Geologic Map of the Eastern Three-Quarters of the Cuyama 30′ x 60′ Quadrangle, California

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Prepared in cooperation with the U.S. Forest Service

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CONVERSION FACTORS

Multiply	By	To obtain
centimeters (cm)	0.3937	inches (in.)
meters (m)	3.281	feet (ft)
kilometers (km)	0.6214	miles (mi)

To convert Celsius (°C) to Fahrenheit (°F), use formula (°C x 1.8) + 32

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Background

Significant new mapping during the last two decades has added considerably to understanding the geologic history of the western Transverse and southern Coast Ranges (Vedder and others, 1994, 1995, 2001; Kellogg, 1999, 2003; Kellogg and Miggins, 2002; Minor, 1999, 2004; Stone and Cossette, 2000). Prior to this time, the late Thomas W. Dibblee, Jr. mapped much of the Cuyama 1:100,000 quadrangle. The recent mapping has allowed us to revise some of Dibblee's interpretations, as well as those of Crowell and others (1964), and to meet the U.S. Geological Survey's (USGS) publication standard by digitally capturing and converting new data within a Geographic Information System (GIS) designed and published by Environmental Systems Research Institute (ESRI).

Students (most notably Sean Mullin) at the University of California at Santa Barbara (UCSB) Department of Geography, under the supervision of Dr. Keith Clarke, worked to digitally capture Dibblee's data and were assisted by Dibblee for several weeks, during which time considerable unpublished data were shared. This UCSB project was completed under a contract with the U.S. Forest Service, and the resulting valuable digital data set has been used with permission of the U.S. Forest Service to fill in many of the areas on the present map. Consequently, this map compilation varies in numerous small ways from Dibblee's published maps (see index map showing sources of geologic data, sheet 2). With the exception of the Cuyama and most of the New Cuyama quadrangles, the Cuyama quadrangle lies entirely within the Los Padres National Forest. The western one-quarter of the Cuyama 1:100,000 quadrangle is not included in this version of the map due to time and financial constraints and uncompleted new mapping in this area.

South of the San Andreas fault, the map has been partitioned into four structural domains (Domains 1–4, sheet 2) based on major discontinuities in stratigraphy across either bounding faults or zones that represent boundaries between clear changes in depositional setting. Where domain boundaries are defined by large faults, total offset across these faults is poorly constrained and similar units in different domains may have been far removed from each other during deposition (for example, Vedder and others, 1995). Consequently, different symbols and different names are used in some cases for similar units in adjacent structural domains (for example, "Mudstone and minor sandstone" (TKs) in Domain 1 and "Mudstone, claystone, and minor sandstone" (TKm) in Domain 2). However, conventional usage in many cases has led to the same name and symbol assigments for some units in different domains (for example, Caliente Formation (Tc) in Domains 1 and 4, and Soda Lake Shale Member of the Vaqueros Formation (Tvs) in Domains 3 and 4). In a few cases, units of one domain extend a short distance into an adjacent domain (for example, sandstone and conglomerate member of the nonmarine rocks of Santa Barbara Canyon (Tnsc) of Domain 2 extends a short distance into Domain 4).

The Ozena fault, within Domain 2, could also be considered a domain boundary, as it separates a package of Monterey Formation (Tm) and Vaqueros Formation (Tv) rock on the southwest side of the fault, that rest unconformably on a very thick section of Eocene marine rocks, from a Vaqueros-Monterey package northeast of the fault that is relatively thin and rests on the lower Miocene and upper Oligocene? "Nonmarine rocks of Santa Barbara Canyon" ("Pato red beds"). However, the northwestern end of the Ozena fault, as mapped by Vedder and Repenning (1975), disappears into a complexely folded sequence of Branch Canyon Sandstone, obscuring a definable domain boundary.

Note on Marine Transgressions and Unconformities South of the San Andreas Fault

Nonmarine Oligocene rocks that overlie a thick section (several kilometers) of upper Eocene marine rocks demonstrates that a major late Eocene-early Oligocene unconformity affected all regions south of the San Andreas fault. This unconformity marks the Ynezian orogeny during which pre-Oligocene marine rocks were folded and uplifted during crustal contraction, forming the widespread San Rafael high (Dibblee, 1950, 1982; Davis and others, 1996). In Domain 1, rocks of the upper Eocene(?) and Oligocene Sespe Formation

(Tsp) lie unconformably on upper Eocene Coldwater Sandstone. In Domain 2, this unconformity is inferred, because the redbeds ("Pato red beds") of the lower Miocene and upper Oligocene? "Nonmarine rocks of Santa Barbara Canyon" are in fault contact across the Ozena fault with rocks as young as the upper Eocene Cozy Dell Shale. In Domain 3 (Caliente Hills), the nonmarine Oligocene? Simmler Formation rests unconformably on the marine Paleocene Pattiway Formation (Tp), and in Domain 4, east of the Cuyama River, rocks of the nonmarine Oligocene and Miocene Plush Ranch Formation and approximately coeval Simmler Formation lie unconformably above upper Eocene Cozy Dell Shale.

Beginning in the late Oligocene, a marine transgression invaded the same region from the southwest. Domains 1 and 2 contain a thick upper Oligocene and Miocene marine section, including rocks of the upper Oligocene and lower Miocene Vaqueros Formation (Tv), lower and middle Miocene Monterey Formation (Tm), middle and upper Miocene Branch Canyon Sandstone (only in Domain 2) and upper Miocene Santa Margarita Sandstone (Tsm). In Domain 2, the Vaqueros unconformably overlies nonmarine rocks as young as early Miocene (Vedder, 1968), implying that the marine transgression was slightly later in this domain. In Domain 3, the marine beds are dominated by the Vaqueros Formation (Tv), which extends to relatively sparse exposures of Vaqueros in the northwestern part of Domain 4. Many of the upper Oligocene and lower Miocene marine units interfinger with coeval terrestrial units, indicating a series of regressions and transgressions during this interval. These relationships, whereby the Miocene marine units pinch out to the east (see Correlation of Map Units, sheet 2), clearly show that there was a Miocene topographic high in the eastern part of the Cuyama quadrangle, coincident with the western flank of the west-trending Frazier Mountain-San Gabriel structural high of Fritsche (1998) and discussed by Kellogg and Minor (2005).

During the late Miocene, the sea once again retreated from the western part of the region. The upper Miocene nonmarine Caliente Formation (Tc) interfingers with the upper Miocene marine part of the Santa Margarita Sandstone in Domain 1 and unconformably overlies the middle and upper Miocene marine Branch Canyon Sandstone in Domain 2. In the Caliente Hills (Domain 3), the lower part of the Caliente overlies the marine Saltos Shale Member of the Monterey Formation (Tmsh) and interfingers with the upper, presumably lower Miocene part of the Vaqueros Formation. In Domain 4, a thin sequence of marine Vaqueros Formation (Tv) interfingers with the terrestrial Simmler Formation. These relationships in Domains 3 and 4 suggest that the marine regression in this part of the Cuyama quadrangle began as early as the middle Miocene.

Description of Map Units

Qa **Active alluvium (Holocene)—**Silt- to boulder-size, moderately rounded to well-rounded, moderately sorted to well-sorted sediments forming channel and overbank deposits in modern floodplains. Maximum thickness greater than 5 m

Qlsy **Young landslide deposit (Holocene)—**Mostly unsorted, unstratified debris deposited by recent and potentially active landslides. Deposits commonly have hummocky topography. Landslide scar partially vegetated to unvegetated, indicated landsliding less than several tens of years old. About 10–20 m thick

Qw **Wetland deposit (Holocene)—**Brown to black, organic-rich, commonly water-saturated soil in flat to nearly flat areas. Only one deposit mapped in Sawmill Mountain quadrangle (Kellogg and Miggins, 2002)

Qac **Alluvium and colluvium, undivided (Holocene and late Pleistocene)—**Mapped where modern alluvium in small channels and sheetwash alluvium on gentle slopes are intimately intermixed with, or difficult to differentiate from, colluvium. Colluvium composed of poorly sorted, poorly bedded to non-bedded, non-indurated, dark-brown to light-gray-brown, angular boulders, cobbles, and pebbles in light-brown clay, silt, and sand matrix that mantle gently to moderately sloping surfaces and are intermixed by downslope movement of weathered bedrock or other surficial deposits. Includes minor loess. Deposits commonly capped by moderately developed to well-developed soil profile. Recognized mostly in eastern part of map (Kellogg, 1999, 2003; Kellogg and Miggins, 2002). Many smaller deposits not mapped. Maximum thickness probably less than 10 m

Qls **Landslide deposit (Holocene and late Pleistocene)—**Ranges from poorly sorted, unstratified to poorly stratified, clay- to boulder-sized consolidated debris. In places, includes almost intact slumped blocks of bedrock as long as several tens of meters. Younger landslide deposits maintain hummocky topography and have identifiable breakaway scarps. Older landslide deposits generally are deeply dissected with rounded topography. Thickness about 10 m to greater than 50 m

Qya **Younger (inactive) alluvium (Holocene and late Pleistocene)—**Mostly inactive alluvial silt, sand, and gravel, unconsolidated, poorly stratified to well stratified, lenticular. Mapped adjacent to active alluvium in terraces at least 2 m above most active channels. Locally includes narrow channels of active alluvium (Qa). Maximum thickness unknown, but at least 70 m under Cuyama Valley (Vedder and Repenning, 1975). Includes younger fan deposits (Qf1) of Kellogg and Miggins (2002) and younger alluvium (Qya) of Vedder (1968) and Vedder and Repenning (1975)

Qoa **Older alluvium (late and middle? Pleistocene)—**Clay, silt, sand, and gravel, poorly to partially consolidated, poorly stratified to well-stratified. Highly dissected and slightly deformed in places; includes small, unmapped areas of active alluvium (Qa) and younger alluvium (Qya). Includes older fan deposits (units Qf1, Qf2, and Qf3) of Cuddy Valley (Kellogg, 2003) and Sawmill Mountain (Kellogg and Miggins, 2002) quadrangles, including alluvium of San Emigdio Mesa, which is tentatively correlated (Davis, 1983) with the 0.13 to 0.45 Ma Riverbank Formation of northeastern San Joaquin Valley (Marchand and Allwardt, 1981). Includes older alluvium (Qoa) and older gravel deposits (Qog) of Dibblee (1972, 1973, 1985a, 1985b, 1986a, 1986b, 1987, 1996). As thick as 60 m

QTa **Old alluvium, locally deformed (Pleistocene and late Pliocene?)—**Light-brown, weakly indurated alluvial sand and gravel. Includes deformed alluvial deposits (Qn) of Vedder and Repenning (1975), older deformed alluvium (Qns) of Vedder (1968), and Paso Robles Formation of Dibblee (1972). May include beds that are, in part, equivalent to Pleistocene and Pliocene Morales Formation (QTm). In places at least 100 m thick

QTd **Boulder diamicton (Pleistocene and late Pliocene?)—**Unsorted to poorly sorted, massive to poorly stratified, unconsolidated deposit containing subangular to subrounded clasts of local origin. Mapped only in Lockwood Valley quadrangle (Kellogg, 1999) and Cuddy Valley quadrangle (Kellogg, 2003). Clasts are mostly granite of Lockwood Peak (Kgl) and, subordinately, augen gneiss of Frazier Mountain (Xag) and are as long as 3 m, although most are considerably smaller. Matrix is pale-tan grus (disintegrated granitic rocks). Forms hilly topography. Mapped by Dibblee (1979) in most places as boulder gravel member of Miocene Caliente Formation (Tc), but in places overlies Pliocene Quatal Formation (Tq) so younger age indicated. Mapped as "terrace deposits" by Carman (1964), but these deposits lack terrace morphology and alluvial origin is not clear. Debris may have been shed from crystalline thrust sheets during south-directed thrusting of Frazier Mountain and South Frazier Mountain thrusts, which were active as recently as the early Pleistocene (Dibblee, 1982). Thickness as much as about 100 m

Rocks South of the San Andreas Fault Zone

Rocks South of Big Pine and Pine Mountain Faults (Domain 1)

Tc **Caliente Formation, undivided (upper Miocene)—**Lithologically diverse fluvial sedimentary rocks exposed in an overturned syncline in footwall block of Pine Mountain fault (Minor, 2004). Conformably(?) overlies and locally intertongues with marine sedimentary rocks of Santa Margarita Formation. Late Miocene age of Caliente south of Pine Mountain Fault is inferred from late Miocene marine fossils from underlying Santa Margarita Formation

Santa Margarita Sandstone (upper and middle? Miocene)—Marine rocks of Santa Margarita Sandstone overlie rocks of Monterey Formation (Tm) with slight angular discordance (Minor, 2004)

Tsmg **Gypsum member—**Greenish-gray, medium to thin-bedded gypsum with common white, coarsely crystalline gypsum partings. Maximum exposed thickness about 25 m

Tsms **Sandstone and mudstone member—**Interbedded white to light-tan, fine- to coarse-grained, thick- to medium-bedded, laminated to massive, crossbedded in places, fossiliferous, arkosic sandstone and subordinate brown, thin-bedded, locally phosphatic mudstone and lesser siltstone (Minor, 2004). Lower sandstone sequence contains abundant shallow-water marine molluscan fossils, including large oysters (*Crassostrea titan*), and foraminifera that together indicate a late Miocene (Mohnian) age (Vedder and others, 1973). Recent magnetostratigraphic studies, however, suggest that Santa Margarita Sandstone was deposited during middle and late Miocene chron C5r (11.0–11.8 Ma) (Wilson and Prothero, 1997), in disagreement with fossil evidence. Maximum thickness about 120 m

Tib **Intrusive basalt (Miocene)—**Altered vesicular basalt in sill-like body as thick as 30 m on west edge of map in Big Pine Mountain quadrangle (Vedder and others, 1995). Intrudes Monterey Formation (Tm), so is probably Miocene in age. Smaller (1 m thick) basalt intrusive also mapped near Indian Creek in Big Pine Mountain quadrangle

Tm **Monterey Formation, undivided (middle and lower Miocene)—**Light-gray to light-tan, thin-bedded, siliceous to dolomitic marine shale, mudstone, and siltstone. Weathers into white, silicic plates. Benthic foraminifera and calcareous nanoplankton collected from near Big Pine fault indicate middle Miocene age (Minor, 2004). Total thickness about 400 m near Big Pine fault (Minor, 2004); about 250 m thick in Little Pine Mountain Quadrangle (Dibblee, 1986a)

Tms **Sandstone member (middle Miocene)—**Beige to light-gray, friable, and poorly cemented, medium- to thin-bedded, tabular, locally crossbedded, fine- to coarse-grained marine sandstone. Locally carbonate cemented. Contains abundant molluscan fossils of probable middle Miocene age (Vedder and others, 1973). Thickness about 50 m

Tml **Lower calcareous member (middle and lower Miocene)—**Occurs in two areas. Near eastern border of map, consists of gray, thin-bedded, fissile, semi-siliceous to hard shale; includes yellowish dolomitic concretions and lenses (Dibblee, 1996). Weathers nearly white and platy. Contains middle and lower Miocene (Relizian and Saucesian) benthic foraminifera. In western part of quadrangle, consists of soft, fissile, semi-siliceous clay shale with thin interbeds of siliceous shale and limestone. Contains Luisian and Relizian benthic foraminifera (Dibblee, 1986a, 1986b). Thickness about 200 m in Little Pine Mountain quadrangle (Dibblee, 1986a)

Tmls **Limestone of Bee Rock (lower Miocene)—**Light-gray massive, hard, algal limestone with a few thin interbeds of dark-gray, cherty shale. Crops out very locally in Little Pine Mountain quadrangle (Dibblee, 1986a). As thick as about 35 m

Tmsu **Unnamed sandstone (lower Miocene)—**Light-gray to tan, fossiliferous, arkosic marine sandstone, locally calcareous. Lower part conglomeratic in places; upper part contains minor shale interbeds. Contains Relizian and Saucesian microfossils (Dibblee, 1986a). Formerly mapped as Temblor Sandstone (Tt) (Dibblee, 1966). Thickness about 130 m

Tr **Rincon Shale (lower Miocene)—**Grayish-brown clay marine shale, locally silty, micaceous, poorly bedded, crumbly where weathered; locally contains yellow dolomitic concretions. Contains Saucesian and upper Zemorrian microfossils (Dibblee, 1986a, 1996). Thickness about 370 m in eastern Lion Canyon Quadrangle (Dibblee, 1987), but pinches out to west in northern Wheeler Springs quadrangle (Vedder and others, 1973). Two lenses, each as thick as 150 m, that interfinger with Vaqueros Formation (Tv) tentatively mapped as Rincon Shale in western Little Pine Mountain quadrangle (Dibblee, 1986a)

Trp **Piedra Blanca Sandstone Member—**Light-gray, crossbedded marine sandstone. In eastern part of quadrangle, forms prominent, very light tan rounded outcrops. About 150 m thick in eastern Lion Canyon quadrangle (Dibblee, 1987)

Tv **Vaqueros Formation, undivided (lower Miocene and upper Oligocene)—**Massive to thick-bedded, tan to light-greenish-gray marine sandstone and minor siltstone; locally calcareous. Zemorrian Stage (Dibblee, 1986a and 1986b, 1996). Unconformably overlies Sespe Formation (Tsp). As thick as about 150 m in southeastern part of quadrangle. Interfingers with Rincon Shale (Tr) in Little Pine Mountain quadrangle, where unit is about 500 m thick. Estimated thickness less than 30 m in Salisbury Potrero quadrangle (T.W. Dibblee, Jr., unpub. mapping, no date)

Tsp **Sespe Formation (Oligocene and upper Eocene?)—**Interbedded maroon to brown, locally tan, crossbedded, fluvial conglomerate, sandstone, siltstone and claystone. Finer-grained beds maroon, brown, and greenish gray. Locally forms prominent, commonly reddish-brown outcrops. Conglomeratic beds, which are found only in lower part, are divided into two sequences, locally separated by an unconformity, based on studies near Santa Barbara (Howard, 1995). However, lower conglomerate member is not mapped everywhere. Predominantly Oligocene, but basal part may be upper Eocene. Thickness variable; about 400–460 m in Wheeler Springs quadrangle (Dibblee, 1985b). As thick as 600 m in Little Pine Mountain quadrangle (Dibblee, 1986)

Tspc **Lower conglomeratic member—**Mostly interbedded, crossbedded, maroon to reddish-brown, locally tan (especially in lowest part) conglomerate, conglomeratic sandstone, and sandstone; contains minor, thin shale or mudstone beds. Lowest part contains clasts of mostly granitic rocks, porphyritic volcanic rocks and quartzite, suggestive of an eastern (Mojave) source; upper conglomeratic sequence contains abundant chert and graywacke clasts, indicating a Franciscan Complex source (Howard, 1995). About 175 m thick in Wheeler Springs quadrangle (Dibblee, 1985b)

Coldwater Sandstone (upper Eocene)

Tcw **Sandstone member—**Well-indurated, tan to light-gray, massive to crossbedded, thick- to thin-bedded, arkosic, marine sandstone with minor interbeds of greenish-gray siltstone and shale. Contains Narizian foraminifera

Tcwm **Mixed sandstone and shale member—**Interbedded tan, thin-bedded, fine-grained marine sandstone and greenish-gray micaceous siltstone and shale

Cozy Dell Shale (upper Eocene)—Predominantly marine shale with minor interbedded sandstone. Contains foraminifera assigned to Narizian Stage and Penutian or lower part of Ulatisian Stages (Vedder and others, 1973). Maximum thickness about 500 m

Tcd **Shale member—**Gray to grayish-tan, argillaceous to silty, micaceous marine shale and minor, thin, fine-grained marine sandstone. Weathers grayish-brown with abundant brown silty chips

Tcds **Sandstone member—**Tan, thin- to thick-bedded sandstone similar to Coldwater Sandstone (Tcw). Less than 60 m thick

Matilija Sandstone (upper and middle Eocene)—Predominantly thick-bedded marine sandstone as thick as about 500 m

Tma **Sandstone member—**Tan, mostly thick-bedded, well-indurated, medium- to fine-grained, massive to crossbedded, feldspathic, marine sandstone, containing thin layers or partings of clay shale. Prominent cliff-forming unit. Tejon and Domengine molluscan stages (Squires, 1987)

Tmas **Shale and sandstone member—**Clay shale similar to Cozy Dell Shale (Tcd) and interbedded, thin, tan arkosic sandstone beds

Tj **Juncal Formation, undivided (middle and lower? Eocene)—**Gray, greenish-gray, and grayish-tan marine conglomerate, quarzofeldspathic marine sandstone, micaceous siltstone and clay shale in thin to thick (as thick as several tens of meters) interbeds. Weathers tan with abundant iron-oxide (rusty) coatings on fractures. Minimum total thickness in Reyes Peak quadrangle 1,500 m (Minor, 2004)

Tjs **Sandstone member—**Tan, medium- to fine-grained, thin- to medium-bedded, well-indurated feldspathic marine sandstone; rare pebble conglomerate

Tjsh **Shale member—**Gray to dark-gray, clayey to silty, micaceous, marine shale, locally containing thin, fine-grained sandstone beds

TKs **Mudstone and minor sandstone (lower Eocene to Upper Cretaceous)—**Grayish-brown, mostly thin to medium-bedded or indistinctly bedded, clayey to silty, micaceous marine mudstone containing thin- to thick-bedded, very fine grained to coarse-grained sandstone beds (finer-grained varieties micaceous), increasing in abundance up section. Commonly calcareous and contains algal detritus in lower part. Base poorly exposed in Big Pine Mountain quadrangle and contact with overlying Eocene rocks gradational (Vedder and others, 1995)

Tsb **Sierra Blanca Limestone (upper Paleocene)—**Hard, massive, medium- to thick-bedded, gray, white-weathering, locally sandy, algal limestone. Commonly brecciated and recemented; sparingly glauconitic locally. Contains upper Paleocene foraminifera and calcareous nannofossils (Vedder and others, 1995). In places, interbedded with mudstone and minor sandstone (TKs) in southwestern part of map area. As thick as about 130 m

Kmd **Mudstone and minor sandstone (Upper Cretaceous)—**Grayish-brown, mostly thin-bedded to indistinctly bedded, micaceous mudstone and thin-bedded marine sandstone. Contains Maastrichtian to Coniacian calcareous nannofossils

Kms **Sandstone and minor mudstone (Upper Cretaceous)—**Tan, fine-grained to very coarse grained, thin- to thick-bedded, crossbedded to massive, lenticular-bedded, feldspathic marine sandstone, locally conglomeratic. Contains minor interbeds of silty or clayey micaceous mudstone; silty rip-up clasts common (Vedder and others, 1995). Similar to mudstone and subordinate sandstone (Ksm) of Domain 2 but mapped separately because intervening Big Pine fault marks major tectonic boundary (Vedder and others, 1995)

Kcg **Conglomerate (Upper Cretaceous)—**Lenticular and interbedded with sandstone; contains well-rounded pebbles, cobbles, and boulders composed of porphyritic siliceous volcanic rocks, granitoid rocks, and sparse quartzite in a sandy feldspathic matrix (Vedder and others, 1995)

KJe **Espada Formation (Lower Cretaceous and Upper Jurassic)—**Dark greenish-gray, thin-bedded shale with thin interbeds of well-indurated, olive-gray feldspathic marine sandstone. Contains carbonaceous material along bedding planes. Locally contains concretions, minor pebble conglomerate beds, and thin lenses and beds of impure, dark-gray limestone. Rest unconformably on rocks of Franciscan Complex in southwestern part of map area. Greater than 1,000 m thick

Franciscan Complex (Jurassic)—Interpreted to be part of a subduction complex (accretionary mélange) that, in part, rose along the Little Pine fault and core of the Agua Caliente anticline

Jfs **Serpentinite—**Strongly sheared, green to black, serpentinite and serpentinized ultramafic rocks, locally altered to silica-carbonate rock near Santa Ynez River (Dibblee, 1986a)

Jfw **Graywacke—**Greenish-brown, well indurated, graywacke and dark-gray micaceous siltstone and shale; in most places moderately to severely sheared

Jfg **Greenstone—**Greenish-brown to black, mostly massive, fine-grained greenstone (meta-basalt); in most places moderately to severely sheared

Jfc **Chert—**Varicolored green, red, and white, thin-bedded, hard, strongly fractured chert; bedding strongly folded

Rocks West of Cuyama River and North of Big Pine Fault (Domain 2)

Quatal Formation (Pliocene)—Nonmarine. Thickness highly variable; combined thickness as much as about 670 m in Fox Mountain quadrangle (Vedder, 1968)

Tqs **Upper sandstone member—**Mostly yellowish-gray and brownish-gray, poorly indurated, thin- to thick-bedded, muddy sandstone and pebbly nonmarine sandstone. Chiefly conglomerate in lower part; clasts derived almost entirely from Eocene sandstone

Tqcc **Coarse conglomerate member—**Brown, massive to weakly bedded, very coarse conglomerate composed entirely of subrounded cobbles and boulders as long as 1 m; clast-supported and matrix-supported varieties both occur

Tqb **Brown clay member—**Dark-brown, massive claystone and silty claystone; very poorly indurated; weathers to a “popcorn” soil; contains numerous gypsum-filled fractures. May be lateral equivalent of Lockwood Clay (Tlc)

Tlc **Lockwood Clay (Pliocene?)—**Brown to reddish-brown, massive claystone, in most places composed of montmorillonite clay, locally gypsiferous along fractures; very weakly indurated. Small wedge of unit just west of Cuyama River pinches out along Ozena fault. Maximum thickness about 50 m. Refer to Domain 4 for full description and discussion of age uncertainty

Tc **Caliente Formation, undivided (Pliocene? and upper Miocene)—**Rocks of map unit tentatively correlated with the Caliente Formation in the southern New Cuyama quadrangle (Vedder and Repenning, 1975) include pale pinkish-gray and white, fine- to coarse-grained, locally clayey, locally tuffaceous, thin- to thick-bedded nonmarine sandstone, and mudstone. Sandstone locally pebbly. Map unit may include beds as young as Pliocene at top (Vedder and Repenning, 1975). Parts of unit correlated with Mint Canyon Formation to the east of quadrangle (T.W. Dibblee, Jr., unpub. data, 2002). Just west of the Cuyama River, the Caliente Formation includes:

Tcg **Granitic-clast fanglomerate member—**Coarse, light-brownish-gray, granitic-clast fanglomerate of late Miocene age. Equivalent to unit Tcg in Domain 4. Unconformable contact with underlying sandstone and conglomerate member (Tnsc) of nonmarine rocks of Santa Barbara Canyon

Tsm **Santa Margarita Sandstone, undivided (upper Miocene)—**Marine sandstone and mudstone. Sandstone is white to yellowish gray, fine to coarse grained, thin to thick bedded, silty to pebbly, lenticular, locally calcareous; mudstone is greenish gray and reddish brown, thin bedded; includes a few thin beds of fresh-water limestone. Magnetostratigraphic studies suggest formation may be as old as middle Miocene (Wilson and Prothero, 1997). However, local unconformity above Branch Canyon

Sandstone, which contains upper Miocene fossils, indicates Santa Margarita Sandstone in Domain 2 must be upper Miocene. Combined thickness variable; as much as 300 m in Fox Mountain quadrangle (Vedder, 1968)

Tsmu **Upper sandstone member—**White and pale-yellowish-gray and greenish-gray, very fine to coarse-grained, thick-bedded to massive sandstone containing a few thin beds of greenish-gray mudstone and clayey siltstone; calcareous in places; locally conglomeratic. Contains upper Miocene mollusks and echinoids (Vedder and Repenning, 1975)

Tsmc **Claystone member—**Interbedded claystone and pale-yellowish-gray to light-greenish-gray, and pale-yellowish-brown, siliceous, laminated to thin-bedded claystone and clayey siltstone; diatomaceous. Contains phosphorite-pellet zones and thin beds of silty, very fine grained sandstone and mudstone

Tsml **Lower sandstone, conglomerate, and claystone member—**Claystone and poorly sorted yellowish-gray to pale-yellowish-brown, thick-bedded to massive, lenticular sandstone and conglomerate

Branch Canyon Sandstone (upper and middle Miocene)—Marine. Combined thickness as much as about 760 m in Fox Mountain quadrangle (Vedder, 1968)

Tbu **Upper member—**Fine- to very coarse grained, pale-yellowish-gray to white, thick-bedded and mostly cross-stratified, poorly indurated, feldspathic marine sandstone. Contains upper Miocene echinoids and mollusks

Tbm **Middle claystone member—**Muddy marine sandstone and silty claystone; locally pebbly. Poorly exposed; forms swale between upper and lower members

Tbl **Lower sandstone member—**Pale-yellowish-gray and pale-yellowish-brown, locally pebbly, thick-bedded to massive, lenticular sandstone. Interfingers westward with Monterey Formation (Tm) north of Ozena fault. Includes sandstone beds east of Santa Barbara Canyon mapped by Vedder (1968) as Saltos Shale (Tmsh)

Tm **Monterey Formation, undivided (middle and lower Miocene)—**Pale-brown to light-yellowish-gray, platy to hackly, thinly laminated, generally hard, silicic, marine claystone and shale; weathers white and platy. Maximum thickness greater than about 500 m in western Fox Mountain quadrangle (Vedder, 1968)

Tmss **Basal sandstone member (middle and lower? Miocene)—**Pale yellowish-gray and pale-yellowish-brown, fine-grained to very coarse grained, locally pebbly, thick-bedded to massive, locally cross-stratified, lenticular, cliff-forming sandstone, similar to Branch Canyon Sandstone. Lowermost part may be early Miocene age (Vedder, 1968)

Tmsh **Saltos Shale Member (middle and lower Miocene)—**Light-gray and pale-olive-gray, poorly indurated, very fine grained sandstone, siltstone, and claystone; indistinctly bedded and contains sparse calcareous concretions. Mapped by Vedder (1968) as interfingering with lower part of Branch Canyon Sandstone east of Santa Barbara Canyon, but former Saltos in this area now included with Branch Canyon

Tv **Vaqueros Formation (lower Miocene)—**White to pale-olive and yellowish-brown, fine-grained to very fine grained, locally pebbly, thick-bedded, cross-stratified marine sandstone; includes calcareous beds containing shell fragments and lenses of pebble-cobble conglomerate. Base locally marked by white waterlain tuff. Mapped as Vaqueros Formation by Hill and others (1958) and Vedder (1968). Units Tvr and Tvs of Vedder (1968), variegated mudstone, claystone, and siltstone beds, are also included with Vaqueros Formation, which includes light-brown marine sandstone mapped between Monterey Formation and Eocene marine beds near western border of map area. From map relationships (Vedder, 1968), inferred to unconformably overlie nonmarine rocks of Santa Barbara Canyon. Maximum exposed thickness about 200 m

Nonmarine rocks of Santa Barbara Canyon (“Pato red beds”) (lower Miocene and upper Oligocene?)—In the Santa Barbara Canyon area (Fox Mountain quadrangle; Vedder, 1968), the following units were originally placed in the Pato Red Member (now abandoned) of the Vaqueros Formation (Tv) by English (1916), but due to their nonmarine depositional environment were subsequently placed in the Caliente Formation (Tc) by Hill and others (1958). However, the early Miocene and late Oligocene(?) age of these rocks is older than Caliente rocks mapped in the Caliente Range that are at least as young as late Miocene (Vedder and Repenning, 1975), as well as rocks in the southern part of the New Cuyama quadrangle, where tentative

Caliente beds overlie upper Miocene rocks of the Santa Margarita Sandstone (Tsm) (Vedder and Repenning, 1975). In addition, in the Lockwood Valley and Dry Creek regions, rocks mapped as Caliente Formation (Tc) are as young as uppermost Miocene (Carman, 1964; James, 1963; Kellogg, 1999; Kellogg and Miggins, 2002), also younger than the nonmarine rocks of Santa Barbara Canyon. The nonmarine rocks of Santa Barbara Canyon also underlie rocks mapped as lower Miocene Vaqueros Formation (unit Tv of this map), which, if they are Caliente Formation, is stratigraphically inconsistent with relationships to the north and east, where Vaqueros beds underlie or interfinger with rocks mapped as Caliente Formation (Vedder and Repenning, 1975; Minor, 2004). The nonmarine rocks of Santa Barbara Canyon, at least in part, may correlate more properly with similar rocks of the nonmarine Sespe Formation (Tsp) to the south in Domain 1. Until these stratigraphic problems are resolved, rocks mapped by Vedder (1968) as "Caliente Formation of Hill, Carlson, and Dibblee (1958)" are here called the nonmarine rocks of Santa Barbara Canyon (informally referred to as "Pato red beds"). Combined thickness about 300 m

Tnp **Red pebble-boulder conglomerate and conglomeratic sandstone member—**Red to pale-red and reddish-brown, thin-bedded to very thick bedded conglomeratic sandstone and pebble-boulder conglomerate. Locally cross-stratified. Interbedded with thin red claystone and mudstone beds. Increasingly coarse grained towards Ozena fault zone, where larger clasts (some greater than 1 m long) were derived mostly from Eocene sandstone. Unit Tc of Vedder (1968)

Tnv **Variegated member—**Reddish, greenish, and purplish, relatively thin-bedded sandstone, mudstone, and claystone. Unit Tcv of Vedder (1968)

Tnsc **Sandstone and conglomerate member—**Reddish-orange to light-olive-gray, locally clayey, thick-bedded and lenticular conglomeratic sandstone and conglomerate; locally gypsiferous. Intertongues with variegated beds (Tnv). Units Tco and Tcr of Vedder (1968)

Tng **Gypsiferous mudstone member—**Pale-olive to yellowish-brown and greenish-gray to bluish-gray, indistinctly bedded, poorly indurated, gypsiferous, tuffaceous(?) claystone and mudstone. Unit Tcg of Vedder (1968)

Tncb **Conglomerate and breccia member—**Light-brown and brownish-gray to pale-reddish-brown breccia and conglomerate; locally red or greenish gray. Massive to poorly stratified. Contains large (as long as 3 m) Eocene sandstone boulders. Interfingers northward with red pebble-boulder conglomerate and conglomeratic sandstone member (Tnp). Equivalent to unit Tcb of Vedder (1968)

Trd **Rhyolite dikes (late Oligocene)—**White to light-gray, porphyritic, 5- to 10-m-thick; phenocrysts are sanidine, plagioclase, quartz, and biotite. Most dikes are partially altered with iron-oxide-coated fractures. Intrudes unnamed Eocene shale and sandstone (units Tum and Tush) near junction of Ozena fault and eastern Big Pine fault. Correlated with rhyolite dikes of Domain 4, which have a $^{40}Ar/^{39}Ar$ age of about 25.0 Ma (Stanley and others, 2000; Wilson and others, 2005)

Tcd **Cozy Dell Shale (upper Eocene)—**Gray to grayish-tan, argillaceous to silty, micaceous marine shale and minor, thin-bedded, fine-grained marine sandstone. Weathers grayish-brown with abundant brown silty chips. Similar to shale member of Cozy Dell Shale (Tcd) as mapped in Domains 1 and 4. Contains foraminifera assigned to Narizian Stage and Penutian or lower part of Ulatisian Stages (Vedder and others, 1973). Lies in core of Madulce syncline. Top of unit eroded in Domain 2; at least 500 m thick

Matilija Sandstone (upper and middle Eocene)—Predominantly thick-bedded sandstone. Contains mollusks assigned to Tejon and Domengine molluscan stages (Squires, 1987). Combined thickness about 1,050 m

Tma **Sandstone member—**Pale yellowish-gray to almost white, medium- to coarse-grained, thick-bedded to massive, locally cross-bedded, locally pebbly sandstone; contains thin beds and laminae of gray siltstone and claystone. Resistant and forms prominent yellowish cliffs

Tmas **Mixed sandstone and shale member—**Pale-yellowish-gray to greenish-gray, mostly fine-grained, thin- to thick-bedded, evenly bedded sandstone. Increasing amounts of gray siltstone and claystone in upper part. Sandstone commonly contains fossiliferous yellowish-brown calcareous concretions and lenses. Corresponds generally to unit Tmaf of Vedder and others (1973)

Unnamed marine units (Eocene)—Units include very thick sequence of marine sandstone, siltstone, and mudstone beds mapped as Juncal Formation (Tj) by Vedder and others (1973) and Minor (2004), but uncertainty as to age and correlations, especially in the Fox Mountain (Vedder, 1968) and Big Pine Mountain (Vedder and others, 1995) quadrangles leads us to leave these rocks unnamed. Total thickness greater than about 5,000 m

Tum **Mixed sandstone and shale—**Roughly subequal amounts of marine sandstone, siltstone, and shale, similar to units described in other unnamed Eocene beds. Mapped as a member of the Juncal Formation (Tj) by Minor (2004)

Tus **Sandstone and minor mudstone—**Olive-gray, yellowish-tan-weathering, feldspathic, fine-grained to very coarse grained, locally conglomeratic, thin- to thick-bedded, micaceous, poorly sorted, lenticular marine sandstone; mudstone occurs in partings and thin, locally lenticular beds. Clasts are as large as cobbles, well rounded, and mostly quartzite and porphyritic, siliceous metavolcanics (Vedder and others, 1995). Abundant carbonaceous material on some bedding planes. Commonly forms ledges or cliffs. Conformable above unit TKm in western part of map area. Unit includes sandstone member of Juncal Formation (Tj) of Vedder and others (1973)

Tush **Claystone, mudstone, and shale—**Dark-gray and brownish-gray to greenish-gray and olive-black, thin-bedded to indistinctly bedded, concretionary marine claystone, mudstone, and shale, with a few thin, fine-grained sandstone beds. Includes claystone, mudstone, and shale member of Juncal Formation (Tj) of Vedder and others (1973) and siltstone and shale member of Juncal Formation (Tj) of Minor (2004)

Tuc **Conglomerate—**Dark-brownish-gray, lenticular-bedded conglomerate; cobbles mostly well rounded and composed chiefly of granitic rock, andesite porphyry, and quartzite in hard sandstone matrix. Includes conglomerate beds of Juncal Formation (Tj) of Vedder and others (1973)

TKm **Mudstone, claystone, and minor sandstone (lower Eocene to Upper Cretaceous)—**Olive-gray to brownish-gray, micaceous, thin-bedded to indistinctly bedded, locally concretionary marine siltstone, claystone, and mudstone; includes thin, fine-grained beds of feldspathic sandstone. Mollusks, foraminifera, and palynomorphs indicate age is early Eocene to Late Cretaceous, although Cretaceous rocks may locally be absent. Similar to mudstone and minor sandstone unit (TKs) in Domain 1. Thickness highly variable; as thick as 400 m

Ksm **Mudstone and subordinate sandstone (Upper Cretaceous)—**Silty and clayey, micaceous marine mudstone and varying amounts of thin- to thick-bedded sandstone. Similar to sandstone and subordinate mudstone unit (Kms) in Domain 1 but mapped separately because intervening Big Pine fault marks major tectonic boundary (Vedder and others, 1995)

Kss **Sandstone and subordinate mudstone and conglomerate (Upper Cretaceous)—**Buff, fine- to very coarse-grained, micaceous, locally conglomeratic, thin- to thick-bedded, lenticular feldspathic marine sandstone. Includes interbedded, thin-bedded, micaceous mudstone beds. Contains Upper Cretaceous mollusks in upper part (Vedder and others, 1995). Thickness highly variable; maximum thickness about 600 m

Kcg **Conglomerate (Upper Cretaceous)—**Thick-bedded, lenticular, marine conglomerate composed of well-rounded pebble, cobble, and boulders of mostly porphyritic siliceous metavolcanic rocks, granitoid rocks, and quartzite. Two mapped lenticular beds as thick as 25 m interbedded with mudstone and subordinate sandstone unit (Ksm)

Ksw **White sandstone of Big Pine Mountain (Upper Cretaceous)—**White, medium- to coarse-grained, micaceous, thick-bedded to massive, feldspathic marine sandstone and minor mudstone. Weathering resembles granitic grus. Forms white, cliff-forming beds, lighter in color than buff-colored unit Kms, in Big Pine Mountain quadrangle in western map area (Vedder and others, 1995). As thick as about 140 m

Rocks of the Caliente Hills (Domain 3)

Caliente Formation (Pliocene? to lower Miocene)—Nonmarine fluvial deposits containing alkalic olivine basalt flows in upper part. Total exposed thickness in map area about 760 m

Tcc **Upper sandstone and conglomerate member (lower Pliocene or upper Miocene)—**Pale-red to reddish-brown or grayish-red and very-pale-orange or white arkosic sandstone, pebbly sandstone, and conglomerate; thick bedded to lenticular and poorly stratified; crossbedded in places; contains thin beds of reddish mudstone. Contains mammalian fossils of Hemphillian age (early Pliocene or late Miocene) in lower part. Corresponds to units Tc3 and Tc5 of Vedder and Repenning (1975)

Tcb **Alkalic olivine basalt flows (upper Miocene)—**Dark-gray to brownish-gray, locally vesicular; includes some interbedded sandstone and conglomerate. Corresponds to units Tb and Tb5 and small parts of unit Tc of Vedder and Repenning (1975)

Ti **Intrusive olivine diabase (upper? Miocene)—**Alkalic olivine diabase in sills and small plugs. Locally forms columnar-jointed outcrops (Vedder and Repenning, 1975). Intrudes middle Miocene rocks of lower part of the Caliente Formation and is probably source for olivine basalt flows interbedded with upper Caliente Formation

Tcsl **Lower sandstone and conglomerate member (middle Miocene)—**Variegated, lenticular and thin- to thick-bedded, cross-stratified sandstone, conglomerate, and mudstone; includes thin zones of bentonitic claystone. Contains possibly reworked mammal bones of Barstovian and Hemingfordian age. Corresponds to unit Tc2 of Vedder and Repenning (1975)

Tcs **Mudstone and sandstone member (middle and lower Miocene)—**Dusky-red and grayish-olive, thin-bedded claystone and mudstone interbedded with pale-greenish-gray to yellowish-gray thin- to thick-bedded sandstone and conglomerate. Contains possibly reworked mammal bones of Arikareean age (early Miocene to early Oligocene), but Vedder and Repenning (1975) consider unit no older than early Miocene. Base of unit grades westward into lower Miocene Painted Rock Sandstone Member of Vaqueros Formation (Tvpr). Corresponds to unit Tc1 of Vedder and Repenning (1975)

Tmsh **Saltos Shale Member of Monterey Formation (middle and lower Miocene)—**Greenish-gray to brownish-gray, indistinctly bedded, locally pebbly and concretionary, clayey, marine siltstone and fine-grained sandstone. Locally includes medium- to coarse-grained sandstone that resembles Branch Canyon of the Vaqueros Formation in western Caliente Range but is absent in eastern part of range. Contains early and middle Miocene age mollusks and foraminifera. Thickness about 500 m

Tv **Vaqueros Formation, undivided (lower Miocene)—**Interbedded marine siltstone and sandstone. Mapped in southeastern part of Caliente Range and tentatively includes Soda Lake Shale Member (Tvs) and Quail Canyon Sandstone Member (Tvq) (Vedder and Repenning, 1975)

Tvpr **Painted Rock Sandstone Member—**Pale-greenish-gray, yellowish-gray, brownish-gray, and olive sandstone, siltstone, and claystone; conglomeratic in places, including some pebble- to boulder-conglomerate lenses in lower part. Contains lower Miocene mollusks and foraminifera. About 270 m thick

Tvs **Soda Lake Shale Member—**Brownish-gray, dark-greenish-gray, and olive-gray claystone, siltstone, and shale; laminated to poorly bedded, locally concretionary. Contains a fine- to coarse-grained, light-gray to yellowish-gray, thick-bedded, lenticular, resistant sandstone bed that resembles Painted Rock Sandstone Member (Tvpr). Contains lower Miocene mollusks and foraminifera in upper part and suspected reworked upper Oligocene (Zemorrian) foraminifera in lowermost part; Vedder and Repenning (1975) consider member entirely Miocene in age. Highly variable thickness; as much as about 370 m

Tvq **Quail Canyon Sandstone Member—**Yellowish-gray to light-gray, fine- to medium-grained, thick-bedded and lenticular, locally crossbedded sandstone. Unit thins to west. Contains sparse middle to lower Miocene mollusks (Vedder and Repenning, 1975). Thickness variable; as thick as about 30 m

Simmler Formation (Oligocene?)—Nonmarine. Formation as thick as about 850 m

Tsh **Shale member—**Grayish-red, dusky-red, greenish-gray and olive, thin- to indistinctly bedded claystone and siltstone; interbedded with medium- to coarse-grained, thin- to thick-bedded sandstone. Corresponds to units Ts2 and Ts4 of Vedder and Repenning (1975)

Tss **Sandstone and shale member—**Pale-olive, pale-greenish-gray, and yellowish-gray, fine-grained, thin- to thick-bedded sandstone interbedded with greenish-gray and reddish siltstone and claystone. Corresponds to units Ts1, Ts2, and Ts3 of Vedder and Repenning (1975)

Tp **Pattiway Formation (Paleocene)—**Olive-gray to dark-gray, locally concretionary, clayey to sandy siltstone and light-olive-gray, fine- to medium-grained marine sandstone. Contains numerous lenticular beds of yellowish-gray to pale-greenish-gray, thick-bedded to massive, deeply channeled, pebble to boulder conglomerate and fine- to coarse-grained sandstone. Contains upper Paleocene (Ynezian) foraminifera. Base of formation not exposed; at least 360 m thick

Rocks North of Pine Mountain Fault, East of Cuyama River, and South of San Andreas Fault (including wedge between Eastern Big Pine and Pine Mountain Faults) (Domain 4)

QTm **Morales Formation, undivided (Pleistocene and upper Pliocene)**—Light-gray to light-brownish-gray, medium- to coarse-grained, weakly to moderately indurated, arkosic-lithic fluvial sandstone, pebbly sandstone, and conglomerate. Contains minor gray, fine-grained sandstone and mudstone primarily in the lower part. Generally well bedded. Conglomerate clasts mostly subrounded to rounded and include granitic rocks, gneiss, felsic to intermediate volcanic rocks, sandstone, basalt, quartz, quartzite, and chert. Commonly poorly exposed. Age based on sparse vertebrate fossils of Blancan age (Vedder, 1968), and on paleomagnetic stratigraphy (Ellis and others, 1993). Tuff near top of unit interpreted as middle Pleistocene (Stone and Cossette, 2000). Maximum known thickness in Apache Canyon quadrangle about 1,100 m (Stone and Cossette, 2000)

QTmu **Upper member**—Mostly sandstone and pebble conglomerate (Dibblee, unpub. data, 2001). Mapped largely in Cuyama Peak quadrangle

QTml **Lower member**—Mostly claystone with minor sandstone; basal calcareous layer (Dibblee, unpub. data, 2001). Mapped mostly in Cuyama Peak and Apache Canyon quadrangles

Tq **Quatal Formation, undivided (Pliocene)**—Primarily varicolored fluvial sedimentary sequences consisting of interbedded mudstone, siltstone, sandstone, pebbly sandstone, and conglomerate. Gypsum and gypsiferous mudstone occur locally

Tqu **Upper member**—In Reyes Peak quadrangle (Minor, 2004) consists of brown and brownish-gray massive to poorly bedded, locally sandy claystone; contains a few thin light-gray and pale brown, flaggy to tabular siltstone and fine-grained sandstone. Base of unit in the western exposures of Reyes Peak quadrangle consist of a thin, light-gray sandy conglomerate with subrounded clasts of Monterey Shale. Upper member in Lockwood Valley quadrangle (Kellogg, 1999) consists of coarse-grained, poorly sorted, light orange-brown to orange arkosic sandstone, conglomerate, and minor claystone, suggesting closer source rock than upper member in Reyes Peak quadrangle. Maximum thickness more than 300 m

Tqc **Conglomeratic member**—Tan, yellowish-gray and light-gray, medium- to thick-bedded, variably resistant fluvial conglomerate and conglomeratic sandstone with minor interbeds of clayey to silty sandstone. Clasts are subrounded to well-rounded, rarely as large as boulders, and consist of granitic and gneissic rocks and lesser volcanic rocks, schist, and sandstone. Thickness variable; as great as 300 m (Minor, 2004)

Tqp **Gypsiferous member**—Gray and nearly white gypsum beds as thick as 15 m, locally silty. Exposed in northern Cuyama Peak and Ballinger Canyon quadrangles

Tqw **White sandstone member**—Conspicuous white to light-gray, thick- to medium-bedded, arkosic to lithic-feldspathic sandstone, locally pebbly to conglomeratic. Contains sparse brown partings and thin layers of brown mudstone and siltstone. Overlies Lockwood Clay (Tlc), or Caliente Formation where the Lockwood Clay is absent, mostly in the Sawmill Mountain (Kellogg and Miggins, 2002) and the Reyes Peak quadrangles (Minor, 2004). Includes sandstone of Nettle Spring of Stone and Cossette (2000) in Apache Canyon quadrangle. As thick as 250 m in Reyes Peak quadrangle (Minor, 2004); as thick as 210 m in Sawmill Mountain quadrangle (Kellogg and Miggins, 2002)

Tqg **Green mudstone member**—Medium- to coarse-grained, gray-green silty and clayey sandstone and pebbly conglomerate; minor claystone beds, which become more numerous near base. Beds typically 1 to 3 m thick. Conformable above Lockwood Clay (Tlc); exposed mostly in Lockwood Valley quadrangle (Kellogg, 1999) where it pinches out in north part of quadrangle. As thick as 180 m

Tqx **Sedimentary breccia**—Tan, olive, yellowish-tan, and greenish-gray, thick- to medium-bedded, sedimentary breccia, conglomerate, sandstone, and rare siltstone. Breccia and conglomerate clasts derived mostly from Eocene sandstone and siltstone are as long as 5 m, although most are much smaller. Exposed along Big Pine fault and interpreted as shed from uplifting hanging-wall block of Big Pine fault (Minor, 2004). Minimum exposed thickness about 100 m; probably much thicker at depth

Tlc **Lockwood Clay (Pliocene?)—**Reddish-brown, poorly consolidated, massive montmorillonitic clay, with a small component of kaolin (Carmen, 1964). Weathers to red-brown clayey soil with sparse vegetation, which includes wild onions (*Allium hotwellii*) and buckwheat (*Erigonium ordii* and *E. trichopes*). Protolith uncertain, but may be strongly altered tuff (Carman, 1964) or deeply weathered loess deposit (P.L. Ehlig, oral commun., 1998). Base of unit is disconformable or forms a very low angle unconformity above the Caliente Formation (Tc). Although age is uncertain, local basal unconformity and latest Miocene vertebrate fossils from uppermost part of underlying Caliente Formation in the Sawmill Mountain quadrangle suggest age is early Pliocene. Placed in lowermost part of the Quatal Formation (Tq) by Hill and others (1958). Thickness 0–50 m

Tns **Sandstone of Nettle Springs of Stone and Cossette (2000), Lockwood Clay, and upper part of Caliente Formation, undivided (lower Pliocene and upper Miocene)—**Mapped only at one locality in the north-central Apache Canyon quadrangle (Stone and Cossette, 2000)

Tc **Caliente Formation, undivided (upper to middle Miocene)—**Mostly light-gray to brownish-gray, interbedded fluvial mudstone, siltstone, sandstone and conglomerate; locally gypsiferous and commonly forming badland topography (Carman, 1964; Kellogg and Miggins; 2002, Minor, 2004; Stone and Cossette, 2000). Age is constrained by Hemphillian to late Barstovian (upper to middle Miocene) mammalian fossils collected in and adjacent to the Apache Canyon quadrangle (James, 1963; Kelley and Lander, 1988). Furthermore, basalt flows in type section in Caliente Range have recalculated K/Ar ages of 14.6–14.8 Ma (Turner, 1970), and a thin tuff layer identified in middle Caliente beds in Dry Canyon has a recalculated K/Ar age of 15.6 Ma (James, 1963). Lower part of Caliente Formation in western part of Apache Canyon quadrangle may include part of fanglomerate member of Simmler Formation (unit Tscg) (Paul Stone, written commun., 2006). Maximum observed thickness in Lockwood Valley region about 700 m (Carman, 1964)

Tcb **Alkalic olivine basalt flow—**Dense, black olivine basalt flow between Ballinger Canyon and Quatal Canyon in undivided Caliente Formation (Dibblee, 1972)

Tcu **Upper member—**North of the Lockwood Valley fault, consists of an upper light-brown argillaceous sandstone and sandy mudstone, and a lower white to light-gray arkosic-lithic sandstone and minor conglomerate (Stone and Cossette, 2000). Forms a locally conspicuous light-colored band between the underlying gypsiferous red sandstone and mudstone member (Tcr) and the overlying Lockwood Clay. South of the Lockwood Valley fault, unit consists of a light-gray, buff, and olive-green, arkosic, silt- and clay-rich sandstone and pebble conglomerate. Beds lensoidal. Pebbles consist mainly of granitic, gneissic, and felsic volcanic rocks. Forms well developed badlands topography. As thick as 100 m

Tcg **Granitic-clast fanglomerate member—**Light-gray to light grayish-brown, massive to poorly bedded, granitic-clast sedimentary breccia, conglomerate and subordinate coarse-grained grusy sandstone. Granitic clasts locally longer than 1 m; also contains variable amounts of volcanic and gneissic clasts. Forms basal Caliente facies in the San Guillermo Mountain quadrangle (Minor, 1999), where unit rests unconformably on Eocene rocks and locally interfingers with mostly overlying variegated mudstone and sandstone member (Tcsh). Near Cuyama River, unconformably(?) overlies sandstone and conglomerate member of nonmarine rocks of Santa Barbara Canyon ("Pato red beds") of Domain 2

Tcsc **Sandstone and conglomerate member—**Gray-brown, light-tan, and greenish-brown clayey and silty lithic-arkosic sandstone and conglomerate. Clasts well rounded, as long as 25 cm, and composed predominantly of intermediate to felsic porphyritic volcanic rocks; pink and purple felsite particularly common. Also contains clasts of fine-grained to medium-grained granitic rocks, gneiss, quartz, and basalt. Forms well-developed badlands topography. North of Lockwood Valley fault, lies conformably above and locally interfingers with granitic-clast fanglomerate member (Tcg). South of Lockwood Valley fault, locally forms highest stratigraphic member of formation. Mapped as volcanic-clast conglomerate member in Cuddy Valley quadrangle (Kellogg, 2003).

Tcr **Gypsiferous red sandstone and mudstone member—**Red-brown, reddish-gray, and gray, poorly to moderately indurated, clayey, commonly pebbly sandstone and conglomerate. Contains well-rounded clasts as long as 10 cm. Mostly gypsiferous. In Dry Canyon in western Sawmill Mountain quadrangle, interbedded red and gray beds form conspicuous striped appearance and spectacular badland topography (Kellogg and Miggins, 2002). Also mapped near border between Ballinger Canyon and Cuyama Peak quadrangles (T.W. Dibblee, Jr., unpub. data, 2001). As thick as 275 m but pinches out to south

Tcl **Lower red-and-white-banded member—**Reddish-brown sandy mudstone and white to light-gray arkosic-lithic sandstone, pebbly sandstone, and conglomerate, interbedded to produce a banded appearance. Clasts mostly intermediate volcanic and granitic rocks, but also include gneiss, schist, diorite, quartz, chert, argillite, and sandstone. Abundant vertebrate fossils indicate late Clarendonian to late Barstovian (early late to middle Miocene) age (James, 1963; Kelly and Lander, 1988). Mapped in Apache Canyon area (Stone and Cossette, 2000) where unit overlies granite of Apache Canyon (Kga) and diorite of Apache Canyon (Kda)

Tcsh **Variegated mudstone and sandstone member—**Multi-colored (hues of gray, green, orange, tan, yellow, brown, and red) interbedded sandstone, siltstone, mudstone, and rare claystone; locally gypsiferous. Sandstone is locally pebbly; some granitic-clast conglomerate included (Minor, 1999). Grain size decreases up section and also to east; outcrops near eastern boundary of the San Guillermo Mountain quadrangle are pale-green to pale- greenish-gray and reddish-brown, well-bedded, clay-rich, mudstone, siltstone, and sandstone. Includes both "variegated sedimentary beds" and "clay-rich sedimentary facies" of Minor (1999)

Tcx **Basal breccia member—**Gray, grussy, massive to crudely bedded, sedimentary breccia and minor conglomerate. Clasts of gneiss and granitic rocks derived from underlying units of Plush Ranch Formation. Unit present only along Lockwood Valley fault zone and may result from south-flowing debris flows across active fault

Vaqueros Formation (lower Miocene)—Interbedded marine sandstone and shale

Tvss **Sandstone member—**Light-brown, thin- to thick-bedded, fine- to coarse-grained arkosic sandstone; includes subordinate brown, sandy siltstone and pebbly sandstone

Tvs **Soda Lake Shale Member—**Brownish-gray, dark-greenish-gray, and olive-gray claystone, siltstone, and shale; laminated to poorly bedded, locally concretionary. Interfingers with upper, fanglomerate member of Simmler Formation (Dibblee, 1972)

Simmler Formation (Miocene and Oligocene?)—Divided into two, approximately equally thick non-marine facies, an upper fanglomerate member and a lower conglomerate, sandstone, and shale member

Tscg **Fanglomerate member (Miocene and Oligocene?)—**Upper, southern facies consists mostly of pink sandstone that becomes increasingly coarse and conglomeratic to southeast; includes thin interbeds of reddish, micaceous shale (Dibblee, 1982). North of Quatal Canyon, unit coarsens upsection into red fanglomerate that contains granitic and gneissic detritus probably derived from Mt. Pinos and Sawmill Mountain regions; the uppermost part contains Pelona Schist (Tps) detritus. Exposed in "Cuyama badlands" south of the San Andreas fault in the Ballinger Canyon, Santiago Creek, and Apache Canyon quadrangles. Includes sedimentary breccia of Apache Potrero and sedimentary breccia and sandstone of Cowhead Potrero of Stone and Cossette (2000), which were previously included in Caliente Formation (Tc) (Van Amringe, 1957; Frakes, 1959) and part of Cowhead Potrero Formation of Ziony (1958). Also includes sandstone of Blue Rock Spring of Stone and Cossette (2000), a reddish-brown, thick-bedded, coarse-grained, micaceous lithic sandstone as thick as 40 m that directly underlies the Caliente Formation

Tsc **Conglomerate, sandstone, and shale member (Oligocene?)—**Lower, northern facies composed of pink sandstone and conglomerate, and interbedded reddish-gray, silty claystone. Sequence coarsens upsection and is separated by Dibblee (1971) into lower pink and gray sandstone and shale sequence and upper maroon sandstone and conglomerate sequence

Nonmarine rocks of Santa Barbara Canyon ("Pato red beds") (lower Miocene and upper Oligocene?)

Tnsc **Sandstone and conglomerate member—** Reddish-orange to light-olive-gray, locally clayey, thick-bedded and lenticular conglomeratic sandstone and conglomerate; locally gypsiferous. Part of extensive unit in Domain 2; comprises a tongue that extends about one km into Domain 4. Unconformably underlies granitic-clast fanglomerate member of Caliente Formation (Tcg)

Plush Ranch Formation of Carman (1964) (lower Miocene and Oligocene)—Included with Simmler Formation by Dibblee (1979). Nonmarine

Tprr **Granite and gneiss breccia member—**Light- to dark-gray, massive to poorly stratified conglomerate and sedimentary breccia; moderately to well bedded on a large (tens of meters) scale. Clasts are angular to subrounded, as long as 2 m, and composed of varying proportions of granite of Lockwood Peak (Kgl) and Proterozoic augen gneiss of Frazier Mountain (Xag) (Kellogg, 1999). Interpreted as coarse-grained fan-delta deposits adjacent to a basin-bounding normal fault, proposed to exist at site of present Lockwood Valley fault (Cole and Stanley, 1995). Base not exposed; thickness locally greater than 375 m

Tprs **Sandstone member—**Light-gray-brown, orange-brown, and olive-brown, flaggy to blocky, well-indurated, medium- to coarse-grained, sandy mudstone, well-sorted arkosic sandstone, and subordinate pebble and cobble conglomerate; clasts mostly granitic rocks with minor gneiss and quartzite. Contains interbedded light-gray-brown, moderately indurated sandy siltstone. Interpreted as alluvial-plain deposits and subaqueous fan-delta deposits (Cole and Stanley, 1995). Thickness variable; as much as 820 m thick

Tprl **Lacustrine member—**Light-olive-brown to orange-brown, commonly fissile mudstone, shale, siltstone, evaporites, and fine-grained to very fine grained sandstone. Sandstone is thin bedded, ledgy, tan, well cemented, laterally continuous, and normally graded; some soft-sediment deformation in finer grained beds. Near top of unit are thin-bedded gypsum beds interbedded with dark-brown mudstone. In eastern exposures, thin limestone and shale beds are interbedded with borax-bearing evaporite minerals, mostly colemanite, which was mined until World War I (Carman, 1964). Weathers yellowish tan. Interpreted as basin-center lacustrine deposits (Cole and Stanley, 1995). Thickness highly variable; as much as 900 m thick

Tprb **Basalt member—**Black, medium- to fine-grained, locally vesicular basalt flows and sills. Contains about 62 percent calcic plagioclase, 18 percent clinopyroxene, 15 percent olivine, partially altered to iddingsite, and 5 percent opaque minerals. Plagioclase forms small phenocrysts as long as 2 mm. Mostly massive; faint pillow structures reported at some localities (Carman, 1964; Cole and Stanley, 1995). Interlayered with and locally crosscuts subaqueous mudstone and evaporite deposits of lacustrine member (Tprl) (Kellogg, 2003). Weathers to dark-brown, sandy soil containing abundant basalt clasts. Potassium-argon ages range from 20.9±0.9 to 26.5±0.5 Ma (early Miocene to late Oligocene) (Frizzell and Wiegand, 1993). Maximum thickness of individually mapped units about 200 m

Tprx **Megabreccia member—**Gray, massive, poorly sorted, well consolidated, clast-supported, sedimentary breccia. Clasts entirely granite of Mt. Pinos (Kgp) and as long as 15 m (Bohannon, 1976). Contacts with surrounding mostly mudstone beds of lacustrine member (Tprl) sharp; indents underlying beds indicating soft-sediment deformation during deposition. Interpreted as rockslide deposits that slid into subaqueous sediments of lacustrine member (Tprl) (Cole and Stanley, 1995)

Tprc **Basal conglomerate member (Oligocene?)—** Maroon and reddish-tan, well-indurated, poorly sorted, massively bedded conglomerate and subordinate lenses of tan, coarse-grained feldspathic sandstone as thick as 2 m. Both clast- and matrix-supported clasts are subangular to well rounded, and consist mostly of biotite gneiss and granitic rocks, with minor amounts of quartz and schist similar to Pelona Schist (Tps); possible source areas all within 5 km of exposures. Mapped in Cuddy Valley quadrangle adjacent to the Lockwood Valley fault (Kellogg, 2003)

Trd **Rhyolite dike (late Oligocene)—**White to light-gray, porphyritic, 5- to 10-m-thick, rhyolite dikes. Phenocrysts are sanidine, plagioclase, quartz, and biotite. Most dikes are partially altered with iron-oxide-coated fractures. Intrudes shale and sandstone of Eocene Juncal Formation. $^{40}Ar/^{39}Ar$ age at Wagon Road Canyon just south of eastern Big Pine fault about 25.0 Ma (Stanley and others, 2000; Wilson and others, 2005)

Cozy Dell Shale (upper Eocene)—Predominantly marine shale and subordinate sandstone in core of Piedra Blanca syncline. Upper contact eroded in domain; maximum preserved thickness about 400 m

Tcd **Shale member—**Brown to brownish-gray, silty claystone, mudstone, and shale, laminated to indistinctly bedded; concretionary; contains thin beds and laminae of very fine to medium-grained sandstone (Vedder and others, 1973)

Tcds **Sandstone member—**Pale-yellowish-gray to greenish-gray, thin- to thick-bedded, with interbeds of siltstone and shale. Incompletely mapped in Madulce Peak quadrangle due to inaccessibility (Vedder and others, 1973)

Matilija Sandstone (upper and middle Eocene)—Predominantly thick-bedded marine sandstone and minor mudstone. Maximum thickness about 500 m (Minor, 2004)

Tma **Sandstone member—**Pale yellowish-gray to almost white, medium- to coarse-grained, thick-bedded to massive, crossbedded in places, locally pebbly; contains thin beds and lamina of gray siltstone and claystone

Tmas **Mudstone and sandstone member—**Dark-gray to greenish-gray, thin-bedded to indistinctly bedded, silty claystone and shale; contains a few thin, fine-grained sandstone beds

Juncal Formation (middle and lower? Eocene)—Interbedded marine conglomerate, sandstone, and mudstone. Overlies Late Cretaceous granite of Lockwood Peak (Kgl). Total thickness greater than 1,500 m

Tjs **Sandstone member—**Light-olive-gray to greenish-gray, fine- to very coarse grained and locally pebbly, thin- to thick-bedded sandstone, with thin interbeds and partings of dark-greenish-gray shale. Weathers light tan, with ubiquitous iron-oxide (“rusty”) coatings on fracture surfaces

Tjm **Mixed sandstone and mudstone member—**Approximately equal amounts of thin, greenish-gray to grayish-brown, thin- to thick-bedded sandstone and claystone

Tjsh **Shale member—**Dark-gray and brownish-gray to greenish-gray and dark-olive claystone, mudstone, and shale; laminated or thin bedded; contains thin beds and lamina of fine-grained sandstone. Abundant microfossils and mollusks suggest a middle Eocene age (Vedder and others, 1973)

Tjc **Conglomerate member—**Dark-brownish-gray conglomerate interbedded with pebbly, coarse-grained, quartzofeldspathic sandstone; cobbles are well rounded, mostly matrix supported, and composed of granitic rocks, andesite porphyry, gneiss, and chert; clasts commonly coated with iron oxides. Conglomerate member forms lenses and tongues within other, finer grained facies in southeastern exposures of Juncal Formation

Tem **Marine shale and minor sandstone (lower Eocene)—**Black to dark-brown, fissile, micaceous, mostly indistinctly bedded, marine siltstone and shale, with minor brown, fine- to medium-grained, thin-bedded sandstone. Contains black dolomitic concretions as long as 2 m. Disconformably overlies granite of Mount Pinos (Kgp) along south side of mountain. Contains abundant lower Eocene mollusks and benthic foraminifera (Squires, 1988). Overlain unconformably by rocks of the Plush Ranch Formation. One measured section about 200 m east of North Fork of Lockwood Creek is 605 m thick (Squires, 1988)

Tp **Pattiway? Formation (Paleocene)—**Interbedded sandstone and shale exposed in southern Ballinger Canyon and Santiago Creek quadrangles (Dibblee, 1972, 1973). Tentatively correlated with Pattiway Formation of the Caliente Range (Vedder and Repenning, 1975)

Tmy **Mylonite of Sawmill Mountain thrust fault (Paleocene)—**Greenish-gray to dark-green, very well indurated augen-rich mylonite above trace of Sawmill Mountain thrust fault. Base is ribbony, with thin, white quartz stringers. In most places, contact between mylonite and structurally underlying unmylonitized Pelona Schist (Tps) is sharp. Degree of mylonitization generally decreases upward into overlying gneissic rocks, although locally there are several discrete mylonite zones over a vertical distance as great as 140 m. There is considerable brittle deformation near structural top of mylonite zone, with small offsets and many slickensided surfaces. Greenschist-grade metamorphism and ductile deformation within mylonite reflect mid-crustal conditions during movement. An early Paleocene metamorphic age for the Pelona Schist (Tps) (Kellogg and Miggins, 2002) constrains age of mylonite to be no older than Paleocene

Tps **Pelona Schist (Paleocene)—**Silvery-gray to brownish-gray, medium-grained micaceous quartzofeldspathic schist and micaceous quartzite. Typically contains 30–60 percent quartz, commonly as porphyroblasts as long as about 4 mm containing many small inclusions, 15–20 percent albite, 10–20 percent muscovite, 2–20 percent biotite, 10 percent epidote, 2–5 percent calcite, trace to 2 percent garnet, and traces of zircon and opaque minerals. Foliation is parallel to relict bedding at most localities. Depositional age of protolith probably Late Cretaceous (Jacobson and others, 2000). Metamorphic age of schist is Paleocene based on $^{40}Ar/^{39}Ar$ age on muscovite is 63.24±0.26 (Kellogg and Miggins, 2000), considered best representation of age of post-metamorphic cooling. $^{40}Ar/^{39}Ar$ age on biotite is 56.66±0.15 Ma

Tpsb **Metabasalt—**Local, small outcrops of dark greenish-gray, massive, fine-grained, holocrystalline metabasalt. Contains about 65 percent chlorite, 20 percent quartz, 8 percent opaque minerals, 3 percent biotite, 2 percent calcite, 1 percent euhedral clinopyroxene, and 1 percent 1-mm-long garnets

Kgl **Granite of Lockwood Peak (Late Cretaceous)—** Coarse-grained, equigranular to porphyritic, hypidiomorphic granodiorite and subordinate quartz monzonite. Contains about 20 percent undulatory quartz, 25–50 percent zoned plagioclase (about An_{27}), 5–35 percent microcline, 5–10 percent biotite, 10 percent hornblende, 1–2 percent sphene, 1 percent opaque minerals and trace apatite and zircon. Most exposures are equigranular, but microcline megacrysts as long as 2 cm locally comprise as much as 20 percent of rock. Commonly weathers to light-tan grus and well-rounded boulders. Includes dikes and irregular bodies of quartz monzonite of Sheep Creek (Kellogg, 1999). Concordant uranium-lead zircon age is 76.05±0.22 Ma (Kellogg, 1999; date by W.R. Premo, written commun.,1997)

Kgp **Granite of Mount Pinos (Late Cretaceous)—** Coarse-grained to very coarse grained, pink to pinkish-gray, massive to weakly foliated, porphyritic granite. Contains approximately 10–25 percent quartz, 50–70 percent microcline, mostly as subhedral phenocrysts as long as 2 cm, 15 percent plagioclase, 3–10 percent biotite, commonly clumped and surrounding the microcline phenocrysts, and traces of sphene, zircon, and opaque minerals (Kellogg and Miggins, 2002). Commonly weathers to grusy soil. U/Pb zircon age is 75.1±1.6 Ma (W.R. Premo, written commun., 2006)

Kga **Granite of Apache Canyon (Cretaceous?)—** Massive to weakly foliated, medium-grained, equigranular to slightly porphyritic, leucocratic granite. Forms small outcrops in Apache Canyon quadrangle; may be intrusive into diorite of Apache Canyon (unit Kda) (Stone and Cossette, 2000). Probably Cretaceous age

Kda **Diorite of Apache Canyon (Cretaceous?)—** Massive to weakly foliated, coarse-grained, dark-gray biotite-hornblende diorite. Forms small outcrops in Apache Canyon quadrangle (Stone and Cossette, 2000). Probably Cretaceous age

Kgn **Granite of Cerro Noroeste (Late Cretaceous)—** Medium-grained, massive to strongly foliated, light-gray to tan, biotite granodiorite or monzogranite. Typically contains 15–35 percent quartz, 25–50 percent plagioclase, 10–30 percent microcline, 5–20 percent biotite, 2–4 percent muscovite, trace–2 percent sphene, and traces of garnet, zircon, apatite, and opaque minerals. Cut by numerous aplite and pegmatite dikes. Preliminary $^{40}Ar/^{39}Ar$ age on biotite is 67.2±0.5 Ma (Kellogg and Miggins, 2002). Intrudes gneissic granodiorite, although $^{40}Ar/^{39}Ar$ biotite age is slightly older than $^{40}Ar/^{39}Ar$ age for gneissic granodiorite. Includes “orange granite” of Kellogg and Miggins (2002), and locally contains inclusions of biotite gneiss (Xbg)

Kgd **Gneissic granodiorite (Late Cretaceous)—**Gray to dark-gray, medium- to coarse-grained, massive to well foliated, equigranular to porphyritic granodioritic to tonalitic ortho-gneiss. Phenocrysts commonly deformed and sheared into augen. Grades into zones with well-defined light-and-dark layers (depending on biotite content) by ductile shearing and recrystallization. Preliminary $^{40}Ar/^{39}Ar$ age on biotite is 65.9±0.2 Ma (Kellogg and Miggins, 2002)

MzPsc **Marble, quartzite, and schist (Mesozoic? to Proterozoic?)—**White, vitreous, medium-grained, well-foliated quartzite; gray, medium-grained, well-foliated marble; and dark-gray schist in small inliers in granitic rocks. Age unknown, but protoliths may be as old as Proterozoic

Xbg **Biotite gneiss (Paleoproterozoic)—**Gray and black, layered biotite gneiss. Leucocratic layers contain quartz, plagioclase, microcline (generally less than plagioclase), and biotite. Interlayered with streaks and small lenses of amphibolite, especially adjacent to Sawmill Mountain fault zone. Melanocratic layers contain as much as 60 percent biotite and minor hornblende. Locally migmatitic and cut by numerous aplite and pegmatite dikes (some of which may be Cretaceous in age). Protolith may be part of 1,750–1,680 Ma (Paleoproterozoic) sedimentary assemblage identified in western Transverse Ranges that was subsequently metamorphosed and deformed during high strain associated with major orogenic episode 1,450–1,425 Ma (Mesoproterozoic) (Silver, 1971)

Xag **Augen gneiss of Frazier Mountain (Paleoproterozoic)—**Dark-gray to almost black, well-foliated to massive, xenomorphic augen gneiss, containing white to pink microcline porphyroblasts as long as 5 cm (most are less than 2 cm). Contains approximately 30–35 percent undulatory quartz, 40 percent sodic plagioclase, 10–15 percent microcline (almost entirely as augens), 10–20 percent biotite, 2–5 percent muscovite, 1 percent opaque minerals, and traces of apatite, zircon, and garnet. Protolith is granodiorite porphyry as shown by nearly euhedral microcline phenocrysts in relatively unstrained rock, and dikes of augen gneiss that intrude biotite gneiss (unit Xbg). Numerous pegmatite and aplite dikes and pods, some of which may be Cretaceous in age, cut unit. Ductile shearing may be associated with previously recognized major orogenic episode in region at 1,450–1,425 Ma (Silver, 1971). Unit has discordant, upper-intercept U–Pb zircon age of 1,690±5 Ma (Kellogg, 1999; analysis by W.R. Premo, 1997), interpreted as intrusive age of protolith

KXmg **Migmatitic biotite gneiss (Cretaceous and Paleoproterozoic)—**Biotite gneiss (equivalent to unit Xbg) and minor augen gneiss (equivalent to Xag) interlayered with abundant (greater than about 10 percent by volume) leucocratic, medium-grained granitic melt phase in layers mostly 1–5 cm thick. Many granitic layers were injected from external sources (Cretaceous granitic rocks), although others apparently were derived by *in situ* partial melting, as shown by mafic selvages adjacent to melt layers (Johannes, 1988). Includes areas mapped as biotite-hornblende gneiss and augen gneiss by Kellogg and Miggins (2002), which are variably migmatitic. Cut by numerous aplite and pegmatite dikes, many of which are presumed Cretaceous in age (Kellogg and Miggins, 2002)

Fault-Bounded Rocks of the San Andreas Fault Zone

QTg **Fault gouge (Holocene to Pliocene?)—**Pervasively sheared, comminuted, and fractured rocks produced by intermittent slip and cataclasis along numerous splays of the San Andreas fault. Consists of a variety of rock types, including granitic rocks, sandstone, and quartzite. Movement along present trace of the San Andreas fault in map area began about 5 Ma (Oskin and Stock, 2003; Kellogg and Minor, 2005)

Tws **White arkosic sandstone and conglomerate (Miocene?)—**White to very pale tan, massive to poorly stratified, thick-bedded, arkosic sandstone and conglomerate. Contains large crossbeds and channel fills. About 10 percent of unit is matrix-supported conglomerate containing moderately to well-rounded clasts as long as 30 cm of sandstone, intermediate to mafic volcanic rocks, granitic rocks, dark-purple quartzite, gneiss, and quartz. Contains a few thin, discontinuous olive-brown silty stringers. Dips steeply at all localities. Weathers into distinctive rounded knobs. Occurrence limited to Sawmill Mountain (Kellogg and Miggins, 2002) and Cuddy Valley (Kellogg, 2003) quadrangles. Tentatively correlated with Caliente Formation (Tc) by Davis (1983) and Davis and Duebendorfer (1987), but is distinct from recognized facies of Caliente in region. Neither top nor base of unit exposed; minimum thickness about 300 m

Tph **Marine shale, sandstone, and limestone of "Peanut Hill" (Miocene, Oligocene, or Eocene)—**Olive-gray, olive-green, olive-brown, and grayish-brown, poorly bedded marine shale, mudstone, and siltstone, with local, thin arkosic sandstone stringers. Sequence becomes sandier down section and lower part contains interbedded, tan, well-indurated, poorly sorted, coarse-grained, locally pebbly and locally laminated, carbonate-cemented, arkosic sandstone; graded bedding, crossbedding, and ripples typical of turbidites. Western exposures contain a few fine-grained, pale-pinkish-brown limestone beds. Locally deformed into tight, disharmonic folds. Unit mostly exposed in large, fault-bounded hill ("Peanut Hill" of Duebendorfer, 1979). Unit greater than 300 m thick

TKbx **Green silicified clastic rocks (Tertiary or Cretaceous)**—Pale-green, fine-grained to very coarse grained, very well indurated, massive to well-bedded silicic siltstone, sandstone, conglomerate, and sedimentary breccia. Clasts predominantly fine-grained quartzite or chert, but also include granitic rocks, black limestone, quartz, and basalt. Gray quartzite clasts are as long as 8 cm and clasts of granite as long as 20 cm. Graded bedding common. Matrix arkosic and overgrown by secondary epidote, chlorite, actinolite, and silica, indicating greenschist-facies metamorphism. Cut by numerous small white quartz veins. Bounded by faults along north side of San Andreas fault zone in northern Sawmill Mountain quadrangle. Neither top nor base exposed; greater than about 150 m thick

Rocks North of the San Andreas Fault Zone

[For a detailed discussion of the middle and lower Tertiary stratigraphic units (as young as Monterey Formation) north of the San Andreas fault, and the history of nomenclature, refer to Nilsen and others (1973). For a detailed discussion of intrusive rocks, refer to Ross (1989).]

QTt **Tulare Formation (Pleistocene and Pliocene)**—Nonmarine, poorly indurated, light-tan or buff to gray arkosic sandstone, conglomeratic sandstone, conglomerate, and brown siltstone; contains local, thin boulder-gravel lenses (Davis, 1983). Well bedded, commonly lenticular

Tucl **Claystone (Pliocene)**—Predominantly nonmarine, greenish-gray poorly indurated claystone and siltstone with thin beds of light-gray limestone and gray sandstone; contains gray or tan, lenticular conglomeratic sandstone and conglomerate beds with interbeds of brown siltstone; locally abundant clasts of siliceous shale (Monterey Formation) (Davis, 1983). Upper portion interfingers in places with Tulare Formation (QTt)

Tusg **Sandstone and conglomerate (Pliocene)**—Poorly indurated sandstone and minor pebble conglomerate; includes some marine sandstone (Dibblee, 1973)

Ts **Sand (Pliocene)**—Mostly terrestrial sand and pebble gravel (Dibblee, 1973)

Te **Etchegoin Formation (Pliocene and upper Miocene?)**—Upper grayish-brown, sandy marine siltstone with a few thin- to medium-bedded, fine-grained sandstone beds; contains abundant Pliocene mollusks. A lower facies consists mostly of grayish-brown marine sandstone (Davis, 1983). Contains upper Miocene foraminifera, although a vitric tuff in Etchegoin Formation from Kettleman Hills northwest of quadrangle is correlated with a tuff with a potassium-argon age of 4.0–4.5 Ma (early Pliocene) (Sarna-Wojcicki and others, 1979)

Tbw **Bitterwater Creek Shale (upper Miocene)**—Marine, thin-bedded, diatomaceous-siliceous mudstone; contains Mohnian foraminifera (Dibblee, 1973). Weathers into platy, white fragments, similar to many parts of Monterey Formation. Lies unconformably above Monterey Formation (Dibblee, 1973)

Monterey Formation (upper to lower Miocene)—Marine sedimentary rocks

Tmb **Black siliceous shale**—Black and dark-gray, thin-bedded siliceous and semi-siliceous shale and clay shale; deep marine; weathers into white plates. Contains upper to middle Miocene (Mohnian) foraminifera

Tmg **Gould Shale Member**—Gray, marine siliceous shale. Contains Relizian and Saucesian (middle and lower Miocene) foraminifera

Tmt **Sandstone**—Nonmarine pink sandstone interbedded with Gould Shale Member (Tmg) in easternmost part of quadrangle; locally called Mint Canyon Formation by Dibblee (1973). Also includes unnamed buff, marine sandstone at base of Monterey Formation (Dibblee, unpub. data, 2001)

Tgcg **Granitic-clast conglomerate (Miocene)**—Unnamed nonmarine cobble and boulder conglomerate consisting of granitic clasts and interbedded sandstone and clay beds. Unconformable above Tecuya Formation in eastern part of quadrangle and tongues westward into lower part of Monterey

Formation. Interpreted as alluvial fan complex to southeast adjacent to mountain front (Nilsen and others, 1973)

Tt **Temblor Formation (lower Miocene and upper Oligocene?)—**Brown marine shale and interbedded, crossbedded buff sandstone. Contains Saucesian and late Zemorrian age foraminifera (Nilsen and Link, 1975). Sharp angular unconformity where formation overlies Tejon and San Emigdio Formations and parts of Pleito Formation (Nilsen and others, 1973). Well exposed in San Emigdio Canyon. Thickness in lower Santiago Creek about 1,650 m; thins dramatically to east and is about 300 m thick near Brush Mountain

Tts **Sandstone member—**Thick-bedded to massive, locally crossbedded buff sandstone and conglomeratic sandstone in lower part of formation

Tecuya Formation (lower Miocene to upper Eocene)—Mostly nonmarine. Interbedded dacite and andesite flows and older basalt flows were mapped separately from Tecuya Formation by Dibblee (1973) but are included with Tecuya by Nilsen and others (1973) and so are considered here as informal members. Tecuya Formation is about 700 m thick near eastern boundary of quadrangle, but thins to west and pinches out near Pleito Creek (Nilsen and others, 1973). Conformable on rocks of Tejon formation

Ttc **Sandstone and clay member—**Mostly nonmarine red, green, buff, and blue-gray sandstone and clay with interbedded, crudely bedded pebble and cobble conglomerate. Tongues westward into Pleito and Temblor Formations (units Tpl and Tt)

Ttg **Conglomerate and minor sandstone member—**Interbedded red to brown pebble and cobble conglomerate and sandstone

Tvd **Dacite and andesite member—**Blue-gray dacite flows with small plagioclase phenocrysts in an aphanitic groundmass; overlies basalt unit. Interbedded extensively with both Tecuya and Temblor (Tt) Formations. Age is early Miocene

Tvb **Basalt member—**Black, fine-grained ophitic basalt; locally scoreaceous. Interbedded extensively with both Tecuya and Temblor (Tt) Formations. Age is early Miocene

Pleito Formation (Oligocene)—Marine sandstone, shale, and claystone. On east side of San Emigdio Canyon, measured section is 700 m thick (Nilsen and others, 1973). Conformable on rocks of San Emigdio Formation

Tpl **Claystone and shale member—**Brownish-gray, marine claystone and shale with minor interbedded buff sandstone. Basal conglomerate exposed in San Emigdio Canyon. Contains Saucesian and Zemorrian foraminifera

Tpls **Sandstone member—**Gray, buff, and tan, massive, medium-grained micaceous marine sandstone mostly in eastern areas of Pleito Formation outcrop where it grades eastward into lower part of Tecuya Formation. Thick, massive, brown sandstone and basal conglomerate in San Emigdio Creek

San Emigdio Formation (Oligocene and upper Eocene)—According to Nilsen and others (1973), upper part comprises alternating sequence of buff, yellowish-brown, and gray thick-bedded to flaggy arkosic marine sandstone and dark-red to gray, lenticular beds of fossiliferous (mostly mollusks) sandstone; some conglomeratic stringers. However, Dibblee (1973) mapped two units which are shown on this map: an upper shale member (Tse) and a lower sandstone member (Tses). Conformable above Tejon Formation. Well exposed in San Emigdio Canyon, where formation is 330 m thick (Nilsen and others, 1973). Formation thins to east and is about 210 m thick near eastern boundary of quadrangle; to the west, formation thickens to an estimated 1,300 m at Santiago Creek (Nilsen and others, 1973)

Tse **Shale member—**Mostly bluish-gray to black, planar-bedded, sandy, micaceous marine shale and greenish-gray mudstone

Tses **Sandstone member—**Tan thin- to thick-bedded to massive marine arkosic, nonfossiliferous marine sandstone; locally pebbly (Nilsen and others, 1973; Dibblee (1973; unpub. data, 2001)

Tejon Formation (Eocene)—Formation attains maximum thickness of about 1,200 m near Pleito Creek but thins to less than 600 m thick at San Emigdio Creek and is about 300 m thick near Santiago Creek (Nilsen and others, 1973)

Ttm **Metralla Sandstone Member (upper Eocene)—**Buff marine sandstone and gray silty shale

Ttl **Live Oak Shale Member (middle Eocene)—**Brownish-gray to gray, hard, platy, thin-bedded, shale and fine-grained sandstone

Ttu **Uvas Conglomerate Member (middle or lower Eocene)—**Brown, ledgy arkosic sandstone and interbedded conglomerate beds several tens of meters above base;

clasts mostly well-rounded black and gray chert with some quartz and intermediate composition porphyry

TKrs **Rand Schist (Paleocene or Late Cretaceous)—** Silvery-gray to black, fine-grained, biotite schist and subordinate biotitic quartzite. Consists of about 25–50 percent fine-grained, undulatory quartz, 10 percent sericitic sodic plagioclase, 40–60 percent biotite, 10 percent epidote, 5 percent epidote, 2–3 percent apatite, 1–2 percent opaque minerals, 0–5 percent garnet, and trace muscovite. Contains many thin (as wide as about 2 cm) quartz stringers. Map unit correlated with Rand Schist of southern California, with which it shares many characteristics (Ehlig, 1968; Haxel and Dillon, 1978; Ross, 1989). The metamorphic age of Rand Schist is Paleocene or possibly Late Cretaceous (Haxel and Dillon, 1978)

Kgbm **Monzogranite of Brush Mountain (Late Cretaceous)—**Light-gray, medium- to coarse-grained, mostly massive biotite monzogranite. Average mode contains 30 percent plagioclase (An_{30}), 34 percent microcline, 33 percent quartz, 3 percent biotite, and traces of zircon, apatite, and hematite (mostly derived from biotite alteration (Ross, 1989). Clearly intrudes Lebec Granodiorite (Kle) and "appears" to intrude mafic metamorphic rocks and Rand Schist (TKrs) (Ross, 1989). Weathers yellowish-tan

Kle **Lebec Granodiorite (Late Cretaceous)—**Gray (black-and-white speckled), medium-grained, locally porphyritic to seriate, mostly massive to weakly foliated biotite granodiorite; ranges from monzogranite to tonalite. Average mode contains 50 percent zoned plagioclase, 25 percent quartz, 13 percent microcline, 11 percent biotite, 1 percent hornblende, and traces muscovite, allanite, zircon, apatite, and sphene; opaque minerals are notably rare (Ross, 1989). Locally consists of a fine-grained, relatively leucocratic, sugary facies. Originally named the Lebec Quartz Monzonite by Crowell (1952). U/Pb zircon age is 88.7±2.1 Ma (W.R. Premo, written commun., 2006)

Kap **Quartz diorite of Antimony Peak (Early Cretaceous)—**Gray, coarse-grained, hypidiomorphic, equigranular, massive to weakly foliated quartz diorite and tonalite. Average mode contains 60 percent plagioclase (An_{38}), 1 percent microcline, 10–20 percent quartz, 13 percent hornblende, 8 percent biotite (commonly altered to chlorite), and traces of epidote, apatite, garnet, and opaque minerals. $^{40}Ar/^{39}Ar$ age on hornblende is 99.8±0.6 Ma (latest Early Cretaceous; Kellogg and Miggins, 2002). $^{87}Sr/^{86}Sr$ of 0.70337 indicates a mafic oceanic source (Ross, 1989). Includes small areas of quartz diorite mapped adjacent to monzogranite of Brush Mountain (Dibblee, 1973; unpub. data, 2001)

Khd **Hornblende diorite (Cretaceous?)—**Dark-gray to black, medium to locally coarse-grained rock composed mostly of hornblende and sodic to calcic plagioclase; locally contains veinlets of epidote (T.W. Dibblee, Jr., unpub. data, 2001)

MzPzg **Granitic and metamorphic rocks (Cretaceous to Paleozoic)—**Mostly Cretaceous granitic rocks, gneiss, and metasedimentary rocks (marble, schist, quartzite); includes some migmatite near and east of San Emigdio Creek

Mafic-ultramafic complex (Middle Jurassic to upper Paleozoic)—Probably related to the Middle Jurassic Coast Range ophiolite (Shervais and others, 2005), although Ross (1989) suggests it may, instead, be related to the Kings River ophiolite of suggested latest Paleozoic or early Mesozoic age (Saleeby and others, 1978); in either case, this complex is regarded as a fragment of Mesozoic or upper Paleozoic oceanic crust

MzPzgb **Gabbro and pyroxenite—**Black gabbro consisting of calcic plagioclase (labradorite-bytownite), pale-green amphibole, clinopyroxene, minor orthopyroxene, and opaque minerals; locally anorthositic. Local layering suggests a cumulate texture. Pyroxenite is composed mostly of partially serpentinized clinopyroxene and orthopyroxene (Ross, 1989)

MzPzqd **Hornblende quartz diorite to tonalite—** Approximately 50 percent plagioclase (andesine to labradorite), 30 percent hornblende, and 20 percent quartz, with minor biotite and opaque minerals (Ross, 1989). Presumably intrusive into gabbro and pyroxenite unit (MzPzgb)

MzPzmd **Metadiabase, amphibolite, gabbro, and pyroxenite—**Fine- to medium-grained, locally coarse-grained, mafic volcanic rock with local diabasic texture; dominantly composed of calcic plagioclase and pale-green hornblende, now essentially an amphibolite. Forms wall rock to gabbroic, dioritic, and tonalitic rocks (Ross, 1989)

Metasedimentary rocks (Mesozoic or Paleozoic)—No fossil evidence for age, but are correlated by Davis and Deubendorfer (1987) to metasedimentary roof pendants in Kings Canyon region that contain Lower Jurassic to Upper Triassic bivalves (Saleeby and others, 1978). However, Ross (1989) suggests these rocks may be as old as Paleozoic

MzPzm **Marble**—Gray or white, medium-grained, strongly foliated, calcitic marble in roof pendants and inliers in granitic rocks

MzPzq **Quartzite**—Gray, fine- to medium-grained, hard, mostly foliated quartzite. Locally contains as much as 10 percent muscovite

MzPzs **Schist, gneiss, calc-silicate hornfels, and quartzite**—Interlayered calcareous, siliceous, and pelitic schist, gneiss, and hornfels (Ross, 1989). Schist and gneiss is dark gray, fine to medium grained, biotitic, and locally migmatitic (Kellogg, 2003)

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