorted, very clayey; trace of medium-dark-gray shale; contorted bedding	Tray 3
Sandstone, as above; 35 percent dark-gray shale; contorted bedding	Tray 4
Cored 26 ft, recovered 28 ft (2 ft over-recovery) (10 trays)	9,476–9,502
Shale, dark-gray, silty, slightly limy and phosphatic; 40 percent brownish-gray very fine to medium-grained limy clayey sandstone; (reported dip 45°)	Tray 1
Sandstone, as above; some coarse grains; 30 percent shale as above; fine banding in sandstone and shale beds, contorted bedding	Tray 2
Sandstone, as above; mostly very fine to fine-grained; 30 percent shale as above	Tray 3
Shale, siltstone, and sandstone in about equal amounts; graded bedding	Tray 4
Sandstone, medium-light-gray, fine- to coarse-grained, limy, clayey	Tray 5
Sandstone, similar to above	Tray 6
Sandstone, medium-light-gray, very fine to medium-grained, scattered coarse grains, silty, limy, clayey, micaceous, trace of glauconite; some sandstone pieces have little cement left after acid treatment, others are clayey and silty	Tray 7
Sandstone, similar to above	Trays 8, 9
Sandstone, as above; many dark-gray shale laminae (probably 5 percent of sample)	Tray 10
Cored 23 ft, recovered 18 ft (6 trays)	9,502–9,525
Sandstone, as above; thin contorted shale laminae. Dull brownish-gray silty dolomite in two beds (5	

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Carneros Sandstone Member—Continued	
Second Carneros sand—Continued	
and 2 cm thick) in lower part of core; (reported dip about 45°)	Tray 1
Sandstone, as above; trace of shale laminae	Tray 2
Sandstone, light-gray, very fine to medium-grained, scattered coarse grains, silty, limy, micaceous, clayey, slightly glauconitic	Tray 3
Sandstone, similar to above; 5 percent dark-gray slightly phosphatic shale laminae	Tray 4
Sandstone, similar to above; contorted shale bed (½ in. thick) near middle of core	Tray 5
Sandstone, light-brownish-gray, very fine to medium-grained, scattered coarse grains, silty, limy to very limy, slightly dolomitic and glauconitic, clayey. The brown part of sandstone has more carbonate and less clay in cement	Tray 6
Drilled, no sample	9,525–9,527
Cored 13 ft, recovered 8 ft (3 trays)	9,527–9,540
Sandstone, as above (10 percent); grades through brownish-gray limy phosphatic very clayey and silty sandstone into silty medium-dark-gray phosphatic shale; (reported dip 40°)	Tray 1
Sandstone, similar to above; light-gray in large part; 40 percent medium-dark-gray silty sandy shale	Tray 2
Sandstone, light-gray, very fine to medium-grained, silty, limy, clayey; trace of dark-gray silty shale	Tray 3
Cored 13 ft, recovered 13 ft (5 trays)	9,540–9,553
Sandstone, medium-light-gray, medium- to coarse-grained, trace of very coarse grains, limy to very limy, glauconitic, slightly silty and clayey; coarser grained, more limy (falls apart in acid), and less clayey than most sandstone above; trace of dark-gray silty shale	Tray 1
Sandstone, similar to above; no shale	Tray 2
Sandstone, similar to above; finer grained, less limy, and more clayey	Tray 3
Sandstone, as above	Trays 4, 5
Cored 8 ft., recovered 8 ft. (3 trays)	9,553–9,561
Sandstone, medium-light-gray, very fine to medium-grained, silty, slightly limy, very clayey; trace of glauconite; (reported dip 40°–45°)	Tray 1
Sandstone, as above; grades into medium-gray very clayey silty fine- to medium-grained sandstone; trace of silty shale. Contorted bedding includes folds, boudinage structures, pull-aparts, and flow structures	Tray 2
Sandstone, light-gray, very fine to fine-grained, limy, clayey; 25 percent medium-dark-gray silty shale	Tray 3

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member:	
Cored 10 ft., recovered 10 ft. (4 trays)	9,561–9,571
Shale, medium-dark-gray, silty, slightly limy, phosphatic, hard, diatomaceous(?), finely banded in more silty part; trace of calcite as fracture fillings; (reported dip 40°–45°)	Tray 1
Shale, similar to above; more siltstone laminae	Tray 2
Shale, similar to above; little or no siltstone	Tray 3
Shale, medium-dark-gray, silty, limy, dolomitic, slightly phosphatic, hard; many calcareous Foraminifera(?) and diatoms(?) showing slight preferred orientation, fish scales; hint of fine banding	Tray 4
Cored 13 ft., recovered 12 ft. (5 trays)	9,571–9,584
Shale, as above; Foraminifera; 10 percent medium-light-gray limy siltstone; (reported dip 40°)	Tray 1
Shale, similar to above; trace of siltstone laminae	Tray 2
Shale, dark-gray to brownish-black, siliceous, silty in part, slightly limy and phosphatic; trace of Foraminifera	Tray 3
Shale, similar to above	Tray 4
Shale, similar to above; 20 percent medium-light-gray limy siltstone	Tray 5
Cored 24 ft., recovered 24 ft. (13 trays)	9,584–9,608
Shale, medium-dark-gray to dark-gray, silty, siliceous, limy, hard; 20 percent medium-light-gray very finely sandy siltstone in graded beds; medium sand-sized Foraminifera abundant, especially at base of siltstone layers	Tray 1
Shale, similar to above	Trays 2, 3
Shale, similar to above; 40 percent siltstone; trace of fractured dolomitic limy material (may be limestone or fracture fillings)	Tray 4
Shale, similar to above; 45 percent siltstone; graded laminations of siltstone and shale well developed; trace of Foraminifera	Tray 5
Shale, similar to above; more than half siltstone; many large Foraminifera	Tray 6
Shale, medium-dark-gray, silty, limy; about 50 percent finely sandy limy slightly bentonitic siltstone; slickensides associated with bentonitic material	Tray 7
Bentonite, medium-light-gray to medium-gray, silty, limy in part, medium soft, slickensided; trace of light-olive-gray limy fine- to medium-grained sandstone	Tray 8
Shale, medium-dark-gray, silty, limy; interlaminated with 40 percent siltstone	Tray 9
Bentonite, medium-light-gray, silty, slightly micaceous, nonlimy, very slightly phosphatic, slightly banded to massive; slickensides (with gypsum). Bentonite forms gel in water	Tray 10

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
Siltstone, medium-light-gray, very finely sandy, slightly limy, phosphatic, finely micaceous; interlaminated with (finely banded in part) medium-dark-gray phosphatic shale; trace of fish debris	Tray 11
Siltstone, as above; 25 percent shale as above	Tray 12
Siltstone and shale, as above; slightly phosphatic	Tray 13
Cored 21 ft., recovered 21 ft. (7 trays)	9,608–9,629
Shale, medium-dark-gray to brownish-black, slightly limy, micaceous; 10 percent medium-light-gray siltstone in graded laminae; (reported average dip 45°)	Tray 1
Shale, similar to above; many large (0.5–1.0 mm) Foraminifera	Tray 2
Shale, similar to above; more limy	Tray 3
Shale, medium-dark-gray, silty, limy, phosphatic; interbedded with 30 percent medium-gray limy very finely sandy siltstone; fish scales	Tray 4
Shale, medium-dark-gray to brownish-black, silty, slightly limy, finely micaceous; trace of olive-gray siltstone laminae (1–5 mm thick) that have sharp bases and grade upward into shale	Tray 5
Shale, similar to above; about 40 percent siltstone	Tray 6
Shale, similar to above; very silty; about 30 percent siltstone; trace of plant fragments	Tray 7
Cored 24 ft., recovered 24 ft. (10 trays)	9,629–9,653
Shale, as above; about 20 percent siltstone in contorted laminae; (reported dip 35°–45°)	Tray 1
Shale, medium-dark-gray to brownish-gray, silty, slightly limy and phosphatic; interlaminated with 5–10 percent medium-gray siltstone; trace of large (1.0 mm) Foraminifera	Tray 2
Shale, similar to above; 30 percent siltstone as above	Tray 3
Shale, similar to above; 10 percent siltstone as above	Tray 4
Shale, similar to above; 30 percent very finely sandy siltstone to very fine grained sandstone	Tray 5
Shale, medium-dark-gray, silty, slightly limy to limy, slightly phosphatic, hard; Foraminifera	Tray 6
Shale, similar to above; limy to very limy; fish debris	Tray 7
Shale, similar to above. After acid treatment resembles massive diatomaceous siltstone (diatomite)	Tray 8
Shale, similar to above; more silty; some siltstone laminae	Tray 9
Shale, medium-dark-gray to brownish-black, silty, limy, phosphatic, hard; Foraminifera, trace of fish debris	Tray 10
Cored 13 ft., recovered 13 ft. (5 trays)	9,653–9,666
Shale, as above; (reported dip 40°–45°)	Tray 1
Shale, similar to above; one very thin-shelled pelecypod (questionable "mud pecten"), abundant Foraminifera	Tray 2

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
Shale, similar to above; more clayey; abundant Foraminifera	Tray 3
Shale, similar to above; more silty; fewer Foraminifera, questionable diatoms	Tray 4
Shale, similar to above; very limy; some siliceous Foraminifera and (or) diatoms. After acid treatment rock is brownish-gray, porous; resembles reworked diatomaceous siltstone (diatomite)	Tray 5
Cored 6 ft., recovery unknown (2 trays)	9,666–9,672
Shale, medium-dark-gray, silty, slightly limy, phosphatic, finely micaceous, hard; trace of Foraminifera	Tray 1
Shale, similar to above; more limy, more microfossils	Tray 2
Note: Correct depth from (under-hole)	9,672–9,663
Cored 9 ft., recovered 8 ft. (3 trays)	9,633–9,672
Shale, medium-dark-gray to brownish-gray, silty, slightly limy, phosphatic, hard; trace of microfossils; (reported dip 45°)	Tray 1
Shale, similar to above; many fish scales	Tray 2
Shale, similar to above; fish scales; may be reworked diatomaceous siltstone (diatomite)	Tray 3
Drilled, no samples	9,672–9,685
Cored 25 ft., recovered 25 ft. (10 trays)	9,685–9,710
Shale, as above; includes several light-brown limy very phosphatic questionably organic masses that may be as large as 1 in. in diameter (may be bone); (reported dip 40°–45°)	Tray 1
Shale, medium-dark-gray, silty, limy, phosphatic, hard; trace of siltstone laminae; microfossils, fish debris	Tray 2
Shale, similar to above	Tray 3
Shale, similar to above; 10 percent siltstone	Tray 4
Shale, similar to above; little or no siltstone	Tray 5
Shale, similar to above; about 10 percent siltstone, graded laminae in part	Tray 6
Shale, medium-gray, silty, slightly limy and phosphatic, micaceous; 20 percent medium-light-gray very finely sandy siltstone	Tray 7
Shale, similar to above; much fine silt (probably reworked diatoms), slightly limy; 10 percent medium-light-gray siltstone laminae; Foraminifera, fish debris	Tray 8
Shale, similar to above	Tray 9
Shale, similar to above; 20 percent siltstone as above showing graded bedding	Tray 10
Well cuttings; shale, as above	9,710–9,739
Cored 25 ft., recovered 25 ft. (12 trays)	9,739–9,764
Shale, medium-dark-gray, silty, limy, phosphatic; (reported dip 45°)	Tray 1
Shale, medium-gray, silty, slightly limy and	

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
phosphatic, hard	Tray 2
Shale, similar to above; trace of siltstone laminae	Tray 3
Shale, medium-dark-gray, silty, slightly limy, phosphatic, hard, probably diatomaceous; microfossils	Tray 4
Shale, similar to above	Tray 5
Shale, similar to above; trace of siltstone laminae	Tray 6
Shale, medium-dark-gray, silty, slightly limy, micaceous, phosphatic, hard	Tray 7
Shale, similar to above; microfossils	Tray 8
Shale, medium-dark-gray, silty, limy, slightly phosphatic, hard; Foraminifera, fish scales	Tray 9
Shale, similar to above	Trays 10–12
Drilled, no samples	9,764–9,786
Cored 23 ft., recovered 23 ft. (10 trays)	9,786–9,809
Shale, medium-dark-gray, limy, slightly phosphatic, silty, hard, probably diatomaceous; Foraminifera; (reported dip 40°–45°)	Tray 1
Shale, similar to above	Trays 2, 3
Shale, similar to above; 10 percent phosphatic limy micaceous siltstone laminae; pull-apart structures	Tray 4
Shale, similar to above; trace of siltstone	Tray 5
Shale, similar to above; 10 percent siltstone, some contorted beds	Tray 6
Shale, similar to above; 10 percent siltstone	Tray 7
Shale, similar to above; 20 percent very finely sandy siltstone; trace of "mud pectens"	Tray 8
Siltstone, medium- to medium-dark-gray, very finely sandy, limy, phosphatic, micaceous, clayey; contorted beds and pull-apart structures; 50 percent shale as above	Tray 9
Shale, medium-dark-gray, silty, limy, slightly phosphatic, hard	Tray 10
Drilled, no samples	9,809–9,824
Cored 18 ft., recovered 10 ft. (4 trays)	9,824–9,842
Shale, medium-dark-gray, silty, slightly limy to limy, slightly phosphatic, hard; microfossils; (reported dip about 45°)	Tray 1
Shale, similar to above	Tray 2
Shale, similar to above but darker; many Foraminifera, trace of "mud pectens"	Tray 3
Shale, similar to above; nearly 10 percent silty very fine grained sandstone (laminae or burrow fillings)	Tray 4
Drilled, no samples	9,842–9,852
Cored 21 ft., recovered 16 ft. (6 trays)	9,852–9,873
Shale, medium-dark-gray, silty, limy, phosphatic, micaceous; 20 percent medium-light-gray limy micaceous siltstone laminae that grade upward into shale; Foraminifera; (reported dip about 40°)	Tray 1
Shale, similar to above; less siltstone; questionable	

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
burrow fillings; large (1 mm) Foraminifera	Tray 2
Shale, medium-dark- to dark-gray, silty, limy, slightly phosphatic, micaceous; Foraminifera	Tray 3
Shale, similar to above; fish scales	Tray 4
Shale, medium-dark-gray, very silty, limy, slightly phosphatic, micaceous, hard; fish scales and vertebrae	Tray 5
Shale, similar to above; much fine silt (probably cryptocrystalline quartz derived from diatoms)	Tray 6
Well cuttings. Shale, similar to above	9,873–9,936
Cored 16 ft., recovered 9 ft. (3 trays)	9,936–9,952
Shale, medium-gray, silty, limy, slightly phosphatic, micaceous; trace of siltstone laminae; fish debris, Foraminifera; (reported dip 30°–40°)	Tray 1
Shale, medium-dark-gray, silty, slightly limy to limy, slightly phosphatic, probably diatomaceous; Foraminifera	Tray 2
Shale, as above; 40 percent medium-light-gray siltstone laminae	Tray 3
Well cuttings. Shale, medium-dark-gray, silty, slightly limy and phosphatic, probably diatomaceous; many Foraminifera	9,952–10,023
Cored 11 ft., recovered 9 ft. (3 trays)	10,023–10,034
Shale, medium-gray, silty, limy, slightly phosphatic, hard, diatomaceous(?), Foraminifera; (reported dip 45°)	Tray 1
Shale, similar to above; trace of siltstone	Trays 2, 3
Well cuttings.	
Shale, medium-dark-gray, silty, limy, slightly phosphatic; many microfossils. Residue from acid looks like diatomaceous siltstone (diatomite)	10,034–10,148
Cored 8 ft., recovered 2 ft. (1 tray)	10,148–10,156
Shale, medium-gray, very silty, slightly limy and phosphatic; much silt (questionable diatoms) and much clastic siltstone. Unit probably grades downward into siltstone; (reported dip 55°)	Tray 1
Well cuttings. Silty shale, as above	10,156–10,180
Shale, similar to above; dark-brownish-gray very dolomitic siltstone or silty dolomite; tiny "spicules"	10,180–10,210
Shale, medium-dark-gray, silty, slightly limy to dolomitic; diatomaceous(?); interbedded with medium-light-gray limy to dolomitic glauconitic silty very fine to fine-grained sandstone with trace of medium grains; trace of dark-brownish-gray limy silty dolomite	10,210–10,229
Cored 15 ft., recovered 4½ ft. (2 trays)	10,229–10,244
Sandstone, medium-light-gray, very fine to fine-grained, scattered medium grains, silty, very limy, dolomitic, pyritic, glauconitic, clayey; (reported dip 50°)	Tray 1
Shale, medium-gray, silty, slightly limy to limy (may be dolomitic), slightly phosphatic, even-	

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
grained and hard (may be diatomaceous); trace of Foraminifera	Tray 2
Drilled, no sample	10,244–10,252
Cored 25 ft., recovered 18 ft. (7 trays)	10,252–10,277
Shale, as above; pyrite, Foraminifera; (reported dip about 45°)	Tray 1
Shale, similar to above	Trays 2, 3
Shale, medium-gray, silty, slightly limy or dolomitic, slightly phosphatic, hard, even-grained; trace of fish debris and Foraminifera	Tray 4
Shale, similar to above; less limy in lower part	Trays 5–7
Drilled, no samples	10,277–10,293
Cored 6 ft., recovered 4 ft. (2 trays)	10,293–10,299
Shale, dull medium-dark-gray, silty, very slightly limy, slightly phosphatic, hard; (reported dip 45°–50°)	Tray 1
Shale, similar to above; probably clayey diatomaceous siltstone (diatomite)	Tray 2
Well cuttings. Shale, similar to above; several pieces of brownish-gray silty dolomite (probably out of place)	10,299–10,353
Cored 6 ft., recovered 4 ft. (2 trays)	10,353–10,359
Shale, dull medium-dark-gray, silty, very slightly limy to nonlimy, slightly phosphatic, even-grained, hard, diatomaceous(?); trace of fish scales; (reported dip 45°)	Tray 1
Shale, similar to above; 50 percent medium-light-gray slightly limy siltstone	Tray 2
Well cuttings. Shale, dark-brownish-gray, slightly limy, phosphatic; Foraminifera. In these samples there is as much as 50 percent medium-light-gray limy slightly phosphatic glauconitic silty very fine to medium-grained sandstone (may be out of place)	10,359–10,414
Cored 15 ft., recovered 12 ft. (5 trays)	10,414–10,429
Siltstone, medium-light- to medium-gray, dolomitic, phosphatic. Lighter colored rock is coarsest; some of the darker rock grades into very siliceous dolomite. Contorted laminae and beds; (reported dip 50°–55°)	Tray 1
Siltstone, similar to above; 20 percent medium-gray siltstone (questionably diatomaceous)	Tray 2
Siltstone, similar to above; many medium sand grains in a few lenses; 20 percent siltstone or silty shale, probably diatomaceous (diatomite)	Tray 3
Siltstone, medium-light-gray, very finely sandy, limy, slightly phosphatic, clayey; 20 percent brownish-gray dolomitic siltstone or silty dolomite (may be siderite), may be diatomaceous	Tray 4
Shale (or diatomite), medium-gray, silty, slightly limy and phosphatic, hard, poorly laminated	Tray 5
Cored 19 ft., recovered 22 ft. (3 ft. over-recovery) (9 trays)	10,429–10,448
No samples	Tray 1

Miocene Series—Continued
Temblor Formation—Continued
Santos Shale Member—Continued

	Depth (ft)
Shale, dull medium-gray, silty, slightly limy and phosphatic, hard; contorted laminae; may be diatomaceous (diatomite); trace of microfossils; (reported dip 45° to 50°)	Tray 2
Shale, similar to above; trace of siltstone in discontinuous contorted beds	Tray 3
Shale, dull medium-dark-gray, silty, limy, slightly phosphatic, hard; trace of fish scales	Tray 4
Shale, similar to above; contorted siltstone laminae	Tray 5
Siltstone, dull medium-gray, slightly limy (or dolomitic) and phosphatic, clayey; some silty shale as above	Tray 6
Siltstone, similar to above; 50 percent silty shale	Tray 7
Shale, as tray 4; laminae of siltstone	Tray 8
Shale, similar to above; 15 percent medium-light-gray glauconitic fine-grained sandstone	Tray 9
Cored 16 ft, recovered 12 ft (4 trays)	10,448–10,464
Shale, dull medium-gray, silty (upper 16 in.), slightly limy and phosphatic; medium-light-gray limy slightly phosphatic glauconitic silty clayey fine-grained sandstone (lower 11 in.); (reported dip 45°–60°)	Tray 1
Sandstone, medium-light-gray, very fine to fine-grained, scattered medium grains, silty, limy, slightly phosphatic, clayey	Tray 2
Shale, dull brownish-black, silty, slightly limy, phosphatic, more clayey than most samples above; slickensides; fish scales	Tray 3
Shale, dull medium-gray to brownish-gray, silty, limy to very limy (silty limestone in part), slightly phosphatic. Residue after acid treatment looks like dull brown diatomaceous siltstone (diatomite)	Tray 4
Cored 14 ft., recovered 14 ft. (6 trays)	10,464–10,478
Siltstone, medium-light-gray, well sorted, very slightly limy; 40 percent medium-gray slightly phosphatic silty shale; (reported dip 50°–55°)	Tray 1
Shale, dull medium-dark-gray, silty, slightly limy and phosphatic, hard	Tray 2
Shale, similar to above	Tray 3
Siltstone, dull medium-gray, slightly limy and phosphatic, clayey; interbedded with 30 percent shale as above; slickensides	Tray 4
Siltstone, similar to above; trace of medium-gray clayey very fine to medium-grained sandstone	Tray 5
Shale, dull medium-dark-gray, silty, slightly limy, hard; trace of siltstone as above	Tray 6
Drilled, no samples	10,478–10,534
Cored 9 ft., recovered 2 ft. (1 tray)	10,534–10,543
Siltstone, dull medium-light- to medium-gray, slightly limy, phosphatic, clayey; grades into medium-dark-	

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
gray phosphatic shale; fish scales; (reported dip 30°–40°)	Tray 1
Well cuttings. Mostly shale similar to above; some dark-gray phosphatic shale; some siltstone as above	10,543–10,600
Cored 6 ft., recovered 4 ft. (2 trays)	10,600–10,606
Siltstone, dull medium-light- to medium-gray, slightly limy and phosphatic, clayey; laminae and stringers of medium-dark-gray shale; (reported dip 40°–45°)	Tray 1
Siltstone, medium-light-gray, very finely sandy, slightly limy and phosphatic, clayey; trace of dark-gray shale; dull earthy brownish-gray silty dolomite (probably nodules)	Tray 2
Well cuttings. Shale, medium-dark-gray, silty, slightly limy; laminae of medium-gray siltstone and medium-light-gray silty very fine grained sandstone; trace of Foraminifera	10,606–10,652
Cored 7 ft., recovered 5 ft. (2 trays)	10,652–10,659
Shale, dull dark-brownish-gray, very silty, slightly limy (or dolomitic) and phosphatic; 10 percent medium-gray siltstone laminae	Tray 1
Shale, as above; 30 percent siltstone as above; very little lime in shale	Tray 2
Well cuttings. Shale as above; some siltstone and sandstone; slickensides, some fracture-filling	10,659–10,678
Dolomite, dull brownish-gray, very limy, clayey, siliceous, fractured in part	10,678–10,686
Shale, dull medium-dark-gray, very silty	10,686–10,721
Cored 8 ft., recovered 4 ft. (2 trays)	10,721–10,729
Dolomite, medium-light-gray, limy, silty, clayey, finely granular to dense; fractures filled with clear calcite; 10 percent medium-light-gray finely sandy siltstone; (reported dip about 40°)	Tray 1
Sandstone, medium-light-gray, very fine to medium-grained, silty, slightly dolomitic to dolomitic, clayey; 10 percent dolomite as above	Tray 2
Well cuttings. Sandstone, light- to medium-light-gray (some "salt and pepper"), very fine to fine-grained, scattered medium grains, silty, limy, slightly dolomitic, clayey; interbedded with medium-dark-gray silty shale	10,729–10,770
Sandstone and shale, as above; 10 percent medium-light-gray to light-brownish-gray dense dolomite	10,770–10,780
Sandstone, medium-light-gray, very fine to fine-grained, medium grains in part, silty, dolomitic, slightly glauconitic; interbedded with dark-gray silty shale	10,780–10,793
Cored 9 ft., no recovery	10,793–10,802
Cored 13 ft., recovered 15 feet (2 ft. over-recovery) (5 trays)	10,802–10,815
Sandstone, light-gray, very fine to fine-grained, trace	

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
of medium grains, silty, limy, dolomitic, clayey, glauconitic, much light-gray matrix—may be dolomitic clay (may be largely of volcanic origin); 50 percent medium-gray dolomitic slightly phosphatic shale and siltstone; fish scales; (reported dip 45°–50°)	Tray 1
No samples	Trays 2, 3
Sandstone, similar to above; more siltstone and less sandstone; dark-gray imbricated plant fragments in lower 4 in. of core	Tray 4
Siltstone, medium-light-gray, very dolomitic, scattered very fine sand; fish scales, plant fragments	Tray 5
Cored 8 ft., recovered 8 ft. (3 trays)	10,815–10,823
Siltstone, as above; (reported erratic dips 40°–60°)	Tray 1
Siltstone, similar to above	Tray 2
Siltstone, similar to above; scattered very fine to medium sand	Tray 3
Cored 13 ft., recovered 7 ft. (3 trays)	10,823–10,836
Siltstone, medium-light-gray, dolomitic, very clayey, slightly phosphatic, hard; many dark-gray coalified plant fragments as much as 5 mm long imbricated in some pieces of core; (reported dip 45°)	Tray 1
Siltstone, as above; 35 percent medium-light-gray dolomitic clayey silty very fine to fine-grained sandstone; plant fragments	Tray 2
Siltstone, similar to above; 15 percent sandstone; trace of dull brownish-gray silty dolomite	Tray 3
Well cuttings. Siltstone, similar to above; dark-brownish-gray silty shale; medium-light-gray siltstone; light-gray to "salt and pepper" very fine to fine-grained sandstone; trace of dolomite	10,836–10,901
Cored 9 ft., recovered 7 ft. (3 trays)	10,901–10,910
Shale, medium-gray, silty, slightly dolomitic and phosphatic, hard; 5 percent medium-light-gray slightly limy (or dolomitic) clayey silty very fine to coarse-grained sandstone; (reported dip 55°)	Tray 1
Shale, dull dark-brownish-gray to medium-dark-gray, very silty, slightly limy and phosphatic; trace of medium-light-gray very silty dolomite	Tray 2
Shale, medium- to medium-dark-gray, very silty, slightly limy; interlaminated with (graded laminae) medium-light- to medium-gray clayey dolomitic siltstone	Tray 3
Drilled, no samples	10,910–10,940
Shale, dark-gray; medium-light-gray ("salt and pepper") very fine to fine-grained sandstone	10,940–10,953
Cored 9 ft., recovered 9 ft. (3 trays)	10,953–10,962
Siltstone, medium-light- to medium-gray, slightly limy or dolomitic, clayey; 30 percent medium-gray slightly phosphatic silty shale; (reported dip 50°–60°)	Tray 1

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
Shale, dull brownish-gray to brownish-black, silty, nonlimy, phosphatic; many slickensides; grades into medium-gray clayey siltstone (10 percent of sample)	Tray 2
Shale, dull brownish-gray, silty; slickensides; probably diatomaceous	Tray 3
Well cuttings. Shale, as above; slickensides, trace of fish scales; trace of dark-brownish-gray dolomite mostly in lower part of unit; medium-light-gray ("salt and pepper") very fine grained sandstone and limy fine-grained sandstone (may be caving)	10,962–11,026
Cored 6 ft., recovered 4 ft. (2 trays)	11,026–11,032
Shale, dull medium-dark-gray, silty, slightly limy and phosphatic, hard; trace of slickensides; a few siltstone laminae; (reported dip 50°–55°)	Tray 1
Shale, similar to above; contaminated sample	Tray 2
Well cuttings. Shale, dull dark-gray, silty; medium-light-gray ("salt and pepper") very fine to fine-grained sandstone; trace of dolomite	11,032–11,070
Shale, as above; 50 percent light-gray ("salt and pepper") very limy dolomitic pyritic very fine grained sandstone	11,070–11,080
Cored 8 ft., recovered 5½ ft. (2 trays)	11,080–11,088
Siltstone, medium-light-gray, very dolomitic; interlaminated with (graded laminae) slightly darker more clayey less dolomitic siltstone; (reported dip 55°–58°)	Tray 1
Siltstone, as above; some grades into medium-gray silty shale; medium-light-gray limy clayey silty slightly glauconitic very fine to medium-grained sandstone (lower 6 in. of core)	Tray 2
Well cuttings. Shale, dark-gray; slickensides; medium-light-gray ("salt and pepper") very fine to fine-grained sandstone; trace of medium-light-gray siltstone. Poor samples	11,088–11,143
Cored 8 ft., recovered 6 ft. (2 trays)	11,143–11,151
Shale, dull medium-dark-gray, silty, very slightly limy, slightly phosphatic, hard; contorted laminae (pullaparts) of slightly limy siltstone; (reported dip 55°)	Tray 1
Shale, as above; 50 percent medium-light-gray slightly limy very finely sandy siltstone in contorted graded laminae	Tray 2
Well cuttings. Shale, dull dark-gray, silty; some medium-light-gray siltstone and very fine to medium-grained sandstone	11,151–11,190
Shale, as above; 30 percent medium-light-gray limy clayey silty very fine to medium-grained sandstone, trace of coarse grains; plant debris	11,190–11,215
Cored 13 ft., recovered 6 ft. (2 trays)	11,215–11,228
Shale, dull dark-brownish-gray, silty, slightly limy and	

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
phosphatic, finely micaceous; trace of microfossils, plant debris; 1 ft. of medium-light-gray slightly limy clayey silty very fine to medium-grained sandstone, trace of coarse grains; (reported dip 55°)	Tray 1
Sandstone, as above (1½ ft.); shale as above; trace of siltstone	Tray 2
Cored 18 ft., recovered 13 ft. (5 trays)	11,228–11,246
Siltstone, medium-gray, sandy, clayey, slightly limy and phosphatic, scattered sand grains and one granule; laminae of dark-gray shale, probably slumped graded laminae; (reported dip 45°)	Tray 1
Sandstone, medium-light- to medium-gray, very fine to coarse-grained (sand in mudstone matrix), very clayey, silty, slightly limy (or dolomitic) and phosphatic; interlaminated with (graded laminae) medium-dark-gray shale and medium-light-gray siltstone	Tray 2
Shale, medium-dark-gray to dark-brownish-gray, slightly phosphatic, finely micaceous; more of a shale fracture than most shale above	Tray 3
Shale, as above; 20 percent medium-light-gray slightly limy siltstone in graded laminae	Tray 4
Sandstone, medium-light-gray, very fine to coarse-grained, silty, limy, clayey, glauconitic; trace of contorted shale laminae	Tray 5
Cored 20 ft., recovered 8 ft. (3 trays)	11,246–11,266
Sandstone, medium-light-gray, very fine to very coarse grained, abundant subangular to subrounded grains of feldspar and rock fragments, very silty and clayey, slightly limy to limy; trace of medium-dark-gray shale with siltstone laminae; (reported dip 55°)	Tray 1
Shale, medium-dark-gray, very silty, slightly phosphatic; 20 percent sandstone as above	Tray 2
Shale, medium-dark-gray, silty, slightly limy and phosphatic; interbedded with light-gray siltstone; 4 in. of medium-light-gray slightly limy very clayey and silty fine- to coarse-grained sandstone at base	Tray 3
Cored 20 ft., recovered 6 feet. (2 trays)	11,266–11,286
Shale, medium-gray, silty, slightly limy and phosphatic, hard; interbedded with medium-light-gray slightly limy siltstone and medium-light-gray very fine to fine-grained sandstone; (reported dip 45°–60°)	Tray 1
Siltstone, medium light-gray, finely sandy, limy, clayey; interlaminated with medium-dark-gray shale, some very thin graded laminae	Tray 2
Cored 8 ft, recovered 3 ft (1 tray)	11,286–11,294
Siltstone, as above; 20 percent shale as above; many plant fragments in each	Tray 1
Well cuttings. Shale and siltstone, as above	11,294–11,326

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
Cored 10 ft., recovered 3 in. No samples available	11,326–11,336
Reported description:	
11,326–11,326¼ Shale, dark-grayish-brown, silty, hard; interlaminated with gray very fine grained silty sandstone; dip about 20°.	
11,326¼–11,336 Lost.	
Cored 12 ft., no recovery	11,336–11,348
Well cuttings. Sandstone, medium light-gray ("salt and pepper"), very fine to fine-grained, trace of coarse grains, silty, slightly limy, clayey	11,348–11,373
Cored 4 ft., recovered 3 in. (1 tray)	11,373–11,377
Sandstone, medium-light-gray ("salt and pepper"), very fine to fine-grained (2 in. piece), silty, slightly limy; medium-dark-gray shale	Tray 1
Well cuttings. Shale, medium-dark-gray, silty; 20 percent medium-light-gray ("salt and pepper") silty limy very fine to medium-grained standstone, trace of coarse grains; trace of slightly banded medium-light-gray ("salt and pepper") siltstone	11,377–11,410
Sandstone, medium-light-gray ("salt and pepper"), very fine to fine-grained, silty, limy, clayey, micaceous, glauconitic, faintly banded	11,410–11,450
Sandstone, as above; 50 percent shale, probably from above	11,450–11,472
Cored 14 ft., recovered 5 ft. (2 trays)	11,472–11,486
Sandstone, light-gray, very fine to coarse-grained, silty, slightly limy and dolomitic, very clayey, glauconitic, micaceous; 10 percent medium-dark-gray shale; (reported dip about 60°)	Tray 1
Sandstone and shale, as above	Tray 2
Well cuttings. Sandstone, as above; 50 percent shale (may be caving)	11,486–11,508
Cored 13 ft., recovered 7 ft. (3 trays)	11,508–11,521
Sandstone, light- to medium-light-gray ("salt and pepper"), very fine to coarse-grained, very silty and clayey, limy, slightly phosphatic, glauconitic, slightly banded or laminated; (reported dip 45°–55°)	Tray 1
Sandstone, as above; mostly fine-grained	Tray 2
Sandstone, medium-light-gray, very fine to fine-grained, trace of medium grains, silty, limy, clayey, slightly phosphatic	Tray 3
Well cuttings. Sandstone, as above; many pieces are 30 percent coarse grains	11,521–11,565
Cored 8 ft., recovered ½ ft. No samples available	11,565–11,573
Reported description:	
11,565–11,565½ Shale, dark-grayish-brown, silty, micaceous, hard; dip about 55°.	
11,565½–11,573 Lost.	
Well cuttings. Sandstone, as above; lower 10 ft. probably shale as below	11,573–11,617

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
Cored 5 ft., recovered 3 ft. (1 tray)	11,617–11,622
Shale, medium-dark-gray, silty, nonlimy, slightly phosphatic; siltstone laminae; (reported dip about 60°)	Tray 1
Well cuttings. Shale, dark-gray, silty; 40 percent medium-light-gray very fine to coarse-grained sandstone (probably caving)	11,622–11,669
Cored 9 ft., recovered 3 ft. (1 tray)	11,669–11,678
Shale, dull dark-gray, silty, nonlimy, slightly dolomitic, micaceous; a few laminae of medium-gray siltstone; (reported dip 60°–70°)	Tray 1
Well cuttings. Shale, as above; interbedded with medium-light-gray ("salt and pepper") very fine to coarse-grained sandstone and medium-light-gray siltstone	11,678–11,735
Sandstone, medium-light-gray ("salt and pepper"), very fine to coarse-grained, silty; interbedded with dark-gray shale. Poor samples	11,735–11,769
Cored 9 ft., recovered 7 ft. (3 trays)	11,769–11,778
Siltstone, medium-light-gray, slightly limy; interlaminated with 30 percent medium-dark-gray finely micaceous slightly phosphatic silty shale; (reported dip 70°–80°)	Tray 1
Siltstone, medium-light-gray ("salt and pepper"), slightly limy, clayey; a few dark-gray shale partings; contorted laminae; coalified plant debris	Tray 2
Siltstone, medium-light-gray, very finely sandy, limy, clayey; interlaminated with (graded laminae) 40 percent medium-dark-gray shale; contorted laminae	Tray 3
Well cuttings. Shale, dull medium-dark-gray; some siltstone as above and trace of medium-grained sandstone. Poor samples	11,778–11,819
Cored 3 ft., recovered 1½ ft. (1 tray)	11,819–11,822
Shale, dark-gray to olive-black, nonlimy, slightly phosphatic; questionable microspicules; (reported dip about 75°)	Tray 1
Well cuttings. Shale, as above	11,822–11,869
Cored 6 ft., recovered ½ ft. No sample	11,869–11,875
Well cuttings. Shale, as above. Poor samples	11,875–11,930
Shale, dark-gray, slightly phosphatic; some slickensides. Poor samples	11,930–11,950
Shale, dark-brownish-gray. Poor samples	11,950–11,994
Cored 6 ft., no recovery	11,994–12,000
Cored 6 ft., recovered 11 ft. (5 ft. over-recovery) (4 trays)	12,000–12,006
Shale, medium-dark-gray, silty, nonlimy, phosphatic; may be reworked diatomaceous siltstone (diatomite); (reported dip about 75°)	Tray 1
Shale, similar to above	Trays 2–4

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
Well cuttings. Shale, as above; some slickensides; trace of light-gray siltstone and sandstone in lower part	12,006–12,062
Cored 13 ft., recovered 10 ft. (4 trays)	12,062–12,075
Shale, medium- to medium-dark-gray, finely micaceous, slightly phosphatic (upper 1 ft.); light-gray slightly limy siltstone; some finely mottled limy pyritic questionably fossiliferous siltstone; (reported dip 70°)	Tray 1
Siltstone, light-gray, finely mottled, finely micaceous	Tray 2
Siltstone, light-gray (mottled with medium-light-gray spots), slightly limy, very finely micaceous. Siltstone crushed in clove oil, 95 percent microcrystalline, index less than oil, includes questionable shards (W. A. McCracken)	Tray 3
Siltstone, similar to above; slightly coarser mica	Tray 4
Well cuttings. Shale, dark-gray, silty; trace of sandstone. Poor samples	12,075–12,100
Casing cemented	12,100
Samples mostly pipe scale; trace of siltstone as below	12,100–12,161
Cored 14 ft., recovered 13 ft. (5 trays)	12,161–12,175
Siltstone, pale-yellowish-brown, finely sandy, slightly limy. Siltstone crushed in clove oil, 90 percent microcrystalline, low birefringence, trace of shards, 3–6 percent quartz and feldspar silt (W. A. McCracken). Interbedded with medium-gray slightly phosphatic silty shale; (reported dip 60°–65°)	Tray 1
Shale, as above; 30 percent siltstone as above; more very fine sand	Tray 2
Siltstone, medium-gray, very slightly limy, slightly phosphatic; much coalified plant debris; 30 percent medium-gray silty shale	Tray 3
Siltstone, as above; 60 percent pale-yellowish-brown and 40 percent medium-light-gray; contains plant debris	Tray 4
Siltstone, light-gray, slightly limy; interbedded with 20 percent medium-gray silty shale; trace of plant debris	Tray 5
Cored 4 ft., recovered 5 ft. (1 ft. overrecovery) (2 trays)	12,175–12,179
Siltstone, medium-light- to light-gray, slightly limy and phosphatic, fiinely sandy in part; grades into and interbedded with medium-gray to olive-gray slightly limy and phosphatic hard silty shale; some medium-light-gray soft flaky bentonite(?); (reported dip 65°)	Tray 1
Siltstone, medium-gray, slightly limy and dolomitic, clayey, hard, very finely sandy in part, very clayey in part; plant debris	Tray 2
Cored 47 ft., recovered 47 ft. (18 trays)	12,179–12,226
Siltstone, as above; 50 percent slightly darker and finer-grained, 50 percent lighter and coarser-	

Miocene Series—Continued
Temblor Formation—Continued
Santos Shale Member—Continued

	Depth (ft)
grained; (reported dip 60°–70°)	Tray 1
Siltstone, medium-light-gray, slightly limy, clayey, hard; trace of medium-gray clayey siltstone with coalified plant fragments	Tray 2
Siltstone, medium-light-gray, nonlimy, very slightly phosphatic; trace of plant fragments	Tray 3
Siltstone, medium-light-gray, nonlimy to slightly limy; scattered very fine sand in some pieces of siltstone, other pieces "dense"	Tray 4
Siltstone, medium-light-gray, finely sandy, slightly limy (acid etches only certain grains), micaceous; trace of small structures that look organic but probably are volcanic (almost pelletal); calcareous masses (about 3 mm) especially about 8 in. above base; trace of dark-gray plant fragments	Tray 5
Siltstone, similar to above; some medium "sand"; volcanic glass observed under petrographic microscope	Tray 6
Siltstone, medium-light-gray to yellowish-brown, slightly limy; little or no sand; dull yellowish-brown part is flaky but does not form gel in water	Tray 7
Siltstone, medium-light-gray, finely sandy, slightly limy, clayey. Some pieces of siltstone contain no sand and have a mottled "pelletal" texture; trace of plant debris	Tray 8
Siltstone, medium-light-gray, slightly limy, hard; interbedded with 50 percent medium-gray hard silty shale	Tray 9
Siltstone, medium-light- to medium-gray, very slightly limy, finely laminated in part; trace of plant debris	Tray 10
Siltstone, light-gray, slightly limy to limy (may be dolomitic)	Tray 11
Siltstone, medium-light-gray, slightly limy, laminated in part, very mottled and "pelletal" in part and contains alined plant fragments. Probably grades upwards into laminated siltstone in a sequence of graded beds	Tray 12
Siltstone, light-gray, limy; 30 percent medium-light-gray "dense" siltstone. Both types finely mottled	Tray 13
Siltstone, similar to above; trace of plant fragments. Coarser-grained beds have load casts at basal contact with finer-grained beds	Tray 14
Siltstone, medium-light-gray, slightly limy; grades into shale; light-yellowish-gray calcareous masses (1–3 mm); plant fragments in shale	Tray 15
Siltstone, light-gray, slightly limy; plant fragments; 1 in. bed of olive-gray silty shale 5 in. above base	Tray 16
Siltstone, light-gray, slightly limy; plant fragments	Tray 17
Siltstone, light-gray, limy, slightly dolomitic; 50 percent medium-gray shale; plant debris in siltstone	Tray 18

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
Cored 20 ft., recovered 19 ft. (7 trays)	12,226–12,246
Siltstone, medium-light-gray, slightly limy; trace of medium-gray shale; plant fragments throughout; (reported dip 65°–68°)	Tray 1
Siltstone, medium-light-gray, slightly limy; trace of plant debris	Tray 2
Siltstone, similar to above	Tray 3
Siltstone, similar to above; micaceous	Tray 4
Siltstone, medium-light-gray, slightly limy; grades into medium-gray shale; plant debris	Tray 5
Shale, medium-light-gray, slightly limy; calcite fracture fillings; plant debris	Tray 6
Siltstone, medium-light- to light-gray, limy to very limy, dolomitic, "sandy"; many plant fragments. In sharp contact with medium-gray slightly phosphatic silty shale	Tray 7
Cored 25 ft., recovered 25 ft. (12 trays)	12,246–12,271
Shale, medium-gray, silty; trace of medium-light-gray limy siltstone; (reported dip 65°–75°)	Tray 1
Shale, similar to above	Tray 2
Shale, medium-dark-gray, silty, slightly limy and phosphatic; trace of plant debris and microfossils	Tray 3
Shale, similar to above	Tray 4
Shale, as above; interlaminated (may be graded laminae) with medium-light-gray slightly limy siltstone	Tray 5
Shale, medium-dark-gray to dark-brownish-gray, silty, slightly limy and phosphatic, finely micaceous, slightly pyritic	Tray 6
Shale, as above, few siltstone laminae, glauconite, pyrite, questionable burrow fillings	Tray 7
Shale, medium-dark-gray to dark-brownish-gray	Tray 8
Shale, medium-dark-gray to dark-brownish-gray, silty, slightly limy and phosphatic. Samples in water display abundant silt, glauconite, Foraminifera, mica, pyrite, and burrow fillings	Tray 9
Shale, similar to above; very silty in part	Tray 10
Siltstone, medium-gray to olive-gray, slightly limy, phosphatic, glauconitic; trace of shale as above	Tray 11
Siltstone, light- to medium-light-gray, slightly limy, phosphatic; grades into and interlaminated (may be graded laminae) with medium-dark-gray phosphatic slightly glauconitic silty shale	Tray 12
Well cuttings. Siltstone and shale, as above. Dirty samples	12,271–12,322
Cored 49 ft., recovered 45 ft. No samples available	12,322–12,371
Reported description:	
12,322–12,326 Sandstone, "dirty" gray, fine-grained, very silty, well cemented, hard; interbedded with hard limy dark-gray siltstone;	

	Depth (ft)
Miocene Series—Continued	
Temblor Formation—Continued	
Santos Shale Member—Continued	
irregular streaks and laminae of silty dark-brown shale in lower 1 ft.	
12,326–12,367 Shale, dark-brown to grayish-brown, silty, hard, massive; irregular streaks, laminae, and inclusions of "dirty" gray sandstone and dark-gray limy siltstone as above; few fine pyrite veins and clusters; scattered large plant fragments; dip 60°–65°.	
12,367–12,371 Lost.	
Well cuttings. Shale and siltstone, as above	12,371–12,380
Drilled, no samples	12,380–12,430
Well cuttings. Siltstone, medium-light-gray, slightly limy, very finely sandy in part; 30 percent medium-dark-gray phosphatic silty shale	12,430–12,549
Cored 7 ft., no recovery	12,549–12,556
Well cuttings. Siltstone and shale, as above. Dirty samples	12,556–12,597
Cored 4 ft., recovered 1½ ft. No samples available	12,597–12,601
Description reported:	
12,597–12,598½ Shale, dark-brown, silty, silicious, hard, partly fractured; rare small fragments; dip 50°–60°.	
12,598½–12,601 Lost.	
Well cuttings. Shale, as above; unwashed samples	12,601–12,620
Oligocene Series:	
Temblor Formation—Continued	
Santos Shale Member—Continued	
Shale, medium-dark-gray, slightly limy to limy, phosphatic. Mostly unwashed samples	12,620–12,696
Cored 7 ft., recovered 7 ft. No samples available	12,696–12,703
Description reported:	
12,696–12,703 Shale, brown, silty, hard, massive, micaceous; common small plant fragments; dip about 45°.	
Well cuttings. Shale, medium-dark-gray, slightly limy; slickensides; medium-gray very silty dolomite	12,703–12,760
Drilled, no samples	12,760–12,789
Cored 10 ft., recovered 10 ft. No samples available	12,789–12,799
Description reported:	
12,789–12,799 Shale, dark-brown, silty, hard, massive; abundant plant fragments; dip 35°–40°.	
Well cuttings. Shale, medium-dark-gray, phosphatic; slickensides. Unwashed samples	12,799–12,856
Total depth: Driller	12,856
Electrical log	12,843

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