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CENOZOIC STRUCTURE OF THE VAL VERDE 7 1/2-MINUTE QUADRANGLE AND SOUTH HALF OF THE WHITAKER PEAK 7 1/2-MINUTE QUADRANGLE CALIFORNIA

compiled and edited by

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Cenozoic Structure of the Val Verde 7 1/2-minute Quadrangle and South Half of the Whitaker Peak 7 1/2-minute Quadrangle, California

by

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Abstract

Eocene to early Miocene strata were strongly faulted and folded along southwest-verging structures prior to deposition of upper Miocene (Mohnian) strata of the Modelo Formation. Granodiorite is faulted against Eocene along an overturned unconformity. The Canton fault, separating Mendenhall(?) Gneiss on the east from granodiorite on the west, cuts the basal conglomerate member of the Modelo and is overlain unconformably by younger Modelo strata. This fault, probably a pre-Mohnian strand of the San Gabriel fault, continues for more than 7 km southeast of its surface termination to a subsurface intersection with the San Gabriel fault. Another abandoned strand pre-dates deposition of the Pico Formation. Strata of Miocene and Pliocene age thin sharply toward the northeast against a submarine ridge of basement parallel to the San Gabriel fault. Locally, the Hasley conglomerate member of the Miocene-Pliocene Towsley Formation is absent over structural highs. Post-Saugus structures of late Quaternary age comprise a fold belt cut by the Del Valle, Holser, Hasley, Oak Canyon, and Santa Felicia south-dipping reverse faults. These faults do not become vertical with depth, and the faults post-date at least some of the folds. The Santa Felicia fault apparently overrides the youngest strand of the San Gabriel fault. Tectonic landforms are less apparent in the east Ventura basin fold belt than along the Oak Ridge and San Cayetano faults which die out eastward in the Val Verde quadrangle. However, river terraces north of Potrero Canyon may be widespread there because of downwarping along the Santa Clara syncline. The Del Valle and Holser faults locally control drainage that flows parallel to the faults on the downthrown side. No evidence of Holocene movement has been found.

Introduction

A major element of the western Transverse Ranges is the Ventura basin, where one of the world's thickest sequences of Neogene strata accumulated in an east-trending trough (Figure 1). The western Ventura basin includes the world's thickest accumulation of Pleistocene strata (Yeats, 1977), found between two opposing reverse faults, the Oak Ridge fault on the south and the San Cayetano fault on the north. These faults die out in the southwestern part of the Val Verde quadrangle. The main part of the Val Verde quadrangle (Plate I) and south half of the Whitaker Peak quadrangle (Plate II) consist of a fold belt of Miocene to Quaternary strata cut by south-dipping reverse faults. In the Whitaker Peak quadrangle, the Miocene strata are underlain with angular unconformity by Eocene, Oligocene, and early Miocene beds that are unconformable on and in fault contact with pre-Cenozoic crystalline basement to the north. The San Gabriel right-slip fault crosses the Whitaker Peak quadrangle and separates the Ventura basin from the Ridge basin to

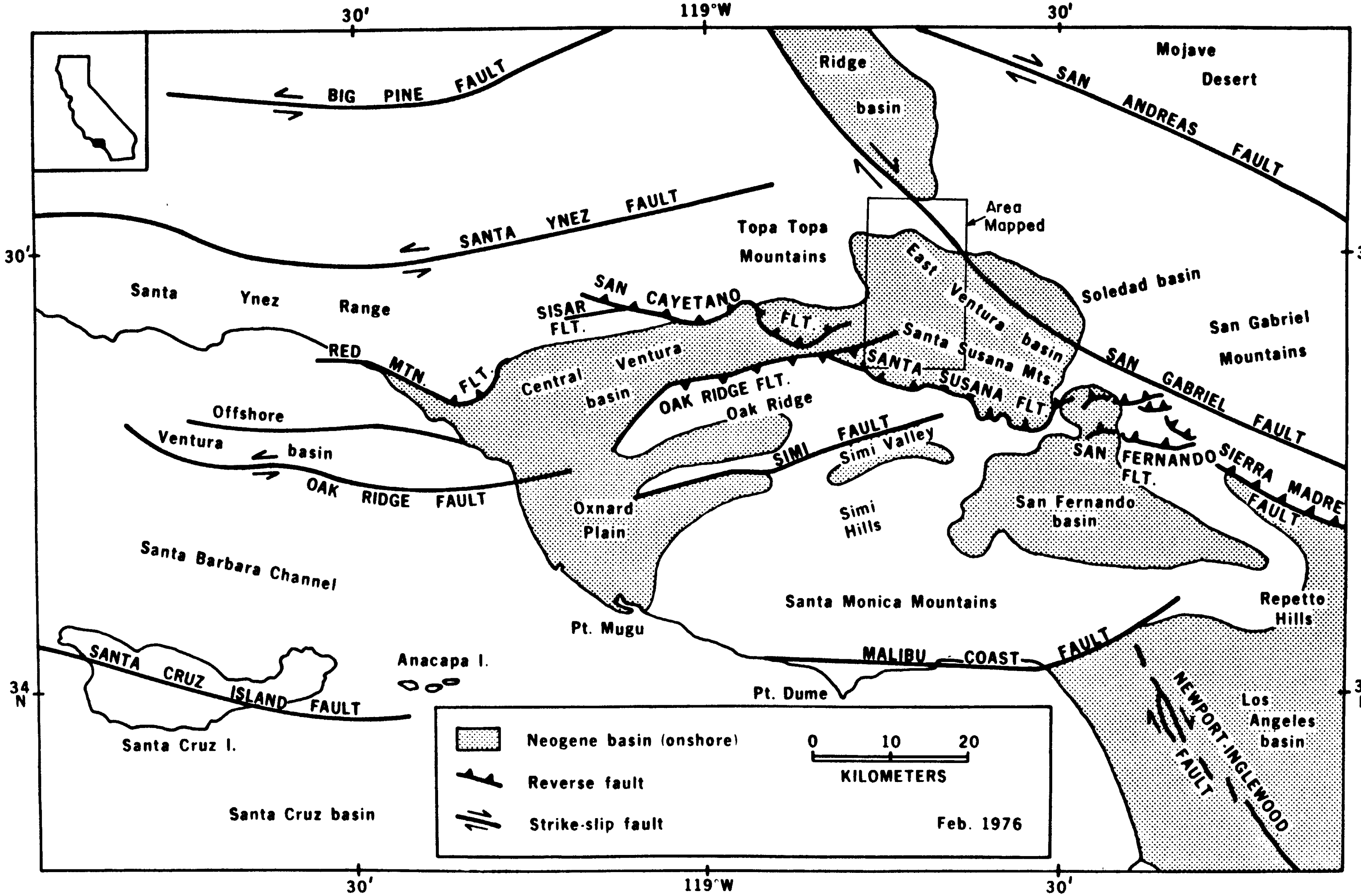

Figure 1 - Tectonic map of the central Transverse Ranges showing onshore Neogene basins and lowlands (shaded) and major Neogene faults (heavy lines). Rectangle shows area mapped. Base map from Jennings (1973).

the east (index map, Figure 1).

The San Cayetano and Oak Ridge faults of the western Ventura basin and the San Gabriel fault bounding the eastern Ventura basin on the east have been studied in considerable detail. Less well understood are the south-dipping reverse faults of the eastern Ventura basin including, from south to north, the Del Valle, Holser, Hasley, Oak Canyon, and Santa Felicia faults. These faults are young. All but the Del Valle fault cut folded Quaternary strata, and the Del Valle fault has some expression in tectonic geomorphology. The Santa Felicia fault apparently overrides the surface trace of the San Gabriel fault. It is important to understand the active-tectonic significance of each of these faults in light of future urban development.

The southeastern quarter of the Val Verde quadrangle was mapped by Winterer and Durham (1962), and our modifications of this work are based largely on the extensive subsurface well data base available to us (Plate III). Other sources used in our compilation are shown in Figure 2A. John Crowell provided us with a copy of an unpublished map (Crowell, 1953) that included all of the south half of the Whitaker Peak quadrangle and part of the northwest corner of the Val Verde quadrangle (Figure 2B). We used other sources in our compilation (Kriz, 1947; Pollard, 1958; Scanlin, 1958; Shepherd, 1960; Stanton, 1960; Weber, 1982) rather than Crowell's map, but our conclusions do not vary significantly from those reached by Crowell (1953) for this area except for the Whitaker, Canton, and Santa Felicia faults.

The present project began with studies by Ricketts and Whaley (1975) and Cemen (1977), supported in part by U.S. Geological Survey Contract 14-08-0001-15886. These studies extended into the western part of the Val Verde quadrangle. Study of the Castaic Hills segment of the San Gabriel fault area (Stitt, 1980, 1982; Stitt and Yeats, 1982) was supported by U.S. Geological Survey Contract 14-08-0001-16747, and the Holser fault was studied by Stitt and Yeats (1983) under U.S. Geological Survey Contract 14-08-0001-19138. The present study is supported by U.S. Geological Survey Contract 14-08-0001-21279. All contracts are part of the Earthquake Hazard Reduction Program.

We collected data from all available wells drilled in the search for petroleum in the two quadrangles (shown on Plate III). These data, provided by the California Division of Oil and Gas and by various petroleum companies, include well logs, well histories, descriptions of cores, sidewall samples, and ditch samples, dipmeter logs, directional surveys, and reports of age and water depths of deposition based on paleontological collections. We used the paleontological reports without re-examining the fossils ourselves or re-evaluating the basis for biostratigraphic correlations. Core samples of pre-Tertiary basement were obtained from the California Well Sample Repository and from various oil operators. Thin sections of these cores were studied by Stitt (1980), and his interpretations are adopted in this report. Extensive field checking of original data sources was necessary to resolve misties between various reports on the surface geology and between the subsurface and surface. Some critical areas had to be re-mapped entirely; others required only minor revision. We concentrated on Quaternary structural relations, but we did not engage in detailed comparisons of late Quaternary surfaces based on soil chronosequences or on trenching. Cross sections included in this report were originally drawn with electric logs of wells at a scale of 1 inch = 500 feet, then reduced to 1 inch = 2000 feet and redrafted without electric logs on Plate IV. For cross sections in the southeast part of the Val Verde quadrangle, refer to

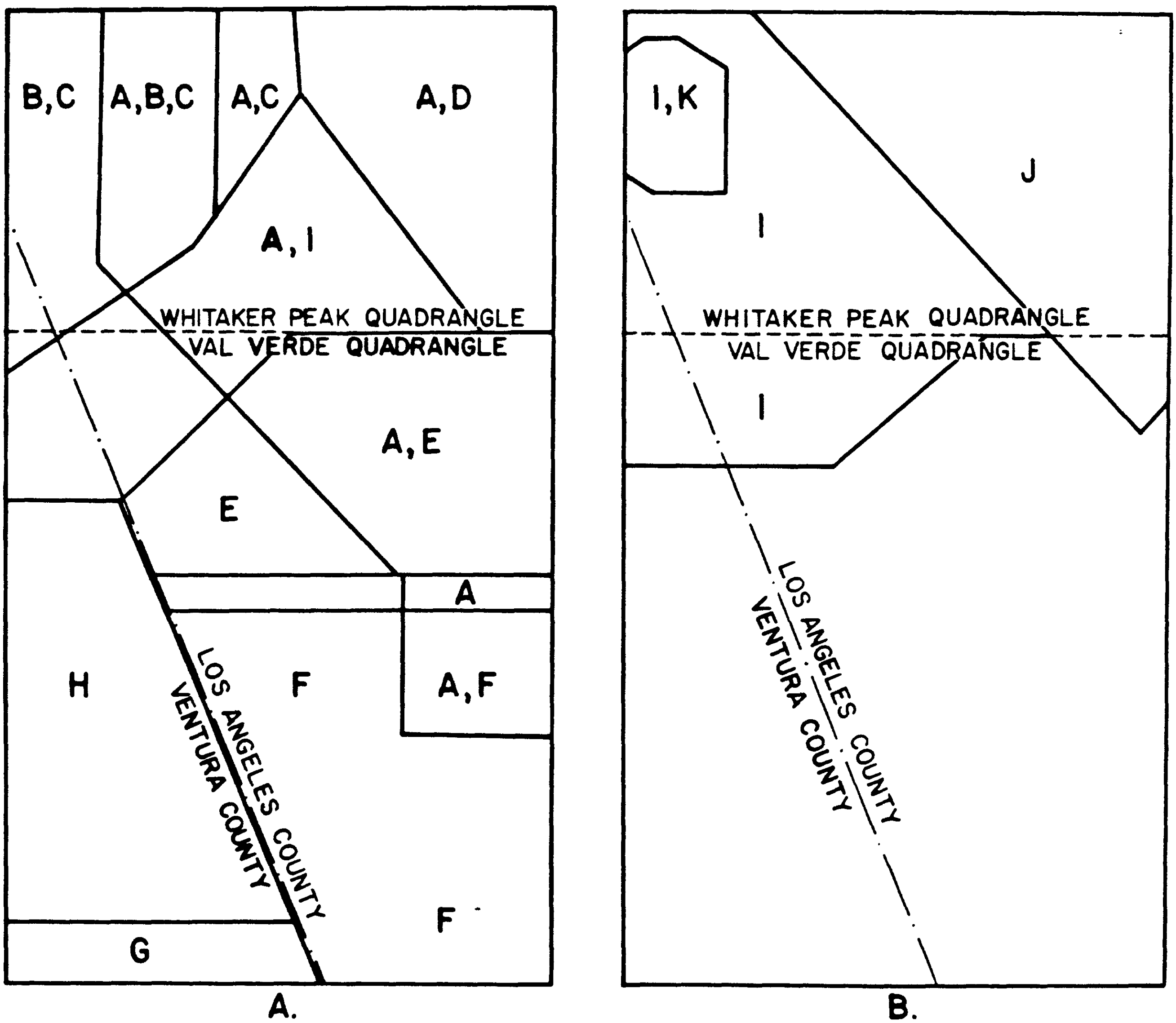

Figure 2. (A) Sources used extensively in compilation: A, Weber (1979, 1982); B, Criz (1947) and Scanlin (1958); C, Shepherd (1960); D, Stanton (1960); E, Pollard (1958); F, Winterer and Durham (1962); G, Ricketts and Whaley (1975); H, Cemen (1977).

(B) Sources consulted but not used extensively in compilation: I, Crowell (1953); J, Crowell et al. (1982); K, Squires (1977).

Winterer and Durham (1962), where they are shown at the same scale as Plate IV.

Stratigraphy

General statement

Two types of pre-Cenozoic basement are recognized, gneissic rocks and granitic rocks. These are in fault contact with (and were originally overlain by) an unnamed marine Eocene sequence, the nonmarine Sespe Formation of Oligocene age, the shallow-marine Vaqueros Formation of Oligocene age, and the shallow-marine to deep(?)-marine Rincon Formation of early Miocene age. These strata are overlain with angular unconformity by the Modelo Formation of middle and late Miocene (Luisian and Mohnian) age. This is overlain by the Towsley Formation of late Miocene and early Pliocene age, the Pico Formation of Pliocene age, and the Saugus Formation of Pleistocene age. The Modelo and Towsley Formation are part of a submarine fan system that shallowed upsection to shallow marine and to nonmarine in the Saugus Formation. East of the San Gabriel fault, the Saugus is underlain with angular unconformity by the marine Castaic Formation of late Miocene age. The Castaic Formation grades laterally westward to Violin Breccia close to the San Gabriel fault. On both sides of the San Gabriel fault, the Saugus is overlain with angular unconformity by late Quaternary alluvial deposits and landslide material.

Pre-Cenozoic basement

Gneiss (gn): Near Palomas Canyon, the Palomas gneiss of Shepherd (1960) crops out as a sliver bounded on the east by the San Gabriel fault and on the west by the Canton fault of Crowell (1954), which separates it from the Whitaker granodiorite of Shepherd (1960). The gneiss is overlain unconformably by strata of the Modelo Formation containing Mohnian microfossils. The most common variety of gneiss is medium grained and crudely banded as a result of layers of quartz and feldspar alternating with layers of dark green hornblende and muscovite. Feldspar augen are common. The Conoco Alexander No. 1 well (Cross Section E-E') penetrated 855 m (2800 feet) of metamorphic rock from which eleven cores were recovered. As described by Stitt (1980), these rocks include apatite-bearing hornblende gneiss, sphene-bearing hornblende-biotite gneiss, and epidote-hornblende gneiss. The most common texture comprises large crystals of potassium feldspar, plagioclase, and quartz in a granulated groundmass of quartz, biotite, hornblende, and feldspar. All thin sections show evidence of shearing; some contain a schistose fabric. Sutured grain boundaries, granulation, fracturing of grains, kinking of biotite cleavage, and undulatory extinction and mortar structure in quartz are common. These rocks in the Alexander well are similar to exposures of gneiss east of the Canton fault.

The gneiss resembles the Mendenhall Gneiss of the western San Gabriel Mountains and gneiss of the Alamo Mountain region northwest of the map area correlated to the Mendenhall Gneiss by Ehlig and Crowell (1982). Zircons from layered gneiss in Soledad basin adjacent to the western San Gabriel Mountains are dated as 1715 ± 30 Ma and 1670 ± 20 Ma (Silver, 1966). Granodioritic augen gneiss in the Alamo Mountain region has an age of 1655 Ma (L. T. Silver in Frizzell and Powell, 1982).

Granodiorite (gr): This unit, the Whitaker granodiorite of Shepherd (1960), is in contact with gneiss on the east along the Canton fault and in contact with Eocene strata along the Whitaker reverse fault, and it is unconformably overlain by strata of the Modelo Formation containing Mohnian microfossils. As described by Shepherd (1960), the rock is predominantly granodiorite, but it is gradational to quartz diorite and to granite. Inclusions of gneiss resembling the Mendenhall Gneiss are present, and some are quite large (Shepherd, 1960; J. C. Crowell, pers. comm., 1985). The rock is fractured and jointed and locally strongly decomposed, and crushed and shattered zones occur near fault contacts. Similar plutons in nearby terranes also containing Mendenhall Gneiss are Mesozoic in age.

The Continental Rynne-Fisher No. 2 well (Cross Section G-G'), Union Alexander No. 1 well (Cross Section D-D'), and Continental Vier Kenny No. 1 well (Cross Section D-D') bottomed in granitic rocks similar to the exposures of granodiorite. The Rynne-Fisher well penetrated fresh to altered granodiorite, medium to coarse grained, with biotite as primary accessory. The Alexander well penetrated 275 m (900 feet) of biotite granite. Thin sections contain plagioclase, potassium feldspar, and biotite with accessory zircon, apatite, and opaque minerals. The major minerals are considerably altered and cataclastically deformed, with the cataclastic deformation younger than the alteration. The Vier Kenny well yielded cores of biotite granite and biotite granodiorite similar to that in the Alexander well (Stitt, 1980). Granitic rocks in all three wells are overlain unconformably by Modelo Formation.

Tertiary strata

Unnamed Eocene strata (Te_1, Te_2, Te_3): Paleogene sedimentary rocks of the Santa Ynez and Topa Topa Mountains extend eastward almost to the San Gabriel fault, with the east end of the outcrop belt in the Whitaker Peak quadrangle. This sequence is more complete in Piru Gorge west of the quadrangle, where rocks of Paleocene (Sage, 1973) and Eocene (Squires, 1977) age are present. In the quadrangle, the sequence is in fault contact with granodiorite along the Whitaker reverse fault (Crowell, 1975). More recently, Crowell has followed Shepherd (1960) and interpreted this contact as an overturned, sheared unconformity, because west of the area, Paleogene strata rest unconformably upon basement rocks (Shepherd, 1960). If so, the Paleogene onlaps the basement from west to east, and only the upper portion of the sequence extends into the Whitaker Peak quadrangle.

Three units are mapped in the Whitaker Peak quadrangle, a lower mudstone member, an overlying white sandstone member, and an upper arkosic sandstone member (Kriz, 1947; Shepherd, 1960; Squires, 1977).

Unnamed mudstone member (Te_1): The oldest member is predominantly olive-brown mudstone with local calcareous clay concretions and lenses of gray siltstone. Thickness is 730 m (2395 feet) (Squires, 1977), increasing westward. Megafossils assigned to the Domengine-Tejon stage and microfossils assigned to the Laiming A-1 and B zones were reported by Shepherd (1960), indicating a middle Eocene age (Squires, 1977). The mudstone overlies granodiorite along an unconformity that was subsequently sheared along the Whitaker reverse fault; the mudstone is overlain conformably by marine Eocene sandstone and unconformably by the Modelo Formation.

Unnamed white sandstone member (Te_2): The mudstone grades upward into 450 to

700 m (1475 to 2300 feet) of mainly white thick-bedded feldspathic sandstone with biotite flakes and thin pebble beds containing clasts of granitic rocks and quartzite. The member is relatively resistant to erosion compared with the lower and upper members. At Canton Canyon, a tongue of variegated sandstone and siltstone grades westward into non-variegated strata (Shepherd, 1960). The sandstone contains megafossils assigned by Squires (1977) to the Domengine and Transition megafossil stages of Clark and Vokes (1936).

Unnamed arkosic sandstone member (Te_3): The upper member of the Eocene sequence consists of 300 m (985 feet) of pink, yellowish brown, and white arkosic sandstone containing Ostrea, lenticular sandy conglomerate, and variegated siltstone and sandy siltstone. Clasts in the conglomerate include granitic rocks, gneiss, quartzite, and purple metavolcanic porphyry. The contacts with the underlying white sandstone and the overlying Sespe Formation are conformable. The Modelo Formation overlies the member with angular unconformity.

Sespe Formation (Tsc, Tss): Two members of the Sespe Formation are differentiated, conglomerate and breccia (Tsc) and a unit in which red-brown sandstone and red mudstone predominate (Tss). The sandstone-dominant unit contains subordinate beds of green and buff sandstone, green mudstone, and gray-green conglomerate (cf. Crowell, 1953). The conglomerate and breccia contain clasts of gneiss, anorthosite, norite, and Lowe Granodiorite as used by Ehlig (1981), rocks characteristic of the western San Gabriel Mountains (Crowell, 1954; Bohannon, 1975; 1976), together with other rock types less diagnostic as to source. Some clasts are subangular and up to 8 m in diameter. Pebble-imbrication data suggest transport from a source area east of the San Gabriel fault (Bohannon, 1975; 1976). The sandstone-dominant unit grades laterally eastward into the conglomerate and breccia unit. Upper and lower contacts appear to be conformable. Thickness is 700 m (2300 feet) in Canton Canyon where the overlying Vaqueros Formation is overlapped by the Modelo Formation (Bohannon, 1976). Age is late Eocene to Oligocene based upon ages of fossil assemblages in underlying and overlying strata.

Vaqueros Formation (Tvq): Overlying the Sespe is the Vaqueros Formation, largely conglomeratic near Canton Canyon, and more sandy with discontinuous beds of conglomerate to the west. The conglomerate and sandstone are brown, and the sandstone contains Oligocene megafossils characteristic of the Vaqueros Formation elsewhere in the Topa Topa and Santa Ynez Mountains. The thickness measured by Crowell (1953) is 110 m (360 feet).

Rincon Formation (Tr, Trss): The Vaqueros is overlain conformably by brown silty mudstone with local beds of clayey limestone and pale green tuffaceous siltstone (Tr). A lens of thick-bedded pebbly sandstone is mapped separately (Trss). The formation is overlain with angular unconformity by Luisian strata of the Modelo Formation and is also in fault contact with Modelo along the Agua Blanca fault. Thickness is 230-280 m (760-910 feet) (Crowell, 1953). Microfossils in the Rincon are Saucesian (early Miocene). Rincon Formation was reached by the Morton & Kohlbush Engman No. 2 well in the Canton Creek oil field (Cross Section G-G') and the Gulf Hathaway No. 1 well (Cross Section B-B'). In both wells, the Rincon is overlain by Relizian Modelo Formation.

Modelo Formation (Tm): The Modelo Formation in this area comprises up to 4,050 m (13,200 feet) of alternating beds of gray-brown siltstone, brown to black laminated mudstone, and gray, arkosic, fine-grained to conglomeratic sandstone largely deposited by turbidity currents. The thickest sequence known in the map area is in the vicinity of the Gulf-Hathaway No. 1 well on the Devil Canyon anticline (Cross Section B-B'). Locally, near the unconformable contact with gneiss, the basal Modelo consists of breccia (Tmcb) in which angular clasts of gneiss with less common clasts of anorthosite and granite occur in a red sandy matrix. In the Union Alexander No. 1 well (Cross Section D-D'), the Modelo basal breccia is repeated along the Santa Felicia reverse fault, and the well bottoms in granite rather than gneiss. In eastern exposures and in the subsurface, the Modelo contains a prominent gray-brown conglomerate, the Devil Canyon conglomerate of Crowell (1953; 1954), shown on the map as Tmdc. The conglomerate contains an early Mohnian fauna and consists of angular to subrounded clasts of anorthosite, granite, metamorphic rock, and volcanic rocks. The largest anorthosite clasts, up to several feet in diameter, are found adjacent to the San Gabriel fault, indicating a source to the northeast (Crowell, 1952; 1954). No anorthosite is now present immediately across the San Gabriel fault, but a source of the appropriate composition is found in the western San Gabriel Mountains, leading Crowell (1952) to propose right slip of about 30 km on the San Gabriel fault since the Devil Canyon conglomerate was deposited. The Devil Canyon conglomerate rests with angular unconformity on granite, marine sedimentary rocks of Eocene age, and the nonmarine Sespe Formation, but farther west in the surface and subsurface, the Devil Canyon is underlain by another 1220 m (4,000 feet) of Modelo. Between the Devil Canyon and Canton faults, an angular unconformity is present within the Modelo at the base of a thick pod of Devil Canyon conglomerate; this unconformity is exposed near the Devil Canyon Fire Road (J. C. Crowell, pers. comm., 1985).

On the map, but not in the subsurface, the Modelo is further subdivided into sequences dominated by gray to greenish-gray siliceous shale, siltstone, and fine-grained sandstone (Tms) and sequences dominated by gray to gray-brown conglomerate, sandstone, and subordinate siltstone (Tmc). Locally in the subsurface, sandstone units that comprise oil-field reservoirs are mapped separately. Most surface exposures of the Modelo contain only Mohnian foraminifers, but in the southwest part of the Whitaker Peak quadrangle, strata with Luisian foraminifers occur in Canton Canyon near the eastern termination of the Agua Blanca fault. Luisian faunas are much more common in the subsurface in a southwesterly direction away from the San Gabriel fault, and in the Gulf Hathaway No. 1 deep-test well drilled on the Devil Canyon anticline (Cross Section B-B') and in the Canton Creek oil field (Cross Section G-G'), Modelo beds with Luisian and Relizian faunas are found resting on Rincon Formation. West of Piru Creek in the type Modelo section, Luisian and Relizian faunas are much more widespread, and the contact with the Saucesian Rincon Formation is conformable. The Modelo has only limited exposure in the northwestern part of the Val Verde quadrangle, but it occurs in the subsurface throughout the quadrangle. Southwest of the quadrangle, in the Santa Susana Mountains, the Modelo rests on the Topanga Formation of middle Miocene age (Winterer and Durham, 1962; Yeats, 1979, and in press).

<u>Castaic Formation</u> (Tc): East of the San Gabriel fault, a sequence of marine siltstone, mudstone, sandstone, and conglomerate of late Miocene age was called the Castaic Formation by Crowell (1954). The Castaic is relatively deficient in sandstone and conglomerate compared to the Modelo. The microfossil assemblage of the Castaic, called the Charlie Canyon fauna by industry, is assigned to the Mohnian and Delmontian(?) stages of Kleinpell (1938) by Skolnick and Arnal (1959), and the megafossils are of late Miocene age (Stanton, 1960). East of the map area, the Castaic rests on Mint Canyon Formation with low-angle unconformity, and locally

the two formations may intertongue (Stitt, 1982). Also east of the map area, the Castaic Formation is overlain with angular unconformity by the Pico and Saugus formations, and the Ridge Basin Group of the Ridge basin is not present (Stitt, 1980, 1982).

Violin Breccia (Tvb): Near the San Gabriel fault, the Castaic Formation intertongues with and overlies the Violin Breccia (Crowell, 1952, 1954; Stitt, 1980). The breccia, now exposed only east of the fault, accumulated as talus at the base of the active scarp of the San Gabriel fault. The southeasternmost surface exposure of the Violin Breccia is a few hundred meters south of the mouth of Violin Canyon, but Stitt (1980) traced the breccia in the subsurface at least 1,340 m (4,400 feet) southeast of the nearest breccia outcrop. The oldest breccia beds intertongue with siltstone of the Castaic Formation that has early Mohnian faunas; there is no evidence of Violin Breccia in the underlying Mint Canyon Formation (Stitt, 1980).

Towsley Formation: Three units are distinguished on the surface map: (1) a basal red-brown conglomerate called the Hasley conglomerate (Tthc), (2) strata in which sandstone or conglomerate dominates (Ttc), and (3) strata in which siltstone or mudstone dominates (Tts). The sandstone and conglomerate were deposited in outer neritic to bathyal waters as submarine fans by turbidity currents (Winterer and Durham, 1962; Stitt, 1980).

The Hasley conglomerate is the most widely distributed member. It contains rounded anorthosite clasts which may be derived from the western San Gabriel Mountains directly, or they may be reworked from the underlying Devil Canyon conglomerate. The Devil Canyon conglomerate subcrops against the base of the Hasley conglomerate near the San Gabriel fault in the subsurface and in outcrop. In the Oak Canyon oil field, the Hasley conglomerate is not present, but the area of non-deposition trends north, whereas the younger Oak Canyon anticline trends west-northwest. Close to the San Gabriel fault, the Towsley Formation rests with angular unconformity on the Modelo, and the paleo-strike of the Modelo was northwest at the time of Hasley conglomerate deposition (Stitt, 1980). The angular nature of the unconformity is apparent in the Whitaker Peak quadrangle where the Towsley overlaps relatively fine-grained Modelo and rests directly on Devil Canyon conglomerate near the San Gabriel fault. Farther southwest, the contact is conformable.

In the Santa Susana Mountains of Los Angeles County, Winterer and Durham (1962) mapped a thick conglomerate and sandstone sequence that predominates in the lower part of the sequence directly over the Modelo. This sequence is also recognized in Ventura County in the southwest corner of the Val Verde quadrangle. Elsewhere, the conglomerate and sandstone members occur throughout the Towsley. The lower part of the Towsley, including the Hasley conglomerate, contains Mohnian foraminifers, and the upper part contains Delmontian foraminifers which are probably of early Pliocene age. In some areas, however, the Delmontian-Mohnian faunal boundary occurs near the base of the Hasley conglomerate. Much of the reason for this is that the Delmontian is not a true faunal stage (cf. Pierce, 1972; Barron, 1976). The fauna described as Delmontian in the eastern Ventura basin is, in addition, strongly influenced by paleoecological factors including water depth at time of deposition.

Pico Formation (Tp): On the surface map, the formation is divided into strata dominated by conglomerate and sandstone with minor siltstone (Tpc) and strata comprising mainly siltstone and fine-grained sandstone (Tps). The Pico is thickest in the Santa Clara syncline in the south half of the Val Verde quadrangle, but thinner sections occur as far north as the southeast corner of the Whitaker Peak quadrangle. This report follows Winterer and Durham (1962) in definition of the Towsley-Pico and Pico-Saugus contacts (Stitt, 1980).

In the Santa Clara syncline (Cross Section C-C'), the Pico consists of up to 3650 m (12,000 feet) of olive-gray and medium bluish-gray siltstone and fine-grained silty sandstone with reddish-brown concretions, and light colored sandstone and conglomerate. The presence of olive-gray siltstone with limonite concretions distinguishes the Pico from the underlying Towsley. The formation contains a Repettian (lower Pliocene) microfauna in its lower part, and an "upper Pliocene" fauna above; the horizon marking the top of the Repettian is mapped on both sides of the Santa Clara syncline except for the area east of the Del Valle fault. Winterer and Durham (1962) noted the gradual shoaling of faunas from 600 m (2000 feet) near the base to near sea level at the top.

North of the Santa Clara syncline, the Pico is generally of shallow-marine origin, and it overlies the Towsley unconformably. In the northeastern corner of the Val Verde quadrangle, the Pico overlies the A-1 strand of the San Gabriel fault, and in the Macson Radovich No. 1 well, Pico rests unconformably on Castaic Formation (Stitt, 1980). The Pico consists of up to 425 m (1,400 feet) of gray, green-gray, and gray-white, lenticular, fine-grained to pebbly sandstone and gray to gray-green, clayey to sandy, bioturbated siltstone (Stitt, 1980). The Pliocene microfaunal stages of Natland and Rothwell (1954) are generally not recognized in the northern areas, and the faunas are generally called "Pliocene" or "Pico."

Quaternary strata

Saugus Formation (Qs): The Saugus disconformably overlies the Pico Formation in most areas except for the Santa Clara Valley between the San Cayetano and Oak Ridge faults, where the contact is an angular unconformity. Near its base, the Saugus consists of green-gray and gray pebbly sandstone and green-gray siltstone which may contain marine to brackish water fossils (Winterer and Durham, 1962; Stitt, 1980). This marine member, the Sunshine Ranch member of Winterer and Durham (1962), is not differentiated on the surface map. In the subsurface, the base of the Saugus is placed at the top of the fossil-bearing sequence. The overlying nonmarine Saugus consists of gray-green siltstone alternating with red-brown and gray pebbly sandstone and with conglomerate. Conglomerate predominates in the more northerly exposures. North of the Holser fault, Weber (1979) subdivided the Saugus on the basis of clast composition of conglomerate: Saugus with clasts of gray-brown sandstone of the San Francisquito Formation but not of Pelona Schist (Qss) and Saugus with clasts of Pelona Schist but not of anorthosite (Qsp). In general, the schist-bearing gravels overlie the sandstone-bearing gravels.

The Saugus contains teeth of *Pliohippus* and remains of a Pleistocene bison (Winterer and Durham, 1962; Stitt, 1980). Two sections in the Newhall quadrangle were sampled for magnetic stratigraphy; one of these, the Santa Clara River section, extends westward into the Val Verde quadrangle. The other section, the Transmission Line section, contains an ash bed correlated by A. M. Sarna-Wojcicki to the Bishop or Friant ash bed of 0.7 Ma age. On the basis of the magnetic stratigraphy and the ash bed correlation, Levi and Yeats (1984) concluded that the Saugus was deposited during the Matuyama and Brunhes epochs, and they also tentatively identified the Olduvai and Jaramillo events. Based on an average sedimentation rate of

0.9 km/m.y. determined from the magnetic stratigraphy, the age of the uppermost Saugus would be 0.2 to 0.1 Ma. by extrapolation from the Brunhes-Matuyama boundary.

Stream terrace material (Qt): These deposits consist of poorly bedded, poorly consolidated gravel, sand, and silt, reddish brown due to soil development. They are preserved on surfaces above present river level, and they may grade into older alluvium. They rest with angular unconformity on Saugus and older formations. The large terraces near the east end of the Del Valle oil field may have been slightly warped (Winterer and Durham, 1962), and the terraces near the west edge of the Val Verde quadrangle contain scarps that may be formed by the Oak Ridge and San Cayetano faults.

Older alluvium (Qoal): Poorly consolidated to unconsolidated sand and gravel with soil development at the top of the sequence grades locally into stream terrace material.

Younger alluvium (Qal): Unconsolidated gravel, sand, and silt, generally without soils or with soils poorly developed, occupy the Santa Clara River Valley and major tributaries. The present floodplain of the Santa Clara River is entrenched about 20 feet in this alluvium (Winterer and Durham, 1962).

Landslide material: Landslides are common throughout the area and include both surficial and bedrock slides. Siltstone of the Towsley and Modelo formations is especially susceptible to sliding.

Structure

General statement

The northwest-trending San Gabriel right-slip fault is the boundary between the eastern Ventura basin on the west and the Ridge basin on the east. The major structure in the Ridge basin is the northwest-plunging, asymmetric Ridge basin syncline. The eastern Ventura basin is an east-trending fold belt associated with young reverse faults; the basin is bounded by basement rocks on the north. Faults in the map area may be divided into five groups: (1) strands of the San Gabriel fault, (2) north-dipping reverse faults of pre-late Mohnian age, (3) south-dipping reverse faults of post-Saugus age, (4) cross-strike faults of the Temescal anticline and the area south of the Newhall-Potrero anticline, and (5) the San Cayetano and Oak Ridge reverse faults flanking the Santa Clara Valley.

Strands of the San Gabriel fault

The Canton fault cuts the basal Devil Canyon conglomerate and is overlain unconformably by younger beds of this conglomerate, as mapped by Crowell (1954, 1975). We agree with the relations illustrated in Fig. 2 of Crowell (1975) except that we consider the Canton fault to be an abandoned strand of the San Gabriel fault, a view now accepted by Crowell (pers. comm., 1985). At its north end, the Canton fault separates gneiss on the east from granodiorite on the west, and the contact between gneiss and granodiorite can be traced in the subsurface (Cross Sections D-D' and E-E') for more than 7 km southeast of its surface termination, at which point it intersects the main strand of the San Gabriel fault (Stitt, 1980;

Stitt and Yeats, 1982). As at the surface, the Canton fault in the subsurface is overlain unconformably by Mohnian strata. To the north, the faulted contact between gneiss and granodiorite intersects the main strand of the San Gabriel fault east of Whitaker Peak (Crowell, 1982; Weber, 1982). Thus the exposure of Precambrian gneiss is a sliver within the San Gabriel fault zone, with the western boundary fault (Canton fault) being considerably older than the eastern boundary fault (main strand of the San Gabriel fault). The offset continuations of gneiss are in the Alamo Mountain region to the west and the San Gabriel Mountains to the east of the San Gabriel fault zone (Ehlig and Crowell, 1982).

The subsurface A-1 strand of the San Gabriel fault (San Gabriel fault C of Stitt, 1980) juxtaposes Castaic Formation against Modelo and Towsley in the Castaic Hills oil field and is overlain unconformably by the Pico Formation. The fault cuts the Morton and Dolley MJM&M-Radovich No. 1 well (Cross Section F-F'). Stitt and Yeats (1982) showed that the horizontal component of post-Pico offset on the San Gabriel fault is only 1890 m (6200 feet), whereas late Miocene strata are offset by about 30 km (18 miles) (Crowell, 1952). Therefore the A-1 strand must have served as the main strand of the San Gabriel fault as it accumulated most of its offset, and the fault jumped to its present position in Pliocene time.

The main strand of the San Gabriel fault has been described in many papers by J. C. Crowell and P. L. Ehlig and their colleagues. For a recent account, see Crowell (1982). These authors showed that most of the right slip had accumulated on the San Gabriel fault by 5 Ma. However, the fault cuts the Saugus, and Weber (1979) found evidence for about 500 m of post-Saugus strike slip. Weber also found evidence in the Newhall quadrangle that the fault cuts late Pleistocene river terrace material. Recently, Holocene faulting has been observed in a deep trench in the same area (W. Cotton, pers. commun., 1983). However, no evidence was found in the Val Verde quadrangle and the south half of the Whitaker Peak quadrangle that the fault cuts sediments younger than Saugus. Instead, the Santa Felicia reverse fault apparently overrides the main strand of the San Gabriel fault and is not cut by it (Cross Sections D-D' and E-E').

North-dipping reverse faults of pre-late Mohnian age

Crowell (1953) mapped several north-dipping reverse faults in the Whitaker Peak and Cobblestone Mountain quadrangles and demonstrated that these faults do not cut the upper part of the Modelo Formation. The Whitaker reverse fault was shown by Crowell (1953, 1954) to be overlain unconformably by the Devil Canyon anorthosite-bearing conglomerate of Mohnian age. In SW/4 Sec. 6, T5N, R17W, the Whitaker fault could be interpreted alternatively as cutting the basal Devil Canyon conglomerate, but if it does so, it is overridden by the Devil Canyon fault 150 m east of the base of the Devil Canyon conglomerate. The Devil Canyon fault does not cut uppermost Modelo fine-grained strata, and the overlying Hasley conglomerate member of the Towsley Formation is not faulted, thereby constraining the age of the Devil Canyon fault as Mohnian. More recently, Crowell (1982) has reinterpreted the Whitaker fault in the Whitaker Peak quadrangle as an overturned, "skidded" unconformity. The field relations clearly show that the overturning, involving the Eocene section and part of the Sespe Formation, occurred prior to deposition of the Devil Canyon conglomerate.

The Agua Blanca fault dips 75° north and brings overturned Rincon Formation over Modelo Formation with Mohnian fossils. The fault bifurcates eastward and is not found east of Canton Canyon, where unfaulted Modelo Formation is mapped across the eastern projection of the fault. Folding of the Rincon, Vaqueros, and Sespe formations predates the deposition of the Modelo, and Modelo with Luisian fossils is overlapped northward by Mohnian Modelo. However, the Blue Point anticline and an unnamed syncline to the north deform the Modelo, and the syncline also involves the Towsley, demonstrating re-folding following the deposition of the Towsley (Cross Section A-A').

Miocene to Pleistocene structural growth

Deformation continued during deposition of the Towsley and Pico formations. In Violin Canyon, immediately west of the San Gabriel fault, the Towsley and Pico formations are relatively thin. To the west, these formations greatly increase in thickness. From north to south in the Val Verde quadrangle, successively younger Pico members appear beneath the base of the Saugus: a lower conglomerate-sandstone member, an upper siltstone-fine-grained sandstone member, and an upper conglomerate-sandstone member that grades laterally into Saugus in its upper part. Locally, the Hasley conglomerate is absent over structural highs. At Oak Canyon, the zone where Hasley conglomerate is absent trends north whereas the Oak Canyon anticline trends west-northwest, demonstrating that the Oak Canyon anticline is younger than the Hasley conglomerate.

Close to the San Gabriel fault, formation boundaries and locally intra-formational contacts are commonly disconformities or low-angle unconformities, whereas farther away, these boundaries are conformable. This is evidence for structural growth of a northwest-trending basement ridge parallel to and southwest of the San Gabriel fault during the Miocene and Pliocene.

South-dipping reverse faults of post-Saugus age

Post-Saugus structures were formed in the late Quaternary. The youngest Saugus could be as young as 0.1 to 0.2 m.y. based on extrapolation upsection of sedimentation rates derived from paleomagnetic stratigraphy (Levi and Yeats, 1984), and even the youngest Saugus strata are strongly deformed. Major south-dipping reverse faults are, from north to south, the Santa Felicia, Oak Canyon, Hasley, Holser, and Del Valle faults. Minor, unnamed faults of the same set cut the Marathon Hathaway No. 3 well (Cross Section B-B'), Arco Lechler No. 1 well (Cross Section C-C'), and Amax Kinler No. 1 and No. 2 wells (Cross Section I-I').

The Santa Felicia fault has no recognized tectonic geomorphic features, although it follows Santa Felicia Canyon for part of its length. However, our mapping suggests that the Santa Felicia fault overrides the main strand of the San Gabriel fault which itself cuts Saugus to the southeast, and a downfaulted patch of Saugus is preserved northeast of the fault (Cross Section E-E'). Southwest-dipping Towsley and Pico from west of the main strand of the San Gabriel fault are thrust over Violin Breccia and Saugus Formation east of the fault. These relations are confirmed by the Conoco Alexander No. 1 well (Cross Section E-E') that spudded in Pico Formation, crossed a fault into Violin Breccia, then crossed another fault into gneiss. The fault between Violin Breccia and gneiss is the San Gabriel fault as mapped in Palomas Canyon to the northwest, and the intersection of this fault with the Santa Felicia fault in the subsurface near the Conoco Alexander well is on trend with the surface trace of the San Gabriel fault to the northwest and southeast. In the subsurface, the Santa Felicia fault overrides the pre-Towsley Devil Canyon fault (Cross Section C-C'). The relation of the Santa Felicia to the age of folding is equivocal. The fault appears to post-date the Loma Verde anticline, but it bends 45° around the axis of the Townsend syncline. Stratigraphic separation is 90 to 240 m (300 to 800 feet). The fault has a moderate dip.

The Oak Canyon fault, with 30 to 60 m (100 to 200 feet) vertical separation, is mapped mainly in the vicinity of Oak Canyon oil field. It dies out eastward in the axis of the North Hasley Canyon syncline, and to the west it cannot be traced through a sequence of Pico conglomerate.

The Hasley fault (American Association of Petroleum Geologists, 1952) is a reverse fault that dips 50° to 60° south at the surface and steepens to about 70° in the subsurface. Maximum separation is 110 m (350 feet) in the Oak Canyon oil field, and this decreases east and west to zero. As is the case with the Oak Canyon and Santa Felicia faults, there is no variation in thickness and facies of strata cut by the fault. The fault cuts Saugus, but it has no tectonic geomorphic features associated with it.

The largest of the south-dipping reverse faults is the Holser fault. As mapped by Winterer and Durham (1962), Cemen (1977), and Weber (1982), the Holser fault extends westward from the San Gabriel fault for a distance of 26 km (16 miles) to the geologically complex Piru Creek area west of the Val Verde quadrangle where the Holser, Del Valle, and San Cayetano faults meet (Cemen, 1977). Stitt and Yeats (1983) divided the Holser fault into five geologically distinct segments, the Piru segment, which contains the intersection of the Holser fault with the north strand of the Del Valle fault and the San Cayetano fault, the Main segment which in general comprises that part of the fault within the Val Verde quadrangle, and the Castaic Junction, Valencia, and Saugus segments in the Newhall quadrangle.

The Main segment of the Holser fault strikes nearly due east for about 12 km (7 1/2 miles) from Piru Creek in the Piru quadrangle to the junction of Castaic Creek and the Santa Clara River in the Newhall quadrangle. Reverse separation is 460 to 1850 m (1500 to 6000 feet) and is maximum at Ramona oil field. From the Del Valle oil field westward, the Holser fault is nearly parallel to bedding (Cross Sections C-C', J-J', and K-K'), whereas from the eastern end of the field eastward, the fault cuts bedding at a high angle (Cross Sections H-H' and I-I'). Furthermore, this eastern area is characterized by a zone of faults at the surface, whereas farther west, there is only a single surface trace. Throughout the Val Verde quadrangle, there is evidence for only one fault in the subsurface, possibly except for the fault in the Kinler wells in Cross Section I-I'. In the western part of Val Verde quadrangle, the Holser fault follows the south side of Holser Canyon, suggesting that the canyon may have developed very close to the fault at a higher erosion level when the fault trace was farther north. Farther east, the fault follows the axis of San Martinez Chiquito Canyon where it trends east, and still farther east, it follows a side tributary to Castaic Creek.

The Del Valle fault is the southernmost member of the set of south-dipping reverse faults, and it contains the most prominent tectonic geomorphic features. San Martinez Grande Canyon is located on the downthrown north block of the Del Valle fault, crossing the fault only at the mouth of the canyon near the termination of the fault. A broad terrace is preserved in Section 16, T5N, R17W, east of the point where the Del Valle fault bends to the south. The axis of the canyon is north of the present fault trace. As was suggested for the Holser fault, the canyon may have developed very close to the fault at a higher erosion level when the fault trace was farther north. Subsequent downcutting of the canyon resulted in a southward migration of the fault trace away from the canyon, and large landslides were directed northward into the canyon. Like the Holser fault north of it, the Del Valle fault is in part a bedding fault, although both bedding and fault dip steeply south. Stratigraphic separation is 400 to 670 m (1300 to 2200 feet). Whereas the Holser fault is involved in both hanging wall and footwall with the Ramona anticline, the Del Valle fault is not associated with a fold except near its eastern end in Los Angeles County, where an anticline plunging east-southeast is terminated at the fault where its trace is about south-southeast. These faults appear to truncate folds rather than be folded by them, and folding may predate faulting. The Del Valle fault bends south to the Santa Clara River, and it cannot be traced across the river.

Cross-strike faults

Four north-trending faults cut the east-plunging Temescal anticline. All but the easternmost fault have the east side down. The westernmost fault shows an apparent right-lateral offset of 150 m (500 feet) of the fold axes of two small folds on the south flank of the Temescal anticline.

The Salt Creek reverse fault dips steeply east, as based on a repeat section in the Sunray RSF No. 103 well (Winterer and Durham, 1962, their Plate 45). South of the Val Verde quadrangle, the fault turns southeast, merges with the axis of the Oat Mountain syncline, and terminates the Pico anticline on the west. There is a zone of high seismicity northeast of the surface trace of the fault, and a focal-mechanism solution from this zone suggests a northeast-dipping reverse fault plane with a component of right slip (Simila and others, 1983), in agreement with subsurface and surface geologic relations. However, there are no tectonic geomorphic features recognized as related to this fault.

Fold belt

The dominant structural feature of the two quadrangles is a set of folds, generally east-trending, which for the most part formed in late Cenozoic time, largely after the Saugus was deposited. The overturned structures involving pre-Modelo strata have already been described as having been formed prior to Modelo deposition. However, the Blue Point anticline and the adjacent syncline to the north fold strata as young as Towsley. Whereas the pre-Modelo structures are south-southwest-verging, the younger folds are upright and show no clear direction of tectonic transport. The folds closest to the San Gabriel fault (Townsend syncline and Loma Verde anticline) are parallel to that fault, suggesting control by the Canton fault and by the southwest slope of the top of basement. However, both folds turn eastward as they approach the fault. Fold trends elsewhere vary from northwest to northeast. Some fold axes show a curved trend convex northward (Devil Canyon anticline, North Hasley Canyon syncline, Santa Felicia syncline, Del Valle anticline) and others are convex southward (Townsend syncline, Loma

Verde anticline, South Hasley Canyon syncline).

The south-dipping reverse faults also show a variable trend, like the folds, but commonly these faults truncate the folds. There is a general tendency for structures to plunge eastward, away from Piru Creek and toward the broad synclinorium of Saugus Formation occupying a lowland east of the Val Verde quadrangle. The more northerly folds expose older rocks than those to the south, with the Santa Clara syncline the lowest structural area.

San Cayetano and Oak Ridge faults

The central Ventura basin consists of a deep trough of late Cenozoic strata including the thickest Pleistocene sequence in the world (Yeats, 1977). This trough is flanked by reverse faults, the San Cayetano fault on the north and the Oak Ridge fault on the south. The east end of this trough occurs in the southwest corner of the Val Verde quadrangle, where a west-plunging syncline with Saugus Formation is overlain with angular unconformity by Santa Clara River alluvium (Cross Section L-L'). The easternmost well in which the San Cayetano fault is recognized is the Union-Camulos Ranch No. 2 well. The stratigraphic separation of the top of the Repettian is about 305 m (1000 feet), but the separation of the base of the Saugus is at least 1220 m (4000 feet) and is probably much larger, because the Saugus does not appear at all in the hanging wall of the San Cayetano fault. The reason for this is not clear. Well data constrain the fault to an east strike, and it approaches the surface at a point where the slope of older alluvium steepens near the Southern Pacific railroad tracks at the western end of the quadrangle. East of a small, unnamed gully, the fault has no surface expression as it crosses a southward-convex bulge in alluvium. Farther east, the surface trace is covered by modern alluvium. The fault ends west of a long exposure of steeply dipping to overturned Pico Formation along State Highway 126 at a point where the Santa Clara River swings north along the northern edge of its floodplain.

Similarly, the Oak Ridge fault shows small separation of the top of the Repettian, but the base of the Saugus shows at least 820 m (2700 feet) separation, and it is probably much more because the Saugus is not present in the hanging wall of the fault. West of the Val Verde quadrangle, the surface trace of the Oak Ridge fault is marked by a north-facing scarp. Within the quadrangle, however, the surface trace is covered by modern alluvium. The subsurface position of the fault is constrained by the Union NLF No. A-1 Core Hole and the Union NLF No. 3 well (Cross Section L-L'), largely as an abrupt change from north-facing strata in the south to south-facing strata on the north, as if the fault occupied the axial surface of a syncline. The fault dies out west of the Pico exposures along Highway 126. The A-1 Core Hole confirms the presence of a sharp anticline in Pico Formation such that Saugus rests on older Pico and Repettian strata with the younger Pico missing. The Saugus is folded also, but this folding is much more open.

Santa Clara syncline

The Santa Clara River is structurally constrained to the axis of the Santa Clara syncline where the Oak Ridge and San Cayetano faults are present. East of these fault traces, no linear topographic steps have been found in the Santa

Clara River Valley. The Santa Clara River flows down the axis of the syncline north of the Oak Ridge fault, but east of the Oak Ridge and San Cayetano faults, the Santa Clara River cuts diagonally across the Santa Clara syncline, Newhall-Potrero anticline, Del Valle anticline, and the southeast termination of the Del Valle fault. River terraces are preserved along the axis of the Santa Clara syncline southeast of the Santa Clara River north of Potrero Canyon. The broad, alluviated valley of Potrero Canyon may be controlled by downwarping on this late Quaternary syncline.

Conclusions

Strata of Eocene to early Miocene age were strongly deformed prior to deposition of the Modelo Formation (Cross Section A-A'). Deformation consisted of two south-southwest-verging monoclines with west-northwest-trending fold axes. The northern monocline brings steeply-dipping Eocene strata and underlying basement rocks in contact with Mohnian deposits of the Modelo Formation. The fold broke along the unconformity between basement and the Eocene to form the Whitaker fault. The southern monocline brings early Miocene strata in contact with Modelo Formation in Canton Creek. Thickening of the Sespe Formation in the unnamed syncline north of the Blue Point anticline shows that the southern monocline was an asymmetric anticline following Sespe deposition but prior to Modelo deposition, with a steep south limb and a gentle north limb (Cross Section A-A'). The southern monocline is associated with the Agua Blanca fault. These structures predate deposition of Mohnian strata that overlie them unconformably, but older Mohnian and Luisian beds of the Modelo are cut by the Agua Blanca fault. Farther west, and in the subsurface, the Modelo contains Relizian microfossils, and the overlap northeastward of the Relizian by the Luisian, and the Luisian by the Mohnian is due to pre-Modelo topography presumably related to the early deformation (Cross Section A-A'). If this is the case, these structures formed during the Relizian, Luisian, and early Mohnian (approximately 16 to 10 Ma). However, the presence of pebbly sandstone within the Rincon Formation, the eastward increase of clast size in the Vaqueros and Sespe formations, and the presence of a tongue of variegated sandstone and siltstone in the middle unnamed member of the Eocene sequence are evidence that a west or southwest slope of basement topography was also present as these formations were deposited.

The Canton fault, apparently an early strand of the San Gabriel fault, is dated as pre-late Mohnian on the basis of its relations with the Modelo in the surface and subsurface. This is about the same age as the south-southwest-verging structures of the eastern Ventura basin described above. However, if the early stage of San Gabriel fault displacement was contemporaneous with contractile tectonics to the west, the later stage of San Gabriel movement was not. There is no evidence of crustal shortening in the east Ventura basin fold belt between the early Mohnian and the late Quaternary. However, south of the Val Verde quadrangle, there is evidence of crustal shortening in the vicinity of the Santa Susana fault during deposition of the Pico Formation and in post-Pico, pre-Saugus time (Yeats, 1979, and in press).

The fold belt formed in Quaternary time, with fold axes influenced by the basement ridge southwest of the San Gabriel fault. Folding in part pre-dated faulting. The folds show no sense of vergence north or south, but the faults dip south at moderate angles. The folds are concentric (uniform thickness of individual folded layers), implying that the folds should disappear downward to a surface of decollement (Davis, 1984). Comparable folds are found in fold-and-thrust belts underlain by a decollement above basement, but the lack of a clear sense of vergence makes uncertain any tectonic comparisons with a decollement. This is an important problem, however, because if these reverse faults are ramps which flatten downward into a decollement within the sedimentary section, their seismic hazard would be less than if they cut crystalline basement.

The strongly negative Ventura trough, marked by thick accumulations of Pleistocene strata flanked by the opposing San Cayetano and Oak Ridge reverse faults, ends where these faults end (Cross Section L-L'). Yet the trough continues eastward as the Santa Clara syncline which is unfaulted but which contains the youngest section of Pico strata (Cross Section C-C'). There is no direct structural connection between the Ventura trough and the synclinal lowland underlain by Saugus Formation east of the area.

The structural style of the region appears to shift from contractile tectonics accompanying early strike slip on the San Gabriel fault (Canton strand) to predominantly strike slip on the San Gabriel fault during deposition of the Castaic Formation, Ridge Basin Group, and Violin Breccia, and finally to predominantly contractile tectonics in the last few million years as right slip shifted east to the San Andreas fault. In the younger contractile phase, the San Gabriel fault appears to have played only a subordinate role, related to the fact that it is a zone of weakness which may penetrate the brittle portion of the crust.

Seismic Hazard

The Agua Blanca, Whitaker, Canton, and Devil Canyon faults predate the deposition of late Mohnian strata (10 to 7 Ma) and thus pose minimal risk of future earthquakes. The San Gabriel, Santa Felicia, Oak Canyon, Hasley, Holser, and Del Valle faults cut Saugus but relatively few tectonic land forms associated with these faults have been preserved. The San Gabriel fault cuts terrace material unconformably overlying Saugus in the Newhall quadrangle, but it is tectonically overlain by the Santa Felicia reverse fault in the Whitaker Peak quadrangle. The San Cayetano and Oak Ridge faults are the youngest-appearing faults in the area, although they die out eastward in the western part of the Val Verde quadrangle. These two faults appear to have the greatest potential in the area for seismic rupture.

Seismic hazard on the south-dipping reverse faults is more difficult to ascertain. Separation on these faults is low except for the Holser and Del Valle faults. If they are structural ramps over a decollement, they would not penetrate rocks of such high strength that they would generate a large-magnitude earthquake. The lack of tectonic geomorphic features suggests that if these south-dipping reverse faults do produce earthquakes, their recurrence interval is very long, perhaps measured in 10^4 to 10^5 years based on a comparison with similar faults in New Zealand (Yeats and Berryman, 1985 and in review; Yeats and others, 1985). Further study of Santa Clara River terraces should improve our understanding of earthquake potential and recurrence interval.

Probably the greatest potential for earthquake generation occurs in the southwest quarter of the Val Verde quadrangle which is underlain at depth by the

Santa Susana reverse fault and the Santa Clara River valley between the Oak Ridge and San Cayetano faults.

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