Preliminary Digital Geological Map of the 30' X 60' Santa Ana Quadrangle, southern California, version 2.0

Compiled by D. M. Morton[1]

Version 2.0 digital preparation by Kelly R. Bovard[1] and Rachel M. Alvarez[1] - 2004
Version 1.0 digital preparation by Rachel M. Hauser[1] and Kelly R. Bovard[1] - 1999

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U. S. DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

Table of Contents
(Blue text indicates hyperlink)

Hyperlink index to geologic units

- **Pauba Formation (Pleistocene)**
  - Qps—**Sandstone member**
  - Qpf—**Fanglomerate member**
- Qlh—**La Habra Formation (Pleistocene)**
- **Sandstone and conglomerate of Wildomar area (Pleistocene and late Pliocene)**
  - QTws—**Sandstone unit**
  - QTwc—**Conglomerate unit**
- Qch—**Coyote Hills Formation (Pleistocene)**
- Qsp—**San Pedro Formation (Pleistocene)**
  - Qsp$_4$—**Sandstone**
  - Qsp$_3$—**Siltstone and claystone**
  - Qsp$_2$—**Sandstone**
  - Qsp$_1$—**Siltstone and claystone**
- **San Timoteo beds of Frick (1921) (Pleistocene and Pliocene)**
  - Qstu—**Upper member (Pleistocene)**
    - Qsts—**Conglomeratic sandstone beds**
    - Qstcq—**Quartzite-bearing conglomerate beds**
  - Tstm—**Middle member (Pliocene)**
    - Tstd—**Highly deformed sandstone, pebbly sandstone, and conglomerate**
  - Tstl—**Lower member (Pliocene)**
    - Tstl$_2$—**Claystone, siltstone, and sandstone characterized by ripple lamination**
    - Tstl$_1$—**Arkosic sandstone**
- QTs—**Unnamed late Cenozoic sedimentary rocks in Riverside and Corona areas (early Pleistocene to late Pliocene?)**
- QTt—**Late Cenozoic conglomerate of Temescal area (early Pleistocene to late Pliocene?)**
- QTc—**Conglomeratic sedimentary rocks of Riverside West 7.5' quadrangle (early Pleistocene to late Pliocene?)**
- QTn—**Late Cenozoic sedimentary rocks of Norco area (early Pleistocene to late Pliocene?)**
- Tta—**Temecula Arkose (Pliocene)**
- Tf—**Fernando Formation (Pliocene)**
  - Tfu—**Upper member**
    - Tfuc—**Mostly conglomerate**
  - Tfl—**Lower member**
    - Tflc—**Mostly conglomerate**
- Tn—**Niguel Formation (Pliocene)**
- Tns—**Sandstone of Norco area (Pliocene)**
- Tc—**Capistrano Formation (early Pliocene and Miocene)**
  - Tco—**Oso Member**
  - Tcs—**Siltstone facies**
- Tme—**Mount Eden Formation of Fraser (1931) (early Pliocene and Miocene)**
  - Tmeus—**Upper sandstone member (early Pliocene and Miocene)**
  - Tmem—**Mudrock member (early Pliocene and Miocene)**
  - Tmels—**Lower sandstone member (Miocene)**
  - Tmea—**Arkosic sandstone member (Miocene)**
    - Tmeb—**Monolithologic tonalite boulder breccia**
  - Tmec—**Conglomeratic sandstone member (Miocene)**
- Tch—**Sandstone and conglomerate in southeastern Chino Hills (early Pliocene and Miocene)**
- Tp—**Puente Formation (early Pliocene and Miocene)**
  - Tpsc—**Sycamore Canyon Member (early Pliocene and Miocene)**
    - Tpscc—**Mostly conglomerate**
  - Tpy—**Yorba Member (Miocene)**
    - Tpyc—**Mostly conglomerate**
  - Tpsq—**Soquel Member (Miocene)**
  - Tplv—**La Vida Member (Miocene)**
- Tlm—**Lake Mathews Formation (Miocene)**
- Tcgr—**Rhyolite-clast conglomerate of Lake Mathews area (Miocene?)**
- Tcg—**Conglomerate of Lake Mathews area (Miocene?)**
- Tm—**Monterey Formation (Miocene)**
- Tvsr—**Santa Rosa basalt of Mann (1955) (Miocene)**
- Tvt—**Basalt of Temecula area (Miocene)**
- Tvh—**Basalt of Hogbacks (Miocene)**
- Tvep—**Basalt of Elsinore Peak (Miocene)**
- Tsob—**San Onofre Breccia (middle Miocene)**
- Tt—**Topanga Formation (middle Miocene)**
  - Ttp—**Paulerino Member**
  - Ttlt—**Los Trancos Member**
  - Ttb—**Bommer Member**
- Tvem—**El Modeno Volcanics (middle Miocene)**
  - Tvema—**Andesitic volcanic rocks**
  - Tvemt—**Tuff and tuff breccia**
  - Tvemb—**Basalt**
- **Volcanic intrusive rocks associated with El Modeno Volcanics (middle Miocene)**
  - Ta—**Andesitic intrusive rocks**
  - Td—**Diabase intrusive rocks**

Tvss—**Vaqueros, Sespe, Santiago, and Silverado Formations, undifferentiated (early Miocene, Oligocene, and Paleocene)**
Tv—**Vaqueros Formation (early Miocene, Oligocene, and late Eocene)**
Ts—**Sespe Formation (early Miocene, Oligocene, and late Eocene)**
Tvs—**Vaqueros and Sespe Formations, undifferentiated (early Miocene, Oligocene, and late Eocene)**
Tcga—**Conglomerate of Arlington Mountain (Paleogene?)**
Tep—**Sandstone of Elsinore Peak (Paleogene?)**
Tsa—**Santiago Formation (middle Eocene)**
Tsi—**Silverado Formation (Paleocene)**
Tsicg—**Basal conglomerate**
Tsis—**Serrano clay**
Kwl—**Williams and Ladd Formations, undifferentiated (Late Cretaceous)**—Sandstone, conglomerate, and siltstone
Williams Formation (Late Cretaceous)
Kwps—**Pleasants Sandstone Member**
$Kwps_1$—**Coarse-grained conglomeratic sandstone**
Kwsr—**Schulz Ranch Member**
Kwsru—**Conglomeratic sandstone**
Kwsrl—**Siltstone interfingering with silty conglomerate**
Kwst—**Starr Member**
Kl—**Ladd Formation (Late Cretaceous)**
Klhs—**Holz Shale Member**
Klhsc—**Sandstone and conglomerate**
Klbc—**Baker Canyon Conglomerate Member**
Ktr—**Trabuco Formation (Late Cretaceous)**
Ktru—**Conglomerate**
Ktrl—**Fanglomerate**

Rocks of the Peninsular Ranges batholith

Klct—**Tonalite of Lamb Canyon (Cretaceous)**
Kmeg—**Granite of Mount Eden (Cretaceous)**
Kthgd—**Granodiorite of Tucalota Hills (Cretaceous)**
Klt—**Tonalite near mouth of Laborde Canyon (Cretaceous)**
Khqd—**Hypersthene quartz diorite (Cretaceous)**
Ktcg—**Monzogranite of Tres Cerritos (Cretaceous)**
Lakeview Mountains pluton (Cretaceous)
Klmp—**Pegmatite dikes**
Klmt—**Tonalite**
Klml—**Leucocratic rocks**
Klmm—**Melanocratic rocks**
Klmtg—**Lakeview Mountains tonalite and granodiorite, undifferentiated**
Klmc—**Comb-layered gabbro**
Klmg—**Hypersthene-hornblende gabbro**
Krct—**Tonalite of Reinhardt Canyon pluton (Cretaceous)**
Kbpg—**Monzogranite of Bernasconi Pass (Cretaceous)**
Kbpm—**Migmatitic rocks within monzogranite of Bernasconi Pass**
Ktbh—**Tonalite of Bernasconi Hills (Cretaceous)**
Box Springs plutonic complex (Cretaceous)
Kp—**Granitic pegmatite dikes**
Kbt—**Biotite tonalite**
Kbfg—**Biotite granodiorite and tonalite**
Kbfgi—**Biotite granodiorite and tonalite containing abundant inclusions**
Kbhg—**Heterogeneous porphyritic granodiorite**
$Kbhg_1$—**Layered heterogeneous porphyritic granodiorite**
Kbg—**Porphyritic granodiorite**
Kbft—**Biotite-hornblende tonalite**
Kbht—**Heterogeneous biotite tonalite**
Kbgt—**Heterogeneous granodiorite and tonalite**
Kba—**Amphibolitic gabbro**
Val Verde pluton (Cretaceous)
Kvt—**Val Verde tonalite**
Kvtk—**Potassium feldspar-bearing tonalite**
Kvti—**Inclusion-rich tonalite**
Kgr—**Granophyre (Cretaceous)**
Green Acres gabbroic complex (Cretaceous)
Kgab—**Heterogeneous mixture of olivine, pyroxene, and hornblende gabbros**
Kgao—**Olivine gabbro**
Kgah—**Hornblende-rich gabbro**
Kgat—**Troctolite**
Kgaa—**Anorthositic gabbro**
Kgam—**Metagabbro**
Gavilan ring complex (Cretaceous)
Kgg—**Hypersthene monzogranite**
Kgt—**Massive-textured tonalite**
Kgtf—**Foliated tonalite**
Kgti—**Tonalite containing abundant mesocratic inclusions**
Kgh—**Hypabyssal tonalite**

Kgct—**Coarse-grained biotite-hornblende tonalite**
Kght—**Heterogeneous tonalite**
Kmp—**Micropegmatite granite (Cretaceous)**
Kmpc—**Micropegmatite and granodiorite of Cajalco pluton, undifferentiated (Cretaceous)**
Ktd—**Tonalite dikes of Mount Rubidoux (Cretaceous)**
Kmrg—**Granite of Mount Rubidoux (Cretaceous)**
Krg—**Granite of Riverside area (Cretaceous)**
Kmhg—**Mount Hole Granodiorite (Cretaceous)**
Klst—**La Sierra Tonalite (Cretaceous)**
Katg—**Granodiorite of Arroyo del Toro pluton (Cretaceous)**
Cajalco pluton (Cretaceous)
Kcto—**Tourmalinized monzogranite and granodiorite**
Kcg—**Monzogranite**
Kcgd—**Granodiorite**
Kct—**Tonalite**
Kcgq—**Granodiorite and quartz latite, undifferentiated**
Kcgb—**Granodiorite and gabbro, undifferentiated**
Kgbd—**Gabbroic dikes, Domenigoni Valley area (Cretaceous)**
Domenigoni Valley pluton (Cretaceous)
Kld—**Quartz latite dikes**
Kdvg—**Granodiorite to tonalite of Domenigoni Valley**
Kgbf—**Fine-grained hornblende gabbro, Rail Road Canyon area (Cretaceous)**
Paloma Valley ring complex (Cretaceous)
Kpvgr—**Granophyre**
Kpvp—**Pegmatite dikes of Paloma Valley ring complex**
Kpvg—**Monzogranite to granodiorite**
Kpvt—**Tonalite**
Kpvgb—**Granodiorite and gabbro, undifferentiated**
Ksmg—**Monzogranite of Squaw Mountain (Cretaceous)**
Kts—**Tonalite of Slaughterhouse Canyon (Cretaceous)**

Generic Cretaceous granitic rocks of the Peninsular Ranges batholith

Kp—**Granitic pegmatite dikes (Cretaceous)**
Kg—**Granitic dikes (Cretaceous)**
Kgu—**Granite, undifferentiated (Cretaceous)**
Kmgt—**Monzogranite and tonalite, undifferentiated (Cretaceous)**
Kgd—**Granodiorite, undifferentiated (Cretaceous)**
Kt—**Tonalite, undifferentiated (Cretaceous)**
Ktm—**Tonalite and mafic rocks, undifferentiated (Cretaceous)**
Kqd—**Quartz diorite, undifferentiated (Cretaceous)**
Kdqd—**Diorite and quartz diorite, undifferentiated (Cretaceous)**
Kd—**Diorite, undifferentiated (Cretaceous)**
Kgb—**Gabbro (Cretaceous)**
Khg—**Heterogeneous granitic rocks (Cretaceous)**

End rocks of the Peninsular Ranges batholith

Ks—**Serpentinite (Cretaceous)**
Kc—**Carbonate-silicate rock (Cretaceous)**
Kvsp—**Santiago Peak Volcanics (Cretaceous)**
Kvspi—**Intrusive rocks associated with Santiago Peak Volcanics (Cretaceous)**
Kvem—**Estelle Mountain volcanics of Herzig (1991) (Cretaceous)**
Kvr—**Rhyolite of Estelle Mountains volcanics of Herzig (1991) (Cretaceous)**
Ksv—**Intermixed Estelle Mountain volcanics of Herzig (1991) and Cretaceous(?) sedimentary rocks (Cretaceous?)**
Kvs—**Intermixed Estelle Mountain volcanics of Herzig (1991) and Mesozoic sedimentary rocks (Mesozoic)**
Deformed granitic rocks of Transverse Ranges province (Mesozoic)
Mzmg—**Mylonitic and cataclastic granitic rocks**
Mzdy—**Diorite, Yucaipa area (Mesozoic)**
Jbc—**Bedford Canyon Formation (Jurassic)**
Jbc_1—**Bedford Canyon Formation, Unit 1**
Jbm—**Marble and limestone**
Mzu—**Mesozoic metasedimentary rocks, undifferentiated (Mesozoic)**
Mzg—**Graywacke (Mesozoic)**
Mzq—**Quartz-rich rocks (Mesozoic)**
Mzqg—**Intermixed quartzite and graywacke (Mesozoic)**
Mzgp—**Intermixed graywacke and phyllite (Mesozoic)**
Mzp—**Phyllite (Mesozoic)**
Mzs—**Schist (Mesozoic)**
Mzm—**Marble (Mesozoic)**
Mzi—**Interlayered phyllite (or schist) and quartzite (Mesozoic)**
Mzmn—**Manganese-bearing rocks (Mesozoic)**
Mza—**Amphibolite (Paleozoic?)**
Mzsgn—**Mixed low metamorphic grade and upper amphibolite grade rocks (Mesozoic)**
Mzds—**Metadunite and serpentinite (Mesozoic)**

Mzsm—**Serpentinized metadunite containing magnesite veins**

Mzdx—**Amphibole- and pyroxene-bearing rocks associated with metadunite-serpentinite (Mesozoic)**

Mzdc—**Marble associated with metadunite (Mesozoic)**

Mzgn—**Biotite gneiss and schist (Mesozoic)**

KgMz—**Intermixed Mesozoic schist and Cretaceous granitic rocks (Mesozoic)**

KgPz—**Intermixed Paleozoic(?) schist and Cretaceous granitic rocks (Cretaceous and Paleozoic?)**

Pzu—**Paleozoic(?) rocks, undifferentiated (Paleozoic?)**

m—**Marble body**

Pzs—**Biotite schist (Paleozoic?)**

Pzq—**Impure quartzite (Paleozoic?)**

Pzm—**Marble (Paleozoic?)**

Pzc—**Calc-silicate rocks (Paleozoic?)**

Pzms—**Marble and schist, undifferentiated (Paleozoic?)**

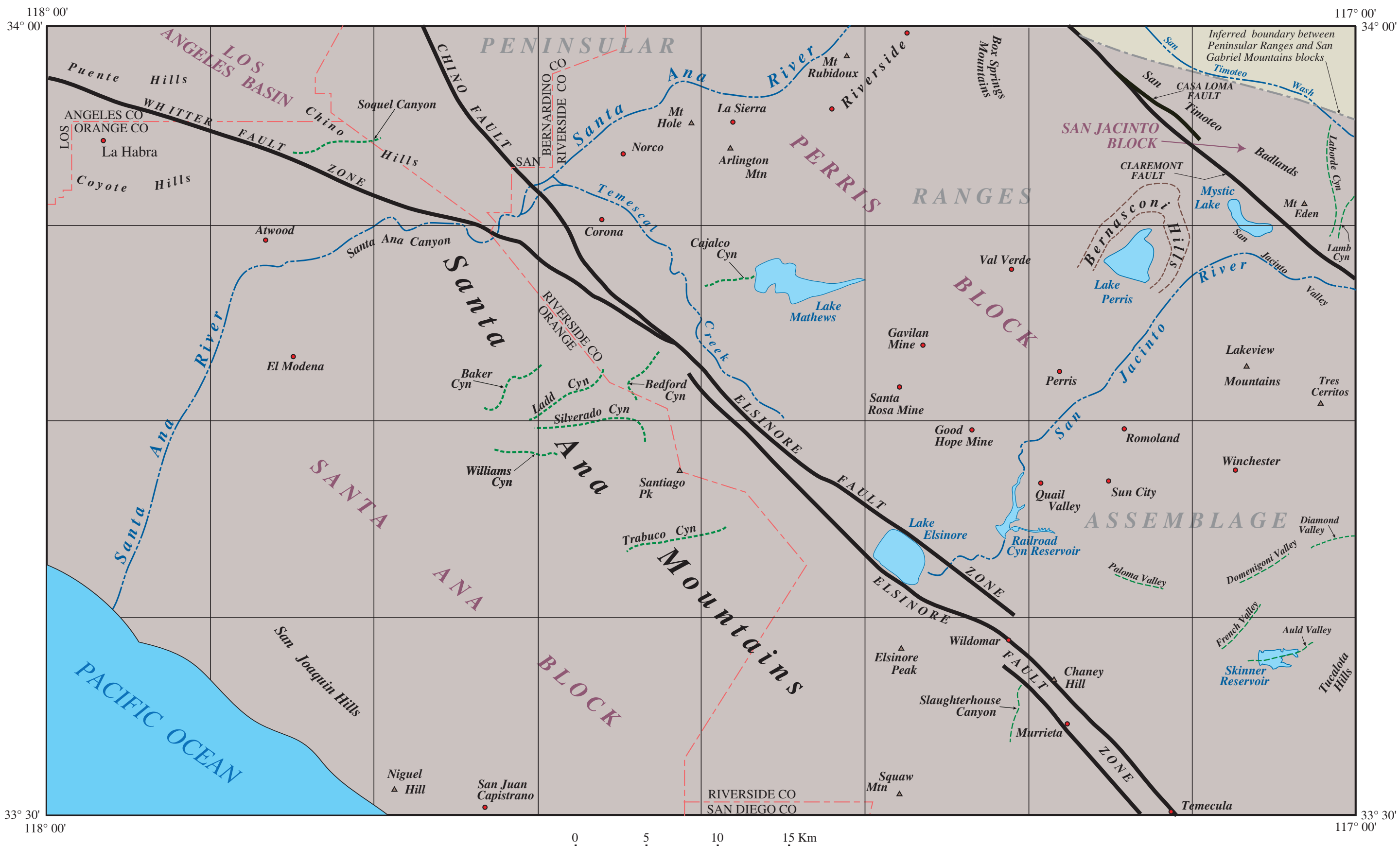


Fig. 1 Map of Santa Ana 30' x 60' quadrangle showing geographic, cultural, and selected geologic and geomorphic features referred to in the text (• town; ▲ mountain peak; ▭ rocks of Peninsular Ranges assemblage; ▭ rocks of the San Gabriel Mountains assemblage). Individual 7.5' quadrangle names given on page *viii*.

La Habra *Source of Mapping:* Yerkes, R.F., 1972; Tan, S.S., 1988; Tan, S.S., and Evans, J.R., 1984 *Digital Preparation by:* Michael L. Dawson, Tim O'Brien, Rachel, M. Alvarez, Kelly R. Bovard	***Yorba Linda*** *Source of Mapping:* Yerkes, R.F., 1972; Tan, S.S., 1988; Tan, S.S., and Miller, R.V., 1984 *Digital Preparation by:* Kelly R. Bovard, Michael L. Dawson, Teddy Bunyapanasarn	***Prado Dam*** *Source of Mapping:* Durham, D.L., and Yerkes, R.F., 1964; Tan, Siang, 1988; McCulloh, T.H., unpublished mapping, 1996, 2000; Morton, D.M., unpublished mapping, 1997 *Digital Preparation by:* Kelly R. Bovard	***Corona North*** *Source of Mapping:* Morton, D.M., and Gray, C.H., Jr., 2002 *Digital Preparation by:* Kelly R. Bovard, Michael L. Dawson	***Riverside West*** *Source of Mapping:* Morton, D.M., and Cox B.F., 2001 *Digital Preparation by:* Rachel M. Alvarez, Van M. Diep	***Riverside East*** *Source of Mapping:* Morton, D.M., and Cox B.F., 2001 *Digital Preparation by:* Michael L. Dawson, Tim O'Brien	***Sunnymead*** *Source of Mapping:* Morton, D.M., and Matti, J.C., 2001 *Digital Preparation by:* Van M. Diep, Ursula Edwards-Howells	***El Casco*** *Source of Mapping:* Matti, J.C., unpublished mapping, 1973-4, 1996-7, 2003; Morton, D.M., unpublished mapping, 1995-7 *Digital Preparation by:* Pam M. Cossette
Anaheim *Source of Mapping:* Morton, P.K., and Miller, R.V., 1981; Eckmann, E.C., and others, 1919; Vedder, J.G., 1975 *Digital Preparation by:* Rachel M. Alvarez	***Orange*** *Source of Mapping:* Tan, S.S., 1995; Eckmann, E.C., and others, 1919 *Digital Preparation by:* Kelly R. Bovard, Teddy Bunyapanasarn	***Black Star Canyon*** *Source of Mapping:* Schoellhamer, J.E., and others, 1981; Morton, P.K., and Miller, R.V., 1981; Tan, S.S., 1990, Morton, D.M., unpublished mapping 1996 *Digital Preparation by:* Kelly R. Bovard, Gary W. Patt, Katherine Koukladas	***Corona South*** *Source of Mapping:* Gray, C.H., Jr., and others, 2002 *Digital Preparation by:* Kelly R. Bovard, Tim O'Brien	***Lake Mathews*** *Source of Mapping:* Morton, D.M., and Weber, F.H., Jr., 2001 *Digital Preparation by:* Van M. Diep, Ursula Edwards-Howells	***Steele Peak*** *Source of Mapping:* Morton, D.M., 2001 *Digital Preparation by:* Rachel M. Alvarez, Van M. Diep	***Perris*** *Source of Mapping:* Morton, D.M., 2003 *Digital Preparation by:* Kelly R. Bovard, Rachel M. Alvarez	***Lakeview*** *Source of Mapping:* Morton, D.M., and Matti, J.C., 2001 *Digital Preparation by:* Rachel M. Alvarez, Pam M. Cossette
Newport Beach *Source of Mapping:* Morton, P.K., and Miller, R.V., 1981; Vedder, J.G., 1975; Eckmann, E.C., and others, 1919; Kern, J.P., 1996; Tan, S.S., undated, unpublished mapping *Digital Preparation by:* Michael L. Dawson, Diane Burns	***Tustin*** *Source of Mapping:* Morton, P.K., and Miller, R.V., 1981; Eckmann, E.C., and others, 1919; Vedder, J.G., 1975; Tan S.S., undated, unpublished mapping *Digital Preparation by:* Rachel M. Alvarez, Diane Burns, Anne G. Garcia	***El Toro*** *Source of Mapping:* Morton, P.K., and Miller, R.V., 1981; Eckmann, E.C., and others, 1919; Tan, S.S., Miller, R.V., and Fife, D.L., 1984 *Digital Preparation by:* Anne G. Garcia	***Santiago Peak*** *Source of Mapping:* Morton, P.K., and Miller, R.V., 1981; Morton, D.M., unpublished mapping, 1997; Tan S.S., undated, unpublished mapping *Digital Preparation by:* Kelly R. Bovard, Michael L. Dawson	***Alberhill*** *Source of Mapping:* Greenwood, R.B., 1992; Weber, F.H. Jr., 1976; Morton, D.M., unpublished mapping, 1996 *Digital Preparation by:* Melinda C. Wright, Diane Burns	***Elsinore*** *Source of Mapping:* Morton D.M., and Weber, F.H., Jr., 2003 *Digital Preparation by:* Rachel M. Alvarez, Diane Burns	***Romoland*** *Source of Mapping:* Morton, D.M., 2003 *Digital Preparation by:* Kelly R. Bovard, Gregory Morton	***Winchester*** *Source of Mapping:* Morton, D.M., 2003 *Digital Preparation by:* Kelly R. Bovard, Gary W. Patt
PACIFIC OCEAN	***Laguna Beach*** *Source of Mapping:* Morton, P.K., and Miller, R.V., 1981; Vedder, J.G., 1975; Tan, S.S., and Edgington, W.J., 1976; Kern, J.P., 1996; Tan, S.S., undated, unpublished *Digital Preparation by:* Kelly R. Bovard; Roland Hall	***San Juan Capistrano*** *Source of Mapping:* Morton, P.K., and Miller, R.V., 1981; Vedder, J.G., 1975; Tan S.S., undated, unpublished mapping *Digital Preparation by:* Kelly R. Bovard, Roland Hall	***Cañada Gobernadora*** *Source of Mapping:* Morton, P.K., and Miller, R.V., 1981; Morton, D.M., unpublished mapping, 1996; Tan S.S., undated, unpublished mapping *Digital Preparation by:* Rachel M. Alvarez, Kelly R. Bovard	***Sitton Peak*** *Source of Mapping:* Morton, P.K., and Miller, R.V., 1981; Eckmann, E.C., and others, 1919; Vedder, J.G., 1975, Tan, S.S., undated, unpublished mapping *Digital Preparation by:* Rachel M. Alvarez, Roland Hall	***Wildomar*** *Source of Mapping:* Kennedy, M.P., 1977; Alvarez, R.M., and Morton, D.M., unpublished mapping, 1996 *Digital Preparation by:* Rachel M. Alvarez, Fernando H. Keller	***Murrieta*** *Source of Mapping:* Kennedy, M.P., and Morton, D.M., 2003 *Digital Preparation by:* Rachel M. Alvarez, Greg Morton	***Bachelor Mountain*** *Source of Mapping:* Morton, D.M., and Kennedy, M.P., 2003 *Digital Preparation by:* Kelly R. Bovard, Diane Burns

Fig. 2 Santa Ana 30' x 60' quadrangle showing constituent 7.5' quadrangles, sources of geologic mapping used in the compilation, and individuals who compiled each of the quadrangles. For complete references refer to page 43.

PRELIMINARY DIGITAL GEOLOGIC MAP OF THE 30' X 60' SANTA ANA QUADRANGLE, VERSION 2.0

Geologic setting

The Santa Ana Quadrangle is in the northern part of the Peninsular Ranges Province as defined by Jahns (1954). The quadrangle is underlain by rocks characteristic of the eastern part of the province except for the northeast corner, which is underlain by basement rocks of the Transverse Ranges Province. A summary of the general geology of the Peninsular Ranges Province is given by Jahns (1954) and a generalized geologic map of this part of the Peninsular Ranges Province is given by Rogers (1965).

Physiographically, the northern part of the Peninsular Ranges Province is divided into three major, fault-bounded blocks, the Santa Ana Mountains, Perris, and San Jacinto Mountains. The Santa Ana Mountains block is the westernmost of the three, extending eastward from the coast to the Elsinore fault zone. Tertiary sedimentary rocks ranging in age from Paleocene through Pliocene underlie most of the western part of the Santa Ana block. East of these Tertiary rocks, in the Santa Ana Mountains, a highly faulted anticlinal structure, is cored by a basement assemblage of Mesozoic metasedimentary and Cretaceous volcanic and batholithic rocks. Overlying this basement is a thick section of primarily upper Cretaceous marine rocks, and Paleogene marine and nonmarine rocks. In the southern part of the Santa Ana Mountains the anticlinal nature of the mountains passes into extensive, nearly horizontal erosional surface that is partly covered by Miocene basalt flows.

North of the Santa Ana Mountains block, the relatively low Puente Hills are underlain principally by folded and faulted Neogene marine sedimentary rocks of the Los Angeles basin (e.g., Yerkes and others, 1965). Up to 8,200 m of middle and late Miocene age rocks are exposed in the Puente Hills, strata equivalent to those from which most of the petroleum of the Los Angeles basin has been produced (Durham and Yerkes, 1964; Yerkes, 1972). Located between the Puente Hills and the Santa Ana Mountains are several anticlinal structures exposing marine Pleistocene strata (Yerkes, 1972).

East of the Santa Ana block and west of the San Jacinto fault zone is the Perris block, a roughly rectangular area of relatively low relief, that has remained relatively stable and undeformed during the Neogene. The Perris block is underlain by lithologically diverse prebatholithic metasedimentary rocks intruded by plutons of the Cretaceous Peninsular Ranges batholith. Supra-batholithic volcanic rocks are preserved in the western part of the block. Several erosional and depositional surfaces are developed on the Perris block (e.g., Dudley, 1936; Woodford and others, 1971) and thin to relatively thick sections of nonmarine, mainly Quaternary sediments discontinuously cover the basement. The older surfaces are of probable Paleogene age and there is suggestive evidence that Paleogene sedimentary deposits once covered at least the western part of the block.

The San Jacinto Mountains block lies east of the Perris block, but only the northern part of it extends into the Santa Ana quadrangle. A thick section of Miocene through Pleistocene nonmarine sedimentary rocks underlies most of the northern San Jacinto Mountains block allowing limited granitic and metamorphic rocks to show through only in the southern part of the quadrangle.

Summary of major structural elements

Faults

Northwest-striking faults of the active San Jacinto (Allen, 1981) and Elsinore (Hull and Nicholson, 1992; Langenkamp and Combs, 1974) fault zones dominate the neotectonic structure of the quadrangle. Both fault zones consist of en echelon faults that have formed extensional basins (Hull, 1990; Kennedy, 1977; Morton and Matti, 1993; Sharp, 1967; Weber, 1976).

The northern part of the San Jacinto structural basin, in the southeast corner of the quadrangle, formed at a right step between the Claremont fault on the east and the Casa Loma fault on the west. The San Jacinto structural basin is the site of rapid subsidence, both tectonic and due to groundwater withdrawal (e.g., Morton, 1977; Proctor, 1962), and contains Quaternary sediments estimated to be about 3000 m thick (Fett, 1968). Both faults are considered to be the source of major earthquakes in the early part of the 20th century.

The Elsinore fault zone consists of a complex assemblage of right-stepping and left-stepping en echelon faults. Movements on these faults have produced a series of extensional basins, which in aggregate result in an elongate, composite, structural trough. The trough includes numerous minor compressional uplifted domains (Hull, 1990; Kennedy, 1977; Weber, 1976), some of which separate the constituent extensional basins. The largest of these extensional basins, the Elsinore structural basin, is largely filled by Elsinore Lake.

Quaternary sedimentary deposits

Quaternary deposits are dominated by nonmarine fluvial deposits except in the coastal area where marine deposits are abundant, and near the Whittier Fault where early Pleistocene marine deposits are exposed in anticlinal structures. Most of the Quaternary nonmarine deposits originated in the drainage basin of the Santa Ana River, which includes most of the area covered by the Santa Ana quadrangle. Because of its unique structural origin, the Santa Jacinto sub-basin is considered separately from rest of the Santa Ana basin in this report.

That part of the Santa Ana River basin (excluding the San Jacinto sub-basin) within the quadrangle consists of three distinct reaches. The broad alluvial valley east of the Puente Hills and northern Santa Ana Mountains forms an upper reach. A central reach is defined by the narrow-floored Santa Ana Canyon, and the broad, complex, alluvial fan below Santa Ana Canyon makes up the third reach.

The valley area upstream from Santa Ana Canyon is flanked by Holocene and Pleistocene alluvial fan deposits with intervening valley and channel fluvial deposits, with a relatively narrow belt of Quaternary alluvium. Holocene and Pleistocene alluvial fan deposits with intervening valley and channel fluvial deposits flank the valley area upstream from Santa Ana Canyon. The third reach is a broad, complex alluvial fan below Santa Ana Canyon. This lower alluvial fan reach is a low-gradient, broad sandy fan that merges with marine deposits near the coast. Differentiation of deposits of the alluvial fan, now largely covered by asphalt, concrete, and yards, is based in part on the soil map of Eckmann and others (1919).

The San Jacinto River sub-basin is a major tributary of the Santa Ana River. The source area of the river is in the San Jacinto Mountains east of the quadrangle and terminates at Lake Elsinore. During most of the Quaternary, the greater part of the sediment derived from the San Jacinto Mountains was deposited in the southern and central part of the San Jacinto structural basin where the rate of sedimentation effectively balances the rate of subsidence. In the northern part of the basin (SE corner of the quadrangle), subsidence rates exceed sedimentation rates resulting in a closed depression periodically filling with water to form ephemeral Mystic Lake. The very low river gradient westward from Mystic Lake forms a broad fluvial plain. The river exits the Perris block though the narrow Railroad Canyon cut into basement rocks. The river terminates at the Elsinore structural basin, a closed depression filled by Lake Elsinore. Several times during the 20th century Lake Elsinore has filled and overflowed northward along the Elsinore fault zone along Temescal Creek to join the Santa Ana River at Corona.

Along the coast of southern California are a large number of Quaternary and late Pliocene marine terrace deposits resulting from tectonic uplift of coastal southern California. Building on earlier work, published and unpublished mapping by Kern and coworkers has led to the recognition of 28 marine terraces that range in age from less than 80,000 to 3,090,000 years and range in elevation from 5-6 m to 408-413 m (Kern, 1996, Kern and others, 1996, and unpublished mapping). In the Santa Ana 30'x60' quadrangle Kern has mapped six of the youngest eight terraces that range in age from 80,000 to 450,000 years and undifferentiated older terrace(s). These terraces, labeled Qop_1, Qop_2, Qop_3, Qop_4, Qop_6, Qop_7 and Qvop on the map, are thin marine deposits on abrasion platforms produced in the intertidal and shallow subtidal zones. Generally the marine deposits are overlain by non-marine sediments.

Quaternary-Tertiary deposits

Deposits spanning the early Quaternary and late Tertiary includes widespread sandstone and conglomerate that underlies the Pauba Formation in the Wildomar area. Also included are a few small, isolated remnants of conglomerate and gravely sand in the Riverside-Norco areas. A thick sequence of Plio-Pleistocene continental deposits underlies the San Timoteo Badlands, at the north end of the San Jacinto block that overlie the Pliocene and Miocene Mount Eden formation.

Neogene deposits

Neogene sedimentary deposits are dominated by thick sections of marine Miocene and Pliocene strata of the Los Angeles basin (e.g., Woodford and others, 1946; Schoellhamer and others, 1981; Yerkes and others, 1965; Durham and Yerkes, 1964; Yerkes, 1972) and the San Joaquin Hills (Morton and Miller, 1981; Vedder 1972). Marine strata extended into the northern end of the Elsinore fault zone south of Corona (Gray,1961) and east onto Cretaceous granitic rocks in the Norco area (Morton and Matti, 1989). Inland, in addition to the Pliocene and Miocene sedimentary rocks of the San Timoteo Badlands, Pliocene strata were deposited in the Temecula area. In the vicinity of Lake Mathews are remnants of additional fluvial and lacustrine Miocene strata.

Initial subsidence of the Los Angeles basin occurred in the middle Miocene, and was followed closely by the main phase of subsidence during the upper Miocene and early Pliocene; basin closing occurred primarily during the Pleistocene (Yerkes and others, 1965). Most of the oil from this prolific basin (over 6 billion barrels estimated ultimate recovery) is from late Miocene and early Pliocene strata (Yerkes and others, 1965). The southern part of the central block and the southeastern part of the northeastern block of the Los Angeles Tertiary basin are included within the Santa Ana quadrangle (Yerkes and others, 1965).

At the south end of the central block, in the San Joaquin Hills area, widespread middle Miocene Topanga Formation* is overlain by the San Onofre Breccia, which is in turn overlain by the Miocene and early Pliocene Capistrano Formation. The San Onofre Breccia was derived from blueschist metamorphic rocks, which Woodford (1925) demonstrated had an offshore provenance. Further north, in the Puente Hills area, the Topanga Formation has a thickness in excess of 480 m (Yerkes, 1972), but is dwarfed by the 4,000+ m aggregate thickness of the overlying Miocene and early Pliocene Puente Formation. The Puente Formation is succeeded by as much as 1,825 m of marine Pliocene Fernando Formation (Yerkes, 1972); a total of over 6,300 m of sedimentary rock deposited in a time period spanning only parts of the Miocene and Pliocene.

* Although the Topanga Formation in the Santa Monica Mountains was elevated by Yerkes and Campbell (1979) to Group rank with three formations, the Topanga Canyon (with four members), Conejo Volcanics, and the Calabasas. The Topanga Formation, with three members in the Santa Ana 30' x 60' quadrangle, has not been correlated with any of units recognized by Yerkes and Campbell. Until the Topanga nomenclature is resolved for areas beyond the Santa Monica Mountains, the existing Topanga Formation nomenclature will be used for the Santa Ana quadrangle.

Basalt volcanism occurred in the Elsinore-Temecula area between 7 and 12 My. Older, more silicic mid-Miocene volcanism occurred in the El Modena and San Joaquin Hills area. Volcanics in the El Modena area are of andesitic basalt and andesitic composition (Yerkes, 1957). In the San Joaquin Hills area are large numbers of andesitic and diabasic intrusives (Vedder, 1975). The El Modeno volcanism is part of widespread mid-Miocene volcanism in the Los Angeles basin area (Shelton, 1955).

Paleogene deposits

Remnants of the extensive package of marine and nonmarine Sespe and Vaqueros Formations of Eocene to early Miocene age are widespread on the west side of the Santa Ana Mountains. Eocene conglomerate and sandstone contains an assemblage of silicic welded tuff, all of which appear to be exotic to southern California (Woodford and others, 1968, 1973). Marine and nonmarine Paleocene deposition occurred during a time of extreme weathering of both pre-Paleocene basement rocks and the Paleocene sedimentary rocks.

Mesozoic rocks

Sedimentary rocks

Upper Cretaceous sedimentary rocks were first recognized in the Santa Ana Mountains by the California Geological Survey before 1865 (Whitney, 1865). These rocks were later included with the Chico Formation of northern California by Packard (in Dickerson, 1914, p. 262-263) where it was subdivided into six units. The upper unit was later determined to be of Paleocene age. In the Santa Ana Mountains, Packard (1916, 1922) named the basal conglomerate unit the Trabuco Formation and grouped the remaining rocks into the Ladd Formation and the Williams Formation. Popenoe (1942), Woodring and Popenoe (1942, 1945), Schoellhamer and others (1954), and Morton and Baird (1976) modified Packard's nomenclature. In current usage the nomenclature of the Upper Cretaceous rocks is in descending order Williams Formation that includes the Pleasants Sandstone Member, Schulz Ranch Member, and the Starr Member; the Ladd Formation that includes the Holz Shale Member and the Baker Canyon Conglomerate Member; and the basal Trabuco Formation.

Peninsular Ranges batholith

The eastern part of the Santa Ana quadrangle is dominated by rocks of the Cretaceous-age Peninsular Ranges batholith. The batholith extends from just north of the Santa Ana quadrangle several hundred miles south (e.g., Larsen, 1948; Silver and Chappel, 1988; Todd and others, 1988). Early descriptions of parts of the batholith in the Santa Ana quadrangle included Dudley (1935), Engel(1959), Miller (1946), and Osborn (1939). The first major synthesis was by Larsen (1948), who conducted field work within the batholith discontinuously from 1906 to 1938. More recent investigations included within the Santa Ana quadrangle have largely centered on topical investigations (e.g., Baird and others, 1974, 1979; Baird and Miesch, 1984; Gromet and Silver, 1987; Krummenacher and others, 1975; Premo and others, 1998; Silver and Chappel, 1988) and investigations of individual plutons (Miesch and Morton, 1977; Morton, 1969; Morton and Baird, 1976; Morton and others, 1969).

The Peninsular Ranges batholith has been variously subdivided into longitudinal zones (Baird and Miesch, 1984; Baird and others, 1974, 1979; Silver and Chappel, 1988, Gromet and Silver, 1987; and Todd and others, 1988). Based upon initial strontium and lithologic criteria. Morton and Kistler (1997) subdivided the northern part of the batholith into four major zones; the western two subdivisions are present in the Santa Ana quadrangle. Of these two, a western zone consists of high-level (shallow) plutons and an eastern zone consists of moderate to deeply exposed plutons. Plutons within the western zone typically consist of massive textured rock containing equant shaped mafic inclusions, having sharp contacts with their wall rocks, and have sparse or are devoid of foliation and/or layering. Pressures of crystallization range from 2-3 Kb (Smith and others, 1991), and emplacement ages range from 126-110 Ma (Premo and others, 1998). The eastern zone plutons have well-developed planar fabric (foliation) containing discoidal to pancake-shaped mafic inclusions, and lack sharp contacts with wall rocks. Pressures of crystallization range from 4.5 - 6.5 Kb (Smith and others, 1991) and emplacement ages range from 98 to 106 Ma (Premo and others, 1998). Emplacement ages appear to systematically decrease in age from west to east across both zones (Premo and others, 1998). U/Pb ages from zircons are considered to be emplacement ages. U/Pb ages for a selected number of granitic rocks have recently been determined for rocks in the Santa Ana quadrangle (Premo and others, 1998).

An extensive strontium and rubidium isotopic database of R.W. Kistler shows the granitic rocks in the western zone have initial Sr values of 0.7036 to 0.7045 indicating only moderate continental crust component (Morton and Kistler, 1997; Kistler, and others, 2003). The rocks of the zone to the east generally have initial Sr values of 0.7045 to 0.7055 indicating a larger continental crust component. Rocks in the eastern two zones have yet larger initial Sr, 0.706-0.708 values. Variation in initial Sm values is in accord with the Sr ratios (Premo and others, 1998).

The description of discrete and/or recognizable batholith units is in order of their known or inferred age of emplacement - youngest to oldest. Generalized (generic) units are non-discrete pluton forming units, are time transgressive, and are here treated as undifferentiated or undivided units.

Isotopic ages referred to in the rock unit descriptions are from W.R Premo and L.W. Snee (Premo and others, 1998 and per. commun., 1999). Pb/U ages are interpreted as emplacement age of the granitic rock and the $^{40}Ar/^{39}Ar$ ages of hornblende, biotite, and potassium feldspar progressive cooling ages.

Volcanic and hypabyssal rocks

A large area of the Santa Ana Mountains and the western part of the adjacent Perris block are underlain by an assemblage of Cretaceous age volcanic and shallow intrusive rocks. Considerable amounts of these volcanic rocks include volcaniclastic and sedimentary rocks. The rocks in the Santa Ana Mountains termed the Santiago Peak volcanics rest uncomformably on the Bedford Canyon and related rocks, and range from basaltic andesite to rhyolite. Included in the Santa Ana block volcanic assemblage is a small serpentine body and associated carbonate-silicate rock. Volcanic rocks of the Perris block are overall more silicic than those of the Santa Ana Mountains block.

Descriptions of these volcanic rocks suggested they had been subject to low grade metamorphism. Herzig (1991) has made a recent and thorough examination of the Santiago Peak volcanics. Zircon ages from these volcanic rocks indicate they are coeval with granitic rocks of the Peninsular Ranges batholith (Anderson, 1991). Herzig (1991) linked mineral assemblages, previously considered being of regional low grade metamorphism, to hydrothermal activity associated with volcanism. Sedimentary rocks interbedded with volcanic rocks correlated with the Santiago Peak volcanics in San Diego County have yielded Late Jurassic fossils (Fife and others, 1967).

Metamorphic rocks

There is a long and convoluted history to the terminology of the metamorphic rocks in the Santa Ana quadrangle. In the Santa Ana Mountains, the name "Santa Ana" was used by Smith (1898) for limestone within the prebatholithic sedimentary rocks of very low metamorphic grade and later used "Santa Ana Slates" (Smith, 1914), a name retained by Engel (1959). Merrill (1914) referred to the metamorphic rocks as the "Santa Ana metamorphic strata". Larsen (1948) used the name Bedford Canyon Formation for exposures of these rocks in Bedford Canyon in the northern Santa Ana Mountains. Smith on the basis of *Rhynchonella sp* assigned a Triassic age to the limestone. Later fossil collections from the northern Santa Ana Mountains were concluded to be of Jurassic age (Imlay, 1963; 1964; 1980; Silberling and others, 1961). The rocks in the area of Bedford Canyon generally appear as well indurated sedimentary rocks with a variety of sedimentary structures such as ripple marks and cross-bedding.

In the northern Perris block the prebatholithic rocks were termed the Elsinore metamorphics by Dudley (1935). Larsen (1948) extended the Bedford Canyon Formation south and east from the Santa Ana Mountains to the Perris block in the vicinity of Domenigoni and Auld Valleys. Larsen noted differences in the lithology of the rocks of the Perris block from those of the Santa Ana Mountains. East of Domenigoni Valley Larsen termed the metamorphic rocks "Paleozoic schists and quartzites". The age designation was based upon a report of a Mississippian coral (Webb, 1939) that was characterized by Larsen (1948, p. 16) as being from schist "which contain limestone beds from which Webb (1939) has described Mississippian fossils." Schwarcz (1969) has clearly shown the single coral specimen found as "float", could not have originated where it was found.

In the Winchester area Schwarcz (1969) retained Larsen's usage of the Bedford Canyon, while noting the lithologic difference with the Bedford Canyon formation in the Santa Ana Mountains. Schwarcz (1969) renamed the "Paleozoic schists and quartzites" the French Valley formation after exposures in the area of French Valley. Schwarcz considered the French Valley Formation to be of Mesozoic age stating "The French valley Formation interfingers with the Bedford Canyon Formation at their contact" (Schwarcz, 1969, p. 22). Schwarcz described within his French Valley formation a remarkable metamorphic gradient increasing from low grade to high amphibolite grade over a distance of about three kilometers. Schwarcz interpreted the metamorphic facies to be a low pressure, high temperature Buchan type. Later Morton (1993) divided the French Valley formation of Schwarcz into a western Mesozoic age assemblage and an eastern assemblage of probable Paleozoic age. The western assemblage Morton included Larsen's Bedford Canyon formation. The eastern package, based only on lithologic similarities was considered probably to be correlative with Paleozoic rocks to the south and east in the Peninsular Ranges. Morton (1993) concluded the Paleozoic(?) and Mesozoic rocks had been structurally juxtaposed along a major suture. At the time of juxtapositioning the Paleozoic(?) rocks were at an elevated temperature (upper amphibolite facies) and the Mesozoic rocks at much lower temperatures. Juxtapositioning resulted in thermal metamorphism of the adjacent Mesozoic rocks described by Schwarcz (1969).

In 1966 M.A. Murphy collected some poorly preserved and deformed fossils from a calc-silicate outcrop within the Mesozoic rocks east of Sun City, Romoland quadrangle. Included were large crinoid stems and pelycepods. Murphy sent a latex impression of a pelycepod to E.C. Allison, who in turn sent the impression to G.E.G. Westermann for identification. Westermann (per. commun. to E.C. Allison dated 10/16/68) stated "This is a poorly preserved, obviously distorted specimen which cannot be identified at the generic or specific level. I dare only the following:

"Right valve of the Bivalvia family Aviculepectinidae; possible ??

Claraia ex. gr. C. *himaica* (Bittner) and C.(?) *occidentalis* (Whiteaves) which would be late Lower Triassic. However, almost any age within the Triassic or even Permian is possible."

Original sedimentary features are preserved within strata in the Bedford Canyon Formation in the northern Santa Ana Mountains (e.g., Gray, 1961; Schoellhamer and others, 1981). South and east from Bedford Canyon original sedimentary structures are progressively obliterated by structural transposition. Just east of the Elsinore fault zone few original sedimentary bedding (S_0) remain. In the vicinity of Railroad Lake essentially all bedding is structurally transposed into a 1st generation mechanical layering, S_1. In the western part of Domenigoni Valley area the 1st generation layering has been folded and progressively eastward transposed into 2nd generation mechanical layering, S_2. Further east towards the suture the 2nd generation layering is progressively transposed into a 3rd generation layering, S_3, which apparently was produced by deformation accompanying the suturing. In the area of the suture only S_3 is present. East of the suture S_3 transposes an older compositional layering of the Paleozoic(?) rocks. S_3 diminishes in intensity eastward with only the older gneissic layering at the eastern edge of the Santa Ana quadrangle.

Here the name Bedford Canyon Formation is restricted to the vicinity of Bedford Canyon in the northern Santa Ana Mountains. Pre-batholithic rocks else where are not assigned formal name but are given designations based upon their principal composition.

Notes regarding features and conventions used in the map and database of the Santa Ana 30' X 60' Quadrangle

1. A question mark (?) attached to a unit label in the database indicates that the identity of the map unit at that particular place is uncertain.

2. Units that are submerged below the present day water level of Lake Perris are designated by a unit label that is followed by the letter (s) in parentheses.

3. Subscripts used for relative age subdivisions of some Quaternary deposits designate decreasing age by increasing numbers, e.g. Qyf_4 is younger than Qyf_3. Where known, grain size is indicated by a subscripted letter or letters following unit symbols as follows: b, boulder; g, gravel; a, arenaceous; s, silt, c, clay; e.g. Qyf_a is a predominately sandy young alluvial fan deposit. Multiple letters are used for more specific identification or for mixed units, e.g., Qyf_{sa} is a silty sand. In some cases, mixed units are indicated by a compound symbol; e.g., Qyf_{2sc}.

4. Marine deposits are in part overlain by local, mostly alluvial fan, deposits and are labeled Qopf. Letters designating grain size are attached to the Qopf label.

5. The Ma following U/Pb ages have attached subscripts; Ma_{id} for isotope dilution analyses, and Ma_{ip} for ion probe analyses.

6. Where units have limited extent or specific occurrences of units are geologically important, the 7.5' quadrangle(s) in which they are found are given in the unit descriptions.

DESCRIPTION OF MAP UNITS

Qaf **Artificial fill (late Holocene)**-Deposits of fill resulting from human construction, mining, or quarrying activities; includes compacted engineered and noncompacted nonengineered fill. Most large deposits are mapped, but in some areas, no deposits are shown

Qw **Wash deposits (late Holocene)**-Unconsolidated bouldery to sandy alluvium of active and recently active washes. Includes:

Qw_3 **Wash deposits (late Holocene)**-Unconsolidated bouldery to sandy alluvium of active and recently active washes. Young part of Qw

Qf **Alluvial fan deposits (late Holocene)**-Active and recently active alluvial fans. Consists of unconsolidated, bouldery, cobbley, gravelly, sandy, or silty alluvial fan deposits, and headward channel parts of alluvial fans. Trunk drainages and proximal parts of fans contain a greater percentage of coarse-grained sediment than distal parts. Includes:

Qf_1 **Alluvial fan deposits, Unit 1 (late Holocene)**-Recently active alluvial fans. Consists of unconsolidated, bouldery, cobbley, gravelly, sandy, or silty alluvial fan deposits, and headward channel parts of alluvial fans. Trunk drainages and proximal parts of fans contain greater percentage of coarse-grained sediment than distal parts. Old part of Qf

Qa **Axial channel deposits (late Holocene)**-Active and recently active fluvial deposits along canyon floors. Consists of unconsolidated sandy, silty, or clay-bearing alluvium. Does not include alluvial fan deposits at distal ends of channels

Qv **Alluvial valley deposits (late Holocene)**-Active and recently active fluvial deposits along valley floors. Consists of unconsolidated sandy, silty, or clay-bearing alluvium

Qsw **Slope wash deposits (late Holocene)**-Unconsolidated sand, cobbles, and pebbles deposited by water not confined to channels. Some deposits are angular, multi-mineralogic sand derived from in-place weathering of granitic rocks, but many include larger clasts transported by torrential storms or clasts spalled from up-slope outcrops of bedrock

Qc **Colluvial deposits (late Holocene)**-Active and recently active sand and silt colluvial deposits on hillsides and at the base of slopes; in some places includes rubble and coarse debris not normally deposited by colluvial processes. Unconsolidated

Qls **Landslide deposits (late Holocene)**-Highly fragmented to largely coherent active landslides. Unconsolidated to consolidated. Most mapped landslides contain scarp area as well as slide deposit. Many originated in Pleistocene and all or part was reactivated during Holocene

Qe **Eolian deposits (late Holocene)**-Unconsolidated, active or recently active sand dune deposits, along coast (Newport Beach 7.5' quadrangle)

Qm **Marine deposits (late Holocene)**-Unconsolidated, active or recently active sandy beach deposits along coast

Qes **Estuarine deposits (late Holocene)**-Unconsolidated, active, sandy, silty, and clayey organic-rich estuarine deposits (Newport Beach 7.5' quadrangle)

Ql **Lacustrine deposits (late Holocene)**-Dominantly gray, clayey, silty, and fine-grained sandy lacustrine deposits. Underlies the floor of the closed pull-apart depression in the Elsinore Fault Zone partly filled by Lake Elsinore (Alberhill and Elsinore 7.5' quadrangles)

Qlv **Lacustrine and fluvial deposits (late Holocene)**-Dominantly gray, clayey, silty, and fine-grained sandy lacustrine deposits interbedded with fluvial deposits. Underlies the floor of the closed pull-apart depression in the San Jacinto Fault Zone partly filled by ephemeral Mystic Lake (Lakeview and El Casco 7.5' quadrangles)

Qyw **Young wash deposits (Holocene and latest Pleistocene)**-Unconsolidated bouldery to sandy alluvium of active and recently active washes

Qyf **Young alluvial fan deposits (Holocene and latest Pleistocene)**-Unconsolidated deposits of alluvial fans and headward drainages of fans. Consists predominately of gravel, sand, and silt. Trunk drainages and proximal parts of fans contain higher percentage of coarse-grained sediment than distal parts. Includes:

Qyf_7 **Young alluvial fan deposits, Unit 7 (late Holocene and latest Pleistocene)**-Unconsolidated alluvial fan deposits. Consists of gravel, sand, and silt; youngest part of Qyf. In part distinguished on basis of relative terrace levels

Qyf_6 **Young alluvial fan deposits, Unit 6 (late Holocene and latest Pleistocene)**-Unconsolidated alluvial fan deposits. Consists of gravel, sand, and silt; young part of Qyf. In part distinguished on basis of relative terrace levels

Qyf_5 **Young alluvial fan deposits, Unit 5 (late Holocene and latest Pleistocene)**-Unconsolidated alluvial fan deposits. Consists of gravel, sand, and silt; intermediate to young part of Qyf. In part distinguished on basis of relative terrace levels

Qyf_4 **Young alluvial fan deposits, Unit 4 (late Holocene and latest Pleistocene)**-Unconsolidated alluvial fan deposits.

Consists of gravel, sand, and silt; youngest part of Qyf. In part distinguished on basis of relative terrace levels

Qyf_3 **Young alluvial fan deposits, Unit 3 (late and middle Holocene)**-Unconsolidated alluvial fan deposits. Consists of gravel, sand, and silt; young part of Qyf. In part distinguished on basis of relative terrace levels

Qyf_2 **Young alluvial fan deposits, Unit 2 (early Holocene)**-Unconsolidated alluvial fan deposits. Consists of gravel, sand, and silt; intermediate part of Qyf. In part distinguished on basis of relative terrace levels

Qyf_1 **Young alluvial fan deposits, Unit 1 (early Holocene and late Pleistocene)**-Unconsolidated alluvial fan deposits. Consists of gravel, sand, and silt; old part of Qyf. In part distinguished on basis of relative terrace levels

Qya **Young axial channel deposits (Holocene and latest Pleistocene)**-Fluvial deposits along canyon floors. Consists of unconsolidated sand, silt, and clay-bearing alluvium. Includes:

Qya_6 **Young axial channel deposits, Unit 6**-Fluvial deposits along canyon floors. Consists of unconsolidated sand, silt, and clay-bearing alluvium. Intermediate to young part of Qya. In part distinguished on basis of relative terrace levels

Qya_5 **Young axial channel deposits, Unit 5**-Fluvial deposits along canyon floors. Consists of unconsolidated sand, silt, and clay-bearing alluvium. Intermediate to young part of Qya. In part distinguished on basis of relative terrace levels

Qya_4 **Young axial channel deposits, Unit 4**-Fluvial deposits along canyon floors. Consists of unconsolidated sand, silt, and clay-bearing alluvium. Intermediate part of Qya. In part distinguished on basis of relative terrace levels

Qya_3 **Young axial channel deposits, Unit 3**-Fluvial deposits along canyon floors. Consists of unconsolidated sand, silt, and clay-bearing alluvium. Intermediate part of Qya. In part distinguished on basis of relative terrace levels

Qyv **Young alluvial valley deposits (Holocene and late Pleistocene)**-Fluvial deposits along valley floors. Consists of unconsolidated sand, silt, and clay-bearing alluvium. Includes:

Qyv_1 **Young alluvial valley deposits, Unit 1 (early Holocene and late Pleistocene)**-Fluvial deposits along valley floors west of Casa Loma Fault. Consists of unconsolidated sand, silt, and clay-bearing alluvium

Qyc **Young colluvial deposits (Holocene and late Pleistocene)**-Sand and silt colluvial deposits on hillsides and at the base of slopes; inactive. In some places, may include rubble and coarse debris not normally deposited by colluvial processes

Qyls **Young landslide deposits (Holocene and latest Pleistocene)**-Highly fragmented to largely coherent landslide deposits. Unconsolidated to consolidated. Most mapped landslides contain scarp area as well as slide deposit. Many landslides in part reactivated during late Holocene

Qye **Young eolian deposits (Holocene and latest Pleistocene)**-Sand dune deposits, unconsolidated, inactive (Corona North 7.5' quadrangle)

Qypt **Young peat deposits (Holocene)**-Deposits of low density peat and peaty sediments, (Newport Beach 7.5' quadrangle)

Qow **Old alluvial wash deposits (late to middle Pleistocene)**-Unconsolidated to moderately indurated, gravel and sand alluvial wash deposits

Qof **Old alluvial fan deposits (late to middle Pleistocene)**-Reddish brown, gravel and sand alluvial fan deposits; indurated, commonly slightly dissected. In places includes thin alluvial fan deposits of Holocene age. Includes:

Qofv **Old alluvial fan deposits and young alluvial valley deposits (Holocene and late to middle Pleistocene)**-Reddish-brown, gravel and sand alluvial fan deposits; moderately indurated. Includes discontinuous younger alluvial valley deposits locally

Qof_3 **Old alluvial fan deposits, Unit 3 (late to middle Pleistocene)**-Reddish brown, gravel and sand alluvial fan deposits; indurated, commonly slightly dissected. Young part of Qof. In places includes thin alluvial fan deposits of Holocene age

Qof_1 **Old alluvial fan deposits, Unit 1 (late to middle Pleistocene)**-Reddish brown, gravel and sand alluvial fan deposits; indurated, commonly slightly dissected. Old part of Qof. In places includes thin alluvial fan deposits of Holocene age

Qoa **Old axial channel deposits (late to middle Pleistocene)**-Fluvial sediments deposited on canyon floors. Consists of moderately indurated, commonly slightly dissected gravel, sand, silt, and clay-bearing alluvium. Locally capped by thin, discontinuous alluvial deposits of Holocene age. Includes:

Qoa_7 **Old axial channel deposits, Unit 7 (late Pleistocene)**-Fluvial sediments deposited on canyon floors. Consists of moderately indurated, slightly dissected gravel, sand, silt, and clay-bearing alluvium. Youngest subdivision of Qoa. Correlates with Qoa_7 unit in the Oceanside 30' x 60' quadrangle to the south of the Santa Ana 30' x 60 quadrangle

Qoa_3 **Old axial channel deposits, Unit 3 (middle Pleistocene)**-Fluvial sediments deposited on canyon floors. Consists of moderately indurated, slightly dissected gravel, sand, silt, and clay-bearing alluvium. Intermediate part of Qoa. Correlates with Qoa_3 unit in the San Bernardino 30' x 60' quadrangle to the north of the Santa Ana 30' x 60 quadrangle

Qoa_1 **Old axial channel deposits, Unit 1 (middle Pleistocene)**-Fluvial sediments deposited on canyon floors. Consists of moderately indurated, slightly dissected gravel, sand, silt, and clay-bearing alluvium. Differs from Qoa in degree of dissection and in places by relative terrace levels. Some deposits include thin alluvial deposits of Holocene age. Older part of Qoa

Qov **Old alluvial valley deposits (late to middle Pleistocene)**-Fluvial deposits along valley floors. Consists of moderately indurated, commonly slightly dissected sand, silt, and clay-bearing alluvium. Some deposits include thin alluvial deposits of Holocene age

Qoc **Old colluvial deposits (late to middle Pleistocene)**-Colluvial deposits on hillsides and at the base of slopes. Ranges from rubble to sand. Unconsolidated to slightly indurated

Qols **Old landslide deposits (late to middle Pleistocene)**-Mostly fragmented rock debris. Landslide morphology moderately to greatly modified

Qop **Old paralic deposits, undivided (late to middle Pleistocene)**-Paralic deposits consisting of poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of silt, sand and cobbles. The paralic deposits extend from the Newport area south to the quadrangle boundary. These deposits rest on the now emergent wave cut abrasion platforms preserved by regional uplift. Where more than one number is shown (e.g. Qop_{2-4}) those deposits are undivided. Qop_5 is not known to occur in the Santa Ana quadrangle. Includes:

Qop_7 **Old paralic deposits, Unit 7**-Paralic deposits consisting of poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of silt, sand and cobbles. These deposits rest on the 9-11 m Bird Rock terrace. Age about 80,000 years

Qop_6 **Old paralic deposits, Unit 6**-Paralic deposits consisting of poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of silt, sand and cobbles. These deposits rest on the 22-23 m Nestor terrace. Age about 120,000 years

Qop_4 **Old paralic deposits, Unit 4**-Paralic deposits consisting of poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of silt, sand and cobbles. These deposits rest on the 34-37 m Stuart Mesa terrace. Age about 200,000-300,000 years

Qop_3 **Old paralic deposits, Unit 3**-Paralic deposits consisting of poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of silt, sand and cobbles. These deposits rest on the 45-46 m Guy Fleming terrace. 320,000-340,000 years

Qop_2 **Old paralic deposits, Unit 2**-Paralic deposits consisting of poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of silt, sand and cobbles. These deposits rest on the 55 m Parry Grove terrace. Age about 413,000 years

Qop_1 **Old paralic deposits, Unit 1**-Paralic deposits consisting of poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of silt, sand and cobbles. These deposits rest on the 61-63 m Golf Course terrace. Age about 450,000 years

Qop_{2-6} **Old paralic deposits, Units 2-6, undivided**-Paralic deposits consisting of poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of silt, sand and cobbles. These deposits rest on the 22-55m terraces

Qop_{3-6} **Old paralic deposits, Units 3-6, undivided**-Paralic deposits consisting of poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of silt, sand and cobbles. These deposits rest on the 22-46 m terraces

Qopf **Old paralic deposits (late to middle Pleistocene) overlain by alluvial fan deposits**-Areas where old paralic deposits are capped by extensive but thin, discontinuous, younger, locally derived, sandy alluvial fan deposits

Qos **Old surficial deposits, undivided (Holocene and late Pleistocene)**-Reddish-brown alluvial deposits not assigned to any specific surficial materials unit of this age. Chiefly sand- to boulder-sized clasts that are moderately consolidated and slightly to moderately dissected. May include alluvial-fan, colluvial, or valley-filling deposits

Qvof **Very old alluvial fan deposits (middle to early Pleistocene)**-Mostly well-dissected, well-indurated, reddish-brown alluvial fan deposits. Grain size chiefly sand and gravel. Includes:

$Qvof_3$ **Very old alluvial fan deposits, Unit 3 (early Pleistocene)**-Moderately well-dissected, well-indurated, reddish-brown alluvial-fan deposits. Grain size chiefly sand and gravel. Represents young part of Qvof

$Qvof_1$ **Very old alluvial fan deposits, Unit 1 (early Pleistocene)**-Mostly well-dissected, well indurated, reddish-brown alluvial fan deposits. Grain size chiefly sand and gravel. Represents old part of Qvof

Qvoa **Very old axial channel deposits (middle to early Pleistocene)**-Fluvial sediments deposited on canyon floors. Consists of moderately to well-indurated, reddish-brown, mostly very dissected gravel, sand, silt, and clay-bearing alluvium. In places, includes thin, discontinuous alluvial deposits of Holocene age. Deposits on Gavilan-Lakeview surface in Lakeview Mountains are moderately well-indurated light gray gravelly sand and contain abundant biotite. Deposits in Quail Valley and Railroad Canyon area contain rounded cobbles. Includes:

$Qvoa_5$ **Very old axial channel deposits, Unit 5 (middle to early Pleistocene)**-Fluvial sediments deposited on canyon floors. Consists of moderately to well-indurated, reddish-brown, mostly very dissected gravel, sand, silt, and clay-bearing alluvium. Younger part of Qvoa

$Qvoa_4$ **Very old axial channel deposits, Unit 4 (middle to early Pleistocene)**- Fluvial sediments deposited on canyon floors. Consists of moderately to well-indurated, reddish-brown, mostly very dissected gravel, sand, silt, and clay-bearing alluvium. Younger part of Qvoa

$Qvoa_3$ **Very old axial channel deposits, Unit 3 (middle to early Pleistocene)**-Fluvial sediments deposited on canyon floors. Consists of moderately to well-indurated, reddish-brown, mostly very dissected gravel, sand, silt, and clay-bearing alluvium. Intermediate part of Qvoa

$Qvoa_2$ **Very old axial channel deposits, Unit 2 (early Pleistocene)**-Fluvial sediments deposited on canyon floors. Consists of moderately to well-indurated, reddish-brown, mostly very dissected gravel, sand, silt, and clay-bearing alluvium. In places, includes thin, discontinuous alluvial deposits of Holocene age. Represents intermediate age part of Qvoa

$Qvoa_1$ **Very old axial channel deposits, Unit 1 (early Pleistocene)**-Fluvial sediments deposited on canyon floors. Consists of moderately to well-indurated, reddish-brown, mostly very dissected gravel, sand, silt, and clay-bearing alluvium. In places, includes thin, discontinuous alluvial deposits of Holocene age. Represents old part of Qvoa

Qvov **Very old alluvial valley deposits (late to middle Pleistocene)**-Fluvial deposits flanking valley floors or perched erosional remnants. Consists of well-indurated, moderately dissected sand, silt, and clay-bearing alluvium. Some deposits may include thin alluvial deposits of Holocene age

Qvols **Very old landslide deposits (middle to early Pleistocene)**-Chiefly coherent landslide debris having highly modified landslide morphology. Inactive and unlikely to reactivate under current climatic and seismic conditions

Qvop **Very old paralic deposits, undivided (middle to early Pleistocene)**-Paralic deposits consisting of Mostly poorly sorted, moderately permeable, reddish-brown, interfingered strandline, beach, estuarine and colluvial deposits composed of silt, sand and cobbles. These deposits rest on the now emergent wave cut abrasion platforms preserved by regional uplift

Qvor **Very old regolith (Pleistocene)**-Developed on both in situ and transported material. Deeply weathered rock and soil regolith in the San Timoteo Badlands (El Casco 7.5' quadrangle). Reddish-brown, highly dissected

Pauba Formation (Pleistocene)-Siltstone, sandstone, and conglomerate (Murrieta, Wildomar, and Bachelor Mountain 7.5' quadrangle). Named by Mann (1955) for exposures in Rancho Pauba area about 3.2 km southeast of Temecula. Vertebrate fauna from Pauba Formation are of late Irvingtonian and early Rancholabrean ages (Reynolds and Reynolds, 1990a; 1990b). Includes two informal members:

Qps **Sandstone member**-Brown, moderately well-indurated, cross-bedded sandstone containing sparse cobble- to boulder-conglomerate beds

Qpf **Fanglomerate member**-Grayish-brown, well-indurated, poorly sorted fanglomerate and mudstone

Qlh **La Habra Formation (Pleistocene)**-Nonmarine mudstone, fluvial sandstone, and conglomerate. First described by Eckis (1934) for deposits in the La Habra area. Durham and Yerkes (1959) formalized name. Occurs in the La Habra and Yorba Linda 7.5' quadrangles. Upper two-thirds of formation is chiefly friable, gray to brown, sandy to pebbly mudstone. Lower part of formation is gray to brown, massive to crudely bedded, coarse-grained to pebbly sandstone. Unit has basal conglomerate consisting of yellowish-tan to brownish-gray massive or very crudely bedded, pebbly sandstone and conglomerate, which fills channels cut in underlying strata. Conglomerate has about 15 degree discordance with underlying beds. Locally contains clasts of white siltstone derived from Puente Formation Mudstone in upper part locally contains thin marly beds, which have freshwater snails, ostracods, and plant remains. Formation ranges from 60 to 300 m thick

Sandstone and conglomerate of Wildomar area (Pleistocene and Pliocene)-Unnamed sandstone and conglomerate unit unconformably overlain by the Pauba Formation (Kennedy, 1977) (Murrieta and Wildomar 7.5' quadrangles). Lower part yields vertebrate fauna of late Blancan age, 2 to 3 Ma; upper part yields fauna of Irvingtonian-age, less than 0.85 Ma (Reynolds and Reynolds, 1990a, 1990b; Reynolds and others, 1990). At Chaney Hill in Murrieta area, unit contains 0.7 Ma Bishop ash (Merriam and Bishoff, 1975). Estimated maximum thickness is 75 m. Includes informal subdivisions:

QTws **Sandstone unit**-Primarily friable, pale yellowish-green, medium-grained, caliche-rich sandstone

QTwc **Conglomerate unit**-Primarily cobble-and-boulder conglomerate. Conglomerate clasts are locally derived

Qch **Coyote Hills Formation (Pleistocene)**-Chiefly nonmarine mudstone and pebbly sandstone (La Habra 7.5' quadrangle), containing some intertidal (?) deposits in western part. Mudstone is grayish, massive, and friable; sandstone is medium to coarse grained or pebbly, and thickly bedded. First described and named by Yerkes (1972) for deposits in Coyote Hills south of Puente Hills. At its type locality unit is about 220 m thick; upper 150 m is 60 percent mudstone and 40 percent sandstone, lower 65 m is pebbly sandstone (Yerkes, 1972). Coyote Hills Formation unconformably rests on San Pedro Formation

Qsp_4, Qsp_3, Qsp_2, Qsp_1, Qsp **San Pedro Formation (Pleistocene)**-Shallow marine sandstone and pebbly sandstone (La Habra quadrangle). Upper part consists of white to brown, friable, massive sandstone, which contains abundant marine mollusks, and locally includes conglomerate beds. In places, pebbly sandstone forming base of upper part is locally well indurated. Lower part consists of brown to gray, massive, silty sandstone which contains scattered marine mollusks. First described as San Pedro sand by Dall in 1898; named for exposures at Harbor Hill, near head of San Pedro Harbor. Formalized as San Pedro Formation by Kew (1923). Maximum exposed thickness in Puente Hills area is 100 m; thickness in subsurface is about 535 m (Yerkes, 1972). Divided in the southern La Habra 7.5' quadrangle into four mappable units. In succession is a lower sequence of siltstone and claystone (Qsp_1), overlain by sandstone (Qsp_2), that in turn is overlain by siltstone and claystone (Qsp_3), and an upper unit of sandstone (Qsp_4)

San Timoteo beds of Frick (1921) (Pleistocene and Pliocene)-Lithologically diverse sandstone, conglomeratic sandstone, and conglomerate (El Casco and Sunnymead 7.5' quadrangles). Nearly all sandstone is arkosic and much is lithic. Named by Frick (1921) for upper Pliocene, vertebrate-bearing, nonmarine strata in San Timoteo Canyon. Upper part of San Timoteo beds contain vertebrate fauna of earliest Pleistocene Irvingtonian I age (Repenning, 1987); Eckis had earlier suggested a Pleistocene age for upper part of section in 1934. Albright (1997) shows vertebrate fossils are throughout most of upper part of unit. Lower part of San Timoteo beds of Frick (1921) is Pliocene. Clasts within unit appear to be entirely derived from Transverse Range sources similar in composition to rocks presently exposed in eastern San Gabriel Mountains, central San Bernardino Mountains, and in San Bernardino-Yucaipa area (Matti and Morton, 1993). In past, contact between San Timoteo beds of Frick (1921) and underlying Mount Eden Formation inconsistently placed at various stratigraphic positions. In this report, contact is placed at boundary between older fluvial-lacustrine deposits (Mount Eden Formation) and younger fluvial-alluvial fan deposits (San Timoteo beds of Frick (1921)). Age of this boundary is about 4.3 Ma (B. Albright, per. commun., 1998). Includes three informal members, and five subdivisions of members:

Qstu

Upper member (Pleistocene)-Gray coarse-grained, moderately indurated sandstone and conglomerate. Contains early Pleistocene Irvingtonian I, Shutt Ranch and El Casco local faunas, about 1.8 Ma (Repenning, 1987). Erodes to form sharp-ridged badlands topography. Locally subdivided into:

Qsts

Conglomeratic sandstone beds-Conglomeratic sandstone that appears to be derived from adjacent sedimentary beds. Forms small lens-shaped body along crest of anticline in the western part of the San Timoteo Badlands

Qstcq

Quartzite-bearing conglomerate beds-Distinctive, well-indurated, conglomerate consisting largely of clasts derived from central part of San Bernardino Mountains. Characterized by quartzite clasts derived from Precambrian terrain and by megaporphyry clasts (Matti, and Morton, 1993; Morton and others, 1986). Beds found in upper part of upper member. Contains early Pleistocene Irvingtonian I, Olive Dell local fauna (Repenning, 1987), about 1.3 Ma

Tstd Tstm

Middle member (Pliocene)-Dominate lithology is light-gray, pebbly to cobbley, moderately to well-indurated, medium- to coarse-grained sandstone containing conglomerate beds up to 9 m in thickness. Pale brown- to light-gray fined-grained sandstone to pebbly sandstone is subordinate. Overall, member consists of about 70 percent sandstone and 30 percent conglomerate; conglomerate more abundant in upper part. Includes common reddish-brown stratigraphic intervals consisting of oxidized sandstone, which are not paleosols, and reddish-brown clay-rich intervals, which may be paleosols. Erodes to form sharp-ridged badlands topography. Forms hogbacks on north side of San Timoteo Canyon. Included within Tstm is highly deformed sandstone, pebbly sandstone, and conglomerate (Tstd) located along western part of badlands adjacent to San Jacinto fault zone. Its stratigraphic position within Tstm is not resolved

$Tstl_1$ $Tstl_2$ Tstl

Lower member (Pliocene)-Mostly gray, moderately well indurated, well-sorted fine-grained sandstone containing subordinate pebble lenses, and sparse medium-grained sandstone beds. Represents distal flood plain deposit. Erodes to form slightly more rounded badlands topography than younger part of San Timoteo beds. Included within and at the base of Tstl is an interval of buff to reddish-brown fine- to thick-bedded coarse-grained arkosic sandstone ($Tstl_1$). Above the basal $Tstl_1$ is a section of mostly greenish-gray claystone and siltstone with thick and crudely bedded coarse-grained sandstone characterized by ripple lamination ($Tstl_2$)

QTs **Unnamed late Cenozoic sedimentary rocks in Riverside and Corona areas (early Pleistocene to late Pliocene?)**-Lithologically diverse, moderately indurated, gray to brown, coarse-grained sandstone, pebbly sandstone, and conglomerate. In the Riverside West 7.5' quadrangle, most clasts in unit were derived from San Bernardino Mountains. In Riverside area, unit appears to be derived from units found in Santa Ana River drainage. Southeast of Riverside (Riverside East 7.5' quadrangle), clasts are locally derived from Peninsular Ranges sources

QTt **Late Cenozoic conglomerate of Temescal area (early Pleistocene to late Pliocene?)**-Cobble conglomerate deposited on deeply weathered surface of Paleocene(?) age (Corona South 7.5' quadrangle). Clasts appear to be locally derived

QTc **Conglomeratic sedimentary rocks of Riverside West 7.5' quadrangle (early Pleistocene to late Pliocene?)**-Boulder conglomerate containing locally derived granitic and metamorphic clasts. Underlain by cobble conglomerate containing clasts derived from San Bernardino basin and San Bernardino Mountains area. Locally derived boulder conglomerate is brownish gray. The underlying cobble conglomerate is gray and contains rusty and black-stained clasts locally. Cobble conglomerate appears to be derived from units in Santa Ana River drainage

QTn **Late Cenozoic sedimentary rocks of Norco area (early Pleistocene to late Pliocene?)-In Norco area (Corona North 7.5' quadrangle)** unit includes locally derived clasts as well as clasts derived from the San Bernardino Mountains

Tta **Temecula Arkose (Pliocene)**-Mainly pale greenish-yellow, medium- to coarse-grained, indurated sandstone (Bachelor Mountain 7.5' quadrangle). Includes thin discontinuous beds of tuffaceous sandstone, siltstone, and claystone, and some pebble and conglomerate beds having locally derived clasts. Named by Mann (1955) for exposures of nonmarine fluvial sandstone exposed southeast of Temecula. Kennedy (1977) assigned unit late Pliocene Blancan IV-V mammal age (2.2 to 2.8 My) based on vertebrate assemblages collected east of quadrangle. Assemblages include *Nannippus*, *Hypolagus*, *Tetrameryx*, *Equus*, and *Odocoileus* (Golz, and others, 1977). Later work establishes first occurrence of *Tetrameryx* as Irvingtonian I rather than late Blancan (Woodburne, 1987), placing Temecula Arkose age nearer 1.9 Ma (late Pliocene) than 2.2 Ma. A microtine fauna from unit in Radec area, about five miles east of Santa Ana quadrangle, is considered to have age of 4.6 Ma (Blancan I) (Repenning, 1987). Thickness of the Temecula Arkose ranges from 90 to over 550 m (Kennedy, 1977)

Tf **Fernando Formation (Pliocene)**-Siltstone, sandstone, pebbly sandstone, and conglomerate; widespread in the northwestern Santa Ana Mountains and southern Puente Hills. Name introduced by Eldridge and Arnold (1907) for marine deposits on northwest side of San Fernando Valley. Formalized by Kew (1924) for similar-appearing rocks in Ventura basin. Durham and Yerkes (1964) defined current usage in Santa Ana quadrangle. In Puente Hills, Fernando Formation is about 1825 m thick (Yerkes, 1972). Lower part equivalent to Repetto Formation (Woodring, 1938). Includes two members separated by regional erosional unconformity:

Tfuc Tfu **Upper Member**-In eastern part of Puente Hills consists of sandstone, pebbly sandstone, and sandy conglomerate. In western part of Puente Hills, upper member consists of three units. From youngest to oldest, (1) 250 m of pale gray, thick-bedded to massive, friable, fine- to medium-grained sandstone and brownish-gray, massive, pebbly sandstone; (2) 590 m of pale gray, massive, poorly sorted, friable, micaceous rock ranging from siltstone to medium-grained sandstone; (3) 200 of sandstone, pebbly sandstone, and pebbly conglomerate (Yerkes, 1972). Sandstone is generally massive, pale gray to brownish gray, silty, fine to coarse grained, poorly sorted, and friable. Pebbly sandstone is brownish gray thick bedded to massive, poorly sorted, and friable. The conglomerate is brownish and consists of clasts up to 45 cm in length. Abundant marine mollusks occur in upper part of member. Included in Tfu is zone of predominantly conglomeratic rock (Tfuc), which is about 490 m thick in western part of Puente Hills

Tflc Tfl **Lower Member**-Siltstone, sandstone and conglomerate in northwestern part of Puente Hills. Includes brownish-gray to pale-gray, sandy, micaceous siltstone, fine- to medium-grained friable sandstone, and brownish-gray, unsorted, massive, pebbly conglomerate. Contains local beds of intraformational breccia, and locally common foraminifera. Conglomerate at base of member contains angular clasts of white Miocene-age siltstone and near-black diabase. Member is up to 730 m thick. Included in Tfl is zone of predominantly conglomeratic rock (Tflc) of unknown thickness and unknown extent

Tn **Niguel Formation (Pliocene)**-Marine interbedded sandstone, conglomeratic sandstone, and conglomerate. Named by Vedder (1957) for exposures in San Juan Capistrano 7.5' quadrangle. Sandstone is brownish gray, coarse grained, and poorly sorted. Brownish-gray conglomerate, consists of unsorted clasts 2.5 to 25 cm in diameter, and contains blocks of locally derived siltstone. Marine mollusks suggest deposition in sublittoral-depth water (Vedder, 1960)

Tns **Sandstone of Norco area (Pliocene)**-Poorly exposed, unnamed, marine sandstone near city of Norco (Corona North 7.5' quadrangle). Unconsolidated, greenish-yellow sandstone and sparse conglomerate lenses. Locally contains abundant, poorly preserved shallow marine fossils including *Anadara* cf. *A. trilineata* (Conrad), *Chione* sp., *Lucinoma* cf. *L. annulata* (Reeve), and *Diodora* sp. (J.D. Mount, per. commun., 1973). Unit may represent shallow-water eastward extension of Fernando Formation. Sparse conglomerate lenses include clasts of exotic silicic volcanic rocks. In places, nonconformably buttressed against granitic rock. Ash at base of formation deposited on granite in what are interpreted to have been tide pools, is ash of Taylor Canyon (per. commun., A.M. Sarna-Wojcicki, 1990) having age of 2.6 Ma

Tc **Capistrano Formation (early Pliocene and Miocene)**-Marine sandstone and siltstone; widespread unit in the San Joaquin Hills area. Named by Woodford (1925) for exposures of marine strata near city of San Juan Capistrano. Includes one member and one separately mapped facies:

Tco **Oso Member**-White to light gray, massive, medium- to coarse-grained, friable sandstone. Contains scattered matrix-supported pebbles and cobbles. Named by Vedder and others (1957) for marine sandstone in coastal Orange County. Upper part contains foraminifera of Kleinpell's upper Mohnian or Delmontian Stage (Vedder and others, 1957), and in area of San Juan Capistrano to Dana Point, late Miocene and early Pliocene foraminifera, shark teeth, echinoids, and whalebones (White, 1956, 1971; Ingle, 1971, 1972; Vedder, 1972)

Tcs **Siltstone facies**-White to pale gray, massive to crudely bedded, friable, siltstone and mudstone. Informally designated by Morton and Miller (1981) for exposures in southern Orange County. Contains sandstone and calcareous mudstone beds, and sparse diatomaceous and tuffaceous beds. Up to 730 m thick

Tme **Mount Eden Formation of Fraser (1931) (early Pliocene and Miocene)**-Sandstone, mudrock, conglomeratic sandstone, and sedimentary breccia (Lakeview and El Casco 7.5' quadrangles). First described as Eden beds by Frick (1921), but name was preempted. Fraser (1931) informally designated same unit the Mount Eden Formation. Named for exposures in the vicinity of Mount Eden (El Casco 7.5' quadrangle). Albright (1997), Frick (1921), May and Repenning (1982), and Repenning (1987), described vertebrate fauna from Mount Eden Formation and Axelrod (1937, 1950) described flora. Includes five informal members:

Tmeus

Upper sandstone member (early Pliocene and Miocene)-Consists principally of interbedded sandstone and mudrock. Dominant lithology is moderately well indurated, ledge-forming, thin- to medium-bedded, well-sorted pale-brown sandstone. Sandstone contains characteristic climbing ripple laminations, convoluted bedding, and locally cross-laminations. Interbedded with subordinate thin- to medium-bedded intervals of fissile to hackly-fracturing mudrock. Unit has prominently reddish-brown interval in the Lamb Canyon area

Tmem

Mudrock member (early Pliocene and Miocene)-Hackly fracturing to locally fissile, dark gray-green mudrock. Weathers to form smooth rounded slopes

Tmels

Lower sandstone member (Miocene)-Green, olive green, and gray sandstone, pebbly sandstone, and minor limestone; locally contains abundant limey concretions. Mudrock subordinate in this member. Southeastward, unit is progressively better indurated, and in southeastern exposures is ledge-forming sandstone and pebbly sandstone. Well indurated rock north of Mount Eden contains middle Miocene, late Hemphillian Mount Eden local fauna; about 5.3 Ma (Repenning, 1987) or 5.6 Ma (Albright, 1997)

Tmeb Tmea

Arkosic sandstone member (Miocene)-Mostly thick-bedded, indistinctly bedded, moderately to well-indurated, buff, gray, greenish-gray, and reddish-brown, coarse-grained arkosic sandstone, pebbly sandstone, and conglomerate. Contains some interbeds of fine-grained sandstone, siltstone, and rare shale. Includes sparse limey concretions, which are not as common as in the overlying Lower sandstone member. Unit is possibly coeval or in part coeval with conglomeratic sandstone. Contains tongues of monolithologic boulder breccia (Tmeb). Giant clasts in breccia are up to 6 m in diameter. Apparently represents debris flow deposits. Breccia tongues occur at several different horizons mostly in Lamb Canyon and Laborde Canyon areas. Clasts are entirely tonalite of Lamb Canyon, a massive sphene-bearing biotite-hornblende tonalite, which crops out in northeastern part of El Casco 7.5' quadrangle

Tmec

Conglomeratic sandstone member (Miocene)-Reddish-brown, massive to indistinctly bedded, coarse-grained sandstone, pebbly sandstone, and conglomerate. Basal unit of Mount Eden Formation of Frasier (1931). Lower part is dominated by conglomerate and upper part by sandstone. Moderately well decomposed clasts are locally derived Peninsular Ranges Province basement rocks

Tch

Sandstone and conglomerate in southeastern Chino Hills (early Pliocene and Miocene)-Poorly exposed marine and nonmarine sedimentary sandstone and conglomerate in the Arena Blanca syncline area of southeastern Chino Hills (Prado Dam 7.5' quadrangle). Stewart and Stewart (1930) and Woodford and others (1944) reported Pliocene foraminifera from these rocks. Similar appearing rocks southeast to Wardlow Wash, Bedford Canyon, and Brown Canyon are included in this unit (Gray, 1961). Smith (1960) described Pliocene foraminifera from these rocks. A meager megafauna was collected on northwest side of Bedford Canyon and included a fragment of *Cantharus* sp. of Pliocene age (Gray, 1961). In the Chino Hills this unit was differentiated from underlying Puente Formation by Daviess and Woodford (1949) and by Gray (1961) but was included within Puente Formation by Durham and Yerkes (1964). Fossils obtained from sand-and-gravel quarry included marine invertebrate and nonmarine vertebrate faunas and nonmarine flora (R.E. Reynolds, per. commun., 1998). Vedder (per. commun. to T.H. McCulloh, 1997) identified a relatively large molluscan taxa from material collected by Reynolds. Vedder considered best correlation of molluscan taxa is to lower part of Fernando Formation and upper part of Capistrano Formation. Foraminifera collected in 1996(?) were identified as Delmontian age (T.H. McCulloh, per. commun., 1997). Indicates unit at least in part coeval with Sycamore Canyon member of Puente Formation

Tp

Puente Formation (early Pliocene and Miocene)-Marine sandstone, siltstone, and shale underlying most of the Puente Hills and extending into adjacent areas. Named by Eldrige and Arnold (1907) for exposures in Puente

Hills. English (1926) extended distribution of Puente Formation to area south of Puente Hills, subdividing three units, from youngest to oldest, (1) shale, sandstone, and conglomerate (2) sandstone, and (3) shale. Daviess and Woodford (1949) subdivided Puente Formation in northwestern Puente Hills into four members, from youngest to oldest, (1) Sycamore Canyon member, (2) upper siltstone member, (3) sandstone member, and (4) lower siltstone member. Schoellhamer and others (1954) later designated formalized member names that are in current usage

Tpscc Tpsc

Sycamore Canyon Member (early Pliocene and Miocene)-Predominantly sandstone and pebble conglomerate. Named by Daviess and Woodford (1949) for exposures at Sycamore Canyon (San Dimas 7.5' quadrangle) just north of the Santa Ana quadrangle in the northwestern Puente Hills. Sycamore Canyon Member is laterally variable, composed of varying amounts of pale gray, thick-bedded to massive, medium- to coarse-grained, friable sandstone; pale gray, thin-bedded, siliceous siltstone; pale gray, poorly bedded siltstone, and brownish-gray, massive conglomerate. Contains bathyal depth foraminiferal fauna (Yerkes, 1972). Included in Tpsc is a zone of predominantly conglomeratic rock (Tpscc) of unknown extent

Tpyc Tpy

Yorba Member (Miocene)-Siltstone and sandstone; siltstone predominates. Named by Schoellhamer and others (1954) for Yorba bridge east of the community of Atwood. White to gray, thin bedded, micaceous and siliceous siltstone and sandy siltstone. Siltstone contains beds of fine-grained sandstone and white to pale gray limy concretions and concretionary beds. In eastern Puente Hills, upper part of Yorba contains large boulders in relatively fine-grained rocks and is interpreted as turbidity current deposit (Durham and Yerkes, 1959). Included in Tpy is a zone of predominantly conglomeratic rock (Tpyc) of unknown extent

Tpsq

Soquel Member (Miocene)-Sandstone and siltstone; sandstone predominates. Named by Schoellhamer and others (1954) for exposures in Soquel Canyon in eastern Puente Hills. Gray to yellowish-gray, massive to well-bedded, medium- to coarse-grained, poorly sorted sandstone interbedded with matrix-supported pebbly sandstone. Many sandstone beds are graded. Locally conglomeratic. Lower part of section commonly contains ellipsoidal calcite-cemented concretions 30 cm to 1.5 m in diameter

Tplv

La Vida Member (Miocene)-Siltstone and subordinate sandstone. Named by Schoellhamer and others (1954) for exposures near La Vida Mineral Springs in eastern Puente Hills. Light-gray to black, massive to well-bedded, generally friable siltstone. Weathered surfaces are typically white or pale gray. Locally consists of porcellaneous siltstone or shale. Contains widespread fish remains, abundant foraminifera, local phosphate nodules, and sparse limy siltstone. Interbedded sandstone beds range from 2 cm to over 1 m in thickness. Includes a few beds of vitric tuff

Tlm

Lake Mathews Formation (Miocene)-Poorly exposed sequence of massive, greenish-gray mudstone and minor conglomerate, and poorly bedded white to gray sandstone, pebbly sandstone, and conglomerate (Lake Mathews 7.5' quadrangle). Name introduced by Proctor and Downs (1963) and formalized by Woodford and others (1971). Contains vertebrate fauna including *Ustattochoeerus* cf. *Californicus* (Merriam) (Proctor and Downs, 1963) indicating a Claredonian age (Woodburne, 1987) for formation

Tcgr

Rhyolite clast conglomerate of Lake Mathews area (Miocene?)-Massive, indurated, coarse-grained, sandstone-matrix, cobble conglomerate (Lake Mathews and Steele Peak 7.5' quadrangles). Matrix feldspars largely altered to clay. Cobbles include exotic red rhyolite in addition to locally derived clasts. Occurs as three slightly elevated channel deposit remnants on 640 m Gavilan-Lakeview erosional surface of Woodford and others (1971)

Tcg

Conglomerate of Lake Mathews area (Miocene?)-Massive, indurated, coarse-grained, sandstone-matrix, cobble conglomerate (Lake Mathews 7.5' quadrangle). Similar to rhyolite clast conglomerate of Lake Mathews area, but lacks rhyolite clasts

Tm **Monterey Formation (Miocene)**-Siliceous and diatomaceous marine siltstone and sandstone correlated with Monterey Formation (Blake, 1856; Kew, 1923; Bramlette, 1946) of central California. Predominately siltstone and sandstone. Interbedded white to pale brown, thinly laminated siltstone and tan, fine- to medium-grained feldspathic sandstone. Contains abundant foraminifera and fish remains; locally contains diatom fragments. In the Capistrano area, lower part of Puente Formation grades laterally southward into Monterey Formation (Vedder, and others, 1957)

Tvsr **Santa Rosa basalt of Mann (1955) (Miocene)**-Remnants of basalt flows having relatively unmodified flow surfaces (Murrieta, Wildomar, and Sitton Peak 7.5' quadrangles). Hawkins (1970) provides detailed petrologic description of basalt. Originally described by Fairbanks (1892) and informally named by Mann (1955) for basalt flows in vicinity of Rancho Santa Rosa, west of Temecula. Name also has been applied to basalts in general area of Temecula and Santa Ana Mountains, but in this report, is restricted to rocks in area west of Temecula. Southwestern part of Santa Rosa basalt of Mann (1955) extruded on deeply weathered surface of low relief similar to Paleocene age surfaces found elsewhere in southern California. Also, western part of unit and where found in vicinity of Elsinore Peak, was extruded on sedimentary rocks closely resembling Paleogene-age rocks. Morton and Morton (1979) report whole-rock conventional potassium-argon ages for Santa Rosa basalt of 6.7 and 7.4 Ma. Slightly older age of 8.7 Ma was obtained by Hawkins (1970)

Tvt **Basalt of Temecula area (Miocene)**-Includes scattered exposures of basalt north and east of Temecula, and a small exposure of vesicular basalt within valley area of Elsinore Fault zone near Wildomar (Mann, 1955; Kennedy, 1977; Hull, 1990). East of Temecula there are a few exposures of vesicular basalt and what appears to be a dissected cinder cone and scattered volcanic bombs (Mann, 1955)

Tvh **Basalt of Hogbacks (Miocene)**-Basalt capping Hogbacks northeast of Temecula (Murrieta 7.5' quadrangle). Remnant of channel-filling basalt flow. Thin deposit of unconsolidated gray stream gravel underlies axial part of channel-filling basalt. Basalt is less vesicular than most of Santa Rosa basalt of Mann (1955) and tends to break into slabby fragments. Whole-rock conventional potassium-argon ages are 10.4 and 10.8 Ma (Morton and Morton, 1979)

Tvep **Basalt of Elsinore Peak (Miocene)**-Black vesicular basalt capping Elsinore Peak. Overlies a thin sequence of Paleogene(?) sandstone. Whole rock conventional potassium-argon age of basalt is 11.6 Ma and $^{40}Ar/^{39}Ar$ age is 11.2 Ma (R. Fleck, per. commun., 1998). Occurs in the Wildomar 7.5' quadrangle

Tsob **San Onofre Breccia (middle Miocene)**-Chiefly marine sedimentary breccia, conglomerate, and lithic sandstone (Laguna Beach and San Juan Capistrano 7.5' quadrangles). Named by Ellis and Lee (1919) for exposures in San Onofre Hills, San Diego County. Detailed descriptions of petrology and paleontology are given by Woodford (1925), who described unit as "San Onofre facies of the Temblor Formation" based on occurrence of *Turritella ocoyana* fauna in sandstone underlying breccia. San Onofre Breccia consists of green, greenish-gray, gray, brown, and white, massive to well bedded, mostly well-indurated breccia with interbedded conglomerate, sandstone, siltstone, and mudstone. Well-bedded fine-grained parts and poorly bedded to massive coarse parts of unit are discontinuous, grading laterally into one another. Local diatomaceous shale and tuff beds. Contains *Turritella ocoyana*. Breccia consists of large angular clasts derived from basement rock sources offshore to west. Unit is characterized by clasts of blueschist and related rocks derived from Catalina Schist (Woodford, 1924). Unit is up to 900 m thick

Tt **Topanga Formation (middle Miocene)**-Marine sandstone, siltstone, and shale. Named by Kew (1923) for predominantly sandstone unit in Santa Monica Mountains; further subdivided by Vedder (1957). Kew (1923) recognized similar rocks in Puente Hills, Santa Ana Mountains, and San Joaquin Hills. At type locality, Topanga Canyon, unit contains middle Miocene fauna characterized by *Turritella ocoyana*. In Santa Ana quadrangle formation includes three members, from youngest to oldest:

Ttp **Paulerino Member**-Pale gray, massive, tuffaceous sandstone and thin-bedded siltstone. Contains some breccia interbeds and locally andesite breccia. Named by Vedder (1957) for exposures in San Joaquin Hills, coastal Orange County. Contains assemblage of middle Miocene foraminifera

Ttlt **Los Trancos Member**-Pale gray to brownish-gray, thin- to medium-bedded siltstone and fine-grained sandstone. Includes some interbedded medium- to coarse-grained sandstone and shale beds. Named by Vedder (1957) for exposures in San Joaquin Hills, coastal Orange County. Foraminifera indicate middle Miocene age. Member is up to 945 m thick

Ttb **Bommer Member**-Gray to brownish-gray, thick-bedded, medium- to coarse-grained sandstone and interbedded fine-grained sandstone and siltstone. Locally conglomeratic. Named by Vedder (1957) for exposures in San Joaquin Hills, coastal Orange County. Contains middle Miocene megafossils

Tvem **El Modeno Volcanics (middle Miocene)**-Andesite, tuff, tuff-breccia, and basalt. Named by Schoellhamer and others (1954) for volcanic rocks exposed 5 km east of settlement of El Modeno on northwestern side of Santa Ana Mountains (not to be confused with town of El Modena). Yerkes (1957) gives detailed description of El Modeno Volcanics. Includes:

Tvema **Andesitic volcanic rocks**-Extrusive volcanic rocks; primarily of andesitic composition

Tvemt **Tuff and tuff breccia**-Clastic volcanic rocks; primarily tuff and tuff breccia

Tvemb **Basalt**-Extrusive volcanic rocks; primarily of basaltic composition

Volcanic intrusive rocks associated with El Modeno Volcanics (middle Miocene)-Dikes, sills, and small irregular shaped bodies. Includes:

Ta **Andesitic intrusive rocks**-Porphyritic intrusive rock primarily of andesitic composition; most are thoroughly altered and decomposed

Td **Diabase intrusive rocks**-Diabasic textured shallow intrusive rocks, most are thoroughly altered and decomposed

Tvss **Vaqueros, Sespe, Santiago, and Silverado Formations, undifferentiated (early Miocene, Oligocene, and Paleocene)**-Sandstone and conglomerate

Tv **Vaqueros Formation (early Miocene, Oligocene, and late Eocene)**-Predominantly sandstone. Originally described as Vaqueros sandstone by Hamlin (1904) for marine deposits in Los Vaqueros Valley along east slope of Santa Lucia Range in central California. Correlation with southern California deposits is based upon *Turritella inezana* fauna. In San Joaquin Hills, unit consists of brownish-gray, massive- to thick-bedded sandstone and sandy siltstone, having interbeds of siltstone and shale, mudstone, and minor conglomerate. Shale and siltstone are thin bedded. Up to 1,160 m thick in quadrangle (Vedder, 1975). Contains early Miocene shallow-water marine megafossil assemblage

Ts **Sespe Formation (early Miocene, Oligocene, and late Eocene)**-In San Joaquin Hills area, Sespe is varied colored from gray to red, massive- to thick-bedded, nonmarine conglomeratic sandstone and clayey and silty sandstone. Bedforms are poorly developed. Watts (1897) originally described unit as Sespe brownstone formation. It was later described by Eldridge and Arnold (1907) and redefined by Kew (1924) for nonmarine conglomeratic deposits exposed in Sespe Creek in Ventura County, where Sespe conformably underlies marine Vaqueros Formation. Continental vertebrate fossil collections range in age from Eocene to early Miocene (Bailey and Jahns, 1954; Woodburne 1987)

Tvs **Vaqueros and Sespe Formations, undifferentiated (early Miocene, Oligocene, and late Eocene)**-Interbedded marine and nonmarine sandstone and conglomerate assigned to the Sespe and Vaqueros Formations. In the Puente Hills, Santa Ana Mountains, and San Joaquin Hills, marine fossil-bearing strata of Vaqueros Formation are bed-by-bed interlayered with nonmarine rocks of Sespe Formation to degree that formations cannot be mapped as separate units. Mixed unit locally includes boulder conglomerate (Woodford and others, 1973)

Tcga **Conglomerate of Arlington Mountain (Paleogene?)**-Cobble conglomerate. Found in two small areas north of Arlington Mountain along the boundary of the Lake Mathews and Riverside West 7.5' quadrangles. Conglomerate is composed of exotic welded tuff clasts, some of which contain piemontite, a characteristic mineral in welded tuff clasts in conglomerates of Poway Group (Woodford and others, 1968). Minor clasts of exotic quartzite also occur within unit. Welded tuff clasts appear identical to those common in Sespe Formation and in conglomerate of Eocene Poway Group found in quadrangle to south. Very localized exposures of identical-appearing conglomerate occurs at crest of ridge east of town of Elsinore in the eastern part of the Elsinore 7.5' quadrangle. Reworked volcanic clasts are also found in some Pleistocene alluvial deposits adjacent to conglomerate

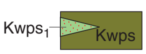
Tep **Sandstone of Elsinore Peak (Paleogene?)**-Basalt capping Elsinore Peak is underlain by a thin sequence of well indurated, white to pale gray, coarse-grained, locally pebbly sandstone (Wildomar 7.5' quadrangle). Some sandstone lacks basalt cover

Tsa **Santiago Formation (middle Eocene)**-Continental and marine sandstone and conglomerate. In Santa Ana quadrangle first described by Dickerson (1914) and correlated with Tejon Formation to north. Later Woodring and Popenoe (1945) proposed name Santiago Formation for exposures at Santiago Creek on west side of Santa Ana Mountains. They considered Santiago Formation to be late Eocene. Later Schoellhamer and others (1981) assigned it to middle Eocene. Lower part of formation consists of conglomerate composed of clasts of quartzite, volcanic rocks, granitic rocks, sandstone, and metaconglomerate, none of which appear to be of local origin (Schoellhamer and others, 1981). Above conglomerate is thick sequence of pale gray feldspathic sandstone and lesser interbedded siltstone. Lower part of sandstone contains marine mollusks; silicified wood is common in upper part of sandstone, which is probably nonmarine

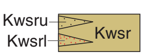
Tsis Tsi Tsicg **Silverado Formation (Paleocene)**-Nonmarine and marine sandstone, siltstone, and conglomerate. Dickerson (1914) first recognized Paleocene rocks in Santa Ana Mountains, and based on faunal similarities, correlated strata with Martinez Formation of central California. Woodring and Popenoe (1945) described unit in detail and named it Silverado Formation. Formation was deposited on deeply weathered erosional surface. Rocks underlying Silverado are characteristically saprolitic. Silverado Formation consists of basal conglomerate overlain by relatively thin sequence of sandstone and siltstone. Distinctive Claymont clay bed overlies sandstone and siltstone sequence, and is overlain by thick sequence of sandstone, siltstone, and conglomerate that includes second clay bed, the Serrano clay bed. Basal conglomerate is thoroughly weathered, 2 to 25 m thick, massive, pale gray to reddish-brown, pebble conglomerate. Very locally is boulder conglomerate. Overlying conglomerate is sandstone and siltstone which is also thoroughly weathered, consisting largely of quartz and clay. Claymont clay bed is 1 to 3 m thick, brown, green, and gray clay that weathers to distinctive brownish red. Bed is mostly clay, partly pisolitic, and has scattered quartz grains in it. Locally, supports large-scale clay operation. Upper part of unit above Claymont clay bed is diverse section of marine and nonmarine sandstone, siltstone, and conglomerate, and includes Serrano clay bed. Latter is about 1 m thick, pale gray to white, and composed of nearly equal amounts plastic clay and quartz. In addition to clay, upper part of section contains carbonaceous shale and lignite beds. Thicker lignite beds were locally mined for fuel. Upper part of unit also contains abundant marine mollusks. Some eastern exposures of formation contain distinctive and diagnostic Paleocene *Turritella pachecoensis*. Locally basal conglomerate is divided and labeled Tsicg. Locally the Serrano Clay is divided and labeled Tsis

Kwl **Williams and Ladd Formations, undifferentiated (upper Cretaceous)**-Sandstone, siltstone, and conglomerate

Williams Formation (upper Cretaceous)-Sandstone and conglomeratic sandstone. Named by Popenoe (1937, 1942) for exposures near mouth of Williams Canyon in northern Santa Ana Mountains. He divided unit into Pleasants Sandstone Member and Schulz Ranch Member. Woodring and Popenoe (1945) renamed Schulz Ranch Member the Schulz Ranch Sandstone Member, which was further subdivided into Schulz Ranch Sandstone Member and Starr Member (Morton, and others, 1979). Later the name Schulz Ranch Sandstone Member was shortened dropping "Sandstone" (Morton, and others, 1979). Formation consists of very resistant, cliff-forming, white to brownish-gray, massive-bedded, poorly sorted feldspathic sandstone, pebbly sandstone, and conglomeratic sandstone. Basal part of section includes conglomerate. Locally contains siltstone beds, 3 to 8 m thick, interbedded with conglomeratic sandstone. Calcite cemented spheroidal concretions a few centimeters to a meter in diameter found locally. Unconformably rests on Holz Shale Member of Upper Cretaceous Ladd Formation. Includes:

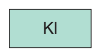


Pleasants Sandstone Member-Marine sandstone Upper part is poorly bedded, white to pale gray, feldspathic sandstone, which generally is coarser grained than sandstone in lower part. Lower part is sandstone and thin-bedded, biotite- and muscovite-bearing sandstone. Massive sandstone contains biotite and black carbonaceous fragments and scattered conglomerate lenses. Fossiliferous concretions are common. Just south of Mojeska in northeastern El Toro 7.5' quadrangle the upper part of the Pleasants Sandstone Member is a coarse-grained conglomeratic sandstone ($Kwps_1$)

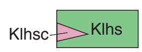


Schulz Ranch Member-Marine sandstone and conglomerate. Sandstone typically coarse grained white to brownish gray. Most is massive; less commonly crossbedded. Contains scattered matrix-supported pebbles and cobbles and sparse siltstone interbeds. Erosionally resistant; forms prominent cliffs. Locally subdivided into Upper Schulz Ranch (Kwsru), consisting of gray-white, coarse- to fine-grained, thin bedded to massive, slightly to moderately consolidated conglomeratic sandstone that grades down section into a lower unit (Kwsl). This lower unit consists of light olive-gray siltstone that is well bedded, well consolidated and is underlain by and interfingers with crudely bedded, well to massive silty conglomerate and very coarse-cobble fanglomerate

Starr Member-Fanglomerate and sandstone. Starr Member is nonmarine, pale gray, deeply weathered fanglomerate and interbedded white friable sandstone. Most clasts are deeply weathered biotite granitoids, but some are from Jurassic Bedford Canyon Formation and Cretaceous Santiago Peak Volcanics. Interfingers with Schulz Ranch Member



Ladd Formation (upper Cretaceous)-Conglomerate, sandstone, siltstone, and shale. Named by Popenoe (1942) for exposures just west of mouth of Ladd Canyon, northern Santa Ana Mountains. Popenoe divided formation into Baker Canyon Conglomerate Member and Holz Shale Member. Includes:



Holz Shale Member-Interbedded marine shale, siltstone, sandstone, and localized conglomerate beds. Sandstone beds are mostly massive, but locally crossbedded. Unit contains 5 cm to 1 m calcite cemented concretions. Foraminifera are widespread and megafossils abundant in places. Except for resistant conglomerate beds, Holz Shale weathers to form smooth rounded slopes. Unit includes prominent zone of concentrated sandstone and conglomerate beds (Klhsc)

Baker Canyon Conglomerate Member-Marine and locally nonmarine(?) conglomerate. Lower part is gray conglomerate containing clasts up to 2 m across, derived mainly from granitic and volcanic rocks. Granitic clasts appear to be from Cretaceous Peninsular Ranges batholith and volcanic clasts from Cretaceous Santiago Peak Volcanics. Upper part of conglomerate is brown conglomeratic sandstone and pebble conglomerate. Sparse sandstone beds contain abundant mollusk shells. Conglomerate is similar to conglomerate of underlying Trabuco Formation, and locally interfingers with it. Pelecypods indicate deposition in primarily shallow-water environment

Ktru Ktrl Ktr **Trabuco Formation (upper Cretaceous)**-Unfossiliferous, mainly brown to maroon, massive, nonmarineconglomerate with local sandstone and siltstone beds (Popenoe, 1941). Packard (1916) named Trabuco Formation for exposures in Harding Canyon, 4.8 km north of Trabuco Canyon in northern Santa Ana Mountains. Clasts, up to 1 m in diameter, but mostly range from 8 to 15 cm. Locally derived from Cretaceous Peninsular Ranges batholith, Cretaceous Santiago Peak Volcanics, and from meta-siltstone and sandstone of Jurassic Bedford Canyon Formation. Trabuco Formation rests unconformably on Santiago Peak Volcanics and Bedford Canyon Formation. Locally divided into an upper unit, labeled Ktru, that consists of reddish-brown, thoroughly weathered bouldery conglomerate, and a lower unit that consists of light brownish-gray fanglomerate, labeled Ktrl. Clast size is larger in the lower unit with the largest clasts as much as 2.4 m

Rocks of the Peninsular Ranges batholith

Klct **Tonalite of Lamb Canyon (Cretaceous)**-Massive to faintly foliated hornblende biotite tonalite. Informally named here for exposures in headward part of Lamb Canyon in the southwest corner of the Beaumont 7.5' quadrangle, just northeast of the northeast corner of the Santa Ana 30' x 60' quadrangle. Included in Lakeview Mountain tonalite by Larsen (1948). Rock is characterized by relatively abundant sphene crystals. Weathers to form landscape of very large boulders. Emplacement age, based on Pb/U composition of zircon is 94 Ma (W.R. Premo, per. commun., 1999)

Kmeg **Granite of Mount Eden (Cretaceous)**-White to pale gray, leucocratic, medium- to coarse-grained, massive to foliated granite. Informally named here for exposures in vicinity of Mount Eden (El Casco and Lakeview 7.5' quadrangles). Included within the Perris quartz diorite by Dudley (1935) and the Lakeview Mountain tonalite by Larsen (1948). Characterized by muscovite and small bright red garnets. Comprises pluton at Mount Eden and forms sills and dikes in metamorphic rocks to southeast Dikes and sill rocks are mostly well foliated, concordant with foliation in surrounding metamorphic rocks

Kthgd **Granodiorite of Tucalota Hills (Cretaceous)**-Elongate pluton comprised of massive, light-colored biotite granodiorite. Informally named here for Tucalota Hills (eastern part of Bachelor Mountain 7.5' quadrangle), which are underlain by the granodiorite. Included within Woodson Mountain granodiorite by Larsen (1948)

Klt **Tonalite near mouth of Laborde Canyon (Cretaceous)**-Intensely fractured biotite hornblende tonalite. Informally named here for exposures just west of mouth of Laborde Canyon (northeast corner of Lakeview 7.5' quadrangle). Fault bounded small discontinuously and poorly exposed tonalite adjacent to Claremont fault. Fairly dark, foliated tonalite having relatively large amounts of hornblende and abundant, thin, small mesocratic inclusions

Khqd **Hypersthene quartz diorite (Cretaceous)**-Highly mafic, hypersthene quartz diorite. Exposed on two small hills between Ryan Airport and State highway 74 (Winchester 7.5' quadrangle). Dark-gray, massive, fine- to medium-grained, homogeneous appearing hypersthene-biotite quartz diorite. Distinguished by relatively high color index, small grain size, lack of inclusions, and abundant hypersthene. Intrusive into monzogranite of Tres Cerritos

Ktcg **Monzogranite of Tres Cerritos (Cretaceous)**-Medium- to coarse-grained, foliated to subgneissic, subporphyritic biotite monzogranite. Informally named here for exposures in eastern part of Tres Cerritos (eastern part of the Lakeview 7.5' quadrangle). Included within Perris quartz diorite by Dudley (1935) and within Bonsall tonalite by Larsen (1948). Pale tan weathering, leucocratic, containing potassium feldspar crystals up to 2.5 cm in length. Biotite comprises about 5 percent of rock inmost of unit; locally as high as 10 percent. Biotite typically forms groups of small plates. In gneissic parts of unit, biotite occurs as coating on s-surfaces. Oligoclase margins are commonly myrmekitic where plagioclase is in contact with potassium feldspar. Includes segregation bodies of aplitic- and granitoid-textured rock, and at south end of Tres Cerritos, several small masses of biotite schist

Lakeview Mountains pluton (Cretaceous)-Composite pluton composed mainly of biotite-hornblende tonalite in the Lakeview and adjacent parts of the Winchester and Perris 7.5' quadrangles. Named Lakeview quartz-hornblende diorite by Dudley (1935) and Lakeview Mountain tonalite by Larsen (1948). Larsen's usage of Lakeview Mountain tonalite included much of granitic and metamorphic rocks in Mount Eden area, and a variety of granitic rocks within San Jacinto Mountains and in area south of Hemet. Morton (1969) restricted usage to pluton underlying most of Lakeview Mountains and southern part of the Bernasconi Hills as originally used by Dudley (1935). Zircon age of tonalite is 100 Ma_{id} and 98 Ma_{ip}. $^{40}Ar/^{39}Ar$ age of hornblende is 98.6 and conventional K/Ar age of biotite is 92.4 Ma (Pb/U age, W.R. Premo per. commun., 1999 and Ar/Ar age, L. W. Snee, per. commun., 1999, K/Ar age, F.K. Miller per. commun., 1980). Includes:

Klmp

Pegmatite dikes-Granitic pegmatites common in central part of pluton and rare elsewhere in the pluton, except for small area near southern margin. Most pegmatite dikes are steeply dipping and tabular-shaped. Dikes are compositionally and texturally zoned, having an outer wall zone of coarse- and extremely coarse-grained intergrowths of alkali feldspar, quartz, and biotite, in which graphic intergrowths of quartz and alkali feldspar are common. Within outer wall zone, is inner core zone of extremely pegmatitic-textured alkali feldspar, quartz, muscovite, schorl, and garnet. Large pegmatite dikes have intermediate zone similar to inner zone but crystals are larger. Single tourmaline crystals in larger dikes are up to 1 m in length. Cores of larger dikes are massive quartz and giant perthite crystals. Epidote and zeolite minerals are widespread minor constituents. A distinctive assemblage of uncommon minerals occurs within larger pegmatite dikes includes bismutite, beyerite, pucherite, bismuthinite, microlite, yttrocolumbite-tantalite, cyrtolite, allanite, pyrochlore, sphalerite, chalcocite, uranophane, xenotime, and thorogummite

Klmt

Tonalite-Gray, medium- to coarse-grained, massive to foliated, biotite hornblende tonalite lacking potassium feldspar. Most abundant rock type in Lakeview pluton. Tonalite characterized by presence of ubiquitous schlieren, and in much of body, tonalite is essentially all schlieren. Schlieren renders tonalite extremely heterogeneous at outcrop scale producing rocks that ranges in composition from leucocratic to melanocratic. Schlieren range in shape from relatively tabular to wispy layers and in size from a few centimeters in width to sizes mappable at 1:24,000 (Morton, 1969; 1972; Morton and others, 1969). Mineralogic composition of tonalite without variability introduced by schlieren is, quartz 13 to 32 percent, plagioclase (andesine) 34 to 70 percent, biotite 7 to 22 percent and hornblende 4 to 29 percent. Mafic minerals average about 25 percent of tonalite. Accessory minerals are apatite, zircon, magnetite-ilmenite, and sphene. Colorless small masses of cumingtonite form central parts of some hornblende crystals. Ellipsoidal melanocratic inclusions are common and widespread. Dark gray tonalite along southern contact of pluton, forms thin septa of foliated, porphyritic looking rock which results from stumpy, black hornblende prisms set in a fine-grained granoblastic matrix of biotite, quartz, and plagioclase. Texture is interpreted as a protoclastic. Length of septa is parallel to pluton contact

Klml

Leucocratic rocks-Elongate masses of white rock composed of andesine and quartz appear to be mega-scale leucocratic schlieren. These leucocratic masses are texturally like typical Lakeview Mountains tonalite, except overall grain size is slightly reduced, due to dearth of mafic minerals which are generally larger than other minerals in rock. Biotite and hornblende, where present in small amounts, are extremely poikilitic. Muscovite, a rare primary(?) constituent, occurs as small crystals interstitial to plagioclase

Klmm

Melanocratic rocks-Lenticular masses of melanocratic and hypermelanic rock that includes compositions ranging from about 50 percent biotite and hornblende to rock that is essentially all biotite and hornblende. Scattered throughout most of pluton, but concentrated in central and northeast part. These bodies are interpreted to be very large-scale schlieren-like masses; minerals are same as those of typical Lakeview Mountains tonalite, but slightly larger in grain size

Klmtg **Lakeview Mountains tonalite and granodiorite, undifferentiated**-Mixed Lakeview Mountains tonalite and granodiorite along margin of Lakeview Mountains pluton in southern part of Bernasconi Hills (Perris 7.5' quadrangle)

Klmc **Comb-layered gabbro**-Along southern margin of pluton is elongate body of comb-layered gabbro (Moore and Lockwood, 1973). Gabbro consists of folded layers of alternating labradorite-rich gabbro and hornblende or augite-rich rock. Labradorite crystals are elongate normal to layering, and mostly branch upwards to form feather-like crystals. Brown-weathering

Klmg **Hypersthene hornblende gabbro**-Small masses of hypersthene hornblende gabbro scattered through pluton, but slightly concentrated in central and northeastern parts. At a distance, readily discernible from tonalite, as they are darker and weather to form brown outcrops. Masses are elongate and range in length from 1 to more than 100 m

Krct **Tonalite of Reinhardt Canyon pluton (Cretaceous)**-Biotite-hornblende tonalite containing abundant and varied inclusions. Informally named Reinhardt Canyon pluton here for arcuate-shaped band of exposures that define the body in Reinhardt Canyon area east side of Lakeview Mountains pluton (Lakeview 7.5' quadrangle). Pluton included in Perris quartz diorite by Dudley (1935) and in Bonsall tonalite by Larsen (1948). Tonalite is gray, medium-grained, generally well-foliated. Biotite and hornblende occur in subequal amounts, aggregating 15 to 20 percent of rock. Very sparse untwinned potassium feldspar occurs locally. Accessory minerals are zircon, magnetite-ilmenite, apatite, sphene, and secondary white mica, epidote, and chlorite. Unit characterized by moderate to abundant dark, discoidal to plate-shaped and elongate-shaped inclusions; the near-vertical elongate-shaped inclusions gives rise to locally a pronounced large-scale lineation. Except for southern 460 m of western boundary, pluton is gradational into Lakeview Mountains pluton; along southern 460 m of western border, two plutons are separated by a thin septum of gneissic rock. Most of eastern contact dips steeply to east or is nearly vertical; locally it is hair-line sharp. Age relations between pluton and Lakeview Mountains pluton are ambiguous. Tonalite of Reinhardt Canyon pluton is distinguished from tonalite of Lakeview Mountains pluton by finer grain size, rare schlieren, and more abundant and more attenuated inclusions

Kbpg **Monzogranite of Bernasconi Pass (Cretaceous)**-Irregularly porphyritic biotite and biotite-hornblende tonalite. Included by Larsen (1948) with rocks he referred to as "granodiorite west of Lakeview", and by Dudley (1935) with Perris quartz diorite. Informally named here for exposures in hills south of Bernasconi Pass (Perris 7.5' quadrangle). Buff- to tan-weathering, medium-grained, hypidiomorphic-granular to porphyritic, foliated biotite and biotite-hornblende monzogranite. Potassium feldspar phenocrysts up to 2.5 cm in length appear to be late forming, and in part replace parts of inclusions. Contains common to abundant, well-oriented, discoidal to plate-shaped melanocratic inclusions. In places rock is migmatitic, composed of nearly equal amounts monzogranite and inclusion-like rock. Weathers to form large boulders, many of which are several meters in length. Southern part of monzogranite contains widespread aplitic dikes. Includes:

Kbpm **Migmatitic rocks within Monzogranite of Bernasconi Pass**-Relatively large bodies of migmatitic rock within Kbpg consisting of about equal amounts monzogranite and mafic rocks, which resemble inclusions and have defuse contacts

Ktbh **Tonalite of Bernasconi Hills (Cretaceous)**-Gray, medium-grained, massive- to crudely foliated, hypidiomorphic-granular biotite hornblende tonalite. Informally named here for series of small elongate tonalite composition plutons exposed in Bernasconi Hills (Perris 7.5' quadrangle). Included within Perris quartz diorite by

Dudley (1935) and within Bonsall tonalite by Larsen (1948). Biotite and hornblende occur in subequal amounts averaging several percent each. Potassium feldspar comprises up to several percent of tonalite. Oriented mafic minerals define foliation. Contains abundant, widespread fine-grained mafic inclusions ranging in size from 2.5 to 30 cm. Inclusions are equant to elongate; elongation parallel to foliation in enclosing tonalite. Unit weathers to form slopes densely covered by gray, well-rounded boulders of disintegration

Box Springs plutonic complex (Cretaceous)-Box Springs plutonic complex is an elliptical, flat-floored basin-shaped granitic complex centered on the Box Springs Mountains (Riverside East and Sunnymead 7.5' quadrangles); it is apparently lower part of a granitic diapir. Complex consists of core of essentially massive to indistinctly layered biotite tonalite surrounded by a layer of foliated biotite granodiorite to tonalite. Outward from biotite granodiorite to tonalite is, respectively, a discontinuous layer of foliated, heterogeneous porphyritic granodiorite, followed by uniform porphyritic granodiorite. Other compositionally and texturally diverse granitic rocks also occur within the complex, but in relatively small amounts. All rocks of complex were included in Perris quartz diorite by Dudley (1935) and in Bonsall tonalite by Larsen (1948). Except for dike rocks, units are described in general order from core outward. Includes:

Kp

Granitic pegmatite dikes-Most are relatively small, typically tabular granitic pegmatite dikes. Subordinate large dikes are compositionally and texturally zoned, having an outer border and wall zone of coarse- and extremely coarse-grained intergrowths of alkali feldspar, quartz, and biotite. Outer zone encloses core of alkali feldspar and quartz. In some dikes, intermediate zone consists of alkali feldspar, quartz and a variety of accessory minerals including garnet, tourmaline, columbite-tantalite, and monazite

Kbt

Biotite tonalite-Massive, fine- to medium-grained, equigranular biotite tonalite that forms core of Box Springs plutonic complex. Much of tonalite has compositional layering that is faintly to moderatelydeveloped and is very regular. Rocks contain about 35 to 40 percent quartz and 6 to 12 percent biotite. Hornblende is absent and potassium feldspar ranges from 1 to 4 percent. Mineral alignment is poorly developed or absent, but much of rock has incipient to well-developed primary layering defined by mineral concentrations. Unit contains sparse equant- to elliptical-shaped, fine-grained, mesocratic inclusions; some have relatively mafic rims. Inclusions tend to be aligned parallel to compositional layering. Zircon age of rock is 98.6 Ma_{id} and 100.4 Ma_{ip} (Pb/U ages, W.R. Premo per. commun., 1999)

Kbfg

Biotite granodiorite and tonalite-Light gray, and medium- to coarse-grained foliated biotite granodiorite and tonalite. Contains 25 to 35 percent quartz, 8 to 15 percent biotite, and minor hornblende. Potassium feldspar occurs as small interstitial grains and sparse subhedral phenocrysts up to 1.5 cm in diameter. Potassium feldspar appears to progressively decrease inward within unit; tonalite most abundant in inner part. Mesocratic discoidal inclusions oriented parallel to foliation are common, but not abundant. Grades into biotite tonalite unit (Kbt)

Kbfgi

Biotite granodiorite and tonalite containing abundant inclusions-Biotite granodiorite and tonalite that contains abundant discoidal, mafic inclusions; restricted to east side of complex

Kbhg

Heterogeneous porphyritic granodiorite-Heterogeneous porphyritic granodiorite and subordinate tonalite. In most places surrounds biotite granodiorite and tonalite unit (Kbfg). Pinches out along west side of complex. Granodiorite is medium to coarse grained, light gray, foliated, and porphyritic. Contains plagioclase, 25 to 35 percent quartz, and 10 to 15 percent mafic minerals, chiefly biotite and subordinate hornblende. Mafic minerals unevenly distributed imparting heterogeneous appearance to rock. Subhedral potassium feldspar crystals are up to 2.5 cm in length. Widespread discoidal mesocratic inclusions oriented parallel to foliation. Dikes and sills of leucocratic granite and pegmatite are abundant

Kbhg$_1$ **Layered heterogeneous porphyritic granodiorite**-Heterogeneous porphyritic granodiorite that has pronounced layering defined chiefly by variations in grain size

Kbg **Porphyritic granodiorite**-Coarse-grained, light gray, foliated, porphyritic biotite granodiorite and subordinate tonalite. In most places grades into heterogeneous porphyritic granodiorite unit (Kbhg). Groundmass is plagioclase, quartz (30 to 40 percent), and mafic minerals (5 to 10 percent). Mafic minerals are biotite and sparse hornblende, which are more evenly distributed than in heterogeneous granodiorite (Kbhg). Subhedral potassium feldspar phenocrysts are up to 2.5 cm in length. Discoidal mesocratic inclusions are oriented parallel to foliation

Kbft **Biotite-hornblende tonalite**-Light- to medium gray, medium- to coarse-grained, foliated tonalite. Contains 20 to 25 percent quartz and about 25 percent biotite and hornblende in subequal amounts. Hornblende and biotite occur as ragged crystals. Potassium feldspar present, but sparse. Anhedral, interstitial sphene is conspicuous accessory mineral. Contains abundant, fine-grained, mesocratic, ellipsoidal- to discoidal-shaped mafic inclusions aligned parallel to foliation

Kbht **Heterogeneous biotite tonalite**-Light-gray, inequigranular, medium- to coarse-grained, foliated biotite tonalite; restricted to northwestern Box Springs Mountains. Dominant rock type is leucocratic tonalite, containing only 1 to 4 percent biotite, which occurs as thin, subhedral plates, irregularly concentrated and aligned to produce a wispy, swirling foliation. Leucocratic tonalite encloses pods and lenses of tonalite containing about 15 percent biotite as large ragged plates. Both types of tonalite contain abundant quartz (30 to 40 percent) and very sparse potassium feldspar (1 percent or less). Contains dispersed, mesocratic, discoidal inclusions. Granitic pegmatite dikes are abundant

Kbgt **Heterogeneous granodiorite and tonalite**-Light- to medium-gray, medium- to coarse-grained, texturally heterogeneous, foliated, hornblende-biotite tonalite and granodiorite; restricted to northern Box Springs Mountains near Pigeon Pass. Common discoidal, mesocratic inclusions oriented parallel to foliation

Kba **Amphibolitic gabbro**-Dark- gray to-black, fine- to medium-grained, foliated, hornblende-rich amphibolitic gabbro forming lenses and elongate masses within heterogeneous granodiorite and tonalite (Kgbt). Foliation is parallel to foliation in that unit

Val Verde pluton (Cretaceous)-Large, relatively uniform pluton composed of biotite-hornblende tonalite extending from the Perris 7.5' quadrangle north to the Riverside East and West 7.5' quadrangles. Termed Perris quartz diorite by Dudley (1935), Val Verde tonalite by Osborn (1939), and included within Bonsall tonalite by Larsen (1948). Name Val Verde is adopted here based on detailed study of Osborn (1939) near Val Verde, Steele Peak 7.5' quadrangle. Name Val Verde is from former settlement and railway siding midway between Perris and Riverside. Apparently steep-walled Val Verde pluton is eroded to mid-pluton level. Emplacement age of the pluton is 105.7 Ma_{id}. $^{40}Ar/^{39}Ar$ age of hornblende is 100 Ma, biotite 95 Ma and potassium feldspar 88.5 Ma (Pb/U ages, W.R. Premo per. commun., 1999 and Ar ages, L. W. Snee, per. commun., 1999). Includes:

Kvt **Val Verde tonalite**-Gray-weathering, relatively homogeneous, massive- to well-foliated, medium- to coarse-grained, hypautomorphic-granular biotite hornblende tonalite; principal rock type of Val Verde pluton. Contains about equal amounts biotite and hornblende, quartz and plagioclase. Potassium feldspar generally present, but constitutes less than two percent of rock. Where present, foliation typically strikes northwest and dips moderately to steeply northeast. Northern part of pluton contains younger, intermittently developed, northeast-striking foliation. In central part of pluton, tonalite is mostly massive, and contains few segregational masses of mesocratic to melanocratic tonalite. Elliptical- to pancake-shaped, meso- to melanocratic inclusions are common

Kvtk **Potassium feldspar-bearing tonalite**-Thin layer of heterogeneous biotite-hornblende tonalite containing more than two percent, but less than 10 percent potassium feldspar; located along part of contact with biotite schist on west side of pluton

Kvti **Inclusion-rich tonalite**-Subequal amounts of biotite-hornblende tonalite and melanocratic inclusion-like rock. Rock has migmatitic appearance

Kgr **Granophyre (Cretaceous)**-Gray, aphanitic to very fine-grained, granophyric textured granitic rock. Composed of granophyric intergrowths of quartz and alkali feldspars. Contains some fine-grained pyrite which oxidizes to give rock rusty appearance

Green Acres gabbro complex (Cretaceous)-Medium- to very coarse-grained olivine-bearing gabbro that weathers gray to black. Named for community of Green Acres on southeast side of Lakeview Mountains (Morton, 1969) (northern part of the Winchester 7.5' quadrangle). Included within San Marcos gabbro by Larsen (1948). Most gabbro is hypidiomorphic-granular; poikilitic rock is common and porphyritic rock less common. Weathers to form semi-smooth slopes littered with scattered small boulders. Includes rare orbicular gabbro and protoclastic flaser gabbro. Contains several small septa of quartzofeldspathic, biotite quartz-feldspar, and graphitic schist. In northern part of gabbro complex are a few occurrences of quartzo-feldspathic mylonite. Includes common granitic pegmatite dikes; some andalusite-bearing dikes. One granitic pegmatite dike in southern part of the complex contains masses of gabbro converted to biotite-hydrobiotite-vermiculite with included andalusite, some of which have cores of blue corundum crystals. Some of the pegmatite dikes have been mylonitized. Color of decomposed gabbro and soil derived from gabbro is typically dark red-brown. Includes:

Kgab **Heterogeneous mixture of olivine, pyroxene, and hornblende gabbros**-Northern part of Green Acres gabbro complex is very heterogeneous mix of gabbro, including olivine, pyroxene, and hornblende gabbro intruded by quartz diorite and tonalite. Slopes covered with gabbro rubble generally mask presence of quartz diorite and tonalite

Kgao **Olivine gabbro**-Southern half of Green Acres gabbro is mostly olivine gabbro, which ranges from a few percent to about one-third olivine (Fo_{75} to Fo_{87}). Kelyphitic rims are common around olivine. Anorthite (An_{90}) makes up 30 to 90 percent of gabbro as anhedral to subhedral, complexly twinned crystals. Stubby, anhedral orthopyroxene in thin section is nearly colorless- to very pale-pink, and pleochroic, commonly forming overgrowths of, or intergrowths with, clinopyroxene or hornblende. Augite occurs as anhedral, tabular- to irregular-shaped, colorless crystals, some of which contain schiller-like intergrowths of a violet, platy, nearly opaque mineral. Augite is commonly mantled with brown and (or) green hornblende. Hornblende occurs as both brown hornblende and nearly colorless to very light green hornblende. Latter occurs primarily in reaction rims (kelyphyitic rims) intergrown with spinel around olivine; brown hornblende occurs most commonly as both interstitial crystals and as subhedral crystals. Opaque minerals, including magnetite, occur adjacent to olivine and as symplektitic intergrowths with amphibole. Colorless- to light-green chlorite is abundant in some protoclastic gabbro. Planar, vein-like hornblende-spinel masses are locally common in gabbro having abundant olivine. Small hornblende gabbro dikes are mineralogically similar to that of enclosing olivine gabbro. Some dikes are fine- to medium-grained, meso- to melanocratic hornblende gabbro; others consist of porphyritic hornblende olivine gabbro

Kgah **Hornblende-rich gabbro**-Fine- to medium-grained, melanocratic hornblende gabbro. In thin section, brown prismatic hornblende imparts a nematoblastic texture to this gabbro. Typically consists of 46 percent brown hornblende, 7 percent green hornblende, 9 percent clinopyroxene, 2 percent olivine, 34 percent calcic plagioclase, and 2 percent opaque minerals

Kgat **Troctolite**-Small elliptical intrusion of distinctive rock composed of about 45 percent anorthite (An_{90}), 36 percent olivine (Fo_{85}), 11 percent clinopyroxene, 3 percent orthopyroxene, 2 percent hornblende, 2 percent spinel, and about 5 percent iddingsite. Kelyphitic rims mantle most olivine crystals. Large subhedral anorthitic plagioclase crystals impart a slightly porphyritic texture to rock

Kgaa **Anorthositic gabbro**-Pale gray-weathering, leucocratic, labradorite-anorthite gabbro. Anorthosite is composed essentially of calcic plagioclase, containing small, variable amounts of olivine and (or) pyroxene

Kgam **Metagabbro**-Several small bodies of metagabbro derived from Green Acres gabbro are included within Lakeview Mountains tonalite and granodiorite (Klmtg) in southern part of Lakeview Mountains. These bodies contain abundant masses of chlorite and blue-green hornblende

Gavilan ring complex (Cretaceous)-Composite ring structure consisting of a variety of granitic rocks that range from monzogranite to tonalite (Steele Peak, Lake Mathews, and Elsinore 7.5' quadrangles). Informally named here for exposures in Gavilan Plateau area (Steele Peak and Lake Mathews 7.5' quadrangles). Western part of complex was termed Estelle quartz diorite and eastern part included in Perris quartz diorite by Dudley (1935). Western part of complex was termed Estelle tonalite and eastern part was included within Bonsall tonalite by Larsen (1948). Hypersthene is a characteristic mineral of many rocks in complex. Based on texture, depth of erosion is greater in eastern part of complex than in western part. Rocks on west side of the complex commonly have hypabyssal texture and appear to grade into volcanic textured rock. Several gold mines (e.g., Good Hope, Gavilan, and Santa Rosa mines), which constituted Pinacate mining district (Sampson, 1935), are located within complex. Gold apparently occurred in arsenopyrite bearing quartz veins. Located in center of ring complex, but not part of it, is near-circular Arroyo del Toro pluton. Includes:

Kgg **Hypersthene monzogranite**-Massive hypersthene monzogranite; nearly black where fresh, dark-brown-weathering. Contains biotite, hornblende, hypersthene, and clinopyroxene as mafic phases. Rock has sparse small mesocratic inclusions, which are commonly lighter colored than monzogranite. Quarried as "black granite" building stone in past. Zircon age is 109 Ma_{id} and 106 Ma_{ip}. $^{40}Ar/^{39}Ar$ age of biotite is 104.5 Ma and potassium feldspar 99.3 Ma

Kgt **Massive textured tonalite**-Brown-weathering, massive, relatively heterogeneous, hypersthene-bearing biotite-hornblende tonalite. Most abundant rock type in complex. Equant-shaped mesocratic to melanocratic inclusions are common. Zircon age is 112.9 Ma_{id} and 113.6 Ma_{ip} (Pb/U ages, W.R. Premo per. commun., 1999)

Kgtf **Foliated tonalite**-Gray, medium-grained, foliated biotite-hornblende tonalite containing discoidal mafic inclusions. Most of tonalite lacks hypersthene. Unit restricted to northern part of complex

Kgti **Tonalite containing abundant mesocratic inclusions**-Moderately fine-grained tonalite containing abundant, small, platy mesocratic inclusions. Tonalite lacks hypersthene, which is common to most of complex. Zircon age is 108.6 Ma_{id} and 109.1 Ma_{ip}. $^{40}Ar/^{39}Ar$ age of hornblende is 106 Ma, biotite 103 Ma and potassium feldspar 98.5 Ma (Pb/U ages, W.R. Premo per. commun., 1999 and Ar ages, L. W. Snee, per. commun., 1999)

Kgh **Hypabyssal tonalite**-Massive, hypabyssal-textured tonalite and lesser granodiorite in southwestern part of complex. Contains small, equant shaped mesocratic inclusions

Kgct **Coarse-grained biotite-hornblende tonalite**-Massive to foliated, relatively light colored, coarse-grained tonalite that weathers to form very large boulders of disintegration

Kght **Heterogeneous tonalite**-Medium-grained, foliated biotite-hornblende tonalite, containing moderately abundant to abundant, small, biotite-hornblende granodiorite intrusions. Rock contains moderately abundant elliptical- to pancake-shaped, mesocratic to melanocratic inclusions

Kmp **Micropegmatite granite (Cretaceous)**-Named by Larsen (1948) for pink-tinted, leucocratic outcrops of granite (Corona North quadrangle). Granite is very distinctive in thin section due to micropegmatitic texture

Kmpc **Micropegmatite and granodiorite of Cajalco pluton, undifferentiated (Cretaceous)**-Mixed unit of micropegmatite and massive granodiorite to monzogranite. Related to, but not mapped as part of Cajalco pluton

Ktd **Tonalite dikes of Mount Rubidoux (Cretaceous)**-Light gray, fine- to medium-grained, massive to foliated, hornblende-clinopyroxene-hypersthene-biotite tonalite (Riverside West 7.5' quadrangle). Contains discoidal mafic inclusions

Kmrg **Granite of Mount Rubidoux (Cretaceous)**-Massive granite characterized by coarse grain size and presence of hypersthene and fayalitic olivine (Riverside West 7.5' quadrangle). Termed "coarse leucogranite of Rubidoux Mountain" by Larsen (1948). Inequigranular; average grain size 5 mm; Potassium feldspar crystals are up to 12 mm in length. Biotite and hornblende aggregate about 5 percent and hypersthene and olivine occur as sparse constituents. Most of granite is devoid of inclusions. Zircon ages are 109 Ma_{id} and 107.3 Ma_{ip} and $^{40}Ar/^{39}Ar$ age of biotite is 98 Ma and potassium feldspar 93 Ma (Pb/U ages, W.R. Premo per. commun., 1999 and Ar ages, L. W. Snee, per. commun., 1999)

Krg **Granite of the Riverside area (Cretaceous)**-Medium- to coarse-grained, massive- to faintly-foliated, leucocratic biotite granite (Riverside East and West 7.5' quadrangles). Contains about 1 to 3 percent biotite. Inclusions are sparse or absent except locally in western part of body where granite contains 2 to 8 percent biotite and sparse to abundant inclusions of quartz diorite, granodiorite, and fine-grained mafic rock. At Mount Rubidoux, rocks contain sparse hypersthene and fayalitic olivine and moderately abundant equant inclusions of dark-gray fine-grained rock. Rock at Mount Rubidoux termed "fine leucogranite of Rubidoux Mountain" by Larsen (1948)

Kmhg **Mount Hole Granodiorite (Cretaceous)**-Massive, light colored hornblende-biotite granodiorite. Named by Larsen (1948) for exposures at Mount Hole (Corona North 7.5' quadrangle). Weathers to form large boulders of disintegration

Klst **La Sierra Tonalite (Cretaceous)**-Moderately dark-colored, massive biotite tonalite. Named by Larsen (1948) for exposures in the vicinity of La Sierra (Corona North 7.5' quadrangle). Much of tonalite is altered to secondary minerals, especially epidote and chlorite. Includes some zones of tonalite thoroughly altered to epidote, quartz, and chlorite and locally tourmaline and sulfide minerals

Katg **Granodiorite of Arroyo del Toro pluton (Cretaceous)**-Light gray, medium-grained, massive, very homogeneous, and inclusion-free biotite-hornblende granodiorite (Steele Peak and Elsinore 7.5' quadrangles). Some of the rock in the western part of the pluton is slightly porphyritic. Informally named here for Arroyo del Toro, located in center part of pluton. Termed Steele Valley granodiorite by Dudley (1935) and included by Larsen (1948) within Woodson Mountain granodiorite. Near circular Arroyo del Toro is located in center of Gavilan ring complex, but is not part of complex. Zircon ages of the pluton are 108.6 Ma_{id} and 111 Ma_{ip}. $^{40}Ar/^{39}Ar$ biotite age is 104.3 Ma and potassium feldspar 98.5 Ma (Pb/U ages, W.R. Premo per. commun., 1999 and Ar ages, L. W. Snee, per. commun., 1999)

Cajalco pluton (Cretaceous)-Mostly biotite and biotite-hornblende monzogranite and granodiorite (Lake Mathews and Corona North 7.5' quadrangles). Informally named here for exposures in Cajalco area (Lake Mathews 7.5' quadrangle). Rocks of Cajalco pluton were included within Cajalco quartz monzonite by Dudley (1935) and within Woodson Mountain granodiorite by Larsen (1948). Body is a shallow-level pluton emplaced by magmatic stoping within largely volcanic and volcanoclastic rocks. It is tilted eastward and eroded to progressively greater depths from west to east. Upper part of pluton contains a very prominent halo of tourmalinized rock. Zircon ages are 109.5 Ma_{id} and 112.6 Ma_{ip} (Pb/U ages, W.R. Premo per. commun., 1999). Includes:

Kcto **Tourmalinized monzogranite and granodiorite**-Tourmalized monzogranite and granodiorite. Also includes some tourmalinized volcanic rock in western part of pluton. Tourmaline is extremely fine grained to aphanitic. Tourmalinized rock ranges from incipient fracture-replacing-tourmaline, through tourmalinized mafic minerals, to completely tourmalinized coal-black rock-bodies over hundred meters in length. Northeast striking joints are preferential sites for most extensively tourmalinized rock. Tourmaline sequentially replaces biotite and hornblende followed in order by feldspar and quartz. All variations in degree of replacement are found. Where only quartz remains as primary mineral, tourmalinized rock is distinctive, white-dappled, black rock resembling porphyry. Tourmalinized rock contains small amounts of iron sulfide(s) and very locally cassiterite. Tin was discovered about 1853 in a large mass of tourmalinized rock in Eagle Valley area (Lake Mathews 7.5' quadrangle). Cassiterite-bearing rock was intermittently mined from 1860 to about 1892 (Sampson, 1935). Over 250,000 pounds of tin was smelted in 1891-1892. Only rock that is essentially all tourmaline, is mapped as Kcto. Tourmalinized rock is very resistant to erosion and stands out as small, bold, black hills, locally termed tourmaline blow-outs. Cobbles of tourmaline rock are locally abundant in Miocene Lake Mathews Formation. Very locally pink, radiating, fibrous to prismatic masses of dumortierite occur rather than tourmaline. One dumortierite-bearing dike located in Temescal Canyon contains large sprays of radiating prismatic dumortierite

Kcg **Monzogranite**-Most of western part of pluton is medium-grained, equigranular, hypautomorphic-granular to subporphyritic monzogranite and subordinate granodiorite. Includes variable amounts of angular inclusions, mostly, if not entirely derived from stoping of Estelle Mountain volcanics. Number, size, and reliability of identity of inclusion parent rock increases from east to west. In western part of pluton included masses of volcanic rock comprise large volume of pluton. In northern and northeastern part of pluton stoped masses of hornblende gabbro are abundant. Unit includes relatively fine-grained leucogranite, especially in area northwest of Lake Mathews

Kcgd **Granodiorite**-Most of eastern part of pluton is medium-grained, equigranular, hypautomorphic granular granodiorite and subordinate monzogranite. Granodiorite includes variable amounts of angular inclusions

Kct **Tonalite**-Masses of mafic biotite-hornblende tonalite. Represents deepest part of pluton

Kcgq **Granodiorite and quartz latite, undifferentiated**-Nearly equal amounts of plutonic and volcanic rock; in some areas, unit is mostly quartz latite. Found near intrusive contacts with Mesozoic volcanic rocks

Kcgb **Granodiorite and gabbro, undifferentiated**-Mixed granodiorite and gabbro. In northern and northeastern part of pluton granitic rock contains high concentrations of stoped hornblende gabbro. In some areas granite and gabbro are intimately intermixed producing very heterogeneous rock

Kgbd **Gabbroic dikes, Domenigoni Valley area (Cretaceous)**-Relatively fine-grained, massive, black, hornblende gabbro occurs as thin (few meters thick) dikes in Domenigoni valley area (Romoland and Winchester 7.5' quadrangles). Dikes cut both granodiorite of Domenigoni Valley pluton and adjacent metamorphic rocks

Domenigoni Valley pluton (Cretaceous)-Massive, isotropic, gray, medium-grained, biotite hornblende granodiorite and tonalite (Winchester and Romoland 7.5' quadrangles). Larsen (1948) used name Domenigoni granodiorite for exposures in Domenigoni Valley area, but included western part of pluton in his Bonsall tonalite unit. Erosion exposes only upper part of pluton. Pluton consists of two parts separated by pendant of metasedimentary rock and gabbro. Foliated rock found only in southeastern part of pluton. Unit contains moderately abundant to abundant, equant-shaped, mesocratic inclusions, which are sparse or lacking around margins of pluton. Two relatively consistent, steeply dipping, joint sets are present throughout pluton; one strikes northeast, other northwest. Dacite-quartz latite dike swarm was emplaced along northwest striking joint set. Contact between pluton and older rocks is knife-edge sharp. Grain size of granodiorite-tonalite is unchanged at contact. At most places there is little change in mineralogy or fabric of host rocks, except local deflection of schistosity within a few meters of contact. In some places in northeastern part of pluton schistosity is deflected up to 60 to 90 m from contact. Southeastern part of the pluton, however, coincides with westward deflection of metamorphic foliation to parallel contact of pluton. Apophysis of pluton is well exposed in highway cut on US 215 at Sun City. Rock there contains abundant inclusions of contact metamorphosed impure quartzite, lithic graywacke, and phyllite. Siliceous carbonate bearing inclusions consist of pyroxene hornfels mineral assemblages including wollastonite, diopside, and grossularite. East of Quail Valley small apophyses of granodiorite occur in thoroughly fragmented quartz-rich metasedimentary rock that is pervasively penetrated by smaller irregular masses of granodiorite. Includes:

Kld

Quartz latite dikes-Light- to dark-gray, fine-grained, massive to well-foliated, biotite, biotite-hornblende, and hornblende quartz latite. Some dike rock contains small needle-like hornblende crystals. Swarm of quartz latite dikes occur in eastern part of Domenigoni Valley pluton. A few dikes extend into metasedimentary country rock and some occur entirely within metasedimentary rocks. Dikes are more resistant to erosion than the enclosing rock and form conspicuous ribs and walls. Included as part of Domenigoni Valley pluton, because they are largely restricted to pluton. Most are foliated in contrast to massive granodiorite. Streaks of biotite, and less commonly oriented hornblende crystals, give rise to pronounced and regular lineation

Kdvg

Granodiorite to tonalite of Domenigoni Valley-Relatively uniform, massive hornblende biotite granodiorite grading into tonalite. This is principal rock type of Domenigoni Valley pluton. Contains some mafic rich rocks in the southern part of the pluton. Common accessory minerals are zircon, sphene, apatite, and magnetite-ilmenite. Minute rutile crystals impart bluish opalescence to quartz. Small masses of epidote and/or tourmaline rock occur locally and appear to replace granodiorite to tonalite. Contains moderately abundant to abundant equant mafic inclusions. Zircon age is 117.8 Ma_{id} and 112.8 Ma_{ip} and $^{40}Ar/^{39}Ar$ age of 104 Ma for biotite and 95.5 Ma for potassium feldspar (Pb/U ages, W.R. Premo per. commun., 1999 and Ar ages, L. W. Snee, per. commun., 1999)

Kgbf

Fine-grained hornblende gabbro, Railroad Canyon area (Cretaceous)-Fine-grained hornblende gabbro constituting dikes, sills, and small elongate plutons. Emplaced in phyllite in Railroad Canyon area (Elsinore 7.5' quadrangle)

Paloma Valley ring complex (Cretaceous)-Composite ring dike intrusion. Named and described by Morton and Baird (1976) for exposures in Paloma Valley area. Complex is located in the Murrieta, Romoland and Elsinore 7.5' quadrangles. Included within Woodson Mountain granodiorite and San Marcos gabbro by Larsen (1948). Ring complex consists of older, elliptical in plan, single ring-dike and two subsidiary short-arced dikes. A younger ring-set of thin dikes is largely within older ring dike. Older dike consists of granodiorite and monzogranite with vertical walls emplaced into gabbro by ring fracturing and magmatic stoping of gabbro. Younger ring-dike consists of hundreds of granitic pegmatite dikes. Most pegmatite dikes are 30 cm to over 1 m in thickness, and define a domal ring-dike geometry in which outer dikes are moderately to steeply outward dipping and pass inward to near horizontal dikes in center. Spatially associated with younger dikes in center of complex, are bodies of granophyre that contain stringers of granitic pegmatite. Younger dikes are interpreted as products of volatile-rich magma that filled a domal set of fractures resulting from cauldron subsidence. Granophyre is interpreted as a product of pressure quenching of pegmatite magma and attendant loss of volatiles. Zircon ages of rock from atypical hornblende-bearing granodiorite from western part of older dike is 121 Ma_{id} and 118.5 Ma_{ip}. $^{40}Ar/^{39}Ar$ age of hornblende 117.7 Ma and biotite 118.8 Ma (Pb/U ages, W.R. Premo per. commun., 1999 and Ar ages, L. W. Snee, per. commun., 1999) Includes:

Kpvgr

Granophyre-Pale gray, very fine-grained, porphyritic, granophyre. Phenocrysts of altered plagioclase are in groundmass of granophyric intergrowths of quartz within potassium feldspar and sodic plagioclase. Pyrite is ubiquitous accessory mineral, and where oxidized, discolors outcrops reddish-brown. Network of pegmatitic-textured stringers averaging 2.5 cm thick cuts much of granophyre. Stringers are compositionally and texturally zoned, with fine-grained margins and coarse-grained interiors

Kpvp **Pegmatite dikes of Paloma Valley ring complex**-Linear to arcuate, leucocratic pegmatite dikes typically 30 cm to 1 m thick. Most are texturally and compositionally zoned. Outer zones is coarse-grained granite composed of quartz perthite, and sodic plagioclase, and may or may not contain biotite and minor magnetite. Inner zone consists of pegmatitic-textured perthite, sodic plagioclase, quartz, biotite, and (or) muscovite, and accessory magnetite, schorl, garnet, and epidote. Quartz crystal-lined vugs found locally. Graphic intergrowths of quartz and perthite are common in rock transitional between coarse-grained granite and pegmatitic textured granite. Dikes that lack pegmatitic cores consist entirely of coarse- to extremely coarse-grained granitoid textured rock, with or without graphic intergrowths

Kpvg **Monzogranite to granodiorite**-Pale gray, massive, medium-grained hypidiomorphic-granular biotite monzogranite, and less abundant hornblende-biotite granodiorite forming older ring dike. Plagioclase is An^{20} to An^{35}, subhedral, tabular crystals. Contains inclusions of small to large stoped blocks of gabbro

Kpvt **Tonalite**-Foliated biotite-hornblende tonalite. In eastern part of complex grades into granodiorite

Kpvgb **Granodiorite and gabbro, undifferentiated**-Granodiorite of Paloma Valley ring complex containing abundant masses of stoped hornblende gabbro

Ksmg **Monzogranite of Squaw Mountain (Cretaceous)**-Informally named here for exposures of monzogranite at Squaw Mountain (Wildomar 7.5' quadrangle). Consists of massive, fairly homogeneous, moderately leucocratic, coarse-grained, monzogranite. Weathers to form large boulders of disintegration. Zircon age is 120 Ma_{id} and 123 Ma_{ip}. $^{40}Ar/^{39}Ar$ age of hornblende is 111 Ma, biotite 111 Ma, and potassium feldspar 103 Ma (Pb/U ages, W.R. Premo per. commun., 1999 and Ar ages, L. W. Snee, per. commun., 1999)

Kts **Tonalite of Slaughterhouse Canyon (Cretaceous)**-Informally named here for exposures of tonalite along Slaughterhouse Canyon (Wildomar 7.5' quadrangle). Relatively fine-grained dark gray, massive biotite hornblende tonalite. Sample of tonalite from near the head of Slaughterhouse Canyon gave zircon age of 122 Ma_{id} and 125 Ma_{ip}. $^{40}Ar/^{39}Ar$ age of hornblende is 120 Ma, biotite 111 Ma, and potassium feldspar 103 Ma (Pb/U ages, W.R. Premo per. commun., 1999 and Ar ages, L. W. Snee, per. commun., 1999)

Generic Cretaceous granitic rocks of the Peninsular Ranges batholith

Kp **Granitic pegmatite dikes (Cretaceous)**-Leucocratic, mostly tabular, pegmatitic-textured granitic dikes. Most dikes range in thickness from a few centimeters to over a meter. Larger dikes are typically zoned compositionally and texturally, having a border and wall zone consisting of coarse-grained biotite, quartz, and alkali feldspars. Intermediate zone consists of large to giant crystals of quartz and alkali feldspars, and commonly contain muscovite, schorl, and garnet. Core zone consists of quartz and alkali feldspars. Line-rock layering is rare. Pegmatite dikes within gabbro and metadunite may contain andalusite, sillimanite, cordierite, and dumortierite. Where gabbro has been incorporated into pegmatite it is converted to vermiculite-hydrobiotite containing crystals of andalusite, some of which have cores of corundum

Kg **Granitic dikes (Cretaceous)**-Includes texturally diverse group of leucocratic granitic dikes composed mainly of quartz and alkali feldspars. Dikes range in thickness from few centimeters to over a meter and are up to several hundred meters in length. Most are tabular; some are texturally and compositionally unzoned, irregular-shaped bodies. Some dike rock has a foliated or gneissoid fabric. Textures are mostly coarse grained and equigranular granitic but range from aplitic to pegmatitic. Accessory minerals include biotite, muscovite, and garnet

Kgu **Granite, undifferentiated (Cretaceous)**-Leucocratic fine- to coarse-grained massive granite and biotite monzogranite. Most is equigranular and consists of quartz and alkali feldspars. In leucocratic granite, biotite is a widespread varietal mineral. Muscovite-bearing granite occurs at Bell Mountain (Romoland 7.5' quadrangle)

Kmgt **Monzogranite and tonalite, undifferentiated (Cretaceous)**-Undifferentiated biotite monzogranite and biotite-hornblende tonalite. Restricted to single occurrence in the eastern part of the Box Springs Mountains (Sunnymead 7.5' quadrangle)

Kgd **Granodiorite, undifferentiated (Cretaceous)**-Biotite and hornblende-biotite granodiorite, undifferentiated. Most is massive and medium grained

Kt **Tonalite, undifferentiated (Cretaceous)**-Gray, medium-grained biotite-hornblende tonalite, typically foliated

Ktm **Tonalite and mafic rock, undifferentiated (Cretaceous)**-Subequal amounts of foliated, gray, medium-grained biotite-hornblende tonalite and meso- to melanocratic inclusion-like rock, which gives rise to migmatitic appearing rock

Kqd **Quartz diorite (Cretaceous)**-Medium- to coarse-grained biotite-hornblende quartz diorite. Most is slightly to well foliated with discoidal to pancake-shaped melanocratic inclusions in foliation plane. Grades into diorite and biotite-hornblende tonalite

Kdqd **Diorite and quartz diorite, undifferentiated (Cretaceous)**-Dark gray, medium- to coarse-grained mixtures of hornblende diorite and biotite and biotite-hornblende quartz diorite

Kd **Diorite, undifferentiated (Cretaceous)**-Mostly fine- to medium-grained, massive, dark gray to black hornblende diorite

Kgb **Gabbro (Cretaceous)**-Mainly hornblende gabbro. Includes Virginia quartz-norite and gabbro of Dudley (1935), and San Marcos gabbro of Larsen (1948). Typically brown-weathering, medium- to very coarse-grained hornblende gabbro; very large poikilitic hornblende crystals are common, and very locally gabbro is pegmatitic. Much is quite heterogeneous in composition and texture. Includes noritic and dioritic composition rocks

Khg **Heterogeneous granitic rocks (Cretaceous)**-A wide variety of heterogeneous granitic rocks occur in Santa Ana quadrangle. Some heterogeneous assemblages include large proportions of schist and gneiss. Rocks in Santa Ana Mountains include a mixture of monzogranite, granodiorite, tonalite, and gabbro. Tonalite composition rock is most abundant rock type. Tonalite from Hot Springs Canyon (Cañada Gobernadora 7.5' quadrangle), gave zircon age of 119.2 Ma_{id} and 116.5 Ma_{ip} (Pb/U ages, W.R Premo per. commun., 1999). Heterogeneous granitic rocks adjacent to east and south of Lakeview Mountains and Reinhardt Canyon pluton contain large amount of metamorphic rock. Except for southern part, granitic component consists of potassium feldspar-bearing tonalite and granodiorite

End granitic rocks of the Peninsular Ranges batholith

Ks **Serpentinite (Cretaceous)**-Small body of highly deformed, slickensided, greenish-brown serpentine within Santiago Peak volcanics (Corona South 7.5' quadrangle)

Kc **Carbonate-silicate rock (Cretaceous)**-Small body of reddish-brown carbonate-silicate rock spatially associated with serpentinite (Ks)

Kvsp **Santiago Peak Volcanics (Cretaceous)**-Basaltic andesite, andesite, dacite, rhyolite, volcaniclastic breccia, welded tuff, and epiclastic rocks (Herzig, 1991); widespread in the northern Santa Ana Mountains. Originally named Black Mountain volcanics by Hanna (1926), but name was pre-empted. Larsen (1948) renamed unit Santiago Peak Volcanics for exposures in vicinity of Santiago Peak, northern Santa Ana Mountains. Rocks are very heterogeneous, discontinuous, and poorly exposed. Most of unit is hydrothermally altered; alteration was contemporaneous with volcanism. Zircon ages of Santiago Peak Volcanics range from 123 to 134 Ma (Anderson, 1991), making it coeval with older part of Peninsular Ranges batholith

Kvspi **Intrusive rocks associated with Santiago Peak Volcanics (Cretaceous)**-Shallow porphyritic intrusive rocks principally of intermediate composition. Composed of plagioclase, clinopyroxene and altered orthopyroxene. Silicic porphyries composed of plagioclase, quartz, and altered pyroxene and biotite (Herzig, 1991)

Kvem **Estelle Mountain volcanics of Herzig (1991) (Cretaceous)**-Heterogeneous mixture of rhyolite flows, shallow intrusive rocks, and volcaniclastic rocks (Corona South, Lake Mathews, Alberhill and Elsinore 7.5' quadrangles); andesite is rare. Informally named by Herzig (1991) for exposures in vicinity of Estelle Mountain (Lake Mathews 7.5' quadrangle). These rocks were termed Temescal dacite-porphyry by Dudley (1935) and Temescal Wash quartz latite porphyry by Larsen (1948). Zircon age of rock from unit collected west of Lake Mathews (Lake Mathews 7.5' quadrangle), is 125.8 Ma (Anderson, 1991)

Kvr **Rhyolite of Estelle Mountains volcanics of Herzig (1991) (Cretaceous)**-Rhyolite; relatively uniform and homogeneous

Ksv **Intermixed Estelle Mountain volcanics of Herzig (1991) and Cretaceous(?) sedimentary rocks (Cretaceous?)**-Complexly intermixed volcanic and sedimentary rocks, which appear to be coeval; sedimentary rocks predominate

Kvs **Intermixed Estelle Mountain volcanics of Herzig (1991) and Mesozoic sedimentary rocks (Mesozoic)**-Complexly intermixed volcanic and sedimentary rocks; volcanic rocks predominate. West of Lake Mathews much of sedimentary rock predates volcanic rocks. In Elsinore 7.5' quadrangle, much of sedimentary rock appears coeval with volcanics

Deformed granitic rocks of Transverse Ranges Province (Mesozoic)-Assemblage of deformed Mesozoic granitic rocks that are part of an assemblage characteristic of upper plate rocks of Vincent Thrust in Transverse Ranges Province. Restricted to northeast corner of El Casco 7.5' quadrangle. Includes:

Mzmg **Mylonitic and cataclastic granitic rocks**-Fine- to coarse-grained cataclastic granodiorite, tonalite, and quartz diorite. Has non-penetrative and penetrative fabrics, including sheared and crushed rock, brittle cataclastic fabrics, and ductile mylonitic fabrics (northeast corner of the El Casco 7.5' quadrangle)

Mzdy **Diorite, Yucaipa area**-Medium- to coarse-grained, massive to incipiently foliated hornblende-biotite diorite and quartz diorite (northeast corner of the El Casco 7.5' quadrangle)

Jbc **Bedford Canyon Formation (Jurassic)**-Slightly metamorphosed assemblage of interlayered argillite, slate, graywacke, impure quartzite, and small masses of limestone. As used here, Bedford Canyon Formation is areally limited to northern part of Santa Ana Mountains. Most of unit is poorly exposed, best exposures restricted to road cuts. Bedding and primary sedimentary structures are commonly preserved, although tightly folded bedding is common. Fissile, black argillite and slate are very fine grained and consist of beds 2 to 8 cm in thickness. Massive bedded, impure, fine- to medium-grained, pale gray to pale brown quartzite and graywacke beds are 4 to 30 cm thick. Locally carbonaceous. Lenses of conglomerate occur sparsely through sequence. Incipiently developed transposed layering, S_1, is locally well-developed. Includes:

Jbc$_1$ **Bedford Canyon Formation, Unit 1**-The southern part of the unit consists of brown-weathering, massive-appearing quartz-rich metasandstone and impure quartzite. Locally some thin-layered fine-grained sandy intervals with discontinuous small folds (6-8cm). Locally contains abundant fine-grained dissiminated pyrite

Jbm **Marble and limestone**-Small elongate to equant-shaped bodies of gray weathering, fine-grained marble (limestone), some fossiliferous. Ammonites occur at a few places (Imlay, 1963, 1964, and 1980; Silberling, and others, 1961), and rhynchonelloid brachiopod debris is locally abundant (Gray, 1961)

Mzu **Mesozoic metasedimentary rocks, undifferentiated (Mesozoic)**-Wide variety of low- to high-metamorphic grade metamorphic rocks. Most occurrences include biotite schist

Mzg **Graywacke (Mesozoic)**-Predominately lithic graywacke (Romoland and Winchester 7.5' quadrangles). Thick layered, massive, commonly contains angular fragments of phyllite (chips) and discontinuous layers of phyllite in low metamorphic grade rocks or biotite schist is higher grade rocks

Mzq **Quartz-rich rocks (Mesozoic)**-Quartzite and quartz-rich metasandstone (Elsinore and Romoland 7.5' quadrangles)

Mzqg **Intermixed quartzite and graywacke (Mesozoic)**-Intermixed quartzite and lithic metagraywacke; quartzite may or may not be feldspathic (Romoland and Winchester 7.5' quadrangles)

Mzgp **Intermixed graywacke and phyllite (Mesozoic)**-Intermixed lithic metagraywacke and phyllite. Other metasedimentary rocks may be present in small amounts (Romoland and Winchester 7.5' quadrangles)

Mzp **Phyllite (Mesozoic)**-Fissile black phyllite. Occurs in thick sections in the Romoland and Elsinore 7.5' quadrangles. Commonly with sheen produced by very fine-grained white mica on s-surface; locally contains small elongate prisms of fine-grained white mica, which maybe pseudomorphs after chiastolite

Mzs **Schist (Mesozoic)**-Biotite schist, in part gradational with phyllite (Winchester and Bachelor Mountains 7.5' quadrangles). In lower metamorphic-grade rocks, consists of andalusite-biotite schist. In higher metamorphic-grade rocks, includes cordierite biotite schist, and in highest metamorphic-grade rocks sillimanite schist, and less commonly garnet bearing schist

Mzm **Marble (Mesozoic)**-Pod-like masses and elongate layers of marble and calcsilicate rocks. Occurrences in low metamorphic-grade rocks (e.g., phyllite association) are relatively fine-grained, off-white to gray marble. Commonly contains masses of radiating blades of white tremolite. Small mass of fine-grained dark gray to black marble and calcsilicate rock in hills east of Sun City contains deformed and poorly preserved pelycepods and crinoids

Mzi **Interlayered phyllite (or schist) and quartzite (Mesozoic)**-Western part of unit is low metamorphic-grade, interlayered, relatively pure quartzite and phyllite. Eastern part of unit is higher metamorphic-grade quartzite and biotite schist. In western low metamorphic-grade part of unit, some quartzite layers in hinges of slip folds are 8 to 24 cm thick, and may be relic beds (S_0) preserved in hinges. In this area, however, there are also transposed quartzite layers (S_1) in limbs of folds that are 5 to 7 cm thick. In areas of intermediate metamorphic-grade, quartzite layers are retransposed (S_2) and further attenuated to thickness of 1 to 2.5 cm. In easternmost part of unit they are transposed again (S_3) to thickness of about 6 mm (Romoland and Winchester 7.5' quadrangles)

Mzmn **Manganese-bearing rocks (Mesozoic)**-Layers of black manganese-bearing quartz-rich metasediments. Consists of manganese oxides-hydroxides and rhodonite in quartzite. Widespread minor occurrences in Railroad Canyon area (Elsinore and Winchester 7.5' quadrangles). Has been prospected as source of manganese (Sampson, 1935)

Mza **Amphibolite (Mesozoic)**-Black elongate-shaped masses of plagioclase and hornblende mainly within Mzgn. Locally contains garnet in vugs

Mzsgn **Mixed low metamorphic grade and upper amphibolite grade rocks (Mesozoic)**-Tectonically intermixed schist, graywacke, and impure quartzite of Mzs, Mzg, Mzq, and Mzgn (Winchester 7.5' quadrangle). Includes known occurrences of metaserpentine-metadunite and related rocks (Mzds, Mzdx, and Mzdc) which are restricted to this unit. Note: In Version 1 of this map this unit was included in Mzs. Based on reexamination, the eastern part of Mzs is now interpreted as a broad suture zone consisting of a mixture of rocks from both to the west and to the east and includes metaserpentinite and related rocks that appear to be unique to this mixed unit. Included is:

Mzsm **Mzds** **Metadunite and serpentinite**-Assemblage of metadunite, in large part serpentinized, and related metamorphic rocks. Forms several large masses on ridge between Diamond Valley and San Jacinto Valley, locally known as Searl Ridge. Least altered metadunite is composed essentially of olivine and talc. At and near outer margins of some metadunite is a layer consisting of essentially enstatite, and in some places an outer thin (few centimeters) of spinel-rich rock. Surrounding metadunite is selvage 0.5 to 6 m thick of massive rock containing large proportion of 2 to 5 cm poikiloblastic cordierite in sillimanite-biotite rock. Cordierite apparently formed from magnesium in dunite during metamorphism. Granitic pegmatite dikes intruding metadunite have outer parts containing andalusite, sillimanite, dumortierite, and cordierite. Metadunite adjacent to pegmatite is altered to an inner layer of hydrobiotite and vermiculite; and an outer layer of chlorite and amphibole. Thoroughly serpentinized metadunite (Mzsm) contains veinlets of magnesite, which was formerly mined

Mzdx **Amphibole- and pyroxene-bearing rocks associated with metadunite-serpentinite**-Includes wide variety of amphibole and pyroxene bearing rocks spatially associated with dunite. Ranges from white to green to black amphibolite and pyroxenite and pink anthophylite. Includes some carbonate rock and metasomatized schist. Isolated small exposures of these rocks are found in the vicinity of metadunite and serpentinite (Mzds) occurrences at Double Butte and Searl Ridge in the vicinity of Rawson Valley

Mzdc **Marble associated with metadunite**-Coarse-grained impure marble adjacent to metadunite. Marble consists of calcite and variable amounts of olivine, pyroxene, amphibole, spinel, and opaque minerals. Some silicate minerals are concentrated in layers. Marble apparently is metamorphosed silica-carbonate rock associated with serpentinite

Mzgn **Biotite gneiss and schist (Mesozoic)**-Medium- to dark-gray, coarse-grained biotite gneiss and schist, and biotite-quartz-feldspar gneiss and schist (Winchester 7.5' quadrangle). Locally contains sillimanite and cordierite. Commonly includes minor amounts of quartzite and calc-silicate hornfels. Anatectic stringers of granitic material are common. Note: This unit was referred to as Paleozoic? in Version 1 of this quadrangle; subsequent isotopic study of zircons found relic zircons of Mesozoic age (Premo, and others, 2002)

KgMz **Intermixed Mesozoic schist and Cretaceous granitic rocks (Mesozoic)**-Wide variety of Mesozoic schist and related metamorphic rocks mixed with granitic rocks ranging in composition from monzogranite to quartz diorite. Most granitic rocks are tonalite composition

KgPz **Intermixed Paleozoic(?) schist and Cretaceous granitic rocks (Mesozoic and Paleozoic?)**-Varied Paleozoic(?) schist and gneiss intermixed with granitic rocks. Most granitic rocks are tonalite composition

Pzu m **Paleozoic(?) rocks, undifferentiated (Paleozoic?)**-Includes wide variety of metamorphic rocks, most are of sedimentary protolith (El Casco, Lakeview, Riverside East and Riverside West 7.5' quadrangles). Mainly intercalated biotite schist and quartzite, gneiss, and lesser amounts of quartzite, hornblende gneiss, marble and associated skarn and calc-silicate rock. Sillimanite is common in biotite schist and garnet less common. Marble layers (m) within Pzu include coarse- and very coarse-grained white and gray marble occurring as pods and layers within biotite schist and gneiss. Most marble is in contact with or is near granitic rocks; pyroxene hornfels metamorphic mineral assemblages are common. Marble contains small amounts of diopside, forsterite, wollastonite, spinel, and graphite. Mineralogy of spatially associated skarns includes wollastonite, idocrase and garnet

Pzs **Biotite schist (Paleozoic?)**-Medium- to dark-gray, fine-grained biotite schist and biotite-quartz-feldspar schist. Locally contains sillimanite and cordierite. Commonly includes minor amounts of quartzite and calc-silicate hornfels

Pzq **Impure quartzite (Paleozoic?)**-Light-gray to light-greenish-gray, fine- to medium-grained, layered to massive, impure quartzite. Locally consists of intensely slip-folded quartzite interlayered with wollastonite rock. Weathers reddish-brown or orangish-brown

Pzm **Marble (Paleozoic?)**-White to light gray, locally bluish-gray, and pale to medium blue, coarse- to extremely coarse-grained marble. Locally includes calc-silicate hornfels, quartzite, biotite schist, and skarn. Most of the skarn occurs along the contact between marble and tonalite. Where in contact with tonalite marble, has mineral assemblages of pyroxene hornfels facies. Contact zones contain a wide variety of minerals, some uncommon or rare. Marble at New City Quarry (Victoria Ave Quarry) in Riverside, for example, contains borate-bearing skarn, ludwigite-pageite-vonsenite, associated with magnetite. Larger marble bodies which have been mined for various purposes

Pzc **Calc-silicate rocks (Paleozoic?)**-Heterogeneous, massive to well-layered calc-silicate rocks accompanied by variable amounts of marble, quartzite, and biotite schist

Pzms **Marble and schist, undivided (Paleozoic?)**-Heterogeneous mixture of marble and biotite schist; massive to foliated

REFERENCES

Albright, L.B., III, 1997, Geochronology and vertebrate paleontology of the San Timoteo Badlands, southern California: Ph.D dissertation, Riverside, California, Univ. California, 328 p.

Allen, C.R., 1981, The modern San Andreas fault, in, Ernst, W.G., ed., The geotectonic development of California; Ruby volume 1: Englewood Cliffs, New Jersey, Prentice-Hall, p. 511-534.

Anderson, C.L., 1991, Zircon uranium-lead isotopic ages of the Santiago Peak volcanics and spatially related plutons of the Peninsular Ranges batholith, southern California: M.S. thesis, San Diego, California, San Diego State University, 111 p.

Axelrod, D.I., 1937, A Pliocene flora from the Mt. Eden beds, southern California: Carnegie Institution Washington, Pub 576, p. 125-184.

______, 1950, Further studies of the Mt. Eden flora, southern California: Carnegie Institution. Washington, Pub. 590, p. 73-118.

Bailey, T.L., and Jahns, R.H., 1954, Geology of the Transverse Range Province, southern California, in, Jahns, R.H., ed., Geology of southern California: California Division of Mines Bull. 170, Chpt. II, p. 83-106.

Baird, A.K., Baird, K.W., and Welday, E.E., 1974, Chemical trends across Cretaceous batholithic rocks of southern California: Geology, v. 2, p. 493-496.

_____, 1979, Batholithic rocks of the northern Peninsular and Transverse Ranges, southern California: in Abbott, P.L., and Todd, V.R., eds., Mesozoic crystalline rocks: San Diego State Univ. Depart. Geol. Sci., p. 111-132

Baird, A.K., and Miesch, A.T., 1984, Batholithic rocks of southern California - A model for the petrochemical nature of their source materials: U.S. Geol. Survey Prof. Paper 1284, 42 p.

Blake, W.P., 1856, Notice of remarkable strata containing the remains of Infusoria and Polythalmia in the Tertiary formation of Monterey, California: Acad. of Nat. Sciences Philadelphia Proc., v. 7, p. 328-331.

Bramlette, M.N., 1946, The Monterey formation of California and the origin of its siliceous rocks: U.S. Geol. Survey Prof. Paper 212, 57 p.

Dall, W.H., 1898, A table of north America Tertiary horizons, correlated with one another and with those of Western Europe, with annotations: 1897 House Doc. 5, 55th Congress, 2nd session, 1898 U.S. Geol. Survey 18th Annual Rept., Pt. 2., p. 323-348.

Daviess, S.N., and Woodford, A.O., 1949, Geology of the northwestern Puente Hills, Los Angeles County, California: U.S. Geological Survey Oil and Gas Investigation, Preliminary Map 83.

Dickerson, R.E., 1914, The Martinez and Tejon Eocene and associated formations of the Santa Ana Mountains: Univ. California, Dept. Geol. Sciences, Bull., vol. 8, n. 11, p. 257-274.

Dudley, P.H., 1935, Geology of a portion of the Perris block, southern California: California Journal Mines and Geology, v. 31, p. 487-506.

______, 1936, Physiographic history of a portion of the Perris Block, southern California: Jour. Geology, v. 44, p. 358-378.

Durham, D.L., and Yerkes, R.F., 1959, Geologic map of the eastern Puente Hills, Los Angeles Basin, California: U.S. Geol. Survey Oil and Gas Map OM-195.

_______, 1964, Geology and oil resources of the eastern Puente Hills, southern California: U.S. Geol. Survey Prof. Paper 420-B, 62 p.

Eckis, R. W., 1934, South coastal-basin Investigations: Geology and ground water storage capacity of valley fill - south coastal basin investigation: California Div. Water

Resources Bull. 45, 279 p.
Eckmann, E.C., Strahorn, A.T., Holmes, L.C., and Guernsey, J.E., 1919, Soil survey of the Anaheim area, California: U.S. Dept. Agriculture, Advance Sheets - Field Operations of the Bureau of Soils, 1916, 79 p.
Eldridge, G. H., and Arnold, R., 1907, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U.S. Geol. Survey Bull. 309, 266 p.
Ellis, A. J., and Lee, C.H., 1919, Geology and ground waters of the western part of San Diego County, California: U.S. Geol. Survey Water Supply Paper 446.
Engel, Rene, 1959, Geology of the Lake Elsinore quadrangle, California: California Div. Mines Bull. 146, p. 1-59.
English, W.A. 1926, Geology and oil resources of the Puente Hills Region, California: U.S. Geol. Survey Bull. 768. 110 p.
Fairbanks, H.W., 1892, Geology of San Diego County; also of portions of Orange and San Bernardino Counties, in, Yale, G.Y., editor, Eleventh report of the State Mineralogist: California State Mining Bureau Eleventh Report, p. 76-120.
Fett, J.D., 1968, Geophysical investigations of the San Jacinto Valley, Riverside County, California: M.A. thesis, Riverside, California, University of California, 75 p.
Fife, D.L., Minch, J.A., and Crampton, P.J., 1967, Late Jurassic age of the Santiago Peak Volcanics, California: Geol. Soc. of America Bull., v. 78, p. 299-304.
Fraser, D.M., 1931, Geology of the San Jacinto quadrangle south of San Gorgonio Pass, California: California Mining Bureau Report 27, p. 494-540.
Frick, Childs, 1921, Extinct vertebrate faunas of the badlands of Bautista Creek and San Timoteo Canyon, southern California: Univ. California Pub., Depart. Geol. Sciences Bull., v. 12, p. 277-409.
Golz, D.J., Jefferson, G.T., and Kennedy, M.P., 1977, Late Pliocene vertebrate fossils from the Elsinore fault zone, California: Jour. Vertebrate Paleontology, v. 51, p. 864-866.
Gray, C.H. Jr, 1961, Geology of the Corona South quadrangle and the Santa Ana Narrows area, Riverside, Orange, and San Bernardino Counties, California: California Div. Mines Bull. 178, 120 p.
Gromet, L.P., and Silver, L.T., 1987, REE variations across the Peninsular Ranges batholith: Implications for batholithic petrogenesis and crustal growth in magmatic arcs: Jour. Petrology, v. 28, p. 75-125.
Hamlin, Homer, 1904, Water resources of the Salinas Valley, California: U.S. Geol. Survey Water Supply and Irrigation Paper n. 89, 91 p.
Hanna, M.A., 1926, Geology of the La Jolla quadrangle, California: Calif. Univ. Pub. Dept. Geol. Science Bull., v. 16, n. 7, p. 187-246.
Hawkins, J.W., 1970, Petrology and possible tectonic significance of Late Cenozoic volcanic rocks, southern California and Baja California: Geol. Society of America Bull., v. 81, no. 11, p. 3323-3338.
Herzig, C.T., 1991, Petrogenetic and tectonic development of the Santiago Peak Volcanics, northern Santa Ana Mountains, California: Ph.D dissertation, Riverside, California, University of California, 376 p.
Hull, A.G., 1990, Seismotectonics of the Elsinore-Temecula trough, Elsinore fault zone, southern California: Ph.D. dissertation, Santa Barbara, California, University of California, 233 p.
Hull, A.G., and Nicholson, Craig, 1992, Seismotectonics of the northern Elsinore Fault zone, southern California: Bull. Seismological Soc. Amer., v. 82, p. 800-818.
Imlay, R.W., 1963, Jurassic fossils from southern California: Jour. Paleontology, v. 37, n. 1, p. 97-107.
_____, 1964, Middle and upper Jurassic fossils from southern California: Jour. Paleontology, v. 38, n. 3, p. 505-509.
_____, 1980, Jurassic paleobiogeography of the conterminous United States in its continental setting: U.S. Geol. Survey Prof. Paper 1062, 134 p.
Ingle, J.C., 1971, Paleoecologic and paleobathymetric history of the late Miocene-Pliocene Capistrano Formation, Dana Point area, Orange County, California: in Geologic guidebook, Newport Lagoon to San Clemente, Orange County, California: Soc. Econ. Paleontologists and Mineralogists, Pacific Sect., 88 p.
_____, 1972, Biostratigraphy and paleoecology of early Miocene through early Pleistocene benthonic and

planktonic Foraminifera, San Joaquin Hills, Newport Bay, Orange County, California, in The proceedings of the Pacific Coast Miocene biostratigraphic symposium: Soc. Econ. Paleontologists and Mineralogists, Pacific Section, 47 Annual Convention, p. 255-283.

Jahns, R.H., 1954, Geology of the Peninsular Ranges Province, southern California and Baja California, in Jahns, R.H. editor, Geology of southern California: California Div. of Mines Bull. 170, chapter 2, p. 29-52.

Kennedy, M.P., 1977, Recency and character of faulting along the Elsinore fault zone in southern Riverside County, California: California Div. Mines and Geology, Special Report 131, 12 p.

Kern, J.P., 1996, Are Quaternary marine terrace shorelines horizontal from Newport Beach to Del Mar?, in Munasinghe, T., and Rosenberg, P., editors, Geology/natural resources of coastal S.D. County, p. 25-41.

Kern, J.P., Derrickson, A., and Burke, T., 1996, Preliminary geologic map of Quaternary marine terraces at Dana Point, Orange County, California, in Munasinghe, T., and Rosenberg, P., editors, Geology/natural resources of coastal S.D. County, p. 10-15.

Kew, W.S.W., 1923, Geologic formations of a part of southern California and their correlation: Amer. Assoc. Petroleum Geologists Bull., v. 7, p. 411-420.

______, 1924, Geology and oil resources of a part of Los Angeles and Ventura Counties, California: U.S. Geol. Survey Bull. 753, 202 p.

Kistler, R.W., Wooden, J.L., and Morton, D.M., 2003, Isotopes and ages within the northern Peninsular Ranges batholith, southern California: U.S. Geological Survey Open-file Report 03-489, 45 p.

Krummenacher, D., Gastil, R.G., Bushee, J., and Doupont, J., 1975, K-Ar apparent ages, Peninsular Ranges batholith, southern California: Geol. Soc. Amer. Bull., v. 86, p. 760-768.

Langenkamp, David, and Combs, Jim, 1974, Microearthquake study of the Elsinore fault zone, southern California: Seismological Soc. America Bull., v. 64, no. 1, p. 187-203.

Larsen, E.S., 1948, Batholith and associated rocks of Corona, Elsinore, and San Luis Rey quadrangles, southern California: Geol. Society America Mem. 29, 182 p.

Mann, J.F., 1955, Geology of a portion of the Elsinore fault zone, California: California Div. Mines Special Report 43, 22 p.

Matti, J.C., and Morton, D.M., 1993, Paleogeographic evolution of the San Andreas fault in southern California: A reconstruction based on a new cross-fault correlation , in, Powell, R.E., Weldon, R.J., and Matti, J.C., eds., The San Andreas fault system: Displacement, palinspastic reconstruction, and geologic evolution: Geol. Soc. America Memoir 178, p. 107-159.

May, S.R., and Repenning, C.A., 1982, New evidence for the age of the Mount Eden fauna, southern California: Jour. Vert. Paleont., v. 2, p. 109-113.

Merriam, Richard, and Bischoff, J.L, 1975, Bishop Ash: A widespread volcanic ash extended to southern California: Jour. Sedimentary Petrology, v. 45, p. 207-211.

Merill, F.J.H., 1914, Geology and mineral resources of San Diego and Imperial Counties: California State Mining Bureau, 113 p.

Miesch, A.T., and Morton, D.M., 1977, Chemical variability in the Lakeview Mountains pluton, southern California batholith -- a comparison of the methods of correspondence analysis and extended Q-mode factor analysis: U.S. Geol. Survey Jour. Research v. 5, n. 1, p. 103-116.

Miller, W.J., 1946, Crystalline rocks of southern California: Geol. Soc. America Bull., v. 57, p. 457-542.

Moore, J.G., and Lockwood, J.P., 1973, Origin of comb layering and orbicular structure, Sierra Nevada batholith, California: Geol. Soc. America Bull. v. 84, p. 1-20.

Morton, D. M., 1969, The Lakeview Mountains pluton, southern California batholith: Part I, petrology and structure: Geol. Soc. America Bull., v. 80, p. 1539-1552.

______, 1972, Geology of the Lakeview -Perris quadrangles, Riverside County, California: California Div. Mines and Geology Map Sheet 19.

______, 1977, Surface deformation in part of the San Jacinto Valley, southern California: U.S. Geol. Survey Jour.

Research, vol. 5, n. 1, p. 117-124.

______, 1993, Metamorphic rocks in the Perris block, northwestern Peninsular Ranges, southern California: Geol. Soc. Amer. Abst with Programs, v. 26, n. 2, p. 76.

Morton, D.M., Baird, A.K., and Baird, K.W., 1969, The Lakeview Mountains pluton, southern California batholith: Part II, chemical composition and variation: Geol. Soc. America Bull., v. 80, p. 1553-1564.

Morton, D.M., and Baird, A.K, 1976, Petrology of the Paloma Valley ring complex, southern California batholith: U.S. Geol. Survey Jour. Research, v. 4, n. 1, p 83-89.

Morton, D.M., and Kistler, R.W., 1997, Sri variation in the northern Peninsular Ranges batholith: Geol. Soc. Amer. Absts. With Programs, v. 29, n. 6, p. A-69.

Morton, D.M., and Matti, J.C., 1989, A vanished late Pliocene to early Pleistocene alluvial-fan complex in the northern Perris Block, southern California, in Colburn, I.P., Abbott, P.L., and Minch, J., eds., Conglomerates in basin analysis: A symposium dedicated to A.O. Woodford: Pacific Section Society of Economic Paleontologists and Mineralogists, v. 62, p. 73-80.

______, 1993, Extension and contraction within an evolving divergent strike-slip fault complex: the San Andreas and San Jacinto fault zones at their convergence in southern California, in, Powell, R.E., Weldon, R.J., and Matti, J.C., eds., The San Andreas fault system: Displacement, palinspastic reconstruction, and geologic evolution: Geol. Soc. Amer Mem. 178, Boulder, Colorado, p. 217-230.

Morton, D.M., Matti, J.C., Miller, F.K., and Repenning, C.A., 1986, Pleistocene conglomerate from the San Timoteo Badlands, southern California: Constraints on strike-slip displacements on the San Andreas and San Jacinto faults: Geol. Soc. America Abst. with Programs, v. 18, p. 161.

Morton, J.L., and Morton, D.M., 1979, K-Ar ages of Cenozoic volcanic rocks along the Elsinore Fault zone, southwestern Riverside California: Geol. Soc. America Abstracts with programs, v. 11, p. 119.

Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral deposits: California Div. Mines and Geology Bull. 204 (scale 1:48,000).

Morton, P.K., Miller, R.V., and Evans, J.R., 1979, Environmental Geology of Orange County, California: California Division of Mines and Geology Open-file Rept. 79-8, 474 p.

Osborn, E.F., 1939, Structural petrology of the Val Verde Tonalite, southern California: Geol. Soc. America Bull., v. 50, p. 921-950.

Packard, E.L., 1916, Faunal studies in the Cretaceous of the Santa Ana Mountains of southern California: Univ. California Depart. Geol. Sciences Bull., vol. 9, no. 12, p. 137-159.

Packard, E.L., 1922, New species from the Cretaceous of the Santa Ana Mountains, California: Univ. California Depart. Geol. Sciences Bull., vol. 13, no. 10, p. 413-462.

Popenoe, W.P., 1937, Upper Cretaceous Mollusca from southern California: Jour. Paleontology, v. 11, n. 5, p. 379-402.

_______, 1941, The Trabuco and Baker conglomerates of the Santa Ana Mountains: Jour. Geol., vol. 49, no. 7, p. 738-752.

_______, 1942, Upper Cretaceous formations and faunas of southern California: Amer. Assoc. Petroleum Geologists Bull., v. 26, n. 2, p. 162-187.

Premo, W.R., Morton, D.M., Snee, L.W., and Bern, A.M., 2002, SHRIMP U-Pb ages of provenance from detrital zircons populations of intra-batholithic metasedimentary rocks, n. Peninsular Ranges batholith, southern California: Implications for their tectonic setting: Geological Society of America Abstracts with Programs vol. 34, No. 6, p. 124.

Premo, W.R., Morton, D.M., Snee, L.W., Naeser, N.D., and Fanning, C.M., 1998, Isotopic ages, cooling histories, and magmatic origins for Mesozoic tonalite plutons from the northern Peninsular Ranges batholith, southern California: Geol. Soc. Amer. Abstracts with programs, v. 30, n. 5, p. 59.

Proctor, R.J., 1962, Geologic features of a section across the Casa Loma fault, exposed in an aqueduct trench near San Jacinto, California: Geol. Soc. America Bull., v. 73, p. 1293-1296.

Proctor, R.J., and Downs, Theodore, 1963, Stratigraphy of a new formation containing early Pliocene vertebrates at Lake Mathews, near Riverside, California: Geol. Soc. America, Abs. for 1962, Spec. Paper 73, p. 59.

Repenning, C.A., 1987, Biochronology of the microtine rodents of the United States, in, Woodburne, M.O., ed., Cenozoic mammals of north America: Geochronology and biostratigraphy: Berkeley and Los Angeles, Univ. California Press, p. 236-268.

Reynolds, R.E., Fay, L.P., and Reynolds, R.L., 1990, An early-late Irvingtonian land mammal age fauna from Murrieta, Riverside County, California: San Bernardino County Museum Association Quarterly, v. XXXVII, p. 35-36.

Reynolds, R.E., and Reynolds, R.L., 1990a, A new late Blancan faunal assemblage from Murrieta, Riverside County, California: San Bernardino County Museum Association Quarterly, v. XXXVII, p. 34.

_______, 1990b, Irvingtonian? Faunas from the Pauba Formation, Temecula, Riverside County, California: San Bernardino County Museum Association Quarterly, v. XXXVII, p. 37.

Rogers, T.H., 1965, Santa Ana sheet: California Div. Mines and Geology Geologic Map of California, scale 1:250,000.

Sampson, R.J, 1935, Mineral resources of a portion of the Perris block, Riverside County, California: California Journal of Mines and Geology, v. 31, p. 507-521.

Schoellhamer, J.E., Kinney, D.M., Yerkes, R.F., and Vedder, J.G., 1954, Geologic map of the northern Santa Ana Mountains, Orange and Riverside Counties, California: U.S. Geol. Survey Oil and Gas investigations Map OM 154 (scale 1:24,000).

Schoellhamer, J.E., Vedder, J.G, Yerkes, R.F., and Kinney, D.M., 1981, Geology of the northern Santa Ana Mountains, California: U.S. Geol. Survey Prof. Paper 420-D, 109 p.

Schwarcz, H.P., 1969, Pre-Cretaceous sedimentation and metamorphism in the Winchester area, northern Peninsular Ranges, California: Geol. Soc. Amer. Special Paper 100, 63 p.

Sharp, R.V., 1967, San Jacinto fault zone in the Peninsular Ranges of southern California: Geol. Soc. America Bull., v. 78, p. 705-729.

Shelton, J.S., 1955, Glendora volcanic rocks, Los Angeles Basin, California: Geol. Soc. Amer. Bull., v. 66, n. 1, p. 45-89.

Silberling, N.J., Schoellhamer, J.E., Gray, C.H., and Imlay, R.W., 1961, Upper Jurassic fossils from Bedford Canyon Formation, southern California: Amer. Assoc. Petroleum Geologists Bull., v. 45, n. 10, p. 1746-1748.

Silver, L.T., and Chappel, B.W., 1988, The Peninsular Ranges batholith: An insight into the evolution of the Cordilleran batholiths of southwestern Northern America: Trans. Royal Soc. of Edinburgh, Earth Sciences, v. 79, p. 105-121.

Smith, D.K., Morton, D.M., and Miller, F.K., 1991, Hornblende geobarometry and biotite K-Ar ages from the northern part of the Peninsular Ranges batholith, southern California: Geol. Soc. Amer. Abst. with Programs, v. 23, p. 273.

Smith, J.P., 1898, Geographic relations of the Trias of California: Jour. Geology, vol. 6, p. 776-786.

_____, 1914, The middle Triassic marine invertebrate faunas of North America: U.S. Geol. Prof. Paper 83, 145 p.

Smith, P.B., 1960, Foraminifera of the Monterey Shale and Puente Formation, Santa Ana Mountains and the San Juan Capistrano area, California: U.S. Geol. Survey Prof. Paper 254-M, p. 463-495.

Stewart, R.E., and Stewart, K.C., 1930, "Lower Pliocene" in the eastern end of the Puente Hills, San Bernardino County, California: Am. Assoc. Petroleum Geologists Bull., v. 14, p. 1445-1450.

Todd, V.R., Erskine, B.G., and Morton, D.M., 1988, Metamorphic and tectonic evolution of the northern Peninsular Ranges batholith, southern California: Ruby vol. VII, p. 894-937.

Vedder, J.G., 1957, New stratigraphic names used on geologic map of the San Joaquin Hills-San Juan Capistrano area, Orange County, California in Vedder, J.G., Yerkes, R.F., and Schoellhamer, J.E., Geologic map of the San Joaquin Hills-San Juan Capistrano area, Orange County, California: U.S. Geol. Survey Oil and

Gas Inv. Map OM-193.

______, 1960, Previously unreported Pliocene Mollusca from the southeastern Los Angeles basin: U.S. Geol. Survey Prof. Paper 400-B, p. B326-B328.

______, 1972, Review of stratigraphic names and megafaunal correlations of Pliocene rocks along the southeast margin of the Los Angeles basin, California, in Stinemeyer, E.H., ed., Pacific Coast Miocene Biostratigraphic Symposium: Soc. Econ. Paleontologists and Mineralogists, Pacific Sec., Bakersfield, Calif., March, 1972, p. 158-172.

______, 1975, Revised geologic map, structure sections, and well tables, San Joaquin Hills-Capistrano area, California: U.S. Geol. Survey Open-file Rept. 75-552.

Vedder, J.G., Yerkes, R.F., and Schoellhamer, J.E., 1957, Geologic map of the San Joaquin Hills-San Juan Capistrano area, Orange County, California: U.S. Geological Survey Oil and Gas Inv. Map OM-193.

Watts, W.L., 1897, Oil and gas yielding formation of Los Angeles, Ventura, and Santa Barbara Counties, California: Calif. Mining Bur., Bull. 11, 72 p.

Webb, R.W., 1939, Evidence of the age of a crystalline limestone, southern California: Jour. Geol., v. 47, p. 198-201.

Weber, F.H. Jr, 1976, Preliminary map of faults of the Elsinore and Chino fault zones in northeastern Riverside County, California, showing accompanying features related to character and recency of movement: California Div. Mines and Geology Open-file Report 76-1 LA.

White, W.R., 1956, Pliocene and Miocene Foraminifera from the Capistrano Formation, Orange County, California: Jour. Paleontology, v. 30, p. 237-270.

_____, 1971, Biostratigraphy of the Capistrano Formation, Dana Point, California, in Berger, F.W., ed., Geological guide book Newport Lagoon to San Clemente, Orange County, California: Soc. Econ. Paleontologists and Mineralogists, Pacific Section, p. 50-54.

Whitney, J.D., 1865, Geological Survey of California, Geology, v. 1, Report of progress and synopsis of field work from 1869-1864, 498 p.

Woodburne, M.O., 1987, ed., Cenozoic mammals of north America: Geochronology and biostratigraphy: Berkeley and Los Angeles, Univ. California Press, 336 p.

Woodford, A.O., 1924, The Catalina Metamorphic Facies of the Franciscan series: University of California Pub. Geol. Sciences, v. 15, n. 3, p. 49-68.

_______, 1925, The San Onofre breccia: Its nature and origin: California Univ. Pubs., Dept. Geol. Sci. Bull., v 15, no. 7, p. 159-280.

Woodford, A.O., McCulloh, T.H., and Schoellhamer, J.E., 1973, Paleographic significance of metatuff boulders in middle Tertiary strata, Santa Ana Mountains, California: Geol. Soc. America Bull. v. 83, no. 11, p. 3433-3436.

Woodford, A.O., Moran, T.G., and Shelton, J.S., 1946, Miocene conglomerates of Puente and San Jose Hills, California: Am. Assoc. Petroleum Geologists Bull., v. 30, p. 514-560.

Woodford, A.O., Shelton, J.S., and Moran, T.G., 1944, Geology and oil possibilities of Puente and San Jose Hills, California: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 23.

Woodford, A.O, Shelton, J.S., Doehring, D.O., and Morton, R.K., 1971, Pliocene-Pleistocene history of the Perris Block, southern California: Geol. Soc. America Bull., v. 82, no. 12, p. 3421-3448.

Woodford, A.O., Welday, E.E., and Merriam, Richard, 1968, Siliceous tuff clasts in the upper Paleogene of southern California: Geol. Soc. America Bull., v. 79, p. 1461-1486.

Woodring, W.P., 1938, Lower Pliocene mollusks and echinoids from the Los Angeles basin, California, and their inferred environment: U.S. Geological Survey Prof. Paper 190, 67 p.

Woodring, W.P., and Popenoe, W.P., 1942, Upper Cretaceous formations and faunas of southern California: Amer. Assoc. Petroleum Geologists Bulletin, vol. 26, no. 2, p. 166-176.

_______, 1945, Paleocene and Eocene stratigraphy of northwestern Santa Ana Mountains, Orange County, California: U.S. Geol. Survey Oil and Gas investigations Prelim. Chart OC 12.

Yerkes, R.F., 1957, Volcanic rocks of the El Modeno area, Orange County, California: U.S. Geol. Survey Prof.

Paper 247-L, p. 313-334.
______, 1972, Geology and oil resources of the western Puente Hills area, southern California: U.S. Geol. Survey Prof. Paper 420-C, 63 p.

Yerkes, R.F., McCulloh, T.H., Schoellhamer, J.E., and Vedder, J.G., 1965, Geology of the Los Angeles basin, California -- An introduction: U.S. Geol. Survey Prof. Paper 420-A, 57 p.

Yerkes, R.F., and Campbell, R.H., 1979, Stratigraphic nomenclature of the central Santa Monica Mountains, Los Angeles County, California: U.S. Geol. Survey Bulletin 1457-E, 31 p.

Sources of mapping used in the Santa Ana 30' x 60' quadrangle listed by 7.5' quadrangle

Alberhill

Greenwood, R.B., 1992, Geologic map of the Alberhill 7.5' quadrangle: California Division of Mines and Geology Open-file Report 92-10; Weber, F.H. Jr, 1976, Preliminary map of faults of the Elsinore and Chino fault zones in northeastern Riverside County, California, showing accompanying features related to character and recency of movement: California Div. Mines and Geology Open-file Report 76-1; Morton, D.M., unpublished mapping, 1996.

Anaheim

Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral deposits: California Division of Mines and Geology Bull. 204; Eckmann, E.C., Strahorn, A.T., Holmes, L.C., and Guernsey, J.E., 1919, Soil survey of the Anaheim area, California: U.S. Dept. of Agriculture, Advance Sheets - Field Operations of the Bureau of Soils, 1916, 79 p.; Vedder, J.G.,1975, Revised geologic map, structure sections, and well tables, San Joaquin Hills-Capistrano area, California: U.S. Geol. Survey Open-file Rept. 75-552.

Bachelor Mountain

Morton, D.M., and Kennedy, M.P., 2003, Geologic map of the Bachelor Mountain 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of03-103.

Black Star Canyon

Schoellhamer, J.E., Vedder, J.G., Yerkes, R.F., and Kinney, D.M., 1981, Geology of the northern Santa Ana Mountains, California: U.S. Geological Survey Prof. Paper 420-D, 109 p.; Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral deposits: California Division of Mines and Geology Bull. 204; Tan, S.S. 1990, Landslide hazards in the northern half of the Black Star Canyon quadrangle, Orange County, California: California Division of Mines and Geology Open-File Report 90-19; Morton, D.M., unpublished mapping, 1996.

Cañada Gobernadora

Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral deposits: California Division of Mines and Geology Bull. 204; Morton, D.M., unpublished mapping, 1996; Tan, S.S., undated, unpublished mapping.

Corona North

Morton, D.M., and Gray, C.H., Jr., 2002, Geologic map of the Corona North 7.5' Quadrangle, Riverside and San Bernardino Counties, California. http://geopubs.wr.usgs.gov/open-file/of02-022

Corona South

Gray, C.H., Jr., Morton, D.M., and Weber, F.H., Jr., 2002, Geologic map of the Corona South 7.5' Quadrangle, Riverside and Orange Counties, California. http://geopubs.wr.usgs.gov/open-file/of02-021

El Casco

Matti, J.C., unpublished mapping, 1973-4, 1996-7, 2003; Morton, D.M., unpublished mapping 1995-7

Elsinore

Morton, D.M., and Weber F.H., Jr., 2003, Geologic map of the Elsinore 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of03-281

El Toro

Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral deposits: California Division of Mines and Geology Bull. 204; Eckmann, E.C., Strahorn, A.T., Holmes, L.C., and Guernsey, J.E., 1919, Soil survey of the Anaheim area, California: U.S. Dept. of Agriculture, Advance Sheets - Field Operations of the Bureau of Soils, 1916, 79 p.; Tan, S.S., Miller, R.V., and Fife, D.L., 1984, Geology of the north half of the El Toro quadrangle, Orange County, California: California Division of Mines and Geology Open-File Report 84-28.

Laguna Beach

Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral

deposits: California Division of Mines and Geology Bull. 204; Vedder, J.G., 1975, Revised geologic map, structure sections, and well tables, San Joaquin Hills-Capistrano area, California: U.S. Geol. Survey Open-file Rept. 75-552; Tan, S.S., and Edgington, W.J., 1976, Geology and engineering geologic aspects of the Laguna Beach quadrangle, Orange County, California: California Division of Mines and Geology Special Report 127; Kern, J.P., 1996, Geological mapping of marine terraces and marine terrace deposits in coastal southern California: California Division of Mines and Geology unpublished reports, Interagency Agreement 1094-046.; Tan, S.S., undated, unpublished mapping.

La Habra

Yerkes, R.F., 1972, Geology and oil resources of the western Puente Hills area, southern California: U.S. Geological Survey Prof. Paper 420-C, 63 p.; Tan, S.S., 1988, Landslide hazards in the Puente and San Jose Hills, southern California: California Division of Mines and Geology Landslide Identification Map no. 12B-SE, 12B-W, Open-file Report 88-21.; Tan, S.S., and Evans, J.R., 1984, Geology of the south half of the La Habra quadrangle, Orange County, California : California Division of Mines and Geology Open-File Report 84-24.

Lake Mathews

Morton, D.M., and Weber F.H., Jr., 2001, Geologic map of the Lake Mathews 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of01-479

Lakeview

Morton, D.M., and Matti, J.C., 2001, Geologic map of the Lakeview 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of01-174

Murrieta

Kennedy, M.P., and Morton, D.M., 2003, Preliminary Geologic map of the Murrieta 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of03-189

Newport Beach

Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral deposits: California Division of Mines and Geology Bull. 204.; Vedder, 1975; Eckmann, E.C., Strahorn, A.T., Holmes, L.C., and Guernsey, J.E., 1919, Soil survey of the Anaheim area, California: U.S. Dept. of Agriculture, Advance Sheets - Field Operations of the Bureau of Soils, 1916, 79 p.; Kern, J.P., 1996, Geological mapping of marine terraces and marine terrace deposits in coastal southern California: California Division of Mines and Geology unpublished reports, Interagency Agreement 1094-046.; Tan, S.S., undated, unpublished mapping.

Orange

Tan, S.S., 1995, Landslide hazards in the Orange quadrangle, Orange County, California: California Division of Mines and Geology Landslide Identification Map no. 34, Open-file Report 95-11; Eckmann, E.C., Strahorn, A.T., Holmes, L.C., and Guernsey, J.E., 1919, Soil survey of the Anaheim area, California: U.S. Dept. of Agriculture, Advance Sheets - Field Operations of the Bureau of Soils, 1916, 79 p.

Perris

Morton, D.M., 2003, Geologic map of the Perris 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of03-270

Prado Dam

Durham, D.L., and Yerkes, R.F., 1964, Geology and oil resources of the eastern Puente Hills, southern California: U.S. Geological Survey Prof. Paper 420-B, 62 p.; Tan, S.S., 1988, Landslide hazards in the Puente and San Jose Hills, southern California: California Division of Mines and Geology Landslide Identification Map no. 12B-SE, 12B-W, Open-file Report 88-21; McCulloh, T.H., unpublished mapping, 1996,2000; Morton, D.M., unpublished mapping, 1997

Riverside East

Morton, D.M., and Cox, B.F., 2001, Geologic map of the Riverside East 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of01-452

Riverside West

Morton, D.M., and Cox, B.F., 2001, Geologic map of the

Riverside West 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of01-451

Romoland

Morton, D.M., 2003, Geologic map of the Romoland 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of03-102

San Juan Capistrano

Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral deposits: California Division of Mines and Geology Bull. 204; Vedder, J.G., 1975, Revised geologic map, structure sections, and well tables, San Joaquin Hills-Capistrano area, California: U.S. Geol. Survey Open-file Rept. 75-552; Tan, S.S., undated, unpublished mapping

Santiago Peak

Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral deposits: California Division of Mines and Geology Bull. 204; Morton, D.M., unpublished mapping, 1997; Tan, S.S., undated, unpublished mapping

Sitton Peak

Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral deposits: California Division of Mines and Geology Bull. 204; Alvarez, R.M. and Morton, D.M., unpublished mapping, 1996, 2003.

Steele Peak

Morton, D.M., 2001, Geologic map of the Steele Peak 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of01-449

Sunnymead

Morton, D.M., and Matti, J.C.. 2001, Geologic map of the Sunnymead 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of01-450

Tustin

Morton, P.K., and Miller, R.V., 1981, Geologic map of Orange County, California showing mines and mineral deposits: California Division of Mines and Geology Bull. 204.; Eckmann, E.C., Strahorn, A.T., Holmes, L.C., and Guernsey, J.E., 1919, Soil survey of the Anaheim area, California: U.S. Dept. of Agriculture, Advance Sheets - Field Operations of the Bureau of Soils, 1916, 79 p.; Vedder, J.G., 1975, Revised geologic map, structure sections, and well tables, San Joaquin Hills-Capistrano area, California: U.S. Geol. Survey Open-file Rept. 75-552; Tan, S.S., undated, unpublished mapping.

Wildomar

Kennedy, M.P., 1977, Recency and character of faulting along the Elsinore fault zone in southern Riverside County, California: California Div. Mines and Geology, Special Report 131, 12 p.; Alvarez, R.M., and Morton, D.M., unpublished mapping, 1996

Winchester

Morton, D.M., 2003, Preliminary Geologic map of the Winchester 7.5' Quadrangle, Riverside County, California. http://geopubs.wr.usgs.gov/open-file/of03-188

Yorba Linda

Yerkes, R.F., 1972, Geology and oil resources of the western Puente Hills area, southern California: U.S. Geological Survey Prof. Paper 420-C, 63 p.; Tan, S.S., 1988, Landslide hazards in the Puente and San Jose Hills, southern California: California Division of Mines and Geology Landslide Identification Map no. 12B-SE, 12B-W, Open-file Report 88-21; Tan, S.S., and Miller, R.V., 1984, Geology of the south half of the Yorba Linda quadrangle, Orange County, California: California Division of Mines and Geology Open-File Report 84-24.

DIGITAL PREPARATION OF INDIVIDUAL 7.5' QUADRANGLES

Alberhill
Melinda C. Wright, Diane Burns
Anaheim
Rachel M. Alvarez
Bachelor Mountain
Kelly R. Bovard, Diane Burns
Black Star Canyon
Kelly R. Bovard, Gary W. Patt, Katherine Koukladas
Cañada Gobernadora
Rachel M. Alvarez, Kelly R. Bovard
Corona North
Kelly R. Bovard, Michael Dawson
Corona South
Kelly R. Bovard, Tim O'Brien
El Casco
Pam M. Cossette
Elsinore
Rachel M. Alvarez, Diane Burns
El Toro
Anne G. Garcia
Laguna Beach
Kelly R. Bovard, Roland Hall
La Habra
Michael L. Dawson, Tim O'Brien, Rachel M. Alvarez, Kelly R. Bovard
Lake Mathews
Van M. Diep, Ursula Edwards-Howells
Lakeview
Rachel M. Alvarez, Pam M. Cossette
Murrieta
Rachel M. Alvarez, Greg Morton
Newport Beach
Michael L. Dawson, Diane Burns
Orange
Kelly R. Bovard, Teddy Bunyapanasarn
Perris
Kelly R. Bovard, Rachel M. Alvarez
Prado Dam
Kelly R. Bovard
Riverside East
Michael Dawson, Tim O'Brien
Riverside West
Rachel M. Alvarez, Van M. Diep
Romoland
Kelly R. Bovard, Gregory Morton
San Juan Capistrano
Kelly R. Bovard, Roland Hall
Santiago Peak
Kelly R. Bovard, Michael L. Dawson
Sitton Peak
Rachel M. Alvarez, Roland Hall
Sunnymead
Van M. Diep, Ursula Edwards-Howells
Steele Peak
Rachel M. Alvarez, Van M. Diep
Tustin
Rachel M. Alvarez, Diane Burns, Anne G. Garcia
Wildomar
Rachel M. Alvarez, Fernando H. Keller
Winchester
Kelly R. Bovard, Gary W. Patt
Yorba Linda
Kelly R. Bovard, Michael L. Dawson, Teddy Bunyapanasarn

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
CALIFORNIA GEOLOGICAL SURVEY

OPEN-FILE REPORT 99-172
Version 2.0 - 2004
Sheet 1 of 2
SCAMP - *Southern California Areal Mapping Project*

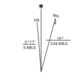
Base map digital layers (roads, topographic contours, and hydrography) were prepared from publicly available digital line graph (DLG) data, Santa Ana 1:100,000 metric quadrangle.
Universal Transverse Mercator projection, zone 11

SCALE 1:100,000

1 .5 0 1 2 3 4 5 6 7 MILES

1 .5 0 1 2 3 4 5 6 7 KILOMETERS

CONTOUR INTERVAL 50 METERS



PRELIMINARY DIGITAL GEOLOGIC MAP OF THE SANTA ANA 30' X 60' QUADRANGLE, SOUTHERN CALIFORNIA

Version 2.0

Compiled by
D. M. Morton[1]

Version 2.0 digital preparation by
Kelly R. Bovard[1] and Rachel M. Alvarez[1]
2004

Version 1.0 digital preparation by
Rachel M. Hauser[1] and Kelly R. Ruppert[1]
1999

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125

U.S. DEPARTMENT OF THE INTERIOR
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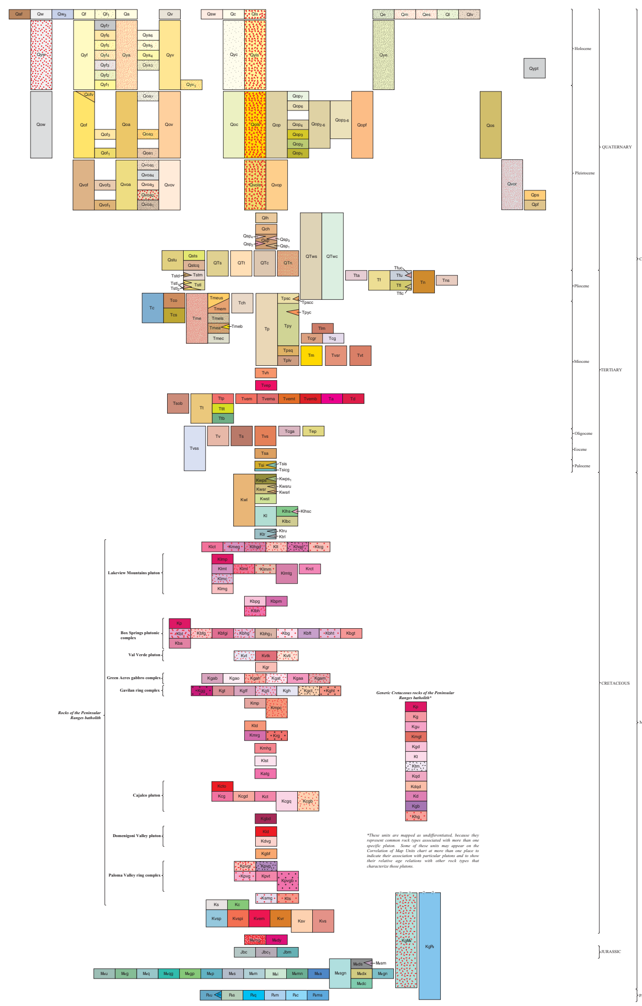
CORRELATION OF MAP UNITS



EXPLANATION

DESCRIPTION OF MAP UNITS

Old paralic deposits, undivided (late to middle Pleistocene)—Silt, sand and cobbles. Interfingered strandline, beach, estuarine, and colluvial deposits. Includes:

Old paralic deposits, Unit 7 (late to middle Pleistocene)—Silt, sand and cobbles resting on 9-11 m Bird Rock terrace. Age about 80,000 years

Old paralic deposits, Unit 6 (late to middle Pleistocene)—Silt, sand and cobbles resting on 22-23 m Nestor terrace. Age about 120,000 years

Old paralic deposits, Unit 4 (late to middle Pleistocene)—Silt, sand and cobbles resting on 34-37 m Stuart Mesa terrace. Age about 200,000-300,000 years

Old paralic deposits, Unit 3 (late to middle Pleistocene)—Silt, sand and cobbles resting on 45-46 m Guy Fleming terrace. Age about 320,000-340,000 years

Old paralic deposits, Unit 2 (late to middle Pleistocene)—Silt, sand and cobbles resting on 55 m Parry Grove terrace. Age about 413,000 years

Old paralic deposits, Unit 1 (late to middle Pleistocene)—Silt, sand and cobbles resting on 61-63 m Golf Course terrace. Age about 450,000 years

Old paralic deposits, Units 2-6, undivided (late to middle Pleistocene)—Silt, sand and cobbles on 22-55 m terraces

Old paralic deposits, Units 3-6, undivided (late to middle Pleistocene)—Silt, sand and cobbles on 45-55 m terraces

Old paralic deposits (late to middle Pleistocene) overlain by alluvial fan deposits—Old paralic deposits capped by sandy alluvial-fan deposits

Old surficial deposits, undivided (late to middle Pleistocene)—Silt, sand and cobbles. Interfingered strandline, beach, estuarine, and colluvial deposits

Very old alluvial fan deposits (middle to early Pleistocene)—Sandy alluvium; reddish-brown, well-indurated, fan surfaces well-dissected. Includes:

Very old alluvial fan deposits, Unit 3 (early Pleistocene)—Gravel, sand, and silt; reddish-brown, surfaces well-dissected. Intermediate to young part of Qvof

Very old alluvial fan deposits, Unit 1 (early Pleistocene)—Gravel, sand, and silt; reddish-brown, fan surfaces well-dissected. Old part of Qvof

Pegmatite dikes of Paloma Valley ring complex—Leucocratic pegmatite dikes

Monzogranite to granodiorite—Biotite monzogranite, and less abundant hornblende-biotite granodiorite; gray, medium grained, hypidiomorphic-granular, massive

Tonalite—Biotite-hornblende tonalite; foliated. Grades to granodiorite in eastern part of Paloma Valley ring cmplex

Granodiorite and gabbro, undifferentiated—Mixed biotite granodiorite and hornblende gabbro

Monzogranite of Squaw Mountain (Cretaceous)—Biotite monzogranite; coarse-grained, moderately leucocratic, massive

Coarse grained; locally contains sillimanite and cordierite

Intermixed Mesozoic schist and Cretaceous granitic rocks (Mesozoic)—Heterogeneous mixture of schist and granitic rocks

Intermixed Paleozoic(?) schist and Cretaceous granitic rocks (Cretaceous and Paleozoic?)—Intermixed Paleozoic(?) schist and gneiss and Cretaceous granitic rocks, mostly of tonalite and granodiorite composition

Paleozoic(?) rocks, undifferentiated (Paleozoic?)—Biotite schist, quartzite, gneiss, and lesser amounts of hornblende gneiss, marble and associated skarn and calc-silicate rock. Coarse- and very coarse-grained marble bodies (m) mapped separately

Biotite schist (Paleozoic?)—Biotite schist and biotite-quartz-feldspar schist; medium- to dark-gray, fine-grained

Impure quartzite (Paleozoic?)—Quartzite; impure, light-gray to light-greenish-gray, fine-to medium-grained, layered to massive

Marble (Paleozoic?)—Marble; white to light-gray, locally bluish-gray, and blue, coarse- to extremely coarse-grained

Calc-silicate rocks (Paleozoic?)—Heterogeneous, massive to well-layered calc-silicate rocks

Marble and schist, undifferentiated (Paleozoic?)—Intermixed marble, calc-silicate rock, and biotite schist

REFERENCES

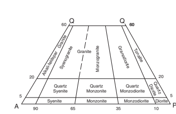
Fraser, D.M., 1931, Geology of the San Jacinto quadrangle south of San Gorgonio Pass, California: California Mining Bureau Report 27, p. 494-540.

Frick, Childs, 1921, Extinct vertebrate faunas of the badlands of Bautista Creek and San Timoteo Canyon, southern California: Univ. California Pub., Depart. Geol. Sciences Bull., v. 12, p. 277-409.

Herzig, C.T., 1991, Petrogenetic and tectonic development of the Santiago Peak Volcanics, northern Santa Ana Mountains, California: Ph.D dissertation, Riverside, California, University of California, 376 p.

Mann, J.F., 1955, Geology of a portion of the Elsinore fault zone, California: California Div. Mines Special Report 43, 22 p.

Streckeisen, A.L., 1973, Plutonic rocks—Classification and nomenclature recommended by the IUGA Subcommission on Systematics of Igneous Rocks: Geotimes, vol. 18, p. 26-30.



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