Lower and Middle Tertiary Stratigraphic Units of the San Emigdio and Western Tehachapi Mountains, California

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By T. H. NILSEN, T. W. DIBBLEE, JR., *and* W. O. ADDICOTT

CONTRIBUTIONS TO STRATIGRAPHY

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LOWER AND MIDDLE TERTIARY STRATIGRAPHIC UNITS OF THE SAN EMIGDIO AND WESTERN TEHACHAPI MOUNTAINS, CALIFORNIA

By T. H. NILSEN, T. W. DIBBLEE, JR., and W. O. ADDICOTT

ABSTRACT

Lower and middle Tertiary stratigraphic units exposed in the San Emigdio and western Tehachapi Mountains, Calif., consist of the Tejon Formation (Eocene), San Emigdio Formation (late Eocene and Oligocene), Pleito Formation (Oligocene), Tecuya Formation (late Eocene(?) to early Miocene), Temblor Formation (early Miocene), and the Monterey Shale and an unnamed conglomerate unit (both middle and late Miocene). These units, well exposed in the central part of the report area, constitute one of the few fossiliferous, continuously deposited marine sedimentary sequences in California of early and middle Tertiary age. This sequence is moderately thick, and the marine strata interfinger eastward into nonmarine beds that contain fossil mammals and include radiometrically dated volcanic rocks. The marine San Emigdio and Pleito Formations and the nonmarine Tecuya Formation are redefined in this paper according to lithology, thickness, stratigraphic relations, depositional environments, ages, type sections, and type localities.

Most of the marine Eocene, Oligocene, and early Miocene strata were deposited on a shallow marine shelf that deepened westward and northward. The nonmarine fluvial strata of the Tecuya Formation to the east were probably deposited as alluvial fans fringing the shallow marine shelf. Climatic and tectonic changes affecting the supply of sediment resulted in a migrating and oscillating shoreline. Tectonic uplift in the southwestern part of the San Emigdio Mountains during Oligocene and early Miocene time produced a local angular unconformity.

INTRODUCTION

The lower and middle Tertiary stratigraphic units exposed in the San Emigdio and western Tehachapi Mountains form a sequence of sedimentary and volcanic rocks that is valuable for related stratigraphic and paleontologic studies in California. The section is moderately thick, complete, and well exposed in most of the area and contains interbedded volcanic rocks that have been radiometrically dated. In addition, the exposures present an east-west cross section of similar rocks that are concealed under the south end of the San Joaquin Valley. The continuous succession of Eocene to middle Miocene shallow-water molluscan assemblages in the central part of the area can be compared with both deeper water foraminiferal assemblages to the west and mammalian assemblages and radiometric dates from nonmarine sedimentary and volcanic rocks to the east.

The ages, stratigraphic relations, and depositional environments discussed in this report are drawn from various sources: original geologic mapping by Dibblee (1961) and subsequent modifications by him, detailed sedimentologic and stratigraphic studies of the Tejon Formation by Nilsen (1972), and analyses by Addicott of paleontologic reports of earlier workers, supplemented by some new fossil collections. Reference should be made to the more detailed maps of Dibblee (1961), Dibblee and Nilsen (1973), and Harris (1950) for outcrop localities.

REGIONAL GEOLOGY

The lower and middle Tertiary sedimentary sequence exposed on the north flanks of the San Emigdio and western Tehachapi Mountains rests unconformably on a pre-Tertiary crystalline basement complex of plutonic and metamorphic rocks, which constitute the greater part of both ranges (fig. 1). Except for the Los Lobos Canyon area in the western part of the San Emigdio Mountains, the basement complex is primarily granitic. These plutonic rocks are presumably of Mesozoic age and cogenetic with the Sierra Nevada batholiths. In the Los Lobos Canyon area, the basement complex is a mass of mafic and ultramafic igneous and metamorphic rocks that Ross (1970) suggested may represent a fragment of Mesozoic oceanic crust.

The lower and middle Tertiary strata generally dip northward off the basement complex and have been folded and faulted along a series of south-dipping thrust faults. The large northeast-plunging syncline in the Devils Kitchen area dominates the structure of the Tertiary rocks in the San Emigdio Canyon area. The Tertiary sequence thickens westward from a few hundred feet in the easternmost exposures to many thousands of feet. Some of the units extend northwestward into the adjoining northwest-trending Temblor Range. The ages and formation names of the lower and middle Tertiary units discussed in this report are shown in figure 2.

Eocene rocks of the San Emigdio and western Tehachapi Mountains consist of the Tejon Formation, the lower part of the San Emigdio Formation, and possibly the lowest part of the Tecuya Formation. Oligocene rocks are represented by the upper part of the San Emigdio

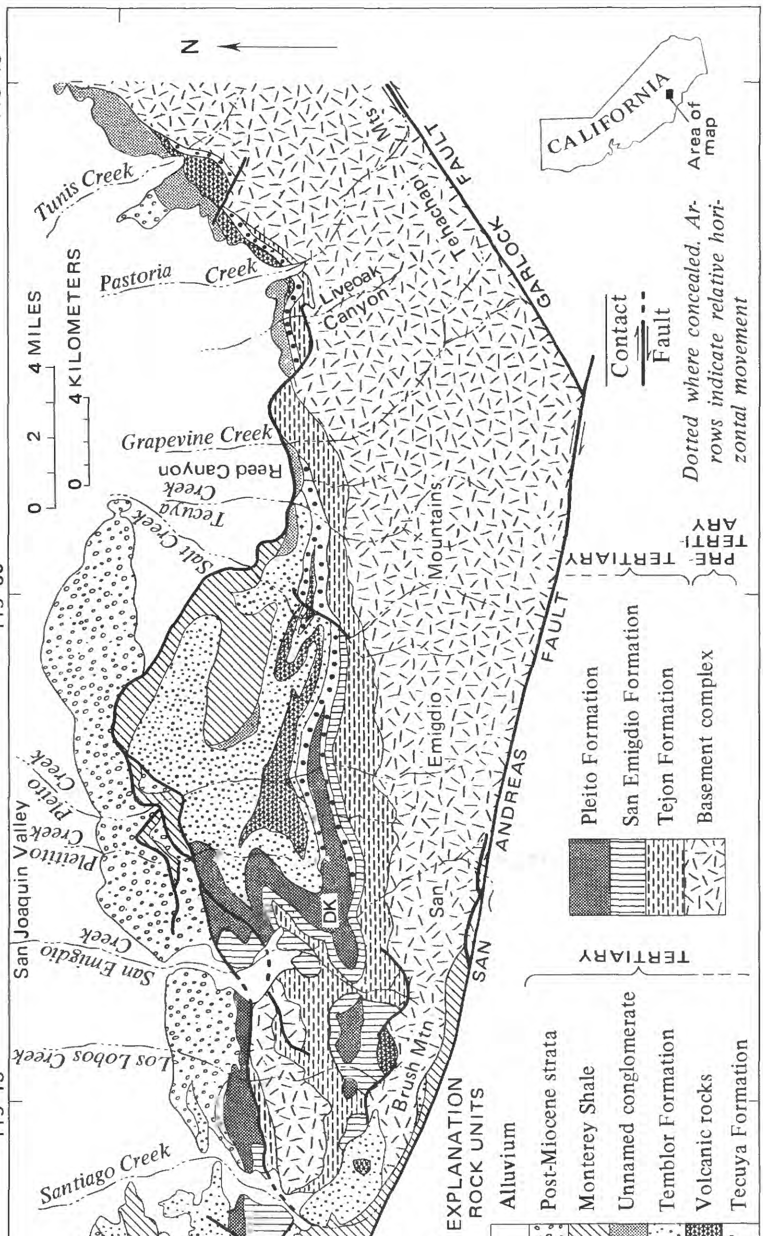

FIGURE 1.—Simplified geologic map of the San Emigdio and western Tehachapi Mountains. Modified from Geologic Map of California (Smith, 1964; Jennings and Strand, 1969). DK, Devils Kitchen area, location of Devils Kitchen syncline.

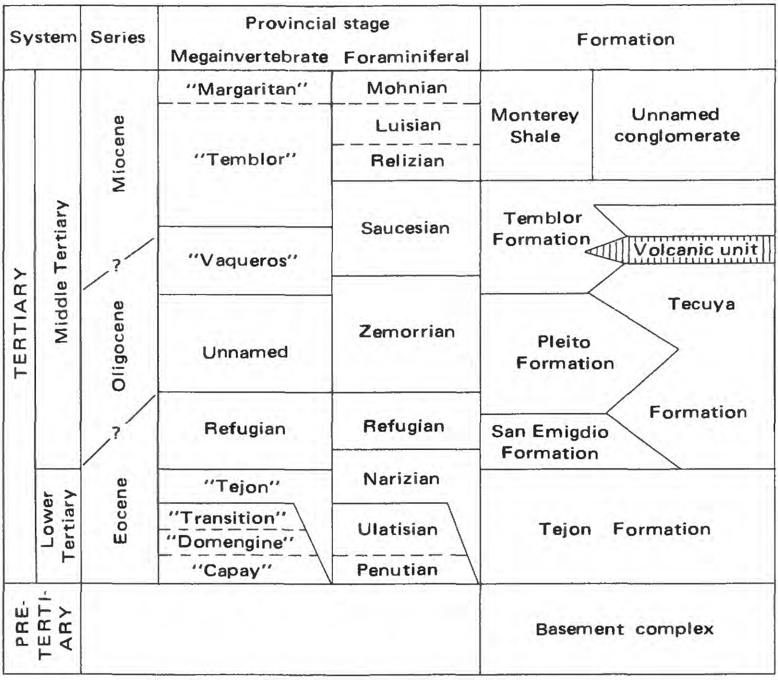

FIGURE 2.—Lower and middle Tertiary formations exposed in the San Emigdio and western Tehachapi Mountains. Foraminiferal stages from Kleinpell (1938) and Mallory (1959); megainvertebrate stages from Weaver and others (1944) and Addicott (1972).

Formation and the Pleito Formation in the western part of the area and by most of the Tecuya Formation in the eastern part. Miocene rocks include the Temblor Formation and the Monterey Shale to the west, the upper part of the Tecuya Formation and the unnamed conglomerate to the east. The lower and middle Tertiary sequence is overlain unconformably by late Cenozoic predominantly nonmarine sedimentary rocks described and mapped by Hoots (1930), Dibblee (1961), and Dibblee and Nilsen (1973).

PREVIOUS WORK

Whitney (1865), working in the San Emigdio Canyon area, was the first to separate unnamed younger marine strata thought to be of early Tertiary age from the underlying Tejon beds, then considered to be of Late Cretaceous age (fig. 1).

Anderson (1908, p. 20) stated that his Temblor beds in the Temblor Range (later Temblor Formation) "occur, however, on the San Emigdio [Creek] and at Kern River."

Anderson (1912) extended the marine Vaqueros Formation, then considered to be of early Miocene age, from the Temblor Range southeastward into the San Emigdio Mountains, applying the name to strata immediately overlying the Tejon beds; he did not clearly defiine its boundaries, however, or show it on a geologic map.

Dickerson (1915) reviewed the history of the controversy surrounding the age of the Tejon beds, which were eventually proved to be of Eocene age.

Dickerson (1916) and Gester (1917) first mentioned the existence of marine Oligocene beds in the San Emigdio Mountains but did not describe them.

Clark (1918, p. 100) recognized the presence of Oligocene beds in the San Emigdio Mountains and defined a maximum thickness for them in the vicinity of San Emigdio Canyon of between 2500 and 3000 feet. He recognized a fauna similar to that of the San Lorenzo Formation of the Santa Cruz Mountains, then considered to be of Oligocene age (Branner and others, 1909) "in beds which are unconformable below beds contains fauna of the lower Miocene."

Pack (1920) recognized beds of Oligocene age in the San Emigdio Canyon area, but included them in the Vaqueros Formation which he considered to be unconformable on the underlying Tejon Formation.

Stock (1920, 1932) found mammalian fossils of early Miocene age near Tecuya Creek in red beds that he designated the "Tecuya beds"; these beds included interbedded volcanic rocks and were thought to rest unconformably on the Tejon Formation.

Wagner and Schilling (1923) defined and named the San Emigdio and Pleito Formations in the San Emigdio Canyon area and assigned both of these marine units to the San Lorenzo Group, which they correlated with the San Lorenzo Formation of Branner, Newson, and Arnold (1909) in the Santa Cruz Mountains. They considered the San Emigdio Formation to be unconformable on the underlying Eocene Tejon Formation and retained the name Vaqueros Formation for the overlying lower Miocene strata.

Hoots (1930) did not differentiate the San Emigdio and Pleito Formations of Wagner and Schilling, but included both in the San Lorenzo Formation, which he considered to be Oligocene and conformable between the Tejon Formation below and the Vaqueros Formation above. He recognized the nonmarine "Tecuya beds" of Stock (1920) east of Tecuya Creek, but included them in the Vaqueros Formation.

Henny (1938) briefly described the lithology of the San Lorenzo Group west of San Emigdio Canyon.

Marks (1941, 1943) traced the "Tecuya beds" of Stock eastward from Tecuya Creek into the type area of the Tejon Formation around

Grapevine Canyon; he named these nonmarine red beds the Tecuya Formation and considered them to be disconformable on the underlying Tejon Formation. He considered the Tecuya early Miocene in age and noted that volcanic rocks and fossiliferous marine siltstones were interbedded in it.

Dibblee and Kelly (1948) and McGill (1951) abandoned use of the term San Lorenzo Group and mapped the San Emigdio and Pleito Formations of Wagner and Schilling (1923) in the San Emigdio Canyon area.

Harris (1950, 1954) mapped the Tecuya Formation between Pastoria and Tunis Creeks, dividing it into three unnamed members having a total thickness of 1,090 feet; two of the members included marine beds. He noted that the Tecuya was slightly unconformable on the Tejon Formation and that east of Tunis Creek it was unconformable on granitic basement rocks.

Durham, Jahns, and Savage (1954) discussed the vertebrate fauna of the Tecuya Formation in relation to marine Tertiary rocks.

Van Amringe (1957) mapped 680 feet of fossiliferous Oligocene San Emigdio Formation that he thought rested conformably on the Tejon Formation in the Brush Mountain area.

Hammond (1958) measured a thickness of 8,970 feet of fossiliferous Oligocene strata between Los Lobos and Santiago Creeks and designated the strata the San Emigdio–Pleito Formation, undifferentiated.

Dibblee (1961) differentiated the following Tertiary formations on a geologic map of the San Emigdio Mountains in ascending order: the Tejon Formation (Eocene), the San Emigdio Formation (late Eocene and Oligocene), the Pleito Formation (Oligocene and early Miocene), and the Temblor Formation (early Miocene), all marine, and the nonmarine Tecuya Formation, which contains basalt and dacite and intertongues westward into the Pleito and Temblor Formations.

Tedford (1961) discovered new mammalian fossils in the Tecuya Formation, permitting it to be correlated with the marine Vaqueros Formation.

Kleinpell and Weaver (1963) reviewed paleontologic data on the San Emigdio and Pleito Formations, and concluded that the lower part of the San Emigdio is of late Narizian age, the upper part of the San Emigdio and the lower part of the Pleito are of Refugian age, and the upper part of the Pleito is of Zemorrian age.

Crowell (1964) compiled a map of the San Emigdio Mountains from many sources, but used the same Tertiary units as Dibblee (1961).

DeLise (1967) studied the stratigraphy and paleontology of the San Emigdio Formation in San Emigdio Canyon in detail; he considered it to range in age from late Eocene (Narizian) to Oligocene (Refugian) and did not recognize an unconformity at its base or top.

Jennings and Strand (1969) compiled a map of the San Emigdio Mountains from published sources.

Nilsen (1972) suggested that the Tecuya Formation conformably overlies the Tejon Formation and that the two formations represent partly laterally equivalent nonmarine and shallow-marine deposits of a regressing shoreline.

STRATIGRAPHIC SEQUENCE

The stratigraphic relations between the lower and middle Tertiary formations of the San Emigdio and western Tehachapi Mountains are shown in figure 3. Deposition began with the marine Tejon Formation, of Eocene age, which was deposited over most of the area. Overlying the Tejon Formation in the western part of the area is a sequence of conformable marine units, in ascending order, the San Emigdio, Pleito, and Temblor Formations. These formations interfinger eastward into the nonmarine Tecuya Formation, which conformably overlies the Tejon Formation in the eastern part of the area. Sedimentary facies in the central part of the area thus define an oscillating Eocene, Oligocene, and lower Miocene shoreline. The Temblor Formation of the western and central parts of the area is conformably overlain by the Monterey Shale of Miocene age. The Monterey Shale intertongues eastward into an unnamed nonmarine conglomerate which unconformably overlies the Tecuya Formation in the eastern part of the area.

TEJON FORMATION

The Tejon Formation, the oldest Tertiary unit in the San Emigdio Mountains, rests unconformably on the pre-Tertiary basement complex. It consists of marine sandstones and shales, with some interbedded conglomerates and siltstones. Marks (1941, 1943) divided it into four members. Mollusks found in it span the provincial Eocene stages, ranging from the "Capay Stage"[1] near the base of the Tejon Formation near Santiago Creek (USGS loc. M4654) to the "Tejon Stage" (USGS localities between Pleito and Tunis Creeks) (fig. 2). The Tejon gradually thickens westward from a few feet near Tunis Creek to a maximum thickness of about 4,000 feet near Pleito Creek. West of Pleito Creek, it thins to less than 2,000 feet near San Emigdio Canyon and to about 1,000 feet near Santiago Creek (Hammond, 1958). West of Salt Creek, it is overlain by the San Emigdio Formation; east of Salt Creek, by the Tecuya Formation; and near Brush

[1]Stage names are those of Weaver and others (1944).

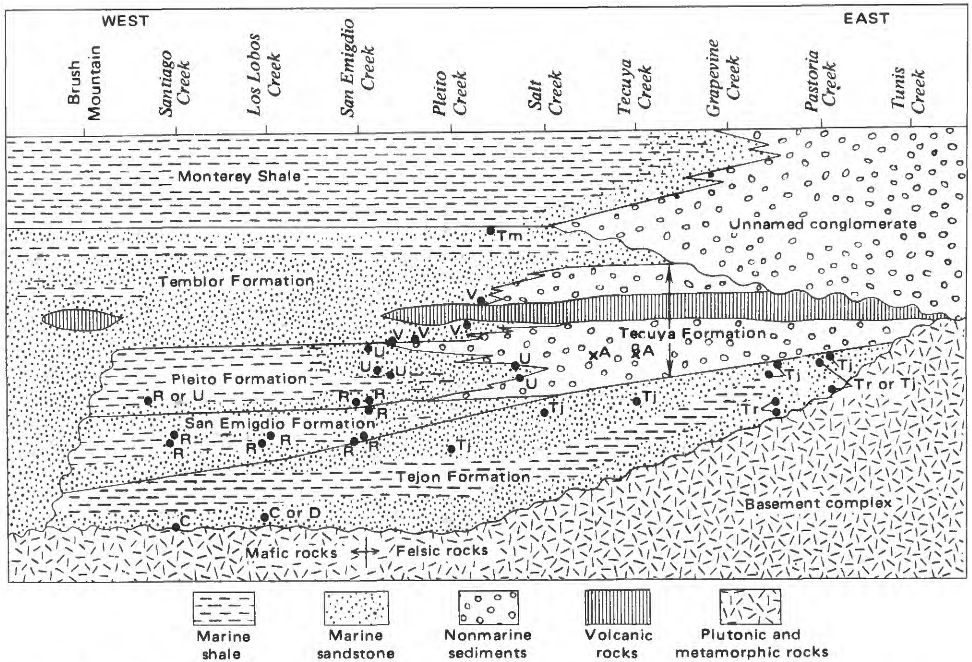

FIGURE 3.—Lower and middle Tertiary stratigraphic units of the San Emigdio and western Tehachapi Mountains from west to east. Unconformities are indicated by wavy lines. Dots with letters indicate critical mega-invertebrate collections and stage assignment: C, "Capay Stage"; D, "Domengine Stage"; Tr, "Transition Stage"; Tj, "Tejon Stage"; R, "Refugian Stage"; U, unnamed stage (Addicott, 1972); V, "Vaqueros Stage"; Tm, "Temblor Stage." Occurrences of early Arikareean mammals in the Tecuya Formation (Stock, 1920, 1932) are indicated by XA. Not drawn to scale nor with reference to time lines.

Mountain, unconformably by the Temblor Formation. The Tejon consists primarily of shallow marine deposits in its eastern exposures and deep marine deposits in its western exposures (Nilsen, 1972).

SAN EMIGDIO FORMATION

DEFINITION

The San Emigdio Formation, named by Gester (1917), was mapped and defined by Wagner and Schilling (1923) as a sequence of marine sandstone and shale about 1,000 feet thick on the east side of San Emigdio Canyon in the Devils Kitchen area. They believed it to lie unconformably on the Tejon Formation and to contain molluscan fossils distinct from those of the Tejon Formation. The name San Emigdio is adopted in this report. The formation is well exposed between Salt and San Emigdio Creeks and discontinuously exposed farther west to Santiago Creek (fig. 1).

TYPE SECTION

The type section of the San Emigdio Formation is designated as the section mesured by DeLise (1967, p. 9–10) on the east side of San Emigdio Canyon in the Devils Kitchen area, 5½ miles south of the San Emigdio Ranch headquarters, in the SE¼ sec. 31, T. 10 N., R. 21 W., San Bernardino base line and meridian, Eagle Rest Peak 7½-minute quadrangle:

Pleito Formation (lower part):	
Gray, buff, and tan, massive, medium-grained micaceous sandstone.	
Conformable contact	
San Emigdio Formation:	
Alternating sequences of buff, yellowish-brown, and gray thick-bedded to flaggy arkosic sandstone and dark-red bands and lenticular bodies of sandstone containing abundant marine megafossils; some stringers of pebble conglomerate	430
Bluish-gray to black sandy shale with interbedded tan to greenish-gray calcareous mudstone	300
Massive to thick-bedded medium-grained arkosic sandstone with thin siltstone interbeds	190
Massive buff to tan medium- to coarse-grained arkosic sandstone with stringers of pebble conglomerate	170
Total thickness (feet)	1,090
Conformable contact	
Tejon Formation (upper part):	
Dark-gray, brown, and greenish-brown sandy shale with thin-bedded to slabby and flaggy fine-grained sandstones.	

LITHOLOGY, THICKNESS, AND STRATIGRAPHIC RELATIONS

In the San Emigdio Canyon area, the lower part of the San Emigdio Formation consists of thickly bedded gray and tan unfossiliferous medium- to coarse-grained locally conglomeratic sandstone beds; the middle part of bluish-black shales; and the upper part of thickly bedded gray and tan sandstone, locally conglomeratic and with thin interbeds of gray to red calcareous sandstones containing abundant molluscan fossils. These richly fossiliferous sandstones form a persistent marker zone traceable on both sides of the Devils Kitchen syncline. As the formation thins to the east, it grades laterally into a continuous sequence of gray fine- to medium-grained sandstone containing abundant molluscan fossils near Pleito Creek and into a gray to white coarse-grained unfossiliferous conglomeratic sandstone with abundant medium and large-scale cross-stratification at Salt Creek. West of San Emigdio Canyon, it grades laterally into a series of locally fossiliferous fine- to coarse-grained conglomeratic sandstones that are interbedded with siltstones and shales (Van Amringe, 1957; Hammond, 1958) and at one place contains a large lens of granitic breccia (Dibblee and Nilsen, 1973).

The San Emigdio Formation is 1,090 feet thick in its type section at San Emigdio Canyon (DeLise, 1967). Eastward it thins gradually to about 700 feet at Salt Creek. West of San Emigdio Canyon it thickens, but because of structural complexity its true thickness cannot be determined; as much as 4,300 feet of the formation may be exposed at Santiago Creek. Hammond (1958) measured a combined stratigraphic thickness of 8,970 feet for the undifferentiated San Emigdio–Pleito Formation near Santiago Creek. On Brush Mountain the San Emigdio Formation is locally missing.

In the Devils Kitchen area, massive conglomeratic sandstone at the base of the San Emigdio Formation conformably overlies thinly interbedded fine-grained sandstones and shales of the Tejon Formation. The thinner bedded upper sandstones of the San Emigdio Formation are conformably overlain by massive medium-grained conglomeratic sandstone beds forming the base of the Pleito Formation. East of the Devils Kitchen area, the San Emigdio Formation is overlain conformably by a thin finger of westward-thinning nonmarine conglomerate of the Tecuya Formation, which separates it from the overlying Pleito Formation with no discordance or evidence of unconformity with the underlying Tejon Formation. West of San Emigdio Canyon, the San Emigdio Formation continues to conformably overlie the Tejon Formation and to be overlain conformably by the Pleito Formation. West of Santiago Creek the San Emigdio Formation is concealed beneath extensive outcrops of the Pleito and Temblor Formations (figs. 2, 3). On Brush Mountain the San Emigdio Formation may be unconformable on the Tejon Formation, although stratigraphic relations are not well defined in this area.

DEPOSITIONAL ENVIRONMENT

Molluscan fossils are locally abundant in the sandstone beds of the San Emigdio Formation, especially in the upper beds. They suggest shallow-water, inner shelf deposition (depths of less than about 20 fathoms). Assemblages from near Pleito Creek suggest deposition in very shallow water, possibly intertidal, and indicate shoaling to the east; Nilsen (1972) suggested that the formation grades laterally eastward into a shoreline facies and then into nonmarine beds of the Tecuya Formation. Foraminiferal assemblages in the lower and middle parts of the formation represent upper bathyal or lowermost outer shelf depths (DeLise, 1967). The mollusks of the San Emigdio Formation are suggestive of unusually cool water conditions, as compared with the warm-water mollusks of the underlying Tejon Formation and of the post-Refugian part of the overlying Pleito Formation (Addicott, 1970).

In the Brush Mountain area, the stratigraphic and thickness irregularities of the San Emigdio Formation, the granitic breccia lens within it, and the possible unconformity at the base of this formation suggest local penecontemporaneous tectonic activity.

AGE

On the basis of molluscan faunas, the San Emigdio and Pleito Formations were assigned by Wagner and Schilling (1923) to the San Lorenzo Group, then considered to be of Oligocene age. The San Emigdio Formation was later included by Schenck and Kleinpell (1936, p. 219) in their Refugian Stage, which they considered to be of late Eocene or early Oligocene age.

The upper part of the type section of the San Emigdio Formation was assigned to the upper part of the Refugian Stage by Kleinpell and Weaver (1963) and DeLise (1967) on the basis of molluscan faunas. The middle and lower parts of the section were assigned to the Narizian Stage by DeLise (1967) on the basis of foraminiferal faunules (fig. 2). North of the Devils Kitchen syncline, however, localities at or near the base of the San Emigdio on the east side of San Emigdio Canyon (USGS locs. M432, M4595, M4658) yield Refugian mollusks including *Turritella variata lorenzana* and *Olequahia lorenzana.* Accordingly, molluscan and foraminiferal provincial ages of the lower part of the San Emigdio seem to be in conflict, as shown in figure 2. Moreover, a molluscan assemblage from the base of the formation (Hammond, 1958) near Santiago Creek includes *Acila shumardi,* indicating a post-Narizian Refugian age. As indicated in figure 2, the Refugian is considered to be entirely of

Eocene age by some workers and in part, or entirely, of Oligocene age by others.

The middle shale unit of the San Emigdio Formation in the Devils Kitchen area, assigned to the Narizian foraminiferal stage by DeLise (1967), is of approximately the same age as the Reed Canyon Silt Member of the Tejon Formation, as defined by Marks (1943, p. 535). The Reed Canyon Member was subsequently renamed the Reed Canyon Siltstone Member by Nilsen (1972). Its type section is in Reed Canyon about 1 mile west of Grapevine Creek (fig. 1). Additional detailed mapping will be required to determine whether the Reed Canyon Siltstone and the middle shale unit of the San Emigdio Formation are discontinuously laterally equivalent rock units or whether they are merely lithologically similar rock units of approximately the same age.

PLEITO FORMATION

DEFINITION

The Pleito Formation was defined and named by Wagner and Schilling (1923), presumably for Pleito Creek, as a sequence of marine sandstones and shales about 2,300 feet thick near San Emigdio Canyon. They considered it to disconformably overlie the San Emigdio Formation and to underlie the Vaqueros Formation and furthermore indicated the occurrence in the Pleito Formation of an Oligocene molluscan fauna distinct from that of the San Emigdio and Vaqueros Formations. The name Pleito Formation is adopted in this report. The formation is exposed between San Emigdio and Salt Creeks and from Los Lobos Creek west to and beyond Santiago Creek.

TYPE SECTION

The type section of the Pleito Formation is designated as the east side of San Emigdio Canyon as described by Wagner and Schilling (1923, p. 239), about 5 miles south of the San Emigdio Ranch headquarters, in the E½ secs. 31 and 32, T. 10 N., R. 21 W., San Bernardino base line and meridian, Eagle Rest Peak 7½-minute quadrangle.

Temblor Formation (lower part):	
Thick-bedded to massive conglomeratic sandstone.	
Conformable contact	
Pleito Formation:	
Massive buff sandstone with local conglomerate near top. Fossiliferous	500
Massive coarse-grained white sandstones and grits	100
Massive buff and yellowish-brown sandstones with fossiliferous zone near top	500
Alternating series of brownish and pearl-gray micaceous shales with minor amount of fine-grained sandstones of same color. Few fossils near base	800

Pleito Formation—Continued	
Pearl-gray and light-yellowish massive micaceous sandstone with minor amount of sandy shale. Very fossiliferous near top. Thin basal conglomerate	400
Total thickness (feet)	2,300
Conformable contact	
San Emigdio Formation (upper part):	
Alternating sequences of buff, yellowish-brown, and gray thick-bedded to flaggy arkosic sandstone and dark-red bands and lenticular bodies of sandstone containing abundant marine megafossils; some stringers of pebble conglomerate.	

LITHOLOGY, THICKNESS, AND STRATIGRAPHIC RELATIONS

In San Emigdio Canyon, the Pleito Formation is composed of thickly bedded light-gray sandstone in the lower and upper parts, thinly bedded fine-grained gray sandstones and silty shales in the middle part. The base of the formation here is marked by very thick massive beds of finely conglomeratic medium- and coarse-grained sandstone.

Eastward, toward Pleito Creek, almost the entire formation becomes light-gray sandstone that interfingers eastward near Pleito and Tecuya Canyons into part of the nonmarine Tecuya Formation (Dibblee, 1961). A westward-thinning tongue of nonmarine conglomerate from the base of the Tecuya Formation separates the Pleito Formation from the underlying San Emigdio Formation east from San Emigdio Canyon (fig. 3). This conglomerate was previously considered to be a basal conglomerate of the Pleito Formation lying unconformably on the San Emigdio Formation (Wagner and Schilling, 1923). West of the nonmarine tongues of the Tecuya Formation, the marine San Emigdio, Pleito, and Temblor Formations can be differentiated by means of their thickly bedded basal sandstones, which overlie more thinly bedded finer grained rocks.

West of Los Lobos Creek, the Pleito and underlying San Emigdio Formation are difficult to differentiate because exposures are poor and structure is complex. However, the Pleito can be separated from the San Emigdio Formation in this area on general lithology and stratigraphic position, although Dibblee (1961) and Hammond (1958) did not distinguish the two formations (fig. 1). In Los Lobos and Santiago Canyons, the Pleito Formation ranges in thickness from 2,000 to 3,000 feet and is divisible into two units: a lower unit, 200–400 feet thick, of light-gray massive sandstone, an upper unit, 1,800–2,500 feet thick, of poorly bedded mudstone. The westernmost exposures of the Pleito Formation are about 3 miles west of Santiago Creek, beyond which it is concealed beneath extensive outcrops of the Temblor Formation (fig. 3).

The Pleito Formation is about 2,300 feet thick on the east side of San Emigdio Canyon and probably maintains approximately the same thickness to the east and west. It is conformable between the San Emigdio Formation below and the Temblor Formation above. To the east, it intertongues with the Tecuya Formation; to the west, it dips beneath younger formations. On Brush Mountain, the lower part of the coarse, conglomeratic sandstone mapped as the Temblor Formation, resting unconformably on the San Emigdio and Tejon Formations, may be in part equivalent to the Pleito Formation.

DEPOSITIONAL ENVIRONMENT

Local abundance of in situ mollusks indicates that the sandstones in the Pleito Formation east of San Emigdio Canyon were deposited in a shallow-water marine environment. Many of the molluscan assemblages are in close proximity to the Oligocene shoreline defined by the interfingering of the marine Pleito Formation to the east with red beds of the Tecuya Formation (fig. 3). Foraminiferal shales of the Pleito between San Emigdio and Pleito Creeks include *Siphogenerina nodifera* (Dibblee, 1961, p. 17) and *Cyclamina incisa* (DeLise, 1967), which are indicative of deep water, middle to lower bathyal (Bandy and Arnal, 1969). Near Santiago Creek to the west, the lower standstones of the Pleito Formation contain molluscan assemblages (Barbat and Von Estorff, 1933; Hammond, 1958) indicative of relatively shallow water deposition. Stratigraphically higher shales in the Pleito Formation of Dibblee (1961) in this area contain foraminifers referable to the middle to lower bathyal biofacies of Bandy and Arnal (1969). Deposition of the Pleito records a series of fluctuations between shallow marine environments in which mollusk-bearing sandstones were deposited and deeper water offshore environments in which foraminiferal shales were deposited. These changing water depths probably correlate with eastward and westward migrations of the shoreline that are defined by the contact between the Pleito and Tecuya Formations to the east. If the Temblor Formation on Brush Mountain is in part equivalent to the Pleito Formation, then local uplift and emergence occurred in this area.

AGE

The lower part of the Pleito Formation was initially assigned to the Refugian Stage by Schenck and Kleinpell (1936) on the basis of molluscan assemblages recorded by Wagner and Schilling (1923). Mollusks from the overlying middle and upper parts of the Pleito have long been recognized as representing a younger time-stratigraphic unit of pre-"Vaqueros" age (Clark in Hoots, 1930, p. 254;

Weaver and others, 1944, chart). This distinctive fauna, characterized by *Pecten sanctaecruzensis* and *Vertipecten* n. sp. has recently been assigned to an unnamed molluscan stage (Addicott, 1972) of provincial late Oligocene age. Foraminifera from the middle and upper parts of the Peito Formation between Pleito Creek on the east (Dibblee, 1961, p. 17) and near Santiago Creek to the west (Kleinpell, 1938, p. 57–60, loc. 12) are of early Zemorrian (Oligocene) age (Kleinpell and Weaver, 1963, fig.; DeLise, 1967).

TECUYA FORMATION

DEFINITION

The "Tecuya beds" of Stock (1920, 1932), later named the Tecuya Formation by Marks (1941, 1943) for Tecuya Creek, is a sequence of mainly nonmarine sedimentary and volcanic rocks exposed nearly continuously for 23 miles from east of Tunis Creek to west of Pleito Canyon (fig. 1). The name Tecuya Formation is here adopted for this unit. The formation intertongues westward into the marine Pleito and Temblor Formations.

TYPE SECTION

The type section of the Tecuya Formation is designated as the crest of the first ridge west of Tecuya Canyon, 3 miles west of Grapevine, in the W½ sec. 25, and E½ sec. 26, T. 10 N., R. 20 W., San Bernardino base line and meridian, Grapevine 7½-minute quadrangle:

Temblor Formation (lower part)	
Thick-bedded to massive conglomeratic sandstone.	
Tecuya Formation:	
Upper unit:	
Crudely interbedded red, green, buff, and blue-gray cobble and pebble conglomerates, sandstones, and mudstones	850
Volcanic unit:	
Black fine-grained ophitic basalt and some scoriaceous basalt	150
Pinkish-brown-weathering blue-gray dacite with small phenocrysts of plagioclase in an aphanitic groundmass	150
Lower unit:	
Interbedded conglomerates, sandstones, and mudstones similar to those of the upper unit, including local breccias in the lower part	1,200
Approximate total (feet)	2,350
Tejon Formation (upper part):	
Reed Canyon Silt Member of Marks (1943), renamed Reed Canyon Siltstone Member by Nilsen (1972):	
Thin-bedded dark-gray siltstone and fine-grained sandstone with few marine megafossils.	

LITHOLOGY, THICKNESS, AND STRATIGRAPHIC RELATIONS

The Tecuya Formation is best exposed in Tecuya Canyon and in two smaller canyons to the west, where it is about 2,350 feet thick and consists of three units. The lower and upper units are composed of interbedded red, green, gray, and brown mudstones, siltstones, sandstones, and pebble and cobble conglomerates; the middle unit is composed of volcanic rocks. In the canyon west of Tecuya Canyon, the formation contains at the base a lens of granitic breccia, 150 feet in maximum thickness. This breccia was mapped by Hoots (1930) as a fault sliver of granitic basement, but we consider it to be more probably a landslide mass or other type of sedimentary breccia deposited when the Tecuya Formation began to accumulate in this area.

Near Tecuya Canyon the lower unit is about 1,200 feet thick. It consists largely of pebble to boulder conglomerates composed primarily of granitic and metamorphic clasts, including clasts of metavolcanic rock and quartzites, in a coarse sandy matrix. It rests with apparent conformity on both shallow marine sandstones of the San Emigdio Formation west of Salt Creek and the Tejon Formation east of Salt Creek. To the west, the lower unit intertongues into shallow marine sandstones of the Pleito and lower parts of the Temblor Formations near Salt and Pleito Canyons (fig. 3). The basal beds of the lower unit extend westward nearly as far as San Emigdio Canyon, as a thin nonmarine tongue between the Pleito and San Emigdio Formations.

East of Tecuya Canyon, the lower unit rests without discordance on the Tejon Formation, in places with a gradational contact, nearly as far east as Tunis Creek, where it rests on granitic basement. Harris (1950) measured 1,090 feet of the lower unit below the volcanic unit in Pastoria Creek and 450 feet near Tunis Creek; east of Tunis Creek, the lower unit laps out between the basement complex and the overlying volcanic unit. Interbeds of fossiliferous marine siltstone and sandstone have been noted by previous workers in the lower unit at several localities (Marks, 1941, 1943; Harris, 1950).

The middle, or volcanic, unit is composed chiefly of flows of black locally scoriaceous basalt and dark-reddish-brown andesite with minor dacite (Marks, 1941; Harris, 1950). Near Tecuya Canyon the unit is 300 feet thick and consists of a lower subunit of dacite and dacite breccia and an upper subunit of basalt. Both subunits are laterally extensive, even though only 100–200 feet thick. West of Tecuya Canyon, the dacite thickens to about 500 feet, the basalt to about 1,500 feet near Pleito Creek. From there both subunits extend westward into the Temblor Formation, pinching out within 2 miles farther west. East of Tecuya Creek, the entire volcanic unit thickens, from about 200 feet at Pastoria Creek to a maximum of 1,500 feet just west of Tunis Creek (Harris, 1950), where the lower part contains several beds of dacitic tuff-breccia. East of Tecuya Creek, it is unconformably overlain by, and in places completely overlapped by, the unnamed Miocene conglomerate. At Tunis Creek the volcanic unit rests directly on granitic basement.

The upper unit of the Tecuya Formation is lithologically similar to the lower unit and is present only in the Tecuya Creek area, where it is about 850 feet thick. It is missing west of some faults near Salt Creek and eastward from Tecuya Canyon is unconformably overlapped by the unnamed Miocene conglomerate. The upper unit is overlain by marine sandstones of the Temblor Formation and intertongues westward into the Temblor in Salt Creek Canyon.

DEPOSITIONAL ENVIRONMENT

The Tecuya Formation was probably deposited as a complex series of coalesced alluvial fans on a coastal plain by streams draining source areas to the east and southeast. The intertonguing of the terrestrial sediments of this formation into marine sediments to the west and also downdip to the northwest, as indicated from well data, defines a shoreline with a general northeasterly trend. A great variety of depositional environments is probably preserved along this nonmarine-marine boundary, with shoreline irregularities probably responsible for the irregular occurrence of marine sediments within the otherwise nonmarine Tecuya Formation. Climatic variations and tectonic movements probably provided varying amounts of sediments to the large alluvial fans, resulting in a shoreline that migrated or oscillated through time. The volcanic rocks were extruded probably from concealed nearby fissures or vents.

AGE

Previous workers have demonstrated that the Tecuya Formation ranges from Oligocene to early Miocene in age. It was assigned an early Arikareean (late Oligocene or early Miocene) age on the basis of mammalian remains found below the volcanic unit near Tecuya Creek by Stock (1920, 1932), Tedford (1961), and Stirton (1960, p. 362). The stratigraphic occurrence of the fossils (Stock, 1920) is in the middle part of the lower unit, which intertongues westward into probable late Oligocene mollusk-bearing strata of the Pleito Formation (fig. 3), rather than into the Vaqueros Formation (Temblor Formation of this report) as previously contended. Accordingly, these strata are probably coeval with strata assigned to the unnamed megainvertebrate stage of Addicott (1972).

The stratigraphically higher parts of the Tecuya Formation, both above and below the volcanic unit, interfinger westward with the Temblor Formation, which carries molluscan assemblages referable to the "Vaqueros Stage" (fig. 3). This stage is coeval with the upper part of the Zemorrian and lower part of the Saucesian Stages of the provincial foraminiferal sequence (fig. 2). Marine mollusks reported by Marks (1941, p. 55) from 150 feet above the base of the Tecuya in a tributary of Tecuya Creek are not age diagnostic.

In wells drilled for oil located about 2 miles (Dibblee and others, 1964) and 5 miles (Turner, 1970, p. 101) northwest of the exposures at Tecuya Creek, strata of the Temblor Formation that directly underlie and interfinger with the volcanic unit are of Saucesian age. Samples of the dacite from Pleito Creek and from between Tecuya and Grapevine Creeks have been radiometrically dated at from 21.5 $\pm$0.7 million years to 22.3$\pm$0.7 million years by Turner (1970, p. 101).

If the Tecuya and Tejon Formations are in part equivalent in age, as postulated by Nilsen (1972), then the Tecuya Formation ranges in age from the late Eocene, "Tejon Stage" to the early Miocene "Vaqueros Stage."

TEMBLOR FORMATION

The Temblor Formation, formerly included in or mapped as the Vaqueros Formation (Pack, 1920; Wagner and Schilling, 1923; Hoots, 1930) and in part as Pleito Formation (Dibblee, 1961, fig. 1), is a thick marine sandstone and shale unit traceable southeastward into the San Emigdio Mountains from the Temblor Range. It is continuously exposed west of lower Santiago Creek, where it is about 5,500 feet thick; here it conformably overlies the Pleito(?) Formation and is overlain unconformably by the Monterey Shale. From lower Santiago Creek to the Devils Kitchen area, a thick-bedded to massive conglomeratic sandstone forms the basal part of the Temblor Formation, permitting it to be differentiated from the underlying Pleito Formation. Eastward, the Temblor thins to about 2,000 feet near Pleito and Salt Creeks, where it conformably overlies the Tecuya Formation and intertongues into the upper part of it. Southeastward from Santiago Creek to Brush Mountain, the Temblor Formation thins to 1,000 feet or less of coarse to pebbly sandstone and unconformably overlaps the San Emigdio and Tejon Formations onto the basement complex. These exposures contain several local lenses of probable extrusive porphyritic dacite, presumably coeval with those found in Pleito Canyon and eastward.

Mollusks from the basal sandstones of the Temblor Formation between Pleito and San Emigdio Creeks include the "Vaqueros

Stage" index species *Macrochlamis magnolia* (USGS loc. 13330). This species has also been reported from the marine tongue of the Temblor below the Tecuya volcanic unit east of Pleito Creek (Loel and Corey, 1932, p. 95). Mollusks from above the volcanic unit (Loel and Corey, 1932) are also referred to the "Vaqueros Stage." Doubtfully identified specimens of *Leptopecten andersoni* from near the top of the formation east of Pleito Creek (Dibblee, 1961, p. 14) suggest assignment of this part of the formation to the "Temblor Stage." The pectinid locality is overlain by Monterey Shale containing foraminifers of lower Relizian age.

Sparse data on foraminifers from exposures of the Temblor Formation indicate a generalized late Zemorrian (Kleinpell and Weaver, 1963) to late Saucesian (Dibblee, 1961) age. In wells along the north margin of the San Emigdio Mountains, the Temblor Formation has yielded foraminifers diagnostic of the upper part of the Zemorrian Stage below the volcanic unit that extends into it from the Tecuya Formation and foraminifers diagnostic of the lower part of the Saucesian Stage from above the volcanic unit (Dibblee, 1961; Turner, 1970).

MONTEREY SHALE AND UNNAMED CONGLOMERATE

The Monterey Shale is a marine thin-bedded siliceous and semisiliceous shale unit of middle and late Miocene age that conformably overlies the Temblor Formation (Dibblee, 1961). In the Temblor Range, northwest of the San Emigdio Mountains, the Monterey Shale is 7,000 feet thick; however, in the area of this report only the lower part, or that of Luisian and Relizian (middle Miocene) and possibly Late Saucesian (early Miocene) age, is exposed.

An unnamed nonmarine conglomerate is exposed in the foothills from west of Grapevine Canyon eastward to and beyond Tunis Creek. It is composed of coarse unsorted granitic detritus, including boulders in a weakly consolidated arkosic matrix. It rests with angular discordance on the Tecuya Formation, overlapping it onto the basement complex east of Tunis Creek; west of Tecuya Creek, it wedges out between the Temblor Formation and the Monterey Shale (Dibblee, 1961). This conglomerate was assigned by Harris to the Temblor Formation (1950) and to the Olcese Formation (1954), but the assignment is not adopted in this report because the conglomerate is nonmarine. This unit presumably intertongues northward and westward into Miocene marine formations. The unnamed conglomerate probably was deposited as a complex of alluvial fans along a coastal plain fronting mountains to the southeast.

SUMMARY

The lower and middle Tertiary sedimentary rocks of the San Emigdio and western Tehachapi Mountains record a series of marine transgressions and regressions, in which shallow marine sandstones and deeper marine shales of the western part of the area interfingered eastward with nonmarine sediments. The depositional cycle began with the Tejon Formation, which accumulated during a major transgression from west to east across the area from early to late Eocene time (Nilsen, 1972). The transgression was followed by a westward regression and deposition of the San Emigdio and Pleito Formations on a shallow marine shelf that deepened westward and northward in Oligocene time. Nonmarine fluvial strata of the Tecuya Formation, probably derived from land areas to the east or southeast, were deposited during that time as alluvial fans fringing the shallow marine shelf. Climatic and tectonic changes affected the supply of sediments, resulting in a migrating and oscillating shoreline. Eruptions of dacite and basalt lava flows covered the terrestrial area extensively during late Oligocene and early Miocene time and flowed partly onto the marine shelf. These probably erupted from fissures, now presumably covered by the flows. Similar dacites were erupted penecontemporaneously in the Brush Mountain area.

The sharp, angular unconformity between the Temblor Formation and the underlying Tejon and San Emigdio Formations in the Brush Mountain area (fig. 2) indicates that uplift and erosion occurred locally during late Oligocene time. This uplift must have been contemporaneous with deposition of the Pleito Formation to the north. If the San Emigdio Formation is also unconformable on the Tejon in this area, then some uplift may have occurred even earlier. The late Oligocene activity was followed by volcanic eruptions in the Brush Mountain area and further east and by later uplift in the Brush Mountain area prior to deposition of the Monterey Shale.

Tipton (1971), in a study of subsurface late Eocene and Oligocene sedimentary units in the southeastern San Joaquin Valley, suggested that the major source of the Oligocene sediments was to the south, toward Santiago Creek in the San Emigdio Mountains. This implies that at least two major sources for Oligocene sediments were present —the Sierra Nevada, Tehachapi, and Mojave Desert regions to the east and southeast and the San Emigdio or other adjacent provenance areas to the south. Subsequent right-lateral movement along the San Andreas fault may have displaced this southern source area many hundreds of kilometers to the north, so that it may not be easily recognized today. The large thickness of Oligocene sedimentary rocks in the area north of Brush Mountain suggests that this part of the basin subsided contemporaneously with uplift to the south. Tipton (1971) concluded that Oligocene sedimentary rocks further north were deposited in deep water, indicating that this part of the basin remained deep from Eocene through Oligocene time. The tectonic and volcanic activity in the Brush Mountain area and the uplift of southern source areas of Oligocene sedimentary rocks were no doubt the local effects of widespread Oligocene diastrophism and volcanism that affected much of central and southern California and climaxed in late Oligocene time.

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