Preliminary Geologic Map of the Los Angeles 30´ x 60´ Quadrangle, Southern California

Version 1.0

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Open-File Report 2005-1019
Detailed Description of Map Units, version 1.0

http://pubs.usgs.gov/of/2005/1019

U.S. Department of the Interior
U.S. Geological Survey

Prepared in cooperation with
CALIFORNIA GEOLOGICAL SURVEY

A product of the *Southern California Areal Mapping Project*
A geologic-mapping project sponsored jointly by the U.S. Geological Survey and the California Geological Survey

Introduction

The Los Angeles 30’ x 60’ quadrangle covers approximately 5,000 km^2 including much of the densely populated urban and suburban areas of the southern California megalopolis. The quadrangle is about 90 km east-west and about 55 km north-south, extending from Fillmore and Thousand Oaks in the west to Vincent in the northeast and Montebello in the southeast. It covers the urban San Gabriel Valley and San Gabriel Mountain foothill communities from Monrovia to Pasadena, as well as Glendale, downtown Los Angeles, Hollywood, Santa Monica, Malibu, and all the communities in the San Fernando Valley, Simi Valley, and the upper Santa Clara River Valley. Population of these urban and suburban areas, as listed in the 2000 Census, totals approximately 5.6 million, and property value is estimated to total hundreds of billions of dollars. The quadrangle also includes large areas of wilderness in the Angeles and Los Padres National Forests, in the Santa Monica Mountains National Recreation Area, and the Sespe Condor Sanctuary. The relief in the quadrangle ranges from about a hundred meters sub sea (in Santa Monica Bay) to more than 2,000 meters above sea level at Pacifico Mountain in the high San Gabriel Mountains. Residents and transient visitors are subject to potential hazards from earthquakes, debris flows and other landslides, floods, wildfires, subsidence from ground water and petroleum withdrawal, and swelling soils; and coastal areas are exposed to flooding and erosion by storm and tsunami waves.

This geologic map is intended to illustrate the distribution of the rocks and surficial deposits of the area and their structural and stratigraphic relations to one another. It provides a regional geologic framework as an aid to better evaluations of the potential for hazard from active earth processes; however, it is not sufficiently detailed to serve as a basis for site-specific evaluations. The map has been compiled from many scientific studies in different parts of the quadrangle, and represents the work of many geologists (Fig. 3, Sheet 2). Most of the source maps are at scales of 1:12,000 to 1:48,000, although in much of the San Gabriel Mountains source map scales are 1:62,500 or smaller. Many of the source maps post-date the 1969 publication of the 1:250,000-scale compilation of the 2-degree Los Angeles Sheet by Jennings and Strand (1969). We have not incorporated any data directly from the 1:24,000-scale maps published by the Dibblee Geological Foundation, however many of our source materials are the same as those cited by the Dibblee Foundation maps. As our compilation progressed, preliminary versions of 23 individual 7.5’ quadrangles were released in digital form. Compilation consisted of: 1) making photocopies of source maps, including reduction or enlargement to a scale of approximately 1:24,000, and tracing the lines that bounded polygons expected to be readable at 1:100,000-scale; 2) scanning the tracings into digital files, then converting the scans to ARC/INFO coverages and registering them to geographic coordinates; 3) tagging the lines and polygons with appropriate attributes; and 4) digitizing selected structure symbols.

None of the source maps were originally mapped to the UTM projection of the 1:100,000-scale base. Most were mapped on U.S. Geological Survey 7.5’ topographic base maps in polyconic projection, so after each 7.5’ quadrangle was compiled the data were reprojected to UTM, Zone 11, coordinates. In a few places, differences in topographic expression between the more detailed contour intervals of the 7.5’ base maps and the 50-m contours of the 30’ x 60’ base map, required minor adjustments in line positions to retain relationships between contours and geologic lines that are appropriate expressions of geologic structure. Clearly, the compilation procedure has many steps where errors can be made and, as this is a digital version, subject to correction as time and new data permit; we invite user comments and corrections.

The Transverse Ranges and the San Andreas Fault

Nearly all of the Los Angeles quadrangle lies within the south-central part of the Transverse Ranges physiographic-structural province, a band of west-trending mountain ranges and valleys, varying from 50 km to 130 km in width that extends about 400 km from Point Arguello on the west-northwest to the eastern San Bernardino Mountains on the east-southeast (Fig. 1). The east-west grain of the Transverse Ranges Province presents a stark and abrupt interruption of the general northwesterly trends of the Peninsular Ranges Province (including the California Continental Borderland) to the south and the northwesterly to northerly grain of the California Coast Ranges, the Great Valley, the Sierra Nevada, and the Mojave Provinces to the north. The southeastern corner of the Los Angeles quadrangle includes the northern part of the petroliferous Los Angeles Basin, which lies at the northern end of the Peninsular Ranges Province. The northwestern quarter of the Los Angeles quadrangle includes the eastern part of the petroliferous Ventura Basin. These two "basins" were the sites of very thick accumulations of marine sediments in the late Miocene and Pliocene. The southern boundary of Transverse Range structures is commonly placed at the Anacapa-Santa Monica-Hollywood-Raymond-Cucamonga zone of interconnected north-dipping thrust faults. West of Santa Monica, the southern limit of Transverse Range structures is the offshore Anacapa Fault, which lies a few kilometers south of the southern boundary of the quadrangle. Northwesterly trending faults in the Peninsular Ranges Province, such as the Newport-Inglewood zone, the Elsinore-Whittier fault, and several faults in the offshore Continental Borderland, appear to be truncated by the east-west zone of interconnected faults.

The Transverse Ranges are a major anomaly embedded across the general grain of the North American Continent and, although middle Miocene and younger tectonism is responsible for much of the present rock distribution and physiographic relief, the distributions of different crystalline basement rocks, and their Cretaceous and Paleogene superjacent strata, suggest the influence of earlier tectonic episodes. The geologic history remains imperfectly understood, and many interpretations concerning specific aspects are actively disputed among earth scientists (e.g., Campbell and others, 1966; Dibblee and Ehrenspeck, 1993). The distinctive physiographic and structural characteristics of the provinces are superimposed on a preexisting framework of Proterozoic through early Cretaceous igneous and metamorphic basement rocks, which occur chiefly in fault-bounded blocks. This simple relationship has been modified in places so that rocks that are commonly associated with one province can be found in an adjacent province. For example, strata found south of the Malibu Coast Fault and west of the Newport-Inglewood zone of faulting and folding include probable Catalina Schist basement overlain by Miocene volcanics and Monterey facies sedimentary strata in a sequence best correlated with that of the Palos Verdes Peninsula-Santa Catalina Island area of the northern Peninsular Ranges. Although Catalina Island and the Palos Verdes Peninsula are dominated by northwesterly trending structures, and are included in the Peninsular Ranges Province, an east-trending band, bounded by the Malibu Coast fault on the north and the offshore Anacapa-Santa Monica fault, is characterized by east-trending folds and north-over-south thrust faults and, therefore, is included in the Transverse Ranges province. Clearly, the province-bounding faults take advantage of pre-existing structures in places, but not everywhere. Major basement rock boundaries are not confined to the margins of the Transverse Ranges, but are also found within the province. For example, the northwest-trending Verdugo Fault separates the cratonic Precambrian to Cretaceous crystalline basement of the San Gabriel Mountains from the oceanic Jurassic metasedimentary basement of the Santa Monica Mountains. Similarly, the Raymond-Cucamonga segment of the southern frontal fault system of the Transverse Ranges approximates the boundary between the San Gabriel Mountains crystalline basement and the oceanic Jurassic basement in the Santa Ana Mountains (northern Peninsular Ranges). It should be noted, however, that the Jurassic of the Santa Ana Mountains is older than the Jurassic of the Santa Monica Mountains, so the two are not directly correlative (Jones and others, 1976). This relatively simple pattern is further complicated by evidence that the cratonic rocks of the San Gabriel Mountains have been thrust over the Pelona Schist, for which the protolith is inferred to be Jurassic oceanic crust (Ehlig, 1981).

Many workers have attempted to reconstruct the rock distribution in the region as it was before the middle Miocene beginning of major structural deformation (e.g., Campbell and Yerkes, 1976; Crouch, 1979; Hornafius and others, 1986; Powell, 1993; Wright, 1991; Yeats, 2004) using recognized translations and rotations of fault-bounded blocks. It seems logical that reconstruction should result in an unbroken western margin for the North American Continent that connects the rocks and structure to the north with those to the south of the Transverse Ranges. However, the pre-middle Miocene positions of individual fault blocks have not been comprehensively established. Partial reconstructions using extensive subsurface data, precise age dating, and well-established minimum fault movements and rotations have demonstrated the difficulty in accurately modeling the early Miocene margin of the North American continent (McCulloh and Beyer, 2004).

The San Andreas Fault crosses the Transverse Ranges Province with an east-southeasterly trend, in sharp contrast to its northwesterly trends to the north, in central California, and to the south, along the west side of the Salton Sea and the Imperial Valley. From Tejon Pass to Wrightwood, the San Andreas approximates the northern boundary of the Transverse Ranges (San Gabriel Mountains), and a short segment of the fault crosses the extreme northeastern corner of the Los Angeles quadrangle. Further east it separates the San Gabriel Mountains from the San Bernardino Mountains, emerging from the south side of Cajon Pass to mark (approximately) the southern boundary of the Transverse Ranges (San Bernardino Mountains), and continues on that trend for another 45 km (approximately) southeasterly to the vicinity of North Palm Springs.

The presently recognized trace of the San Andreas Fault was probably not a single continuous fault before the end of the (Miocene-Pleistocene) tectonism that resulted in the modern Transverse Ranges Province. Some segments that are now connected show displacements that probably predate the late Miocene. The San Gabriel Fault probably was an active part of the San Andreas in late Miocene through early Pliocene time that was subsequently abandoned (Crowell, 1952). The modern through-going structure consists of connected segments of varying ages and tectonic origins, and may be linked by fault segments that did not exist before the opening of the Gulf of California in the late Pliocene. Although the San Andreas Fault is seen only in the extreme northeast corner of the Los Angeles quadrangle, it is an important component of the geologic structure in the quadrangle, and is probably the principal control for the north-south compressive stress field presently imposed on the central Transverse Ranges. The ongoing deformation (Castle and others, 1984) and associated earthquakes are generally considered to be the result of the northwest-trending right-lateral movement of the North American Plate relative to the Pacific Plate as constrained in upper crustal rocks by the geometry of the modern San Andreas Fault.

Geologic units described in context of structural blocks

The geologic map units are divided into several columns in the organization of the “Correlation of Map Units” (CMU) and “Description of Map Units” (DMU) that accompany the map. In part, the distinction is semantic; that is, different authors may have used different names for correlative strata in different parts of the quadrangle; or have used the same names for map units that may be only partly correlative. However, real differences in lithologic character may also be represented by the use of different names for strata of correlative ages. We have not been able to identify all the map unit names that should be extended and those that should be restricted. However, it seems clear that the present distribution of rock units is the result of the convergence of tectonic elements of diverse geologic histories. The subdivision of the CMU into a different columns is our attempt to illustrate the spatial diversity as objectively as possible, while retaining the stratigraphic elements shared in common.

Rocks of the Transverse Ranges Province are subdivided and described under three early Pleistocene and older structural blocks: (1) Topatopa Mountains and the eastern Santa Ynez Range, (2) Oak Ridge, Santa Susana Mountains, Simi Hills, and Santa Monica Mountains, (3) Castaic Valley-Soledad Canyon and western San Gabriel Mountains. The rocks of the northern Peninsular Ranges Province are described in a frame of two middle Miocene and older structural blocks: (1) eastern Los Angeles Basin, and (2) western Los Angeles Basin. Within the Oak Ridge, Santa Susana Mountains, Simi Hills, Santa Monica Mountains block, middle Miocene and older strata are described separately for the Santa Susana Mountains-Simi Hills area and the central and western Santa Monica Mountains, chiefly because of large changes in thickness of the Conejo Volcanics and nomenclatural differences that represent relatively minor facies changes in the middle Miocene and older rocks. In the central Santa Monica Mountains, the strata in the upper plate of the Malibu Bowl Detachment Fault include a number of tongues of the Conejo Volcanics that have not been specifically correlated with the lithologic subdivisions of that unit in the lower plate. The eastern and western Los Angeles Basin blocks correspond to the Northwestern and Central structural blocks of Yerkes and others (1965).

We have retained most of the map unit names used in the source maps, However, the nomenclature of the basement rock units in the San Gabriel Mountains has been modified from the nomenclature of the source maps, on the advice of D.M. Morton and F.K. Miller, to conform with the IUGA Subcommission on Systematics of Igneous Rocks (Streckheisen, 1973), and to provide continuity with their compilation in the

San Bernardino 30' x 60' quadrangle (Morton and Miller, 2003), which adjoins the Los Angeles sheet on the east. The modified nomenclature results in some local generalizations of the map. In addition, the Quaternary surficial deposits have been relabeled according to standardized SCAMP nomenclature where data permit.

The bedrock units of the area are commonly described in two principal groups: 1) Basement rocks – early Cretaceous and older, crystalline metamorphic and igneous rocks; and 2) The superjacent sequence of late Cretaceous and Tertiary strata. The greatest contrast in basement character is at the boundaries of the San Gabriel Mountains-Soledad Basin block. The San Gabriel Mountains form a basement massif that includes components of Proterozoic, Paleozoic, and pre-middle-Cretaceous Mesozoic metamorphic and plutonic rocks. These are the oldest basement rocks in the Los Angeles quadrangle and appear to represent old continental crust at the western margin of the North American craton, and which has been thrust over Jurassic oceanic crust of a different metamorphic facies than is found in adjacent blocks. In the eastern Los Angeles Basin, to the south of the San Gabriel Mountains, and in the Santa Monica Mountains, to the west of the San Gabriel Mountains, the basement rocks are metasedimentary and metavolcanic rocks of Jurassic age, that were probably deposited on a Jurassic oceanic crust, and accreted to the margin of the North American craton; they have been intruded by early Cretaceous granitic bodies of the same age as similar rocks in the San Gabriel Mountains, but the closeness of their relationship is not clear. The basement rocks of the western Los Angeles Basin also are associated with a Jurassic oceanic crust; however, their metamorphic character is significantly different, including blueschist facies schists that represent metamorphism in a subduction zone. The basement in the Topatopa Mountains block is unknown, but in the Santa Ynez Mountains, a few miles to the west, the basement is Franciscan Formation, including schists very much like those of the western Los Angeles Basin basement rocks.

The superjacent sequence consists of Upper Cretaceous and Tertiary sedimentary and volcanic strata that rest unconformably on the crystalline basement. The regional unconformity at the base of the Upper Cretaceous is expressed only in the central Santa Monica Mountains, where the Trabuco Formation overlies basement rocks. Another regional unconformity, at the base of the Paleogene section, can be seen in the western Santa Monica Mountains and the Simi Hills where the Simi Conglomerate overlies the Upper Cretaceous sequence. The middle Miocene disruption of the pre-middle Miocene sequence and the formation of more localized basins is expressed by more restricted unconformities at the bases of late-middle Miocene and younger strata and extreme variations in thickness of late Miocene and younger units.

Acknowledgements

The sources used in the map compilation are cited in the list of references, but it is important to record our gratitude to the large number of colleagues, past and present, whose work has made the construction of this map possible. The map was compiled under the auspices of the U.S. Geological Survey Southern California Areal Mapping Project (SCAMP). D.M. Morton and F.K. Miller provided perceptive reviews of the manuscript map and explanatory text.

The final GIS database was prepared by Rachel Alvarez and Kelly Bovard at the U.S. Geological Survey, SCAMP, GIS facility located at the Department of Earth Sciences, University of California, Riverside. F.K. Miller advised in the initial construction of the CMU, and provided helpful review comments on subsequent revisions. While the compilation was in progress, we benefited from the assistance of many U.S. Geological Survey colleagues, past and present, particularly with regard to the application of GIS tools to geologic cartography. Outstanding among these are: C.M. Wentworth, Todd Fitzgibbon, S. E. Graham, D.W. Ramsey, and Patrick Showalter, U.S. Geological Survey, Menlo Park, California.

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Description of Map Units

Qaf **Artificial fill (late Holocene)**—Deposits of sand silt and gravel resulting from human construction, mining or quarrying activities; includes compacted engineered and noncompacted nonengineered fill. Only large deposits are shown

Qacf **Graded area (late Holocene)**—Undifferentiated cuts and fills; commonly covered by houses, landscaping, and streets, but also includes some debris basins

Qa **Alluvium, undifferentiated (late Holocene)**—Unconsolidated gravel, sand and silt in active or recently active streambeds; chiefly stream deposited, but includes some debris-flow deposits; episodes of bank-full stream flow are frequent enough to inhibit growth of vegetation

Qw **Wash deposits (late Holocene)**—Unconsolidated gravel, sand and silt in active or recently active streambeds; chiefly stream deposited, but includes some debris-flow deposits; episodes of bank-full stream flow are frequent enough to inhibit growth of vegetation. Essentially same unit as alluvium (Qa), but name used by source authors retained here

Qb **Beach deposits (late Holocene)**—Loose fine- and medium-grained sand of active beaches chiefly between elevations of lower-low water and storm strands

Qe **Eolian deposits (late Holocene)**—Loose, fine- to medium- grained sand, silty sand and silt; forms transitory dunes against beach-facing cliff

Ql **Lake deposits (late Holocene)**—Unconsolidated clay, silt, fine-grained sand and plant matter accumulated on floors of ponds and reservoirs

Qfp **Floodplain deposits (Holocene)**—Unconsolidated, stream-deposited silt, sand and gravel; includes overbank deposits of flooding streams; commonly supports trees and other perennial vegetation as compared to barren active channel deposits. In some areas, used to approximate levels of "100-year flood"

Qf **Alluvial-fan deposits (Holocene)**—Unconsolidated bouldery, cobbley, gravelly, sandy, or silty alluvial deposits on active and recently active alluvial fans and in some connected headward channel segments

Qc **Colluvium (Holocene and late Pleistocene?)**—Chiefly active and recently active colluvium on hillsides, but includes inactive accumulations of colluvium that might be as old as late Pleistocene. Clay, silt and sand, locally containing abundant angular rock fragments, derived from disaggregation of underlying bedrock; forms by hill creep and related processes on slopes where thickness is up to 3 m, and thicker along bases of some hillslopes. Older deposits (Qyc and Qoc) mapped separately only in the Mint Canyon 7.5' quadrangle (Saul, 1985; Saul and Wooton, 1983)

Qsw **Slope wash deposits (Holocene and late Pleistocene)**—Unconsolidated silt, sand and gravel, including angular rock fragments, as mapped on slopes in the Mint Canyon, Newhall and Oat Mountain 7.5' quadrangles: some deposits may be as old as late Pleistocene. Much is essentially same as Qc and Qyc, but unit names used by source authors retained here

Qu **Undifferentiated surficial deposits (Holocene and late Pleistocene?)**—Unconsolidated and uncorrelated deposits of silt, sand, and gravel; may include some residual soils

Qls **Landslide deposits (Holocene and late Pleistocene?)**—Rock detritus from bedrock and surficial materials, broken in varying degrees from relatively coherent large blocks to disaggregated small fragments, deposited by landslide processes including slides, slumps, falls, topples and flows; generally unconsolidated; some dissected landslides may be as old as late Pleistocene. A few large landslides toe below present sea level or stream level

Qdt **Debris trains and talus (Holocene and late Pleistocene?)**—Unconsolidated, unsorted gravel, sand and silt, commonly including large angular rock fragments; debris trains are chiefly debris-flow deposits that form medial ridges in some narrow canyon bottoms; talus cones and aprons result from active and recent rockfall and rock topple activity. Some deposits may be late Pleistocene

Qya **Young alluvium, undivided (Holocene and late Pleistocene)**—Unconsolidated, generally friable, stream-deposited silt, sand and gravel on canyon floors; surfaces may show slight to moderate pedogenic soil development. Includes:

Qya_4 **Young alluvium, Unit 4 (Holocene)**—Youngest of as many as 4 subunits of Qya that can be distinguished in some areas. Qya_4g gravel abundant. In part distinguished on basis of relative terrace levels

Qya_3 **Young alluvium, Unit 3 (Holocene and late Pleistocene)**—Older young alluvium, older than Unit 4, younger than Unit 2. In part distinguished on basis of relative terrace levels

Qya_2 **Young alluvium, Unit 2 (late Pleistocene)**—Older young alluvium, older than Unit 3, younger than Unit 1. In part distinguished on basis of relative terrace levels

Qya_1 **Young alluvium, Unit 1 (late Pleistocene)**—Oldest young alluvium. In part distinguished on basis of relative terrace levels

Qyw **Young wash deposits (Holocene and late Pleistocene?)**—Unconsolidated sand, silt and gravel; gravel and boulders common near mountain fronts. In part distinguished from wash deposits (Qw) on basis of relative terrace levels

Qyf **Young alluvial-fan deposits, undivided (Holocene and late Pleistocene)**—Unconsolidated gravel, sand and silt, bouldery near mountain fronts; deposited chiefly from flooding streams and debris flows; surfaces can show slight to moderate pedogenic soil development. Includes:

Qyf_4 **Young alluvial-fan deposits, Unit 4 (Holocene and late Pleistocene)**—Youngest of four subunits of Qyf that can be distinguished in some areas. In part distinguished on basis of relative terrace levels

Qyf_3 **Young alluvial-fan deposits, Unit 3 (Holocene and late Pleistocene)**—Older young fan deposits, older than Unit 4, younger than Unit 2. In part distinguished on basis of relative terrace levels

Qyf_2 **Young alluvial-fan deposits, Unit 2 (Holocene and late Pleistocene)**—Older young fan deposits, older than Unit 3, younger than Unit 1. In part distinguished on basis of relative terrace levels

Qyf_1 **Young alluvial-fan deposits, Unit 1 (Holocene and late Pleistocene)**—Oldest of as many as four subunits of Qyf that can be distinguished in some areas. In part distinguished on basis of relative terrace levels

Qyc **Young colluvium (Holocene and late Pleistocene)**—Unconsolidated clay, silt and sand colluvial deposits on hillsides, commonly containing abundant angular rock fragments; commonly on slopes where it is up to 3 m thick and thicker at the bases of some hillslopes; surfaces may show slight to moderate pedogenic soil development. Mapped only in the Mint Canyon 7.5' quadrangle (Saul, 1985; Saul and Wooton, 1983)

Qyd **Young nonmarine terrace deposits (late Pleistocene)**—Unconsolidated to moderately indurated, clay, silt, sand, and angular gravel including clasts up to boulder size; chiefly debris-flow deposits, but includes some stream-deposited material; surfaces may show slight to moderate pedogenic soil development. Overlies elevated wave-planed bedrock and marine terrace deposits along coast

Qpv **Palos Verdes Sand (late? Pleistocene)**—Massive, gray-green, very coarse-grained to gravelly unconsolidated marine sand; thickness about 15 m; rests on 30 m of loose beach sand; overlain by reddish nonmarine cover. First mentioned by Tieje (1926). (Southernmost Beverly Hills 7.5' quadrangle)

Qym **Young marine terrace deposits (late Pleistocene)**—Unconsolidated (but with small areas locally calcite-cemented) sand, silty sand and gravel; Typically rests on wave-cut bedrock surfaces at two or more altitudes above present sea level; some surfaces show slight to moderate pedogenic soil development. Deposits locally carry molluscan fauna referred to the late Pleistocene (Addicott, 1964)

Qoa **Old alluvium, undivided (late to middle Pleistocene)**—Unconsolidated to moderately indurated gravel, sand and silt; surfaces can show moderate to well-developed pedogenic soil, including a distinctive reddish "B" soil horizon; surfaces moderately to well dissected

Qoa_3 **Old alluvium, Unit 3 (late Pleistocene)**—Youngest of as many as three subunits of Qoa that can be distinguished in some areas. In part distinguished on basis of relative terrace levels

Qoa_2 **Old alluvium, Unit 2 (late Pleistocene)**—Intermediate of as many as three subunits of Qoa that can be distinguished in some areas. In part distinguished on basis of relative terrace levels

Qoa_1 **Old alluvium, Unit 1 (middle Pleistocene)**—Oldest of as many as three subunits of Qoa that can be distinguished in some areas. In part distinguished on basis of relative terrace levels

Qof **Old alluvial-fan deposits, undivided (late to middle Pleistocene)**—Slightly to moderately consolidated silt, sand and gravel deposits on alluvial fans; surfaces dissected in varying degrees; surfaces can show moderately to well-developed pedogenic soils

Qof_3 **Old alluvial-fan deposits, Unit 3 (late Pleistocene)**—Youngest of as many as three subunits of Qof that can be distinguished in some areas. In part distinguished on basis of relative terrace levels

Qof_2 **Old alluvial-fan deposits, Unit 2 (late Pleistocene)** — Intermediate of at least three subunits of Qof that can be distinguished in some areas. In part distinguished on basis of relative terrace levels

Qof_1 **Old alluvial-fan deposits, Unit 1 (middle Pleistocene)**—Oldest of at least three subunits of Qof that can be distinguished in some areas. In part distinguished on the basis of relative terrace levels

Qoc **Old colluvium (late to middle Pleistocene)**—Slightly to moderately consolidated silt, clay and sand, locally containing abundant angular rock fragments; surfaces dissected to varying degrees; can show slight to moderately developed pedogenic soil locally. Mapped only in the Mint Canyon 7.5' quadrangle (Saul, 1985)

Qvof **Very old alluvial-fan deposits (middle to early Pleistocene)**—Moderately dissected to well dissected, moderately to well consolidated, gravel, sand and silt; can contain boulders near mountain fronts

Qpa **Pacoima Formation (middle to early Pleistocene)**—Indurated, yellow-brown, locally intensely folded and faulted fanglomerate; unconformable on the early Pleistocene (?) Saugus Formation; overlain unconformably by relatively undeformed terrace deposits. Named and described by Oakeshott (1952). (Sunland 7.5' quadrangle)

Qsp **San Pedro Formation (early Pleistocene)**—Unconsolidated sandy unit; poorly defined but generally recognized as equivalent to Dall's (1898) San Pedro Sand: "extensive beds of unconsolidated Pleistocene sand replete with molluscan shells in very perfect condition, best exhibited at Harbor Hill". (Moorpark and Beverly Hills 7.5' quadrangles)

Transverse Ranges Province

Topatopa Mountains and eastern Santa Ynez Range

QTsb **Santa Barbara Formation (early Pleistocene to late Pliocene)**—Bluish-gray marine mudstone and siltstone, clay shale, and very fine-grained silty sandstone; includes numerous lenses of pebbly sandstone and conglomerate; laminated to massive, slightly to moderately indurated. Maximum thickness about 1,220 m. Name locality at Packard's Hill, Santa Barbara (Arnold, 1903), extended east into Ventura Basin by Grant and Gale (1931)

Tp **Pico Formation (Pliocene)**—Marine clayey siltstone and sandy siltstone. Soft, olive gray, containing interbeds of very fine-grained sandstone. Siltstone locally contains abundant foraminifera; locally well-cemented shells of invertebrates; as much as 183 m thick (Widespread exposures in east-trending band from Fillmore and Moorpark 7.5' quadrangles on the west, to San Fernando and Sunland 7.5' quadrangles on the east; a few exposures in southeast Topanga 7.5' quadrangle). Name introduced by B. L. Clark (1921); unit described by Oakeshott (1950). Lithologic facies subdivided locally, including:

Tps **Pico Formation, siltstone**—Siltstone. (Val Verde 7.5' quadrangle)

Tpc **Pico Formation, sandstone and conglomerate**—Sandstone and conglomerate. (Val Verde 7.5' quadrangle and adjacent areas)

Tw **Towsley Formation, undivided (early Pliocene and late Miocene)**—Interbedded sandstone, conglomerate, and mudstone; thickness as much as 1,220 m; widespread exposures in eastern Ventura County. Overlies Modelo Formation strata in the Topatopa Mountains; overlies and interfingers with Modelo Formation in the Santa Susana Mountains; overlaps Modelo to rest directly on basement rocks near and east of San Fernando Pass; generally conformably overlain by and gradational into Pico Formation siltstone. As named and described by Winterer and Durham (1954, 1962), includes beds mapped by Kew (1924) as an upper sandstone member of the Modelo Formation. Towsley Formation locally subdivided into:

Tws **Towsley Formation, siltstone (early Pliocene and late Miocene)**—Brown mudstone and siltstone, locally carries foraminifera referred to the Mohnian Stage (late Miocene) of Kleinpell (1938). (Oat Mountain, Simi Valley East (formerly Santa Susana), Val Verde and Piru 7.5' quadrangles)

Twc **Towsley Formation, conglomerate (early Pliocene and late Miocene)**—Pale pebble conglomerate and sandstone in lenticular beds. (Mint Canyon, Oat Mountain, Simi Valley East, Val Verde and Piru 7.5' quadrangles)

Twhc **Towsley Formation, Hasley Conglomerate Member (early Pliocene and late Miocene)**—Basal conglomerate member of formation. (Val Verde and Piru 7.5' quadrangles)

Tm **Modelo Formation, undivided (late Miocene)**—Predominantly gray to brown thin-bedded mudstone, diatomaceous clay shale, or siltstone, containing interbeds of very fine-grained to coarse-grained sandstone; proportion and thickness of sandstone interbeds allows lithofacies to be mapped in some areas. Generally unconformable on older rocks around northern, eastern, and southern margins of Ventura Basin. Base of Modelo Formation is generally unconformable on middle Miocene and older rocks. Name introduced by Eldridge and Arnold (1907) for strata exposed in Topatopa Mountains, north of Piru; subsequently extended to eastern Santa Monica Mountains and described in detail by Hoots (1931); further described in Santa Susana Mountains and San Fernando Pass areas by Winterer and Durham (1962). Five members described by Cemen (1977) in Topatopa Mountains and four mapped as far south as northern Oak Ridge and Santa Susana Mountains

Tm_5 **Modelo Formation, member 5**—Upper shale and siltstone unit; dark brown to gray, moderately- to well-compacted, thin-bedded to laminated silty shale and siltstone; locally siliceous near base. Contains foraminifera assigned to the upper Mohnian and lower Delmontian Stages of Kleinpell (1938). Thickness locally exceeds 458 m. (Cemen, 1977). (Piru 7.5' quadrangle)

Tm_4 **Modelo Formation, member 4**—Upper sandstone unit; white to gray, fine- to coarse-grained arkosic sandstone, containing subordinate thin partings and lenticular interbeds of silty clay shale; locally siliceous. Thickness variable, locally as much as 825 m. (Cemen, 1977). (Fillmore, Piru, Simi Valley East and Oat Mountain 7.5' quadrangles)

Tm_3 **Modelo Formation, member 3**—Middle shale unit; porcelaneous and calcareous shale and porcelaneous mudstone, brown to buff, thin-bedded to laminated, moderately to well indurated, contains thick lenses of gray calcareous sandstone locally; thickness variable but may exceed 763 m.; foraminifera referred to lower part of the Mohnian Stage of Kleinpell (1938) (Cemen, 1977). (Fillmore, Piru and Oat Mountain 7.5' quadrangles)

Tm_2 **Modelo Formation, member 2**—Lower sandstone unit; grayish-white to dark-brown, fine- to medium-grained sandstone, locally interbedded with dark brown siltstone and claystone; locally as much as 915 m. thick, thins westward and pinches out between middle and lower shale units (Cemen , 1977). (Piru, Simi Valley West and Oat Mountain 7.5' quadrangles)

Tm_1 **Modelo Formation, member 1**—Lower shale unit; cherty to porcelaneous shale and mudstone, locally calcareous, locally diatomaceous. Moderately to well indurated, thin-bedded to laminated, generally dark gray to brown. Contains foraminifera referred to Relizian and Luisian Stages of Kleinpell (1938); thickness 214-794 m. (Cemen, 1977). (Fillmore, Piru and Oat Mountain 7.5' quadrangles)

Trn **Rincon Formation (early Miocene)**—Marine shale and mudstone with dolomitic and limonitic concretions as much as 0.65 m in diameter (Fillmore 7.5' quadrangle). Foraminiferal faunas referred to the Zemorrian and Saucesian Stages of Kleinpell (1938). Thickness about 275 m. Overlain, apparently accordantly, by shale and mudstone assigned to the lower part of the Modelo Formation (which, in this area, is designated middle and upper Miocene), and conformably overlies Vaqueros Formation. Type section for Rincon Formation is approximately 30 mi. west in vicinity of Rincon Point where name, Rincon Shale, was suggested by Kerr (1931). (south flank of Santa Ynez Mountains, Fillmore and Piru 7.5' quadrangles; Eschner, 1969) Fritsche (1993) proposed that similar rocks within similar age-range in western Santa Monica Mountains (the Encinal Member of Topanga Canyon Formation and Danielson Member of Vaqueros Formation) should be termed "tongues" of Rincon Formation; however, we have retained nomenclature used in source maps

Tv **Vaqueros Formation, undivided (early Miocene)**—Heterogeneous sequence of thick- and medium-bedded sandstone and interbedded siltstone and mudstone. Sandstone ranges from coarse- to very fine-grained, chiefly biotitic arkosic arenites and wackes; siltstone and mudstone interbeds commonly dark gray, but can be greenish or reddish in color. Commonly carries *Turritella inezana* and other elements of "Vaqueros fauna". Although name was first used in central California (Hamlin, 1904) and subsequently extended on basis of faunal elements, it has long been used in coastal Southern California, and is used consistently throughout intervening areas, to refer to a well-recognized and widespread, predominantly marine sequence that contains a distinctive molluscan fauna (Loel and Corey, 1932). North of Fillmore, easternmost Vaqueros is about 183 m thick (Cemen, 1977; Eschner, 1969; Bailey, 1951)

Ts **Sespe Formation, undivided (late Eocene, Oligocene and early Miocene)**—Nonmarine "redbed" sequence of sandstone, pebbly sandstone, varicolored mudstone, and pebble-cobble conglomerate. Sandstone beds commonly very thick to massive, having strong internal cross lamination; and rare thin interbeds of varicolored reddish, greenish and grayish mudstone. Sandstone beds are characteristically red in color, chiefly as a result of intergranular hematized biotite; several sections include beds that lack characteristic red color. In western Topatopa Mountains, north of Fillmore, Sespe is about 430 m thick between underlying marine Coldwater Formation and overlying marine strata assigned to Vaqueros Formation (Fillmore 7.5' quadrangle). Name, Sespe Formation, was introduced by Watts (1897) and further described by Bailey (1947) for exposures in vicinity of Sespe Creek, north of Fillmore, and has been extended over large parts of coastal southern California by various workers. Generally, it has been applied to a thick nonmarine sandstone, conglomeratic sandstone and siltstone sequence that is underlain by marine Eocene strata and overlain by marine Miocene beds

Tcw **Coldwater Formation (late Eocene)**—Marine arkosic sandstone and shale; contains lenses of pebble conglomerate and oyster reefs; thickness about 390 m. Earliest use of "Coldwater Sandstone Member" by Kew (1924); referred to "Coldwater Formation" by Bailey (1947) who designated a type locality. (Fillmore 7.5' quadrangle; Eschner, 1969)

Tcz **Cozy Dell Formation (late to middle Eocene)**—Well-bedded marine brown clay shale and mudstone; thickness as much as 600 m. Earliest use of "Cozy Dell Shale Member" by Kerr and Schenk (1928); described as "Cozy Dell Formation" by Dibblee (1950). (Fillmore 7.5' quadrangle; Eschner, 1969)

Tpt **Topatopa Formation, undivided (middle to early Eocene)**—Marine sandstone, arkosic, very well indurated; interbedded with mudstone and siltstone. Conformable beneath Cozy Dell Formation; base not exposed in the map area; total thickness exceeds 1 km. Molluscan fossils are of Tejon Stage (late Eocene); interbedded shale contains foraminifera referred to Ulatisian and Narizian (early to middle Eocene) Stages of Mallory (1959); in part, equivalent to the Matilija and Juncal Formations as mapped short distance to west. Name first used by Eldridge (1907). (western Topatopa Mountains; Fillmore 7.5' quadrangle; Eschner, 1969). Includes:

Tpt_2 **Topatopa Formation, subunit 2**—Shale interbeds dominant; foraminifera referred to the Ulatisian and Narizian (middle to early Eocene) Stages of Mallory (1959). (Fillmore 7.5' quadrangle; Eschner, 1969)

Oak Ridge, Santa Susana Mountains, Simi Hills, Santa Monica Mountains

QTs **Saugus Formation, undivided (early Pleistocene to late Pliocene)**—Slightly consolidated, poorly sorted, coarse-grained, cross-bedded sandstone and pebble conglomerate; chiefly nonmarine, but includes a few interbeds of marine and brackish water depositional environment; unconformable on strata of the Pico Formation, and overlain unconformably by beds of Pacoima Formation. Maximum thickness about 1950 m in type area (southeast quarter, Newhall 7.5' quadrangle). Defined and described by Kew (1923); earlier called Fernando Formation by Hershey (1902). Widespread in eastern Ventura County; several authors have mapped members in different areas, including:

QTsu **Saugus Formation, upper member (early Pleistocene)**—Nonmarine sandstone and pebbly sandstone. (Oat Mountain and San Fernando 7.5' quadrangles)

QTsm **Saugus Formation, middle member (early Pleistocene)**—Coarse-grained sandstone and conglomerate. (Oat Mountain, Simi Valley East and Simi Valley West 7.5' quadrangles)

Tsr **Saugus Formation, Sunshine Ranch Member, undivided (late Pliocene)**—Interfingered marine, brackish water, and nonmarine cross-bedded and pebbly to cobbley sandstone; thickness about 915 m in type area (Mission Hills). Named by Hazard (in Oakeshott, 1950). (Mint Canyon and Sunland 7.5' quadrangles). Includes:

Tsru **Saugus Fm, Sunshine Ranch Member, upper facies**—Nonmarine sandy siltstone and mudstone, pebbly sandstone, and sandy conglomerate; thickness as much as 300 m; north of San Gabriel Fault. (southwest part of Mint Canyon 7.5' quadrangle)

Tsrl **Saugus Fm, Sunshine Ranch Member, lower facies**—Nonmarine arkosic sandstone, silty sandstone, pebbly sandstone, and conglomerate; thickness about 120 m; both sides of San Gabriel Fault. (southwest part of Mint Canyon 7.5' quadrangle)

Tp **Pico Formation (Pliocene)**—Marine clayey siltstone and sandy siltstone, soft, olive gray, containing interbeds of very fine-grained sandstone; siltstone locally contains abundant foraminifera and locally well-cemented shells of invertebrates. As much as 183 m thick (widespread exposures in east-trending band from Fillmore and Moorpark 7.5' quadrangles on west, to San Fernando and Sunland 7.5' quadrangles on east; a few exposures in southeast Topanga 7.5' quadrangle). Name introduced by B. L. Clark (1921), unit described by Oakeshott (1950). Includes:

Tps **Pico Formation, siltstone**—Siltstone. (Val Verde 7.5' quadrangle)

Tpc **Pico Formation, sandstone and conglomerate**—Sandstone and conglomerate. (Val Verde 7.5' quadrangle and adjacent areas)

Tw **Towsley Formation, undivided (early Pliocene and late Miocene)**—Interbedded sandstone, conglomerate, and mudstone; thickness as much as 1,220 m; widespread exposures in eastern Ventura County. Overlies Modelo Formation in Topatopa Mountains; overlies and interfingers with Modelo Formation in Santa Susana Mountains; overlaps Modelo to rest directly on basement rocks near and east of San Fernando Pass; generally conformably overlain by and gradational with Pico Formation siltstone. As named and described by Winterer and Durham (1954, 1962), includes beds mapped by Kew (1924) as an upper sandstone member of Modelo Formation. Includes:

Tws **Towsley Formation, siltstone**—Brown mudstone and siltstone, locally carries foraminifera referred to Mohnian Stage (late Miocene) of Kleinpell (1938). (Oat Mountain, Simi Valley East, Val Verde and Piru 7.5' quadrangles)

Twc **Towsley Formation, conglomerate**—Pale pebble conglomerate and sandstone in lenticular beds. (Mint Canyon, Oat Mountain, Simi Valley East, Val Verde and Piru 7.5' quadrangles)

Tm **Modelo Formation, undivided (late Miocene)**—Predominantly gray to brown thin-bedded mudstone, shale, or siltstone, contains interbeds of very fine-grained to coarse-grained sandstone; proportion and thickness of sandstone interbeds allows mappable facies to be distinguished locally; noted for turbidite features indicating submarine fan deposition (Sullwold, 1960). Generally unconformable on older rocks around northern, eastern, and southern margins of Ventura Basin. Base of Modelo is generally unconformable on middle Miocene and older rocks. Along north flank of Santa Monica Mountains the unconformity mapped by Hoots (1931) in eastern part of range, where Modelo locally overlies Santa Monica Slate, has been mapped continuously westward (Yerkes and Campbell, 1980; Weber, 1984; and unpublished 1:12,000-scale mapping by Yerkes and Campbell, 1965-1974, in Canoga Park and Calabasas 7.5' quadrangles) as far as north side of Ventura Freeway (U.S. 101) at west side of Las Virgenes Creek. West of there it becomes accordant with (and apparently conformable on) subjacent strata of Calabasas Formation (Weber, 1984); further west, Modelo and subjacent parts of Calabasas appear to grade progressively westward into more diatomaceous, clayey, Monterey-like lithofacies. Many sandstone and shale beds below unconformity and its westward conformable extension and above Conejo Volcanics are lithologically similar to Modelo but more intensely folded and faulted; these beds have been assigned to Calabasas Formation by Yerkes and Campbell (1979). Fellbaum and Fritsche (1993) include them in Modelo Formation; however, their correlation with Mohnian age strata above unconformity is unlikely. Name, Modelo, was introduced by Eldridge (1907) for strata exposed in the Piru 7.5' quadrangle; extended to the eastern Santa Monica Mountains and described in detail by Hoots (1931); Kleinpell (1938) used unconformity at base (as mapped by Hoots, 1931), well exposed near Mohn Springs in Topanga Canyon, where it is underlain by middle Miocene Topanga strata, as base for his type Mohnian (foraminiferal) Stage (late Miocene). Further described in Santa Susana Mountains and San Fernando Pass areas by Winterer and Durham (1962). Widespread in eastern Ventura Basin; locally extended to include some strata along south flank of Santa Monica Mountains in Pacific Palisades-Westwood area. Lithologically designated subunits are interbedded at different levels of Modelo, but do not constitute a consistent stratigraphic sequence. Where subunits do form a consistent stratigraphic sequence, they have been designated by subscripted numbers

Tm_5 **Modelo Formation, member 5**—Upper shale and siltstone. (Piru 7.5' quadrangle)

Tm_4 **Modelo Formation, member 4**—Interbedded sandstone and shale. (Fillmore, Piru, Simi Valley East and Oat Mountain 7.5' quadrangles)

Tm_3 **Modelo Formation, member 3**—Middle shale. (Fillmore, Piru and Oat Mountain 7.5' quadrangles)

Tm_2 **Modelo Formation, member 2**—Lower sandstone. (Piru, Simi Valley West and Oat Mountain 7.5' quadrangles)

Tm_1 **Modelo Formation, member 1**—Lower shale. (Fillmore, Piru and Oat Mountain 7.5' quadrangles)

Tmd **Modelo Formation, diatomaceous shale**—Diatomaceous shale. (Simi Valley West, Oat Mountain, Canoga Park and Van Nuys 7.5' quadrangles)

Tmst **Modelo Formation, siltstone**—Silty shale and siltstone; includes siliceous shale. (Val Verde and Beverly Hills quadrangles)

Tms **Modelo Formation, sandstone**—Sandstone. (Thousand Oaks, Calabasas, Canoga Park and Van Nuys 7.5' quadrangles)

Santa Susana Mountains and Simi Hills

Tt **Topanga Group, undivided (middle Miocene)**—Heterogeneous sequence of sedimentary and volcanic rocks, containing a marine facies having middle Miocene molluscan fauna diagnostic of "Temblor" Stage (Weaver and others, 1944). First called the Topanga Formation by Kew (1923) for exposures in central Santa Monica Mountains. Yerkes and Campbell (1979) revised nomenclature for thick sequence in central and western Santa Monica Mountains, and designated entire sequence as the Topanga Group. Fossil mollusk species provide chief basis for extending "Topanga Formation" to other areas in eastern Ventura Basin. In Los Angeles quadrangle, those surface and subsurface occurrences that have not been specifically correlated with one or another of the three formations recognized in the central and western Santa Monica Mountains are labeled as "Topanga Group", locally with lithologic subunits recognized by various authors, including interlayered basalt (Ttb). Ttb consists of intrusive and extrusive volcanic rocks, chiefly basaltic and andesitic, interlayered with sandstone and shale assigned to Topanga Group. In part, may be correlative with Conejo Volcanics of central and western Santa Monica Mountains and adjacent areas to northwest; but includes rocks dated as older than oldest contiguous Conejo Volcanics (McCulloh and others, 2002). (Eastern Santa Monica Mountains, Hoots, 1931; Santa Susana Mountains, Evans and Miller, 1978; northeastern Verdugo Mountains, Oakeshott, 1958). Subunits include:

Tt_4 **Topanga Group, unit 4**—Upper sandstone interbedded with siltstone and local pebble conglomerate; sandstone, medium- to coarse-grained arkose. Locally contains *Amusium lompocensis*. Thickness about 140 m. (Oat Mountain 7.5' quadrangle; Saul, 1979)

Tt_3 **Topanga Group, unit 3**—Shale, foram-bearing siltstone, and mudstone, about 122 m thick. (Oat Mountain 7.5' quadrangle; Saul, 1979)

Tt_2 **Topanga Group, unit 2**—Sandstone, fine- to coarse-grained, arkosic, well indurated, massive, about 244 m thick. (Oat Mountain 7.5' quadrangle; Saul, 1979)

Tt_1 **Topanga Group, unit 1**—Shaly siltstone, massive to well bedded, minor lenses of conglomeratic sandstone. Siltstone locally contains microfauna assigned to the Luisian Stage of Kleinpell (1938). (Oat Mountain 7.5' quadrangle; Saul, 1979)

Tv **Vaqueros Formation, undivided (early Miocene)**—Heterogeneous sequence of thick- and medium-bedded sandstone and interbedded siltstone and mudstone. Sandstone ranges from coarse- to very fine-grained, chiefly biotitic arkosic arenites and wackes; siltstone and mudstone interbeds commonly dark gray, but can be greenish or reddish in color. Commonly carries *Turritella inezana* and other elements of "Vaqueros fauna". Name was first used in central California (Hamlin, 1904); subsequently extended on basis of faunal elements. Long been used in coastal Southern California, and is used consistently throughout intervening areas, to refer to a well-recognized and widespread, predominantly marine sequence that contains a distinctive molluscan fauna (Loel and Corey, 1932). In the Simi Valley area, Squires and Filewicz (1983, Fig. 2) show the Vaqueros as approximately 310 m in thickness, intertonguing with and overlying the Sespe Formation; it pinches out eastward beneath the unconformably overlying Conejo Volcanics

Ts **Sespe Formation, undivided (early Miocene, Oligocene, and late Eocene)**—Nonmarine "redbed" sequence of sandstone, pebbly sandstone, varicolored mudstone, and pebble-cobble conglomerate. Sandstone beds commonly very thick to massive, having strong internal cross lamination; and rare thin interbeds varicolored reddish, greenish and grayish mudstone. Sandstone beds are characteristically red in color, chiefly as a result of intergranular hematized biotite; several sections include beds that lack characteristic red color. At west end of Simi Hills about 1365 m of Sespe strata lie accordantly above marine Llajas and unconformably below Conejo Volcanics. Along north side of Simi Valley, Sespe exposures total as much as 1656 m in thickness in the west (Simi Valley West 7.5' quadrangle), but the unit wedges out to the east, north of Santa Susana Pass (Simi Valley East 7.5' quadrangle). Along north flank of Oak Ridge the Sespe can be as much as 2135 m thick, based in part on drill-hole data. The name, Sespe Formation, was introduced by Watts (1897) and further described by Bailey (1947) for exposures in the vicinity of Sespe Creek, north of Fillmore, and has been extended over large parts of coastal southern California by various workers. Applied to a thick nonmarine sandstone, conglomeratic sandstone and siltstone sequence that is underlain by marine Eocene strata and overlain by marine Miocene beds

Tl **Llajas Formation (middle to early Eocene)**—Marine sandstone, very fine- to fine-grained, siltstone, pebble conglomerate and interbedded platy to shaly siltstone and mudstone. Locally contains fossil mollusks assigned to "Domengine Stage" (Weaver and others, 1944). Name for strata exposed on northwest side of north branch of Las Llajas Canyon, on northeast side of Simi Valley (Schenck, 1931, p. 455; McMasters, 1933; Squires, 1983b). (Simi Valley East, Oat Mountain, Thousand Oaks 7.5' quadrangles, and correlative strata in Point Dume, Malibu Beach, and Topanga 7.5' quadrangles) Includes:

Tlc **Llajas Formation, conglomerate**—Basal conglomerate separating Llajas strata from underlying Santa Susana Formation in area northeast of Simi Valley. (Simi Valley East and Oat Mountain 7.5' quadrangles; Evans and Miller, 1978)

Td **Domengine Formation (middle Eocene)**—Marine, gray to greenish, hard calcareous sandstone. Small body exposed about ½ mile east of San Fernando Pass (west-central San Fernando 7.5’ quadrangle); correlated with “Domengine” fauna identified in nearby well, and with “Llajas Formation” as mapped about 16 km to west-southwest (Oakeshott, 1958, p. 58). “Domengine” is a provincial Stage name imported from central California, first used by F. M. Anderson (1905), subsequently used as formation name for mappable beds that carry middle Eocene mega- or microfauna. (San Fernando 7.5’ quadrangle; Oakeshott, 1958, p. 58)

Tss **Santa Susana Formation (early Eocene to late Paleocene)**—Clay shale and fractured mudrock; contains interbeds of fine- to medium-grained sandstone and pebble conglomerate; gray limestone concretions common in shale. Locally contains foraminifera and locally abundant mollusks diagnostic of “Meganos” and “Martinez” Stages (Saul, 1983). Thickness as much as 1,000 m. Named by Clark (1921). (Thousand Oaks, Calabasas and Simi Valley East 7.5’ quadrangles; Squires, 1983a)

Tlv **Las Virgenes Formation (early (?) Paleocene)**—Nonmarine and marine sandstone and mudstone; thin sequence, locally 125 m, but thins westward to zero. Named by Nelson (1925). (Thousand Oaks and Calabasas 7.5’ quadrangles; Squires, 1983a)

Tep **Sedimentary rocks of the Chatsworth reservoir area (Eocene and/or Paleocene)**—Unnamed conglomerate and sandstone; probably Eocene and (or) Paleocene (post-Chatsworth Formation and pre-Sespe). (Canoga Park 7.5’ quadrangle; Shields, 1977)

Tmz **Martinez Formation (Paleocene)**—Coarse-grained marine sandstone, thin interbeds of black shale, and lenticular beds of well-cemented pebble conglomerate. Molluscan stage name, imported from central California first used by Gabb (1869), was used by Kew (1924) and Nelson (1925) for fossiliferous Paleocene strata in Simi Hills. Beds in Simi Hills renamed “Santa Susana Formation” by Colburn and others (1988). “Martinez” also used by Hoots (1931) for strata in the Santa Monica Mountains later renamed Coal Canyon Formation (Yerkes and Campbell, 1979); “Martinez” is retained here only for strata in fault slices in San Gabriel Fault Zone (Oakeshott, 1958; Sunland and San Fernando 7.5’ quadrangles)

Tsi **Simi Conglomerate, undivided (Paleocene)**—Thin, nonmarine cobble-boulder conglomerate mapped at base of Tertiary sequence in Simi Hills, Santa Monica Mountains, and northeast of Simi Valley. Conglomerate contains abundant well-rounded, polished cobbles and boulders of quartzite, granitic, rhyolitic, and gneissic rocks in conglomeratic, coarse-grained sandstone. Yerkes and Campbell (1979) tentatively correlated beds described in Simi Hills by Nelson (1925) as Simi Conglomerate with lithologically similar beds in Solstice Canyon area of Santa Monica Mountains. Correlation is supported by subsequent detailed petrographic work of Colburn and Novak (1989). Correlative strata in Santa Susana Mountains, mapped as “Martinez Formation” by Evans and Miller (1978), are here included with Simi Conglomerate. Evans and Miller (1978) recognized three local lithologic members

Tsic **Simi Conglomerate, conglomeratic member**—Massive, yellowish brown pebble to cobble conglomerate; contains numerous brownish sandstone lenses as much as 1 m thick and continuous for a few tens of meters along strike. Locally contains molluscan fauna referred to Martinez Stage (Evans and Miller, 1978; Oat Mountain 7.5’ quadrangle)

Tsis **Simi Conglomerate, shale member**—Light olive gray micaceous siltstone, silty shale, and shale; contains local thin interbeds of brown, medium- to coarse-grained sandstone. Dark gray limestone occurs in shale as thin, discontinuous beds as well as small pods and lenses (Evans and Miller, 1978; Oat Mountain 7.5’ quadrangle)

Tsia **Simi Conglomerate, sandstone member**—Massive, gray to brownish, coarse- to very coarse-grained sandstone, cemented by silica and hydrous iron oxides;

contains thin interbeds of micaceous siltstone and lenses of boulder, cobble and pebble conglomerate. Locally strongly cemented by calcite (Evans and Miller, 1978; Oat Mountain 7.5' quadrangle)

Kc **Chatsworth Formation (late Cretaceous)**—Dominantly turbidite sandstone, massive, thick-bedded, medium- to coarse-grained, well-cemented; conglomeratic sandstone with rounded, polished clasts of quartzite, porphyry and granitic rocks; contains minor siltstone and conglomerate. Molluscan faunas include ammonite *Metaplacenticeras californicum* and gastropod *Turritella pescaderosensis*, referred to Campanian or Maestrichtian Stages (Popenoe, 1973; Saul and Alderson, 1981). Benthic foraminifera from mudstones in lower-middle part of the sequence are referred to late Campanian. Exposed thickness exceeds 1830 m; base neither exposed nor drilled. Overlain with slight unconformity by Paleocene strata along north side of Simi Hills, elsewhere unconformably overlain by Miocene beds. Name, Chatsworth Formation introduced and defined by Colburn and others (1981) for rocks in eastern Simi Hills near Chatsworth, that were previously mapped as "Chico Formation" or as unnamed "Upper Cretaceous Rocks" ("Chico" is a molluscan Stage name imported from central California). (Calabasas, Thousand Oaks and Oat Mountain 7.5' quadrangles; Weber, 1984)

Central and western Santa Monica Mountains (below Malibu Bowl Detachment Fault)

Tt **Topanga Group, undivided (middle Miocene)**—Thick (>6,000 m), heterogeneous sequence of sedimentary and volcanic rocks, containing a marine facies with middle Miocene molluscan fauna diagnostic of "Temblor" Stage (Weaver and others, 1944). Included in the Topanga Formation by Kew (1923). In the western Santa Monica Mountains, west of Temescal Canyon, this sequence measures more than 6,000 m in thickness, and is readily divisible into the three formations recognized by Durrell (1954): lower sequence of offshore shelf, shoreline, and brackish water sandstone and siltstone extensively intruded with dikes and sills related to the overlying extrusive sequence; middle sequence of chiefly basaltic and andesitic extrusive volcanic rocks, mostly deposited in a marine environment; and upper sequence of deeper water submarine fan turbidite sandstone and interbedded shale. Durrell (1954) called the three-fold sequence the Lower Topanga, Middle Topanga and Upper Topanga Formations, a nomenclature unacceptable to the current code of stratigraphic nomenclature (North American Commission on Stratigraphic Nomenclature, 1983); Yerkes and Campbell (1979) revised the nomenclature to identify entire sequence as Topanga Group and to apply individual formation names, Topanga Canyon Formation, Conejo Volcanics, and Calabasas Formation, respectively, to the three constituent units

Tcb **Calabasas Formation, undivided (early late Miocene and late middle Miocene)**—Interbedded impure, clayey to silty sandstone and silty shale, containing local beds of sedimentary breccia; sandstone is thin-, medium- and thick-bedded, mostly medium to coarse grained, poorly sorted, commonly having wacke texture, commonly shows graded bedding. Shale, locally diatomaceous or phosphatic, locally abundant fish scales, sparse foraminifera, and rust-colored plant casts. Some thicker beds contain zones of large ovoid dolomitic concretions; sedimentary breccia, olistostromes incorporating cobble- to large boulder-size clasts of recognizable older Tertiary strata, including fossil-bearing clasts of Paleocene, Eocene, early Miocene, and middle Miocene strata, as well as volcanic (probable Conejo Volcanics) clasts. Many sandstone beds are lithologically similar to those in overlying, less-deformed Modelo Formation.

Modelo is generally unconformable over Calabasas. West of Malibu Junction and north of Ventura Freeway the two formations are accordant; Calabasas grades westward into finer-grained clayey siltstone and shale much like nearby Modelo; two formations are distinguished only by differences in foraminiferal fauna. (Calabasas there contains foraminifera referred to Luisian Stage of Kleinpell, 1938; Modelo contains foraminifera referred to Mohnian Stage of Kleinpell, 1938. Many foram collections from the Calabasas are not diagnostic as to Stage, and have been reported only as middle Miocene, Relizian or Luisian.) The name is taken from Calabasas Peak, about 3 km east of prominent exposures of Calabasas strata in Stokes Canyon-McCoy Canyon area (Yerkes and Campbell, 1979). Along north flank of Santa Monica Mountains, south of Ventura Freeway (U.S. 101), contact relationships with the underlying Conejo Volcanics are marked by extreme variability, apparently reflecting nearly continuous marine sedimentation, intermittently overwhelmed by episodes of waning submarine volcanic activity, punctuated by episodes of structural disturbance that may have included detachment faulting. Consequently, just east of Medea Creek and south of Agoura (northeast Point Dume 7.5' quadrangle, southeast Thousand Oaks 7.5' quadrangle) Calabasas lies unconformably across one sequence of volcanic strata, yet nearby to east and west base is accordant with different levels in volcanic sequence (Blackerby, 1965). West of Westlake, persistent volcanic conglomerate assigned to Calabasas lies unconformably across Boney Mountain Fault and Conejo Volcanics to west (Weber, 1984). Similar volcanic conglomerate along south and west flanks of Simi Hills intervenes between overlying Modelo Formation and north dipping Cretaceous and early Tertiary strata, and has also been assigned to Calabasas Formation (Weber, 1984)

Tcbs **Calabasas Formation, Stokes Canyon Breccia Member (late middle Miocene)**—Sedimentary breccia of angular boulders and cobbles of redeposited well-cemented sandstone; contains molluscan faunas diagnostic of the "Martinez" (Paleocene) and "Domengine" (middle Eocene) Stages; breccia bed is locally as thick as 60 m; underlain and overlain conformably by Calabasas sandstone and siltstone; locally overlain unconformably by basal conglomerate of Modelo Formation. Thinner, less continuous breccia beds are present at two other horizons nearby. (Stokes Canyon area, northern Malibu Beach and southern Calabasas 7.5' quadrangles; Yerkes and Campbell, 1979, p. E22; Yerkes and Campbell, 1980)

Tcbvc **Calabasas Formation, Volcanic conglomerate (late middle Miocene)**—Volcanic conglomerate, mapped by Weber (1984) as basal Calabasas Formation where it rests unconformably on Chatsworth Formation (Cretaceous) along south flank of Simi Hills, and extends north westward across Paleogene sequence at west end of Simi Hills. This conglomerate may be approximately equivalent to volcanic conglomerates interbedded with lower part of Calabasas Formation sandstone and shale exposed along and north of Ventura Freeway in Agoura area (Blackerby, 1965), and overlying volcanic strata in Thousand Oaks area (Weber, 1984). (Thousand Oaks and Calabasas 7.5' quadrangles)

Tco **Conejo Volcanics, undivided (middle middle Miocene)**—Basalt, andesitic basalt, basaltic andesite, andesite, and dacite in a thick sequence of extrusive volcanic flows, flow-breccias, agglomerates, and epiclastic volcanic breccias, volcanic sandstones and siltstones. Thickest (probably in excess of 3 km) where it underlies north flank of western Santa Monica Mountains, and thinning eastward to as little as 200 m of interbedded flows and volcaniclastic sedimentary rocks on nose of Topanga Anticline. Further east volcanic rocks are relatively thin and discontinuous, and name has not been extended eastward for more than a mile east of Topanga Canyon Road. Thick sequence shows crude compositional layering: pillow basalt, pillow breccia, aquagene tuff, black volcanic sandstone and interbedded black siltstone are common in basal part of

Conejo, associated with basalt, andesitic basalt, and basaltic andesite flows, breccia, and agglomerate. Andesite and basaltic andesite predominate in the central part of sequence with interlayered andesitic basalt. Sequence has upper zone, dominated by andesite and basaltic andesite but includes dacite flows in some areas as well as epiclastic volcanic conglomerates containing andesite and dacite clasts. Durrell (1954) recognized general extent of volcanics that intervene between lower- and upper-middle Miocene sedimentary strata, and called them "Middle Topanga Formation"; but name "Conejo Volcanics" applied by Taliaferro (1924) to rocks in Conejo Mountain area has precedence; adopted by Blackerby (1965) and by Yerkes and Campbell (1979). Basal Conejo is conformable on and interbedded with upper part of underlying Topanga Canyon Formation from about one mile west of Malibu Lake, eastward to area north of Calabasas Peak. Westward, in western part of Point Dume 7.5' quadrangle and eastern part of Triunfo Pass 7.5' quadrangle, contact lies unconformably across Topanga Canyon and Vaqueros strata. Unconformable parts of contact do not require an episode of uplift and erosion; we interpret missing strata as probably removed by faulting, perhaps associated with caldera collapse, leaving a downdropped surface that was backfilled by a sequence of eruptive episodes. Weigand and Savage (1993) have summarized geochemistry of Conejo Volcanics, comparing units with other southern California Miocene volcanic suites. Range in initial Sr^{87}/Sr^{86} is reported as 0.70294-0.704201, indicating parent magmas derived from upper mantle without important crustal rock contamination (Weigand and Savage, 1993, p. 105,106). K-Ar ages on plagioclase from basalt and andesite, reported by Turner and Campbell (1979), range from 15.5$\pm$0.8 Ma near the base of the Conejo to 13.9$\pm$0.4 Ma near the top. McCulloh and others (2002, p. 3) have recalculated older date using updated decay constants to yield 15.9$\pm$0.8 Ma age

Tcode **Conejo Volcanics, dacite-bearing epiclastic lenses**—Epiclastic volcanic rocks, but including basalt, andesite and dacite pyroclastic flows and flow breccia; forms relatively thin layers and lenses interbedded in lower part of Calabasas Formation, which locally includes volcanic sandstone and volcanic conglomerate. (north of Ventura Freeway, Thousand Oaks 7.5' quadrangle; after Blackerby, 1965)

Tcod **Conejo Volcanics, dacite-bearing upper zone**—Interlayered dacite (including trachytic dacite), andesite and basalt flows and pyroclastics; minor volcanic sandstone. Malibu Junction Member of Conejo Volcanics of Blackerby (1965). (south of Ventura Freeway, Thousand Oaks 7.5' quadrangle)

Tcoa **Conejo Volcanics, andesitic central zone**—Interlayered porphyritic and microporphyritic andesite, andesitic basalt, and basaltic andesite flows, agglomerates and flow breccias; includes some crystal tuff, vesicular andesite, pyroclastics and volcanic sandstone; includes Ladyface Member and Medea Member of Blackerby (1965), as well as Potrero and Triunfo Members of Sonneman (1956) and Guynes (1959). (Thousand Oaks, Point Dume, Triunfo Pass and Newbury Park 7.5' quadrangles; Blackerby, 1965 and unpublished mapping 1965-1973; Campbell and others, 1996, and unpublished mapping 1962-1976; Sonneman, 1956; Guynes, 1959; and Weber, 1984). Lithologically recognized subunits, which occur at various stratigraphic levels, and do not form a consistent stratigraphic sequence, include:

Tcoab **Conejo Volcanics, andesitic central zone, andesite breccia**—Andesitic and basaltic breccia and some agglomerate; mostly equivalent to rocks mapped as Triunfo Member by Sonneman (1956) and Guynes (1959); includes rocks mapped as Medea Member by Blackerby (1965). (Topanga, Malibu Beach, Point Dume, Triunfo Pass, Newbury Park and Thousand Oaks 7.5' quadrangles; Yerkes and Campbell, 1980; Campbell and others, 1970; Sonneman, 1956; Guynes, 1959; Weber, 1984; and unpublished 1:12,000-scale mapping by R. H. Campbell and B. A. Blackerby, 1967-1972)

Tcoaf **Conejo Volcanics, andesitic central zone, andesitic flows**—Andesite flows, mapped as Potrero Member of Conejo Formation by Sonneman (1956) and Guynes (1959). (Triunfo Pass 7.5' quadrangle)

Tcoaa **Conejo Volcanics, andesitic central zone, andesitic agglomerate**—Andesite agglomerate and tuff, mapped as part of Potrero Member of Conejo Formation by Guynes (1959). (Triunfo Pass 7.5' quadrangle)

Tcob **Conejo Volcanics, basaltic lower zone, basalt and andesitic basalt**—Chiefly basalt, olivine basalt, basaltic andesite, and andesitic basalt; ranges from trachytic olivine basalt to porphyritic quartz andesite; as flows, breccias, agglomerates, pillow basalts, pillow breccias, and basaltic sand and silt; includes Olivine Basalt and Seminole Members of Blackerby (1965). (Malibu Beach, Point Dume, Triunfo Pass, and Thousand Oaks 7.5' quadrangles; Yerkes and Campbell, 1980; Campbell and others, 1996; Blackerby, 1965; Sonneman, 1956; Guynes, 1959; Weber, 1984; and unpublished 1:12,000-scale mapping by R. H. Campbell and B. A. Blackerby, 1962-1976). Lithologically recognized subunits (flows and breccias) are interlayered at various stratigraphic levels in upper part of zone, and do not form a consistent stratigraphic sequence; however pillow basalt, pillow breccia, and volcanic sand predominate in lower part of zone. Subunits include:

Tcobb **Conejo Volcanics, basaltic lower zone, basalt and andesitic basalt, basaltic breccia**—Basalt, andesitic basalt and basaltic andesite breccias; includes some pillow breccia; in part, mapped as Serrano member of Conejo Volcanics by Sonneman (1956) and Guynes (1959). (Malibu Beach, Point Dume, Triunfo Pass and Thousand Oaks 7.5' quadrangles; Sonneman, 1956; Guynes, 1959; Blackerby, 1965; Yerkes and Campbell, 1980; Weber, 1984; Campbell and others, 1996)

Tcobf **Conejo Volcanics, basaltic lower zone, basalt and andesitic basalt, basalt flows**—Basalt, andesitic basalt and basaltic andesite flows. (Malibu Beach, Point Dume and Thousand Oaks 7.5' quadrangles; Blackerby, 1965; Yerkes and Campbell, 1979 and 1980; Campbell and others, 1996; and Weber (1984)

Tcop **Conejo Volcanics, basaltic lower zone, pillow basalt**—Basalt pillow lavas, pillow breccias and probable aquagene tuffs; included in Seminole Member mapped by Blackerby, 1965, and Serrano Member mapped by Sonneman, 1956, and by Guynes, 1959. (Malibu Beach, Point Dume and Triunfo Pass 7.5' quadrangles; Sonneman, 1956; Guynes, 1959; Blackerby, 1965; Yerkes and Campbell, 1980; Campbell and others, 1996)

Tcobz **Conejo Volcanics, basaltic lower zone, basaltic sand**—Black basaltic sand and siltstone; included in Seminole Member of Blackerby, 1965. (Point Dume and Malibu Beach 7.5' quadrangles; Blackerby, 1965; Yerkes and Campbell, 1980; Campbell and others, 1996)

Tid **Intrusive rocks, dacite (middle middle Miocene)**—Dacite plug intrusive into Topanga Canyon Formation. (eastern Newbury Park 7.5' quadrangle; Dibblee and Ehrenspeck, 1993, p. 89)

Ti **Intrusive rocks, undivided (middle middle Miocene)**—Dikes, sills and irregularly shaped intrusive bodies of diabase, basalt, and andesite; commonly pervasively altered and easily eroded, undercutting slopes and, therefore, commonly spatially associated with toes of landslides; sills are larger and more abundant in Topanga Canyon Formation at shallow stratigraphic depths below base of Conejo Volcanics; intrusive along Malibu Bowl Detachment Fault only where Topanga Canyon Formation and younger strata are carried in upper plate (widespread in central and western Santa Monica Mountains; Yerkes and Campbell, 1980; Campbell and others, 1996)

Tim **Mixed rocks (middle middle Miocene and early or early middle Miocene)**—Very fine- to fine-grained basalt, pervasively intrusive into black siltstone and very fine-grained sandstone of Topanga Canyon Formation (and, possibly, Vaqueros

Formation) on a spacing too fine to map separately at 1:12,000-scale. (Triunfo Pass 7.5' quadrangle; Campbell, unpublished mapping, 1967-1976)

Ttc **Topanga Canyon Formation, undivided (early middle Miocene)**—Marine sandstone, commonly arkosic, with interbedded siltstone, pebbly sandstone and pebble-cobble conglomerate; generally well indurated. Where undivided, thick-bedded sandstone predominates, probably indicative of chiefly shoreface and nearshore depositional environments; locally abundant molluscan fossils assigned to "Temblor" Stage (middle Miocene) of Weaver and others (1944). Conformably overlain by Conejo Volcanics from about one mile west of Malibu Lake eastward to area north of Calabasas Peak. Further west, in western part of Point Dume 7.5' quadrangle and eastern part of Triunfo Pass 7.5' quadrangle, contact is both sharply unconformable in some places and conformable in others. Unconformable segments are probably not result of subaerial erosion, and may have initially been faults (caldera collapse?) associated with volcanism. Conformably overlies Vaqueros Formation, which commonly contains a similar but older molluscan fauna. North of Castro Peak, unit is as much as 1,070 m thick. Interbeds of siltstone and mudstone, suggestive of offshore shelf depositional environments, become progressively thicker and more abundant westward. Durrell (1954) referred to this unit as "Lower Topanga Formation". Yerkes and Campbell (1979) formalized name "Topanga Canyon Formation" for pre-volcanic middle Miocene strata of central and western Santa Monica Mountains, and described four members of distinctly different lithologic character. More recently, Fritsche (1993) has proposed further revision of nomenclature; however, for the purposes of this compilation, usage of source maps is retained (Yerkes and Campbell, 1980; Campbell and others, 1996)

Ttcc **Topanga Canyon Formation, Cold Creek Member**—Marine sandstone, siltstone, and minor pebbly sandstone. Sandstone commonly medium grained, moderately to well sorted arkosic arenite, in laminated and graded beds as much as two meters thick, and locally biotitic. About 707 m thick in northeast corner of the Malibu Beach 7.5' quadrangle, type locality of "Topanga Formation" specified by Kew (1924). Locally abundant molluscan fauna referred to "Temblor Stage" of Weaver and others (1944), including type locality for "Topanga Canyon fauna" (about 50 molluscan species) of Arnold (1907). Named as a member of Topanga Canyon Formation by Yerkes and Campbell (1979). Conformably overlies Fernwood member of Topanga Canyon Formation; overlain, in most places conformably, by Conejo Volcanics; in a few localities in upper Topanga Canyon, Conejo is missing and Cold Creek Member is accordantly overlain by Calabasas Formation. However, in most of Topanga Canyon area Cold Creek Member is separated from older rocks by Malibu Bowl Detachment Fault or basalt intrusive into fault zone. (Malibu Beach, Topanga and Calabasas 7.5' quadrangles; Yerkes and Campbell, 1980; Campbell, unpublished 1:12,000-scale mapping, 1965-1972)

Ttce **Topanga Canyon Formation, Encinal Member**—Chiefly dark gray siltstone or silty mudstone, commonly platy to shaly, but at many localities bedding fissility is obscured by a dominant conchoidal fracture. Lenticular dolomitic concretions locally abundant, particularly along restricted stratigraphic zones as thick as 60 cm. Rare medium- and fine-grained sandstone beds in Encinal Canyon area (western Point Dume 7.5' quadrangle) increase westward in Triunfo Pass 7.5' quadrangle. Encinal siltstone rests conformably on sandstone of underlying San Nicholas Member of Vaqueros Formation, but there is apparent discordance in some places. Encinal member is unconformably overlain by Conejo Volcanics, though missing strata may not have been removed by subaerial erosion (see discussion of base of Conejo, above). Poorly preserved foraminifera in two collections from Encinal Canyon Road exposures are assigned to Relizian (?) Stage and Saucesian or Relizian stages of Kleinpell (1938), respectively (Yerkes and Campbell 1979). Sonneman (1956) reports equivalent strata farther west contained foraminifera assignable to Relizian Stage. Subsequent collection is also assigned a late Saucesian to early Relizian age (Flack 1993). Flack (1993, p. 46) considers Encinal Member, as well as entire Topanga Canyon Formation, to be late early Miocene rather than early middle Miocene. On basis of age and lithologic similarity, Fritsche (1993, p. 9-10) proposed Encinal Member should be considered a tongue of Rincon Formation (early Miocene; Zemorrian and Saucesian Stages) of northern Ventura Basin. Because parts of the Encinal Member are probably Relizian, and major structural features, largely concealed by younger strata, intervene between northern and southern parts of western Transverse Ranges, extension of name, Rincon Formation to Santa Monica Mountains seems questionable, and the usage of source maps is retained. (Point Dume and Triunfo Pass 7.5' quadrangles; Campbell and others, 1996; Campbell, unpublished 1:12,000-scale mapping, 1965-1975)

Ttcf **Topanga Canyon Formation, Fernwood Member**—Paralic-fluvial, estuarine, and marine sandstone, pebbly sandstone, and mudstone; contains minor tuff and limestone; interbedded with grayish-red or olive-gray mudstone and, locally, minor vitric rhyolite tuff and algal (?) limestone. Fluvial sandstone forms thick lenticular ledge-forming beds and is complexly channeled and crossbedded. Locally abundant closely spaced borings normal to sandstone bedding (*ophiomorpha*?), and rare fragments of bone occur; shallow-water gastropod *Melongena*, known only from provincial middle Miocene, occurs in sandstone on a ridge west of Topanga Canyon (in Fernwood area) (Yerkes and Campbell, 1979; Yerkes and Campbell, 1980). Fernwood Member is overlain conformably by and intertongues with Cold Creek Member of Topanga Canyon Formation. Fernwood Member overlies Saddle Peak Member conformably and may intertongue with it. In several parts of Topanga Canyon drainage area Fernwood strata are cut off down dip by Sespe Formation redbeds along Malibu Bowl Detachment Fault or by basalt and diabase intrusive into fault. Fritsche (1993) and Flack (1993) propose that Fernwood Member be assigned to Sespe Formation. However, Fernwood Member has nowhere been observed to be in direct depositional contact with Sespe strata (even though short segments of approximately located contact are shown on map, there is no outcrop exposure of unfaulted contact relationships). Nor does Fernwood Member contain any red sandstone, which is characteristic of (though not always present in) Sespe Formation. Therefore, usage of source maps is retained. (Malibu Beach and Topanga 7.5' quadrangles; Yerkes and Campbell, 1979; Yerkes and Campbell, 1980; Yerkes and Campbell, 1994)

Ttcs **Topanga Canyon Formation, Saddle Peak Member**—Thick-bedded to massive, medium- to coarse-grained marine sandstone, pebbly sandstone, hackly fracturing sandy siltstone, and 1/2-m thick basal pebble conglomerate. Conformably overlain by Fernwood Member; conformably overlies Piuma Member of Sespe Formation. Resistant sandstone near base of Saddle Peak Member contains "Temblor" megafauna that include the gastropod *Antillophos dumbleanus* (Anderson), which is apparently restricted to the middle Miocene. Immediately above this bed is a 10-cm thick layer of well-preserved, in part articulated valves of giant pectinid *Vertipecten nevadanus* (Conrad) (also called *V. bowersi*); entire fauna is referred to middle Miocene "Temblor" provincial Stage. Fritsche (1993) proposed Saddle Peak Member be included with Vaqueros Formation because some elements of fauna are long ranging and are also found in Vaqueros, and because closely similar lithofacies are found in both units. However, detailed mapping shows continuous and overlapping stratigraphic horizons in most areas where Saddle Peak Member is in contact with underlying Vaqueros and two units are mappable separately. Therefore, usage of source maps is retained. Unit is about 220 m thick along Piuma Road on west shoulder of Saddle Peak. (Malibu Beach and Topanga 7.5' quadrangles; Yerkes and Campbell, 1979; Yerkes and Campbell, 1980)

Tv **Vaqueros Formation, undivided (early Miocene)**—A heterogeneous sequence of thick- and medium-bedded sandstone and interbedded siltstone and mudstone; sandstone ranges from coarse- to very fine-grained, chiefly biotitic arkosic arenites and wackes; siltstone and mudstone interbeds commonly dark gray, but some greenish or reddish in color; commonly carries *Turritella inezana* and other elements of "Vaqueros fauna". Although name first used in central California (Hamlin, 1904) and subsequently extended on basis of faunal elements, it has long been used in coastal Southern California, and is used consistently throughout intervening areas, to refer to a well-recognized and widespread, predominantly marine sequence that contains a distinctive molluscan fauna (Loel and Corey, 1932). In Santa Monica Mountains a complete section in vicinity of Castro Peak, where Vaqueros accordantly overlies nonmarine Sespe Formation, is as much as 760 m thick. East of Malibu Canyon, shoreface facies intertongue with nonmarine strata of Sespe Formation, and Vaqueros strata are not present in and east of Topanga Canyon. Along north side of Simi Valley, Vaqueros strata about 600 m thick lie accordantly above Sespe redbeds and are overlain by Conejo Volcanics; Vaqueros wedges-out to east in Simi Valley West 7.5' quadrangle. On south flank of Santa Ynez Mountains, north of Fillmore, easternmost Vaqueros Formation is about 165 m thick. Oborne (1993) described several interbedded lithofacies west of Topanga Canyon and interprets them to represent deposition during rapid marine transgression. Fritsche (1993) proposed lumping Vaqueros and Topanga Canyon Formations into a single "Unnamed Sandstone" unit because both contain similar lithofacies and locally lack their typical distinctive faunal elements. However, in nearly all problematical areas there are sufficient continuous or overlapping beds to provide a realistic basis for mapping separate formations. Therefore, this compilation retains usage and nomenclature of source maps. (western Santa Monica Mountains, western Topatopa Mountains, and north side of Simi Valley; Yerkes and Campbell, 1979; Yerkes and Campbell, 1980; Campbell and others, 1996; Eschner, 1969; Bailey, 1951; Cemen, 1977; Squires, 1983a; Sonneman, 1956; Durrell, 1954). Includes:

Tvn **Vaqueros Formation, San Nicholas Member**—Very thick bedded to massive cliff- and ledge-forming marine sandstone, generally very light gray to pale bluish gray; rare interbeds and partings of siltstone and shale, commonly dark gray. Sandstone, very fine- to very coarse-grained arenite, locally pebbly; thick beds show internal cross lamination, parallel lamination, and disturbed (burrowed?) laminations; local abundant barnacle detritus. Generally conformably underlain by Danielson Member of the Vaqueros Formation; however, locally thinned where it rests on older rocks beneath Zuma Detachment Fault, as in Encinal Canyon. Conformably overlain by Encinal Member of Topanga Canyon Formation. Mapped as "Nicholas Formation" by Sonneman (1956) named for exposures in vicinity of San Nicholas Canyon (Triunfo Pass 7.5' quadrangle); formalized as member of Vaqueros Formation by Yerkes and Campbell (1979). (Triunfo Pass and Point Dume 7.5' quadrangles; Campbell and others, 1996; Campbell, unpublished 1:12,000-scale mapping, 1967-1975)

Tvd **Vaqueros Formation, Danielson Member**—Grayish black, very fine-grained, marine sandy siltstone or mudstone, in medium and thin beds, generally having indistinct parallel lamination; fractures commonly conchoidal or irregularly subparallel to bedding, but locally platy or shaly. In San Nicholas Canyon, several prominent interbeds, 1/3 to 1 m thick, of calcareous very fine-grained sandstone and sandy mudstone contain *Turritella inezana* Conrad in such numbers as to locally form biostromes (Yerkes and Campbell, 1979, p. E12). Mapped as "Danielson Formation" by Sonneman (1956) named for exposures on Danielson Ranch in Big Sycamore Canyon (Triunfo Pass 7.5' quadrangle); formalized as member of Vaqueros Formation by Yerkes and Campbell (1979).

(Triunfo Pass and Point Dume 7.5' quadrangles; Sonneman, 1956; Campbell and others, 1996; Campbell, unpublished 1:12,000-scale mapping, 1967-1975)

Ts **Sespe Formation, undivided (early Miocene, Oligocene, and late Eocene)**—A nonmarine "redbed" sequence of sandstone, pebbly sandstone, varicolored mudstone, and pebble-cobble conglomerate; sandstone beds commonly very thick to massive, with well developed internal cross lamination; and rare thin varicolored reddish, greenish and grayish mudstone interbeds. Sandstone beds are characteristically red, chiefly as a result of intergranular hematized biotite; several sections include beds that lack red color. Only complete section of the Sespe exposed in Santa Monica Mountains is in Solstice Canyon-Castro Peak area, where about 1000 m of strata lie concordantly on marine Llajas Formation, and accordantly beneath marine Vaqueros Formation. Elsewhere in Santa Monica Mountains, both to east and to west, Sespe is in fault contact with underlying older strata, chiefly along the Zuma Detachment Fault. At west end of Simi Hills about 1365 m of Sespe strata lie accordantly above marine Llajas and unconformably below Conejo Volcanics. Along north side of Simi Valley, Sespe is as much as 1656 m thick in west (Simi Valley West 7.5' quadrangle), but wedges out to east, north of Santa Susana Pass (Simi Valley East 7.5' quadrangle). Along north flank of Oak Ridge Sespe is up to 2135 m thick, based in part on drill-hole data. In western Topatopa Mountains, north of Fillmore, Sespe is about 430 m thick between underlying marine Coldwater Formation and overlying marine strata assigned to Vaqueros Formation (Fillmore 7.5' quadrangle). Name, Sespe Formation, was introduced by Watts (1897) and further described by Bailey (1947) for exposures in vicinity of Sespe Creek, north of Fillmore, and has been extended over large parts of coastal southern California by various workers. Generally, it has been applied to a thick nonmarine sandstone, conglomeratic sandstone and siltstone sequence that is underlain by marine Eocene strata and overlain by marine Miocene beds. Includes:

Tsp **Sespe Formation, Piuma Member (early Miocene)**—Sandstone, medium-grained; absence of pebble and cobble conglomerate, abundant interbedded lacustrine or lagoonal siltstone. Member name formalized by Yerkes and Campbell (1979) for the upper of two tongues of Sespe that are easily distinguished where strata of the marine Vaqueros Formation separate them; Vaqueros wedges out eastward, but contact between the Piuma Member and the undivided Sespe below can be carried eastward beyond Vaqueros wedge-out. (Malibu Beach 7.5' quadrangle; Yerkes and Campbell, 1980)

Tl **Llajas Formation (middle to early Eocene)**—Marine sandstone, very fine- to fine-grained, siltstone, pebble conglomerate and interbedded platy to shaly siltstone and mudstone. Locally contains fossil mollusks assigned to the "Domengine Stage" (Weaver and others, 1944). Name taken from strata exposed on northwest side of north branch of Las Llajas Canyon, on northeast side of Simi Valley (Schenck, 1931, p. 455; McMasters, 1933). (Simi Valley East, Oat Mountain, Thousand Oaks 7.5' quadrangles, and correlative strata in Point Dume, Malibu Beach and Topanga 7.5' quadrangles)

Tcc **Coal Canyon Formation (Eocene (?) and Paleocene)**—Marine sandstone, pebble conglomerate, siltstone and algal limestone. Sandstone, very fine to medium grained, poorly to well sorted, consisting of subrounded quartz and feldspar grains in a sparse clay matrix, locally biotitic. Locally contains abundant mollusks; beds commonly are thick and some have graded upper parts and sharp upper contacts. Siltstone and silty claystone present locally in upper part of formation. Closely jointed, conchoidal fracture; contains abundant biotite. Local partings of fine-grained silty biotitic sandstone, and calcareous beds or concretions as thick as 15 cm and as long as 1 m. Pebble-cobble conglomerate forms resistant steep slopes in Carbon and Topanga Canyons. Beds as much as 7 m thick and have scattered pebbles, boulders, slabs, and interbeds of mudstone and medium- to coarse-grained sandstone. Coal Canyon Formation is about 335 m thick in Solstice Canyon, only complete section exposed in the Santa Monica Mountains; however, thickness summed from incomplete sections in the Carbon Canyon-Topanga Canyon area is as much as 450 m. Commonly carries molluscan fauna that includes Martinez-Stage gastropods *Turritella pachecoensis* and *Mesalia martinezensis* (Gabb). Coal Canyon Formation overlies nonmarine Simi Conglomerate or late Cretaceous Tuna Canyon Formation; relations are generally accordant but locally unconformable. In Solstice Canyon Coal Canyon Formation is overlain disconformably (?) by marine strata of Eocene age. Name Coal Canyon Formation was applied by Yerkes and Campbell (1979) to sequence formerly mapped as "Martinez" Formation. "Martinez" is molluscan Stage name, imported from a central California type locality. (Topanga, Malibu Beach, Point Dume and Triunfo Pass 7.5' quadrangles; Yerkes and Campbell, 1980; Campbell and others, 1996). Includes:

Tccl **Coal Canyon Formation, limestone**—Algal limestone; occurs as scattered lenses and pods in siltstone sequences east of Topanga Canyon, most prominently in eastern wall of Santa Ynez Canyon

Tsi **Simi Conglomerate, undivided (Paleocene)**—Thin, nonmarine cobble-boulder conglomerate mapped at base of Tertiary sequence in Santa Monica Mountains, Simi Hills, and northeast of Simi Valley. In Solstice Canyon (eastern Point Dume 7.5' quadrangle), contains abundant well-rounded, polished cobbles and boulders of quartzite and granitic, rhyolitic, and gneissic rocks in conglomeratic, coarse-grained sandstone that includes a 1 m thick bed of brick-red pisolitic clayey sandstone. Yerkes and Campbell (1979) tentatively correlated these beds with Simi Conglomerate in Simi Hills, as described by Nelson (1925); correlation is supported in subsequent detailed petrographic work by Colburn and Novak (1989)

TKb **Sedimentary rocks in the Beverly Hills area (early Tertiary and late Cretaceous)**—Chiefly conglomerate; presumed equivalents of Simi Conglomerate (Paleocene), Coal Canyon Formation (Paleocene), and perhaps, conglomerate of the Tuna Canyon Formation (late Cretaceous). Mapped as a basal conglomerate of "Topanga Formation" (middle Miocene) by Hoots (1931); assigned to "Chico Formation" (Cretaceous) and "Martinez Formation" (Paleocene) by Durrell (1954); and correlated with Paleocene succession of Simi Conglomerate, Las Virgenes Sandstone and Santa Susana Formation by Colburn and Novak (1989). For purposes of this map, exposures of these rocks in Beverly Hills 7.5' quadrangle are labeled "TKb"

Kt **Tuna Canyon Formation, undivided (late Cretaceous)**—Marine sandstone, siltstone and conglomerate. Sandstone, thick-bedded to very thick-bedded, laminated and graded arkosic wacke (turbidite); locally contains abundant fragments of black slate (?); convolute lamination in some beds, load casts, low-angle cross-lamination, or concentrations of carbonized plant fragments or mica. Fossiliferous sandstone and siltstone are present locally as interbeds or thick lenses; in Las Flores Canyon, contains several beds of olive-gray siltstone that locally contain foraminifera. Tuna Canyon Formation is nowhere completely exposed in Santa Monica Mountains; maximum exposed thickness, in Pena Canyon-Tuna Canyon area, is nearly 800 m. East of Santa Ynez Canyon rests on nonmarine red conglomerate (Trabuco Formation, late Cretaceous) and Santa Monica Slate (late Jurassic). Formation is overlain disconformably (?) by Simi Conglomerate in Solstice Canyon, and elsewhere by basal conglomerate of Coal Canyon Formation (Paleocene). In places contains Campanian ammonite *Metaplacenticeras sp.*; foraminifera faunas are referred to zones D-2, E, and F-1 (Maestrictian or Campanian - late Cretaceous) of Goudkoff (1945). Named by Yerkes and Campbell (1979) to replace name "Chico", which was imported from central California and used on earlier maps in Santa Monica Mountains.

(central and eastern Santa Monica Mountains; Campbell and others, 1996; Yerkes and Campbell, 1980; Alderson, 1988; Hoots, 1931). East of Santa Ynez Canyon the formation was subdivided by Alderson (1988) into four informal members:

Kte **Tuna Canyon Formation, informal member e**—Greenish-gray shale with interbedded coarse-grained sandstone in the upper part

Ktd **Tuna Canyon Formation, informal member d**—Fine-grained, thick-bedded, fossiliferous sandstone

Ktc **Tuna Canyon Formation, informal member c**—Pebble-cobble conglomerate and minor sandstone

Ktb **Tuna Canyon Formation, informal member b**—sandstone with minor conglomerate and black shale, carrying Turonian and Coniacian ammonites

Ktr **Trabuco Formation (late Cretaceous)**—Conglomerate having well-rounded, polished pebbles, cobbles and boulders of varicolored quartzite, porphyry, granite, basalt, and angular chips of black slate in matrix of soft, clayey, coarse-grained to pebbly grit. Thickness estimated at 225 m; unconformably overlies Santa Monica Slate. Name applied by Durrell (1954) for rocks of similar composition and stratigraphic position in type area in Santa Ana Mountains, where it was named by Packard (1916); correlation reiterated by Colburn (1973). (Topanga and Canoga Park 7.5' quadrangles; Yerkes and Campbell, 1980; Hoots, 1931)

Kgr **Granitic rocks (late Cretaceous)**—Variety of plutonic igneous rocks; includes quartz monzonite, granodiorite, tonalite, quartz diorite, and diorite; chiefly quartz diorite in eastern Santa Monica Mountains (Durrell, 1954)

Jsm **Santa Monica Slate, undivided (late Jurassic)**—Black slate, sheared metasiltstone, and fine-grained metagraywacke; intensely jointed, isoclinally(?) folded; intruded by Cretaceous granitic pluton forming contact aureole zone of phyllite and spotted cordierite slate; rare pelecypod fragments indicate late Jurassic age for part of unit (Imlay, 1963). Named by Hoots (1931, p. 88). (Van Nuys, Canoga Park, Topanga, and Beverly Hills 7.5' quadrangles; Hoots, 1931). Includes:

Jsms **Santa Monica Slate, spotted slate**—Spotted appearance caused by large crystals of cordierite; outer zone of contact aureole surrounding nearby granitic intrusive rocks; grades to unspotted slate through a zone in which individual spots become progressively smaller outward (Canoga Park, Topanga, and Beverly Hills 7.5' quadrangles; Hoots, 1931)

Jsmp **Santa Monica Slate, phyllite**—Chiefly mica schist and dark gray phyllite; forms inner zone of contact aureole with adjacent granitic intrusive (Beverly Hills 7.5' quadrangle; Hoots, 1931)

Central Santa Monica Mountains (Upper plate of Malibu Bowl Detachment Fault)

Tt **Topanga Group, undivided (middle Miocene)**—(See foregoing description for column titled "Central Santa Monica Mountains (below Malibu Bowl Detachment Fault)"). Topanga Group rocks in the upper plate of the Malibu Bowl Detachment Fault include deep marine shale and sandstone turbidites of the Calabasas Formation, overlying and interbedded with tongues of basalt and andesite breccias and flows of Conejo Volcanics, underlain by shallow marine strata of Topanga Canyon Formation

Tcb **Calabasas Formation, undivided (early late Miocene and late middle Miocene)**—Interbedded impure, clayey to silty sandstone and silty shale, and contains local beds of sedimentary breccia; sandstone is thin-, medium- and thick-bedded, mostly medium to coarse grained, poorly sorted, commonly having wacke texture, commonly shows graded bedding. Shale, locally diatomaceous or phosphatic, locally abundant fish scales, sparse foraminifera, and rust-colored plant casts. Some thicker beds contain zones of large ovoid dolomitic concretions; sedimentary breccia, olistostromes incorporating cobble- to large boulder-size clasts of recognizable older Tertiary strata, including fossil-bearing clasts of Paleocene, Eocene, early Miocene, and middle Miocene strata, as well as volcanic (probable Conejo Volcanics) clasts. Five members were named by Yerkes and Campbell (1979). Dibblee and Ehrenspeck (1993) postulated a "grand unconformity" along the southern flank of the Santa Monica Mountains, above which Conejo Volcanics and Calabasas Formation strata lie in a "buttress unconformity" relationship with underlying older rocks (ranging in age from Cretaceous to early middle Miocene) as an alternative to the detachment faulting described by Campbell and others (1966) and Campbell and others (1970); however, the "buttress unconformity" model appears inconsistent with several observations: 1) the contact (Calabasas Formation over Sespe Formation) exposed on the Newton Motorway, and described by Dibblee and Ehrenspeck (1993) as "depositional" is marked by a greater than 1 m thick zone of well-indurated very fine-grained black material, and includes a 30-cm-thick central zone with closely spaced fractures, sub-parallel to the attitude of the contact, which we interpret as the zone of most-recent movement within a consolidated gouge zone, 2) Vaqueros, Topanga Canyon and Conejo strata, which lie above the Sespe Formation in conformable sequence from Newton and Solstice Canyons north to Malibu Lake, have been tilted northward to about the same degree as the Sespe, yet a significant lens of Vaqueros strata lies discordantly between north-dipping Sespe rocks and relatively flat-lying Conejo Volcanics in the east wall of Zuma Canyon, and 3) pre-volcanic middle Miocene strata (Topanga Canyon Formation) underlie the Conejo Volcanics in the strata above the "unconformity" surface just east of Malibu Canyon. An unconformity of this character (locally as much as 90 degrees discordant with underlying strata) would constitute a submarine escarpment across Sespe beds, required to come into existence before the end of Vaqueros deposition, that must have persisted from Vaqueros (lower Miocene) through Topanga Canyon (lower middle Miocene), Conejo (mid middle Miocene) and into Calabasas (late middle Miocene) deposition. Yet the northward structural tilt of the Sespe appears to have occurred after the Vaqueros, Topanga Canyon, and lower Conejo strata were deposited on it in a conformable sequence, and all are tilted to about the same degree. Tilting the Sespe back to horizontal for the deposition of the accordant overlying Vaqueros and Topanga Canyon beds (in shallow marine environments) would require a steep (locally near-vertical) escarpment, against which Vaqueros strata would be deposited in water more than 1,000 feet deeper than comparable beds in the conformable sequence. These relations require the unlikely interpretation that a long-lived (from lower Miocene through late middle Miocene) south-facing escarpment received unconformable deposition of Vaqueros strata while simultaneously, less than 0.5 km to the north, the top of a thick Sespe section accumulated a conformable cover of about 0.75 km of Vaqueros marine strata. Moreover, the steep escarpment shows no evidence that its surface received deposits of breccia derived from the escarpment. We conclude that the observable structural and stratigraphic relations are best interpreted as the result of late-middle Miocene detachment faulting of a generally conformable sequence

Tcbmp **Calabasas Formation, Mesa Peak Breccia Member (late middle Miocene)**—Sedimentary breccia consisting of angular boulders and cobbles of volcanic rock in very coarse-grained sandstone matrix; maximum thickness approximately 288 m. Overlies Newell Sandstone Member of Calabasas Formation in upper plate of the Malibu Bowl Detachment Fault, west central Malibu Beach 7.5' quadrangle (Yerkes and Campbell, 1979, p. E23; Yerkes and Campbell, 1980)

Tcbn **Calabasas Formation, Newell Sandstone Member (late middle Miocene)**—Poorly sorted turbidite sandstone and interbedded shaly siltstone; contains large dolomitic concretions; overlies and wedges out westward into Malibu Bowl Tongue of Conejo Volcanics; maximum thickness approximately 244 m. (West central Malibu Beach 7.5' quadrangle; Yerkes and Campbell, 1979, p. E23; Yerkes and Campbell 1980)

Tcbd **Calabasas Formation, Dry Canyon Sandstone Member (late middle Miocene)**—Sandstone (proximal turbidites) and subordinate interbedded siltstone, many thin turbidites, locally prominent dolomitic concretions in siltstone. Overlies and tongues eastward into Solstice Canyon Tongue of Conejo Volcanics; underlies and intertongues westward into Escondido Canyon Shale Member of Calabasas Formation; overlain by, and locally intertongues with, Malibu Bowl Tongue of the Conejo Volcanics, and locally overlain by Newell Sandstone member of Calabasas Formation; locally overlain by Latigo Canyon Breccia Member of Calabasas Formation; underlain by Ramera Canyon Tongue of Conejo Volcanics. Approximate maximum thickness 686 m. (east central Malibu Beach 7.5' quadrangle; Yerkes and Campbell, 1979, p. E24; Yerkes and Campbell, 1980)

Tcbl **Calabasas Formation, Latigo Canyon Breccia Member (late middle Miocene)**—Sedimentary breccia, large angular boulders of Sespe Sandstone and fossiliferous Vaqueros sandstone in sandy, tuffaceous or volcanic breccia; intertongues with epiclastic volcanic breccia. Approximate maximum thickness 91 m; underlies Solstice Tongue of Conejo Volcanics and overlies Escondido Canyon shale member of Calabasas Formation. (east central Point Dume 7.5' quadrangle; Yerkes and Campbell, 1979, p. E23; Campbell and others, 1996)

Tcbe **Calabasas Formation, Escondido Canyon Shale Member (late middle Miocene)**—Siltstone, mudstone, shale and minor interbedded thin sandstone turbidites; locally prominent dolomitic concretions. Tongues eastward into Dry Canyon Sandstone Member of Calabasas Formation; approximate maximum thickness 276 m. (west central Point Dume 7.5' quadrangle; Yerkes and Campbell, 1979, p. E24; Campbell and others, 1996)

Tco **Conejo Volcanics, undivided (middle middle Miocene)**—Basalt, andesitic basalt, basaltic andesite, andesite, and dacite in a thick sequence of extrusive volcanic flows, flow-breccia, agglomerate, and epiclastic volcanic breccia, volcanic sandstone and siltstone. Three stratigraphically distinct tongues of volcanic rocks are interbedded with members of Calabasas Formation in upper plate of Malibu Bowl Fault in area between Malibu Canyon and Zuma Canyon:

Tcom **Conejo Volcanics, Malibu Bowl Tongue**—Andesitic and basaltic flows and flow breccias; underlies and tongues eastward into Newell Sandstone Member of Calabasas Formation and overlies Dry Canyon Sandstone Member of Calabasas Formation; as much as 143 m thick. (Malibu Beach 7.5' quadrangle; Yerkes and Campbell, 1979; Yerkes and Campbell, 1980)

Tcos **Conejo Volcanics, Solstice Canyon Tongue**—Basaltic and andesitic flows, breccia, and tuff; local water-laid volcanic sandstone. Underlies and intertongues eastward into upper part of Dry Canyon Sandstone Member of Calabasas Formation, overlies Latigo Canyon Breccia Member of Calabasas Formation; as much as 143 m thick. (eastern Point Dume 7.5' quadrangle and western Malibu Beach 7.5' quadrangle; Campbell and others, 1970; Yerkes and Campbell, 1979; Yerkes and Campbell, 1980; Campbell and others, 1996)

Tcor **Conejo Volcanics, Ramera Canyon Tongue**—Basaltic and andesitic breccia, tuff-breccia, and flows(?); minor volcanic sandstone; underlies, and upper part intertongues with lower part of Escondido Canyon Shale Member of the Calabasas Formation; underlain in some areas by the Malibu Bowl Detachment Fault which rests on rocks as young as Topanga Canyon Formation; as much as 518 m thick. (Campbell and others, 1970; Yerkes and Campbell, 1979; Yerkes and Campbell, 1980; Campbell and others, 1996)

Ttc **Topanga Canyon Formation, undivided (early middle Miocene)**—Marine sandstone, commonly arkosic, with interbedded siltstone, pebbly sandstone and pebble-cobble conglomerate; generally well indurated. Thick-bedded sandstone predominates, probably indicative of chiefly shoreface and nearshore depositional environments; locally abundant molluscan fossils assigned to "Temblor" Stage (middle Miocene) of Weaver and others (1944). In central Santa Monica Mountains contact at base of Topanga Canyon Formation is depositional; unit rests with general accordance on Vaqueros or Sespe strata; however, in many places contact with older rocks is clearly faulted or filled with intrusive basalt related to emplacement of Conejo Volcanics, and probably represents Malibu Bowl Detachment Fault

Castaic Valley-Soledad Canyon and San Gabriel Mountains

QTs **Saugus Formation, undivided (early Pleistocene to late Pliocene)**—Slightly consolidated, poorly sorted, coarse-grained, cross-bedded sandstone and pebble conglomerate; chiefly nonmarine, but includes a few interbeds of marine and brackish water depositional environment; unconformable on strata of Pico Formation, and overlain with great angular discordance by beds of Pacoima Formation. Maximum thickness about 1950 m in type area (southeast quarter, Newhall 7.5' quadrangle). Defined and described by Kew (1923). Widespread in eastern Ventura County; several authors have mapped lithologically defined members in different areas, including:

QTsp **Saugus Formation, pebbly sandstone p (early Pleistocene)**—Pebbly sandstone containing clasts derived from Pelona Schist, a Cretaceous source rock found northeast of San Gabriel Fault (Newhall quad)

QTss **Saugus Formation, pebbly sandstone s (early Pleistocene)**—Pebbly sandstone containing clasts derived from San Francisquito Formation, a Paleogene source rock found to northeast of San Andreas Fault (Newhall and Val Verde 7.5' quadrangles; Dibblee, 1967, p. 41)

QTsg **Saugus Formation, conglomerate (early Pleistocene)**—Conglomerate at base of Saugus Formation in southeastern part of Mint Canyon 7.5' quadrangle. Clasts predominantly igneous and metamorphic rocks presently exposed in northwestern San Gabriel Mountains (Saul and Wooton, 1983)

Tw **Towsley Formation, undivided (early Pliocene and late Miocene)**—Interbedded sandstone, conglomerate, and mudstone; thickness as much as 1,220 m. Widespread in eastern Ventura County; overlies Modelo Formation strata in Topatopa Mountains; overlies and interfingers with Modelo Formation in Santa Susana Mountains; overlaps Modelo to rest directly on basement rocks near, and east of, San Fernando Pass; generally conformably overlain by and gradational into Pico Formation siltstone. As named and described by Winterer and Durham (1954, 1962), includes beds mapped by Kew (1924) as upper sandstone member of Modelo Formation. Includes:

Twc **Towsley Formation, conglomerate**—Pale pebble conglomerate and sandstone in lenticular beds (Mint Canyon, Oat Mountain, Simi Valley East, Val Verde and Piru 7.5' quadrangles)

Tcs **Castaic Formation, undivided (late Miocene)**—Marine tuffaceous or diatomaceous shale, interbedded pebbly sandstone, sparse limestone concretions with well-preserved foraminifera. Named by Winterer and Durham (1954) for marine sandstone strata of late Miocene age (equivalent to the Modelo Formation), north of San Gabriel Fault and east of Newhall. Name extended to north for late Miocene shale interbedded with sandstone and minor pebble conglomerate in Soledad-Ridge Basin area by Crowell (1954) (Mint Canyon and Newhall 7.5' quadrangles)

Tmc **Mint Canyon Formation, undivided (late and middle Miocene)**—Includes a variety of semi-consolidated nonmarine sediments deposited in fluvial and lacustrine environments. First described by Hershey (1902), named by Kew (1924), mapped in detail by Saul (1983), who recognized three intertonguing lithofacies. Jahns and Muehlberger (1954) describe two informal members: a lower member including reddish-brown basement rock breccia, conglomerate, sandstone, siltstone and mudstone (thickness ~ 335 m); and an upper member consisting of thin-bedded brownish or greenish siltstone and interbedded tuff (thickness ~ 790 m). An additional 945 m of fanglomerate with abundant anorthosite clasts, present between the Agua Dulce and Soledad faults (mostly in the Agua Dulce 7.5' quadrangle), was included by Jahns and Muehlberger (1954) in Vasquez Formation; however, on this map beds are assigned to Mint Canyon Formation following usage of Oakeshott (1958), who recognized that base is left-laterally separated about 2.7 km by Agua Dulce Fault. Includes:

Tmc_3 **Mint Canyon Formation, facies 3**—Lacustrine deltaic (foreset) facies. Predominantly fine- to coarse-grained, sparsely-concretionary, crossbedded, arkosic sandstone, interbedded with conglomeratic sandstone, gray to brown sandy siltstone and claystone; tuff and tuffaceous sedimentary beds; marly and nodular carbonate. Sparsely fossiliferous: small clam and snail shells, vertebrate bones and teeth. (Mint Canyon 7.5' quadrangle; Saul, 1983)

Tmc_2 **Mint Canyon Formation, facies 2**—Lacustrine bottomset facies. Interbedded sandstone, silty sandstone, siltstone, claystone and thin beds and lenses of limestone; a few lenses of turbidite sandstone and coarse conglomerate; tuffaceous beds; ostracod shells. Bedding planes commonly darkened by finely divided lignite; graded beds common. (Mint Canyon and Newhall 7.5' quadrangles; Saul, 1983)

Tmc_1 **Mint Canyon Formation, facies 1**—Lacustrine and lake-marginal fluvial deposits of arkosic sandstone and conglomeratic sandstone, with interbedded siltstone and mudstone; some nodular carbonate in siltstone; thin beds of limestone common in mudstone. (Mint Canyon 7.5' quadrangle; Saul, 1983)

Ttk **Tick Canyon Formation, undivided (middle to early Miocene)**—Reddish, fluvial and lacustrine sandstone, siltstone and claystone, and gray, tan, and reddish, well-cemented and well-bedded conglomerates (Mint Canyon, Agua Dulce and San Fernando 7.5' quadrangles; Oakeshott, 1958). Named by Jahns (1940), and separated from overlying lower part of Mint Canyon Formation on the basis of a distinctively older vertebrate fauna

Tvz **Vasquez Formation, undivided (early Miocene to Oligocene?)**—Yellowish and reddish sandstone, conglomerate, and interbedded andesite-basalt, lying on pre-Tertiary crystalline basement rocks and unconformably below strata of Tick Canyon Formation; total thickness as much as 3,810 m (Jahns and Muehlberger, 1954). Includes numerous beds and lenses of megabreccia, many monolithologic. Named by Sharp (1936); further described by Jahns (1939)

Tvzv **Vasquez Volcanics (early Miocene to Oligocene?)**—Flows, breccia masses and intrusive sheets of andesite and basalt. Chiefly in lower part of Vasquez Formation, interlayered with Vasquez Formation sedimentary beds and extending beyond sedimentary deposition eastward to lie directly on older crystalline rocks (Jahns and Muehlberger, 1954)

Kp **Pelona Schist (Cretaceous?)**—Greenish-gray chlorite-albite, actinolite-albite, quartz-albite, and albite-talc schist. Locally interbedded with metachert and brown to black quartzite; forms thick, isoclinally (?) folded sequence. Protolith of Pelona Schist presumably deposited during the mid-Mesozoic, recrystallized during burial to depths of 20-30 km, and later thrust beneath western North America on the Vincent thrust (Ehlig, 1981). Named by Hershey (1902) for outcrops on Sierra Pelona Ridge. (Ehlig, 1981; Jacobson, 1990; northern Mint Canyon 7.5' quadrangle, map after Jahns and Muehlberger, 1954)

Kto **Tonalite (late Cretaceous)**—Mapped by Jahns and Muehlberger (1954) as "granite and other quartz-bearing plutonic rocks"; these rocks are compositionally tonalite (D. M. Morton, oral communication, 2003) in IUGA classification (Streckheisen, 1973). (northern Agua Dulce 7.5' quadrangle)

Ktoqd **Tonalite and quartz diorite (late Cretaceous)**—Mapped by Morton (1973a) as predominantly quartz diorite, grading to granodiorite, quartz monzonite and diorite; compositionally mostly tonalite (D. M. Morton, oral communication, 2003) in IUGA classification (Streckheisen, 1973). (Mount Wilson 7.5' quadrangle)

Ktoqm **Tonalite and monzogranite (late Cretaceous)**—Designated quartz monzonite in source maps; identified as mostly tonalite (D. M. Morton, oral communication, 2003) in IUGA classification (Streckheisen, 1973). (west central Mount Wilson 7.5' quadrangle)

Ktowd **Tonalite, (Wilson Diorite of Miller, 1934) (late Cretaceous)**—Designated granodiorite and quartz diorite on source maps; identified as mostly tonalite (D. M. Morton, oral communication, 2003) in IUGA classification (Streckheisen, 1973). (northern Mount Wilson 7.5' quadrangle)

Kgrgl **Granitic rocks, leucocratic granodiorite (late Cretaceous)**—Light gray to pale tan, fine- to medium- grained granodiorite (Pasadena 7.5' quadrangle; Smith, 1982)

KŦogn **Mixed tonalite and Mount Lowe intrusive suite (Cretaceous and Triassic)**—Relatively uniform light-colored orthogneiss containing porphyroblasts (relict phenocrysts) of hornblende and, less commonly, potassium feldspar in a plagioclase and quartz matrix. Parent plutonic rock is (Triassic) Lowe Granodiorite and was metamorphosed during a Cretaceous orogenic event (Mount Wilson 7.5' quadrangle; Morton, 1973a, p. 9; and D. M. Morton, oral communication, 2003)

Kgrm M**ixed anorthosite and granite (Cretaceous and Precambrian)**—Granitic dikes and irregular masses penetrate margins of anorthosite, cutting sharply across structure of host; also tabular bodies parallel to the platy flow structure of anorthosite. Admixed granitic compositions include granodiorite, quartz monzonite, granite pegmatite, aplite and lamprophyre (Oakeshott, 1958; Agua Dulce 7.5' quadrangle)

Keg **Echo granite (Cretaceous)**—Coarse-grained, pinkish-orange granite and monzogranite; medium-grained, xenomorphic, inequigranular, and showing protoclastic granulation in thin section (Miller, 1946). Named by Miller (1934). (Mount Wilson and Pasadena 7.5' quadrangles; Smith, 1986)

Js **Syenite (Jurassic)**—Massive, dark, red-weathering augite and augite-quartz syenite; 60 to 90 percent microperthite (Oakeshott, 1958). (Acton, Agua Dulce, Sunland, and Condor Peak 7.5' quadrangles; Oakeshott, 1958; Jahns and Muehlberger, 1954)

Mzbhd **Biotite-hornblende diorite (Mesozoic?)**—Medium- to dark-gray, medium-grained biotite-hornblende monzodiorite (40-50 percent plagioclase, 1-10 percent potassium feldspar, 25 percent biotite, 20 percent hornblende, and 5 percent quartz; Smith, 1986); includes scattered small bodies of older brownish-gray coarse-grained weakly gneissic biotite quartz monzonite (40 percent plagioclase, 25 percent potassium feldspar, 10 percent quartz, and 10 percent biotite; Smith, 1986); intruded by leucocratic granodiorite (San Rafael Hills, Pasadena 7.5' quadrangle; Smith, 1986)

Mzbqd **Biotite-quartz diorite (Mesozoic?)**—Medium-grained quartz diorite (50 percent plagioclase, 25 percent biotite, 15 percent quartz, and 10 percent hornblende (Smith, 1986); slightly gneissic. Locally contains inclusions of coarse-grained quartz diorite a few m across, and small elongate bodies of marble, quartzite, and schist of Paleozoic (?) age (Verdugo Mountains, Burbank 7.5' quadrangle; Smith, 1986)

Mza **Alaskite (Mesozoic?)**—Salmon-pinkish-gray, medium-grained, mildly gneissic syenogranite (5 percent plagioclase, 55 percent potassium feldspar, 35 percent quartz, 2 percent hornblende, and 3 percent biotite). Forms long thin klippe over a much larger mass of granitic rock (northern Pasadena 7.5’ quadrangle; Smith, 1986)

Mzgd **Granodiorite (Mesozoic)**—Average composition is quartz diorite using IUGA classification (Streckheisen, 1973), quartz 16 percent, plagioclase 62 percent, orthoclase 3 percent, biotite 11 percent, hornblende 6 percent; includes some rocks mapped as Lowe Granodiorite and Wilson Diorite of Miller (1934); mostly massive, but commonly gneissoid near contacts with older rocks; locally carries large inclusions and pendants of gneiss and Placerita metasediments. (San Fernando and Sunland 7.5’ quadrangles; Oakeshott, 1958)

Mzgc **Granitic complex (Mesozoic?)**—Map unit includes four granitic rock types (none of which is dominant) including: biotite-hornblende diorite, quartz diorite, hornblende diorite, and coarse-grained biotite-quartz monzonite (latter is listed as containing 60 percent plagioclase, 2 percent quartz, 25 percent hornblende, and 13 percent biotite; which would fall in diorite field of IUGA classification of Streckheisen, 1973). (Pasadena 7.5’ quadrangle; Smith, 1986)

Mzdg **Diorite gneiss (early to middle Mesozoic)**—Dark gneiss including metadiorite, massive hornblende diorite, and amphibolite and biotite schist; intrudes the Placerita Formation and intruded by Cretaceous granitic rocks. (Condor Peak, Sunland, San Fernando and Burbank 7.5’ quadrangles; Oakeshott, 1958)

TRlg **Mount Lowe intrusive suite, undivided (Triassic)**—Compositionally layered pluton exposed over a large area in western San Gabriel Mountains and northeastern Soledad Basin; studied and described by Ehlig (1981); varies from hornblende diorite and quartz diorite in lowest part to albite-rich granite and syenite in upper part; large phenocrysts of hornblende, orthoclase and garnet contribute to distinctive appearance (pebbles and cobbles are readily recognizable as clasts in younger gravel deposits); metamorphosed to lower amphibolite facies and upper amphibolite facies. Average composition 60-90 percent feldspar, of which plagioclase (oligoclase to albite) is most abundant and orthoclase occurs chiefly as phenocrysts, quartz ranges from a trace to as much as 25 percent, averages about 10 percent (Ehlig, 1981). Initially named Mount Lowe Granodiorite by Miller (1926 abstract), subsequently termed Lowe Granodiorite by Miller (1934, 1946); renamed Mount Lowe intrusion by Barth and Ehlig (1988). Morton and Miller (2003) renamed unit Mount Lowe intrusive suite. Subdivisions used on most source maps have been retained in this map compilation, but latest name suggested by Morton and Miller (2003) is used for overall unit. U-Pb age on zircon is reported as 220 ± 10 Ma (Silver, 1971), and Rb-Sr whole rock age of 208 ± 14 Ma reported by Joseph and others (1982). Joseph and others (1982) also report high (800-1,100 ppm) Sr content, low initial ^{87}Sr-^{86}Sr ratio of 0.70456 ± 0.00003, and high alkali content ($Na_2O = K_2O \sim 10$ percent). Barth and others (1990) report U-Pb zircon age of 218 Ma. Subunits include:

TRlgb **Mount Lowe intrusive suite, biotite-orthoclase facies**—As much as 10 percent biotite in a nearly white granular plagioclase and subordinate (less than 25 percent) quartz matrix. Has orthoclase phenocrysts; hornblende phenocrysts prominent in other subunits are absent, although a few hornblende-bearing layers occur in the lower part of this subunit (Ehlig, 1981, p. 263)

TRlgg **Mount Lowe intrusive suite, garnet-orthoclase facies**—Garnet phenocrysts, as large as 2 cm; orthoclase phenocrysts larger (as long as 10 cm) than those in the orthoclase-hornblende facies. Has granular matrix of plagioclase and subordinate quartz; garnet also occurs as small crystals concentrated in veinlets (Ehlig, 1981, p. 263)

TRlgh **Mount Lowe intrusive suite, orthoclase-hornblende facies**—Hornblende phenocrysts are larger and less abundant than in hornblende-dominant facies subunit. Hornblende and scattered orthoclase phenocrysts in a matrix of plagioclase and minor quartz. About 700 m thick (Ehlig, 1981, p. 263)

TRlgk **Mount Lowe intrusive suite, hornblende-dominant facies**—Dark gray, medium-grained hornblende diorite in lower part, grading upward into lighter colored, coarser-grained diorite or quartz diorite having hornblende phenocrysts in a plagioclase matrix. About 800 m thick (Ehlig, 1981, p. 263)

MzPzsp **Serpentinite (Mesozoic or Paleozoic)**—Light to dark green, foliated, sheared and slickensided serpentinite, altered peridotite (chiefly augite and olivine); slickensided fragments up to boulder size; boundaries intensely sheared and relations to adjacent rocks obscure. (San Fernando 7.5' quadrangle; Barrows and others, 1975)

Pzgn **Gneiss complex (Paleozoic?)**—Feldspathic gneiss, including granitic to granodioritic augen gneiss, gneissic intrusive rocks of granitic to dioritic composition, amphibole-rich gneiss, and local interlayered schist, quartzite, amphibolite, and marble. Jahns and Muehlberger (1954), consider much of gneiss is of hybrid origin, and some may be part of Placerita Formation that has been closely injected by younger igneous material (Mint Canyon quadrangle)

Pzp **Placerita Formation (Paleozoic)**—Metamorphosed sedimentary rocks, including marble, dolomite, feldspathic gneiss, graphitic marble, quartzite, calcic pyroxene hornfels and a variety of schists including feldspar-tremolite, graphite-tremolite, graphite-biotite-feldspar, and tremolite-talc. Schist and gneiss occur as septa and pendants of all sizes in granodioritic host rock, along with diorite gneiss and migmatite. The best-preserved section may be as much as 600 m thick. Named by Miller (1934), for exposures in Placerita Canyon. The age indicated by Oakeshott (1958) is pre-Cretaceous; however, Morton (oral communication, 2003) indicates the age is Paleozoic. (Central Sunland 7.5' quadrangle, Oakeshott, 1958; southern Mint Canyon 7.5' quadrangle, Saul and Wooton, 1983)

PzꝐms **Siliceous metasedimentary rock (Paleozoic or Proterozoic)**—Medium-gray, metachert(?); fine-grained to microcrystalline; contact with augen gneiss is sheared; this metachert is also in contact with Echo granite. (Northeast Pasadena 7.5' quadrangle; Smith, 1986)

Ꝑgrp **Granite pegmatite (Proterozoic?)**—Chiefly alkali granite pegmatite. Age considered by Oakeshott (1958) to be upper Jurassic(?) or lower Cretaceous(?); however, Morton (2003, oral communication) indicates the age is probably Precambrian. (southern Agua Dulce 7.5' quadrangle; Oakeshott, 1958)

Ꝑgn **Gneiss (Proterozoic?)**—Alternating discontinuous dark brown biotite-rich and light-colored quartz-feldspar-rich layers and lenses; layers generally about 2 cm thick; sheared, as expressed by an intricate structure of gneiss lenses having local small microscopic tight flow-type folds. Described by Morton (1973a) and by Crook and others (1987) as Cretaceous or older, but recently described by Morton (oral communication, 2003) as Precambrian. (northern Pasadena 7.5' quadrangle; Morton, 1973b; Crook and others, 1987)

Ꝑan **Anorthosite (Proterozoic)**—Medium- to very coarse-grained plagioclase rock; light gray and white; contains more than 90 percent plagioclase (andesine) and less than 10 percent mafic minerals (mostly hypersthene); grain size ranges from less than 1 mm to more than 30 cm. Associated facies include diorite, norite, and gabbro. Anorthosite and gabbro are pervasively shattered, sheared and brecciated. Barth and others (1995) indicate a general age of 1,200 Ma on the basis of dated zircons and thermobarometry, substantially older than 930 $\pm$ 90 Ma and 810 $\pm$ 80 Ma lead-alpha zircon ages determined by Neuerburg and Gottfried (1954). Oakeshott (1958) considered "anorthosite-gabbro complex" a result of differentiation of a single parent magma, and separated the relatively uniform "anorthosite" from a more heterogeneous map unit termed "gabbroic and noritic rocks". Widespread in northwestern San Gabriel Mountains (Oakeshott, 1958; Jahns and Muehlberger, 1954; Ehlig, 1981)

Ꝑgb **Gabbro (Proterozoic)**—Gray, mottled with greenish or brownish black, and solid dark greenish and brownish black; mafic mineral content ranges from 10 percent to 65 percent of rock; compositionally ranging from gabbroic anorthosite to norite, diorite, pegmatitic hornblende gabbro, and olivine gabbro. Chiefly xenomorphic granular texture; alternating felsic and mafic bands, from a few inches to several feet in thickness are common, but generally discontinuous. Feldspar is mostly calcic andesine (labradorite in more mafic rocks), in many places partly altered to albite or albite-oligoclase. Pyroxenes (and subordinate amphiboles) commonly altered to chlorite, antigorite and biotite (Oakeshott, 1958). (southwestern Agua Dulce 7.5' quadrangle; Oakeshott, 1958)

Ᵽgbm **Ilmenite-magnetite gabbro (Proterozoic)**—Includes massive titanomagnetite bodies. (northern Sunland 7.5' quadrangle; Oakeshott, 1958)

Ᵽmg **Mendenhall Gneiss (Proterozoic)**—Layered migmatitic felsic gneiss and mafic granulite, having rare interlayered augen gneiss and aluminous gneiss. Gneiss is characterized by large-scale foliation, fracturing, jointing, and blocky shattering. Dikes of anorthosite and associated rocks cut gneiss, and centimeter- to meter-scale fragments of gneiss are scattered through the anorthosite. Most distinctive rock is dark gneiss with tint imparted by blue quartz (Oakeshott, 1958). Named by Oakeshott (1958, p. 21), who designated type locality on Mendenhall Peak. Age of Mendenhall Gneiss is greater than 1,200 Ma age of anorthosite sequence (Silver and others, 1963; Barth and others, 1995)

Peninsular Ranges Province

Los Angeles Basin

QTi **Inglewood Formation (early Pleistocene to late Pliocene)**—Shallow marine, consolidated clay-siltstone and interbedded very fine-grained sandstone, commonly having calcareous, limonitic concretions; relatively dense and moderately expansive where weathered. This unit is recognized as one from which most landslides in Baldwin Hills are derived (Hsu and others, 1982). (southernmost Beverly Hills 7.5' quadrangle)

QTrx **Sedimentary rocks of the Pacific Palisades area (early Pleistocene to late Pliocene)**—A few small exposures of marine siltstone and very fine-grained silty sandstone; very soft and slightly indurated, locally very fossiliferous, fossils referred to late Pliocene or early Pleistocene; maximum thickness about 120 m. (Topanga 7.5' quadrangle, Hoots, 1931)

Fernando Formation (Pliocene)—Massive marine siltstone, massive friable marine sandstone, and pebbly conglomerate (west-central San Fernando 7.5' quadrangle). Name introduced by Eldridge and Arnold (1907); locally contains Repettian-Wheelerian (early to late Pliocene) foraminiferal zone boundary (Lamar, 1970). Durham and Yerkes (1964) described two members, upper and lower, in Puente Hills, which extend into the southeast corner of the El Monte 7.5' quadrangle. Lamar (1970) described three informal lithologic members in Los Angeles and Hollywood 7.5' quadrangles, here labeled members 1 (oldest) through 3 (youngest). Includes:

Tfu **Fernando Formation, Upper Member**—Massive silty sandstone. (El Monte 7.5' quadrangle). Tfuf, fossiliferous; Tfuc, pebbly sandstone and conglomerate

Tfl **Fernando Formation, Lower Member**—Interbedded silty sandstone and massive pebble conglomerate. (El Monte 7.5' quadrangle). Tflc, conglomerate

Tf_3 **Fernando Formation, member 3**—Coarse pebble-cobble conglomerate. (Los Angeles 7.5' quadrangle)

Tf_2 **Fernando Formation, member 2**—Massive sandstone. (Los Angeles 7.5' quadrangle)

Tf_1 **Fernando Formation, member 1**—Massive siltstone. (Los Angeles 7.5' quadrangle)

Tpn **Puente Formation, undivided (early Pliocene and late Miocene)**—Marine siltstone, sandstone, and shale; locally diatomaceous; mostly temporal equivalent of Modelo Formation, but partly younger; named by Eldridge (*in* Eldridge and

Arnold, 1907) from exposures in Puente Hills; strata are associated with Los Angeles Basin (El Monte, Los Angeles and Hollywood 7.5' quadrangles) as contrasted with Modelo strata, which are associated with eastern Ventura Basin. In Los Angeles and Hollywood 7.5' quadrangles Lamar (1970) mapped four non-sequential, interbedded, informal lithologic subunits, which have not been specifically correlated with formal members recognized by Schoellhamer and others (1954)

Tpnz **Puente Formation, siltstone (early Pliocene)**—Well-bedded, light gray siltstone; thickest beds at top of section, also interbeds lower in section (Lamar, 1970, fig. 14)

Tpns **Puente Formation, siliceous shale (early Pliocene)**—Well-bedded, light gray, siliceous shale and siltstone; regularly interbedded with thin, fine- to coarse-grained sandstone beds; most common in a few discontinuous zones, chiefly in upper-central part of formation (Lamar, 1970, fig. 14)

Tpna **Puente Formation, sandstone (late Miocene)**—Well-bedded, very fine- to very coarse-grained sandstone; medium to light brown and light gray; mostly well cemented but less so in uppermost parts; local discoidal concretions; most abundant in lower part of formation (Lamar, 1970, fig. 14)

Tpnsc **Puente Formation, Sycamore Canyon Member (late Miocene)**—Predominantly sandstone and pebble conglomerate, laterally variable; sandstone is thick-bedded to massive, medium- to coarse-grained, friable; siltstone is massive to thin bedded, siliceous; conglomerate is massive, contains pale to brownish-gray pebbles and cobbles. Siltstone locally contains bathyl-depth foraminiferal fauna; Tpnscc, conglomerate bed. Member named by Schoellhamer and others (1954). (El Monte 7.5' quadrangle)

Tpny **Puente Formation, Yorba Member (late Miocene)**—Predominantly siltstone, sandstone interbeds. Named for Yorba Bridge over Santa Ana River, east of Atwood. White to gray, thin-bedded, micaceous and siliceous siltstone; upper part contains large matrix supported boulders in fine-grained material – interpreted to be turbidity current deposit. Named by Schoellhamer and others (1954). (El Monte 7.5' quadrangle)

Tpnsq **Puente Formation, Soquel Member (late Miocene)**—Predominantly sandstone, minor interbedded siltstone; sandstone is gray to yellowish-gray, massive to well bedded, medium- to coarse-grained, poorly sorted; includes interbedded pebbly sandstone, many graded and locally pebbly to cobbley conglomeratic. Lower part of unit contains ellipsoidal, calcite-cemented boulders as large as 1.5 m. Named by Schoellhamer and others (1954). (El Monte 7.5' quadrangle)

Los Angeles Basin—West

The Miocene through basement stratigraphic section south of the Malibu Coast Fault and west of its junction with the Santa Monica Fault, while structurally an intrinsic part of the Transverse Ranges, is best correlated with the rocks identified by Yerkes and others (1965) as the Southwestern Block of the Los Angeles Basin, which crops out most extensively on the Palos Verdes Peninsula south of the quadrangle.

Tmt **Monterey Shale, undivided (late and middle Miocene)**—Marine clay shale, thin interbedded siltstone, minor sandstone and pebble conglomerate, and glassy tuff. Siltstone is commonly diatomaceous, locally bituminous, siliceous, or dolomitic. Sandstone is commonly quartz arenite; some conglomerate contains clasts of glaucophane schist. Shale is gray to dark brownish gray where fresh, weathers to chalky white; contains foraminifera referred to the Relizian, Luisian, or Mohnian Stages (early middle, late middle, or early late Miocene respectively) of Kleinpell (1938). Monterey strata are only exposed south of Malibu Coast Fault; rocks of equivalent age north of fault are referred to Topanga Group and Modelo Formation. Name extended into southern California from type area in

Monterey County, central California (Woodring and others, 1936). Upper part of unit in some areas (chiefly along the Pacific Coast Highway) is late Mohnian in age and locally overlies early Miocene Trancas Formation unconformably; its relation to middle Miocene Monterey strata on Point Dume are obscured, but could be unconformable. Mostly middle Miocene section exposed on Point Dume is about 100 m thick. Monterey Shale is unconformably overlain by unconsolidated Pliocene, Pleistocene and Holocene deposits

Tmtd **Monterey Shale, deformed (middle Miocene)**—Intensely deformed shale, siltstone, and sandstone, commonly dolomitic, locally siliceous, and locally very cherty. Contains foraminifera referred to Relizian or Luisian (middle Miocene) Stages of Kleinpell (1938). In upper plate of Escondido Thrust Fault and south of Malibu Coast Fault beds are tightly folded, with vertical limbs and gently east-plunging axes; thickness across folded beds is at least 650 m

Tr **Trancas Formation, undivided (early and middle Miocene)**—Marine mudstone, silty shale, claystone, sandstone, and locally prominent sedimentary breccia on Lechusa Point and Point Dume. Breccia is distinctive for abundant detritus of Mesozoic Catalina Schist, including glaucophane schist (San Onofre breccia of Woodford and Bailey, 1928). Trancas is very deformed in zone adjacent to and immediately south of Malibu Coast Fault, and no complete section is exposed. Sovereign Oil Company Malibu 1 exploratory well on Point Dume drilled through 290 m of Marine sandstone, mudstone, claystone, and sedimentary breccia (San Onofre Breccia) between base of Monterey Shale and underlying Zuma Volcanics that is assigned to Trancas Formation by Yerkes and Campbell (1979). (Point Dume and Triunfo Pass 7.5' quadrangles; Campbell and others, 1996; Campbell, 1965-1975, unpublished 1:12,000-scale mapping). Siltstone locally contains abundant foraminiferal assemblages assigned to Saucesian (lower Miocene) and Relizian or Luisian (middle Miocene) stages of Kleinpell (1938). Quartz-bearing calcarenites (Tra) in western part of Point Dume 7.5' quadrangle and eastern part of Triunfo Pass 7.5' quadrangle are distinctive for pervasive intergranular disruption that causes original bedding to be completely masked. Further west, at Sequit Point, sandstones are coarse-grained, cross-laminated calcarenites, composed chiefly of barnacle plates and oyster fragments, and have large areas intruded by sandstone of similar composition but in which original fabric is no longer visible (inferred to be result of liquefaction). Trancas Formation appears to intertongue with both Zuma Volcanics and lower part of Monterey Shale, but is locally unconformably overlain by upper (late Miocene) beds of Monterey Shale

Tz **Zuma Volcanics (early? and middle Miocene)**—Basaltic, andesitic and dacitic flows, flow breccia, pillow lava, aquagene tuff, mudflow breccia, volcanic sand and interbedded mudstone, siltstone, sandstone, and minor breccia-conglomerate. All probably deposited in marine environment. No igneous rocks south of Malibu Coast Fault are recognizably intrusive into associated sedimentary rocks. Sedimentary interbeds carry foraminifera referred to Relizian or Luisian Stages (middle Miocene) of Kleinpell (1938). Most samples of Zuma Volcanics (Weigand and Savage, 1993) are in dacite field of the classification of LeBas and others (1986). Plagioclase phenocrysts from basalt near tip of Point Dume have been dated at 14.6 ± 1 Ma (Berry and others, 1976). Base not exposed, but equivalent section in exploratory well, Sovereign Malibu 1 on Point Dume, is about 430 m (stratigraphic) thick above probable metamorphic basement (Catalina Schist). (Campbell and others, 1970 and 1996; Yerkes and Campbell, 1980; and Campbell, unpublished 1:12,000-scale mapping, 1967-1971)

Los Angeles Basin—East

Tt **Topanga Group, undivided (middle Miocene)**—Heterogeneous sequence of sedimentary and volcanic rocks, containing a marine facies having a middle Miocene molluscan fauna. Since the description of the Topanga molluscan fauna by Arnold (1907), and the application of name, Topanga Formation, in mapping by Kew (1924), a middle Miocene molluscan fauna diagnostic of "Temblor" Stage (Weaver and others, 1944) has provided the chief basis for extending the unit name widely in the Los Angeles Basin and the eastern Ventura Basin. West of name locality in western Santa Monica Mountains, this sequence is more than 6 km thick and is readily divisible into three formations. Yerkes and Campbell (1979) revised nomenclature to identify the entire Santa Monica Mountains sequence as Topanga Group (see DMU for Santa Monica Mountains). In Los Angeles quadrangle, surface and subsurface occurrences of the "Topanga Formation" in the Los Angeles Basin are labeled as "Topanga Group". Locally, lithologic subunits have been recognized by various authors; however, their sequence can be different in different areas and none have been specifically correlated with the formations named in the Santa Monica Mountains. Interlayered basalt (Ttb), consists of intrusive and extrusive volcanic rocks, chiefly basaltic and andesitic, interlayered with sandstone and shale assigned to Topanga Group; in part, may be correlative with Conejo Volcanics of central and western Santa Monica Mountains and adjacent areas to northwest; but includes rocks dated as older than oldest contiguous Conejo (McCulloh and others, 2002). (eastern Santa Monica Mountains, Hoots, 1931; Santa Susana Mountains, Evans and Miller, 1978; northeastern Verdugo Mountains, Oakeshott, 1958). Lithologically recognized subunits, which are probably interbedded at various stratigraphic levels and do not form a consistent stratigraphic sequence. Includes:

Ttcg **Topanga Group, conglomerate**—Conglomerate, massive to well bedded, light brown; includes basal breccia locally. (Los Angeles and Pasadena 7.5' quadrangles; Lamar, 1970)

Tta **Topanga Group, sandstone**—Sandstone, medium- to coarse-grained, well-bedded, light brown and gray. (Los Angeles and Pasadena 7.5' quadrangles; Lamar, 1970)

Ttz **Topanga Group, siltstone**—Siltstone, well bedded, medium to dark brown, with interbedded sandstone, shale and chert. (Los Angeles and Pasadena 7.5' quadrangles; Lamar, 1970)

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