DEPARTMENT OF THE INTERIOR

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Geologic map of the northwestern Caliente Range, San Luis Obispo County, California

by

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This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by USGS

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DISCUSSION

INTRODUCTION

The map area lies in the southern Coast Ranges of California, north of the Transverse Ranges and west of the southern San Joaquin Valley. This region is part of the Salinia-Tujunga composite terrane that is bounded on the northeast by the San Andreas fault (fig. 1) and on the southwest by the Nacimiento fault zone (Vedder and others, 1983). The Chimineas fault of this map is inferred to be the boundary between the Salinia and the Tujunga terranes (Ross, 1972; Vedder and others, 1983).

Geologic mapping in the region of the California Coast Ranges that includes the area of this map has been largely the work of T.W. Dibblee, Jr. Compilations of geologic mapping at a scale of 1:125,000 (Dibblee, 1962, 1973a) provide the regional setting for this map, the northeast border of which lies about 6 to 7 km southwest of the San Andreas fault. Ross (1972) mapped the crystalline basement rocks in the vicinity of Barrett Creek, along the northeast side of the Chimineas fault ("Barrett Ridge" of Ross, 1972). Recent 1:24,000-scale mapping in the La Panza Range (fig. 1) (Vedder and others 1986a,b) overlaps onto the southwest edge of this map and provides useful information about the older rocks, mostly southwest of San Juan Creek.

Stratigraphic knowledge of the area, which lies in the northern part of the middle Tertiary Cuyama basin, has evolved over a period of years beginning with the molluscan biostratigraphic work of Anderson and Martin (1914) and Loel and Corey (1932). Hill and others (1958) described the Tertiary stratigraphy of the region and proposed stratigraphic names. This stratigraphy was discussed further by Dibblee (1973b), and his revised nomenclature is used here. Stratigraphic studies in the southeastern Caliente Range (fig. 1) (Repenning and Vedder, 1961; Vedder, 1973) provided valuable information on the interrelations of continental, shallow-marine, and deeper marine facies in the southern part of the Cuyama basin, which have basinwide application. More recent stratigraphic studies by Lagoe (1984, 1985, 1987, 1988) further elaborate on aspects of Miocene basin history and paleogeography.

Contributions to the tectonic history of the area have been made by Schwade and others (1958), on the basis of oil exploration in the Cuyama Valley area (fig. 1) in the 1940's and 1950's; by Bartow (1974), as part of a regional stratigraphic study; by Ballance and others (1983), on the basis of a study of Oligocene and early Miocene sedimentation; and most recently by Davis and others (1988) and Yeats and others (1988), who utilized a variety of new data from seismic reflection and from stratigraphic and structural studies.

Field work for this map was done mostly in 1969-73 as part of a regional study of the Simmler and Vaqueros Formations (Bartow, 1974). Detailed field mapping was, therefore, concentrated on those units; other parts of the area were mapped by geologic reconnaissance and air-photo interpretation that were supplemented by data from published maps (Dibblee, 1973a; Vedder and others, 1986a,b). Mapping of the crystalline basement rocks at "Barrett Ridge" is from Ross (1972, plate 1). The structural style depicted in the accompanying cross sections favors the thrust belt concepts of Davis and others (1988) over the older interpretations of Dibblee (1962) or Cross (1962).

STRATIGRAPHY

Basement rocks

Crystalline basement rocks in the map area comprise two distinct terranes: (1) granitic rocks (Kgr), mostly granite and granodiorite in the La Panza Range; and (2) gneissic rocks (pGgn), including small bodies of alaskite (Kal) and quartzite (pGq), along Barrett Creek. The Chimineas fault, together with connecting faults to the northwest and southeast, is inferred to be the boundary between the granitic rocks of the Salinia terrane and the gneissic rocks of the Tujunga terrane (Ross, 1972; Vedder and others, 1983). Emplacement ages for the granitic rocks are probably within the range of 80 to 90 Ma (Mattinson and James, 1985). Uranium/lead isotopic data from zircons indicate an age of about 1,700 Ma for the gneiss and about 80 Ma for the intruding alaskite (Mattinson, 1983; Mattinson and James, 1985).

Upper Cretaceous sequence

The Upper Cretaceous sequence of the La Panza Range consists mostly of a thick, monotonous sequence of sparsely fossiliferous sandstone, siltstone, and conglomerate (Ksc) that represents turbidite-system deposits. A conglomerate unit at the base of the sequence (Kcg) probably represents nonmarine and (or) shallow-marine environments; hence the section as a whole represents a deepening-upward transgressive sequence (Howell and others, 1977). The conglomerate unit (Kcg) is restricted to the area southwest of the Chimineas fault, although Dibblee (1973a) considered conglomeratic sandstone overlying the gneissic terrane at Deadman Flat northeast of the fault to be part of the conglomerate unit. This conglomeratic sandstone, which has a clast composition similar to that of the La Panza Range conglomerate, is here considered to be part of the sandstone, siltstone, and conglomerate unit (Ksc), as it was so considered by Vedder and others (1986a).

The Upper Cretaceous sequence of this map is part of the Upper Cretaceous and lower Tertiary marine sedimentary sequence of Dibblee (1973a,b) that is exposed in the La Panza Range and Sierra Madre (fig. 1). The sequence is poorly dated, but it is apparently as young as early to middle Eocene in its upper part in the Sierra Madre. There is, however, no known evidence for the presence of Tertiary rocks within or immediately adjacent to the map area (Vedder and others, 1986a); therefore, the part of the sequence that lies within the map area is considered to be of Late Cretaceous age only.

Middle Tertiary sequence

The nonmarine Simmler Formation unconformably overlies older rocks and consists of a sandstone facies (Tss) in the upper plate of the Big Spring thrust fault and a conglomerate and sandstone facies (Tsc) in the lower plate. The minimum age of the sandstone facies is constrained by the earliest Miocene age of the lower part of the overlying Soda Lake Shale Member of the Vaqueros Formation (Lagoe, 1988) and is, therefore, Oligocene. The minimum age of the conglomerate and sandstone facies, on the other hand, is probably early Miocene on the basis of correlation with Simmler strata exposed several kilometers southwest of the map area and southwest of the La Panza fault (fig. 1), where Ballance and others (1983) reported a 23-Ma age for a basalt flow in the lower to middle part of the unit. The Simmler is virtually unfossiliferous, but it is inferred to be mostly Oligocene on the basis of correlation with similar red bed units in southern California that contain fossil mammals (Bartow, 1978). Thus, the overall age of the Simmler Formation in the map area is considered to be Oligocene and early Miocene. The conglomerate and sandstone facies is interpreted to be an alluvial fan deposit, and the sandstone facies is interpreted to be a fluvial deposit, presumbably that of small- to moderate-sized, low-sinuosity streams (Bartow, 1978).

The conglomerate and sandstone facies crops out in two small areas on opposite sides of the Chimineas fault that are somewhat different lithologically and have different conglomerate clast types, but they have very similar sandstone petrology. Sandstone in both areas has quartz-feldspar-lithic (QFL) grain compositions in the range of Q=38-45 percent, F=54-63 percent, and L=2 percent, and a plagioclase/total feldspar ratio of 0.63-0.69. These values are also within the same general range as sandstone from the Simmler sandstone facies and from Miocene marine units in the same area (Bartow, 1974).

In the map area, the Simmler is overlain by a conformable sequence of Miocene marine rocks comprising the Vaqueros Formation, the Monterey Shale (and intertonguing Branch Canyon Sandstone), and the Santa Margarita Formation. This Miocene sequence reflects two major depositional cycles (Lagoe, 1987, 1988). The Soda Lake Shale Member of the Vaqueros Formation was formerly considered to be late Oligocene and early Miocene (Zemorrian and Saucesian) in age (Dibblee, 1973b), but new information indicates that the unit is entirely early Miocene (Saucesian) in age (Lagoe, 1988). The Painted Rock Sandstone Member (of the Vaqueros) is mostly early Miocene (Saucesian), but the top becomes younger northwestward and the uppermost part is middle Miocene (Relizian) in age in the northwestern part of the map area (Cross, 1962; Bartow, 1974). The Monterey Shale is largely middle Miocene (Relizian and Luisian) in age, and the Santa Margarita Formation is assigned to the "Margaritan" (provincial molluscan) Stage of Addicott (1972), which is considered to be of late middle and early late Miocene age.

The basal part of the Soda Lake Shale Member (Tvsl) of the Vaqueros Formation, or the Quail Canyon(?) Sandstone Member (Tvq) (of the Vaqueros), where it is present, represent transgressive deposits of the first cycle conformably overlying the Simmler. The basin deepened rapidly to bathyal depths during deposition of the Soda Lake Shale Member (Lagoe, 1988), then shallowed to neritic or shallower depths during deposition of the Painted Rock Sandstone Member (Tvp). A thinner sandstone unit (Tvs) of the Vaqueros Formation, which lacks the Soda Lake Shale Member, crops out along the northeast flank of the La Panza Range and occurs in the lower plate of the major southwest-verging thrust faults. This thinner unit locally overlaps the Simmler Formation onto the Upper Cretaceous or basement rocks. The sandstone units of the Vaqueros Formation are interpreted as comprising a variety of shallow-marine and deltaic deposits (Bartow, 1974).

Renewed basin subsidence near the end of Vaqueros time began the second basin cycle and led to deposition of the Monterey Shale (Tms, Tmw) at bathyal depths. The shallow-marine Branch Canyon Sandstone (Tbc) intertongues with the upper part of the Monterey and indicates a shallowing-upward trend. Depositional environments and paleogeography of the Monterey Shale are discussed by Lagoe (1984, 1985). Contemporaneous volcanism produced local accumulations of basaltic rocks (Tb) that intertongue with the Branch Canyon Sandstone and Monterey Shale. A lenticular body of basalt in the Vaqueros Formation near Barrett Creek may be a sill. Shallow-marine sandstone of the Santa Margarita Formation (Tsm) appears to have blanketed the area and represents the final fill in the marine basin (Lagoe, 1987).

Pliocene and Pleistocene deposits

The nonmarine Morales Formation (Tmo) of Pliocene age (Hill and others, 1958; Dibblee, 1973b), which is exposed in only one area near the south margin of the map, appears to be a synorogenic deposit that unconformably overlies deformed older units. It shows some deformation in the subsurface and in adjacent areas to the southeast. The nonmarine Paso Robles Formation (QTp) was considered by Dibblee (1973a,b) to be of Pleistocene and partly of probable Pliocene age because of its stratigraphic relations in the Carrizo Plain area and its contained Pliocene fossils near Atascadero and Santa Margarita about 30 to 35 km northwest of the map area. The formation may be entirely Pleistocene in the map area, but because of the nearby Pliocene fossils, it is considered to be late Pliocene(?) and Pleistocene in age. It is only slightly deformed and is a synorogenic to post-orogenic deposit.

STRUCTURE

The principal structures in the map area are the high-angle Chimineas fault, the Big Spring thrust fault, and blind thrust faults associated with the Big Spring thrust. The Big Spring thrust is notable for the juxtaposition of a very thick section of the Simmler and Vaqueros Formations in the upper plate with a much thinner section in the lower plate, and for the large anticline in the upper plate.

The Chimineas fault is part of a set of right-lateral strike-slip faults that extends northwestward from the Cuyama Valley toward a possible junction with the San Andreas fault system northwest of the Red Hills (fig. 1). The southeastern element of the set, the Russell fault, can be traced in the subsurface to within a few kilometers of the Chimineas fault and a connection between them can be reasonably inferred (Bartow, 1974; Calhoun, 1988). An eastern branch of the Russell fault lies 3 to 4 km downdip (northeast) from the Chimineas fault in the map area (Cross, 1962; Calhoun, 1988). The Chimineas fault is inferred to connect northwestward with the San Juan fault (Dibblee, 1973a), but because the northwest continuation of the Chimineas fault is concealed beneath the upper plate of the Big Spring thrust, the location and nature of the transition from the Chimineas fault to the San Juan fault is not known.

Post-Cretaceous right-lateral movement of 13 to 14.5 km on the Chimineas fault has been suggested, on the basis of an apparent offset of both the Cretaceous-basement contact and the Simmler-basement contact (Bartow, 1974; Yeats and others, 1988). Lithologic differences in both the Cretaceous sequence and the Simmler Formation across the Chimineas fault weaken the correlation somewhat, but if the basement rocks are envisioned as having formed an east-west-trending ridge flanked on the north by the Simmler Formation and on the south by Cretaceous strata, the offset seems more believable. An additional 13 to 14 km of right slip has been suggested for the eastern strand of the Russell fault (Yeats and others, 1988). Equivalent offset for both Cretaceous strata and the Simmler Formation indicates that right slip occurred after the earliest Miocene. The southeast end of the fault is overlain by unfaulted Pliocene Morales Formation, which provides the upper age limit on the movement. A deformed wedge of Miocene strata as young as the Santa Margarita Formation in the fault zone indicates significant movement as recent as latest Miocene or possibly earliest Pliocene. Yeats and others (1988) determined that the Russell fault was active between 23 and 4 Ma, but that most of the movement took place between 23 and 19 Ma. This is probably applicable to the Chimineas fault as well.

Thrust faulting on the Big Spring and associated blind thrusts involves rocks as young as the Santa Margarita Formation of late middle and late Miocene age. Deformed rocks of the upper plate are unconformably overlain by the Paso Robles Formation, and the northwest end of the fault also seems to disappear beneath a large outcrop area of the Paso Robles. The period of thrust activity, therefore, is presumably limited to Pliocene time.

One of the most striking aspects of the Big Spring thrust fault is the large difference in thicknesses of the Simmler and Vaqueros Formations between the upper and lower plates. There may be as much as 2,300 m of the Painted Rock Sandstone Member (of the Vaqueros Formation), 750 m of the Soda Lake Shale Member (of the Vaqueros Formation), and 1,500 m of the Simmler Formation in the upper plate. The lower plate, in contrast, has only 150 to 600 m of the Vaqueros and from zero to about 200 m of the Simmler. Strike-slip displacement cannot account for these differences because the Chimineas fault transects the lower plate outcrop belt of both formations without significant thickness change. Normal depositional thickening would require the basin depocenter to be many kilometers to the northeast, but there is no evidence that the basin ever extended very far across the San Andreas fault (Bartow, 1974), which lies 14 to 16 km northeast of the anticline where the thickest section is now preserved. The basin, therefore, was presumably narrow and had a depositional axis lying under the present-day Carrizo Plain, a relation which requires thrust displacements of only 6 to 7 km. The best explanation for the thickness differences is that a set of normal faults formed at the basin margin during Simmler and Vaqueros deposition. These faults are now concealed beneath the upper plate. Basin-margin faulting was first proposed by Schwade and others (1958), and basin-margin normal faults are an important element in the structural model of Davis and others (1988). Because these normal faults are concealed, their exact locations and orientations are indeterminate, but they are inferred to trend subparallel to the northeast basin margin, presently marked by the San Andreas fault. These faults would, then, be approximately parallel to the La Panza and Nacimiento faults to the southwest that were active basin-margin faults during Simmler deposition in the Oligocene and early Miocene (Vedder and Brown, 1968; Bartow, 1974; Bohannon, 1975; Ballance and others, 1983).

An important set of north-south-trending normal faults occurs in the upper plate of the Big Spring thrust fault. Many of these faults are intruded by dikes, presumably the same age as the middle Miocene basaltic rocks in the area for which they were probably the feeders. Although these faults are arrayed along the major anticline in the upper plate of the thrust, they are not perpendicular to the fold axis and are probably not, therefore, genetically related to the folding. The age of faulting is not well constrained, but it was probably contemporaneous with the middle Miocene volcanism.

Cross sections

The cross sections accompanying this map serve two purposes: (1) they show the shallow structure that can be reasonably inferred from outcrop and surface information; and (2) they illustrate deeper structural and stratigraphic relations, as well as an overall structural style, that are more conceptual in nature. Therefore, each section is divided by a heavy dashed line into an upper part, which is relatively well constrained by data, and a lower part, which is more schematic. The structure and stratigraphy in the lower part of each section are consistent with what is known about the geology and tectonic history of the area, although the details are more speculative.

The cross sections are based on (1) surface geology, (2) data from more than 50 exploratory wells within or adjacent to the map area, and (3) one published seismic reflection line from Davis and others (1988, fig. 12). Only selected wells are shown on the map (table 1). The subsurface data support the contention that (1) there is a major thrust system southeast of, and structurally below, the Big Spring thrust; (2) the thrusts flatten northeastward at depth; and (3) the faults ramp upsection to produce fault-bend or fault-propagation folds (Davis and others, 1988). The subsurface data also support the hypothesis, as discussed above, that large-scale growth faults caused the abrupt thickness changes in the middle Tertiary stratigraphic section (Davis and others, 1988). Section A-A' makes the most direct use of seismic data and is a modification of section A-A' of Davis and others (1988, figs. 11, 12), which is located near section A-A' of this map. The other three sections conform to the same general structural model, but they are not directly supported by seismic data.

The tests for geometric validity of cross sections in thrust belts are consistency of bed length and consistency of shortening (Dahlstrom, 1969). Although those tests have been applied to the sections on this map to the extent possible, the sections cannot be rigorously balanced because of the major thickness changes and the strike-slip faulting. The structural interpretations shown on the cross sections are consistent with the known geologic data, but the geologic validity of the interpretation can only be tested with more subsurface data.

TECTONIC HISTORY

The general tectonic history of the Cuyama basin--that is, right slip on the Chimineas-Russell fault sometime between the Cretaceous and the early Pliocene and thrust faulting in the latest Cenozoic--was outlined by Schwade and others (1958). In addition, there was an interval of late Oligocene and Miocene normal faulting at the basin margins, as discussed above. Ballance and others (1983) interpreted the major structural elements in terms of a wrench-fault model, in which transtension controlled events in the early to middle Miocene and transpression became the controlling factor in the late Miocene and Pliocene. Yeats and others (1988) have also stressed the importance of strike slip on the Chimineas-Russell fault set in the evolution of the basin.

The Cenozoic tectonic history of the northern Cuyama basin, drawing principally from the work of Bartow (1974), Ballance and others (1983), and Yeats and others (1988), can be outlined as follows:

1. Late Oligocene northeast-southwest extension and down-to-the-northeast normal faulting on the Nacimiento, La Panza, and inferred basin-margin faults occurred concurrently with the initiation of deposition of the nonmarine Simmler Formation.
2. Early Miocene transtension and consequent right slip on the Chimineas-Russell fault trend and continued down-to-the-northeast normal faulting produced rapid subsidence and marine transgression. Vaqueros deposition began in the central part of the basin while alluvial fan deposition (conglomerate and sandstone facies of the Simmler) continued for a brief time to the southwest. The basin margins were later overlapped by the later phases of Vaqueros deposition.
3. Renewed transtension in middle Miocene time produced basin deepening and initiated the second depositional cycle with deposition of the Monterey Shale. Both the Chimineas-Russell and the San Andreas faults were active during this period, but most movement took place on the San Andreas. The Cuyama basin lay largely between the two faults and the resulting shear couple with east-west extension is evidenced by north-south normal faults and contemporaneous volcanism.
4. The late Miocene was a time of relative stability as the basin filled with shallow-marine deposits of the Santa Margarita Formation.
5. Compression normal to the San Andreas fault beginning in Pliocene time (Zoback and others, 1987) produced southwest-verging thrusts that juxtaposed the thick basinal section with the thinner basin-margin section. The nonmarine Morales Formation is a record of subaerial erosion of the deformed thrust belt rocks.

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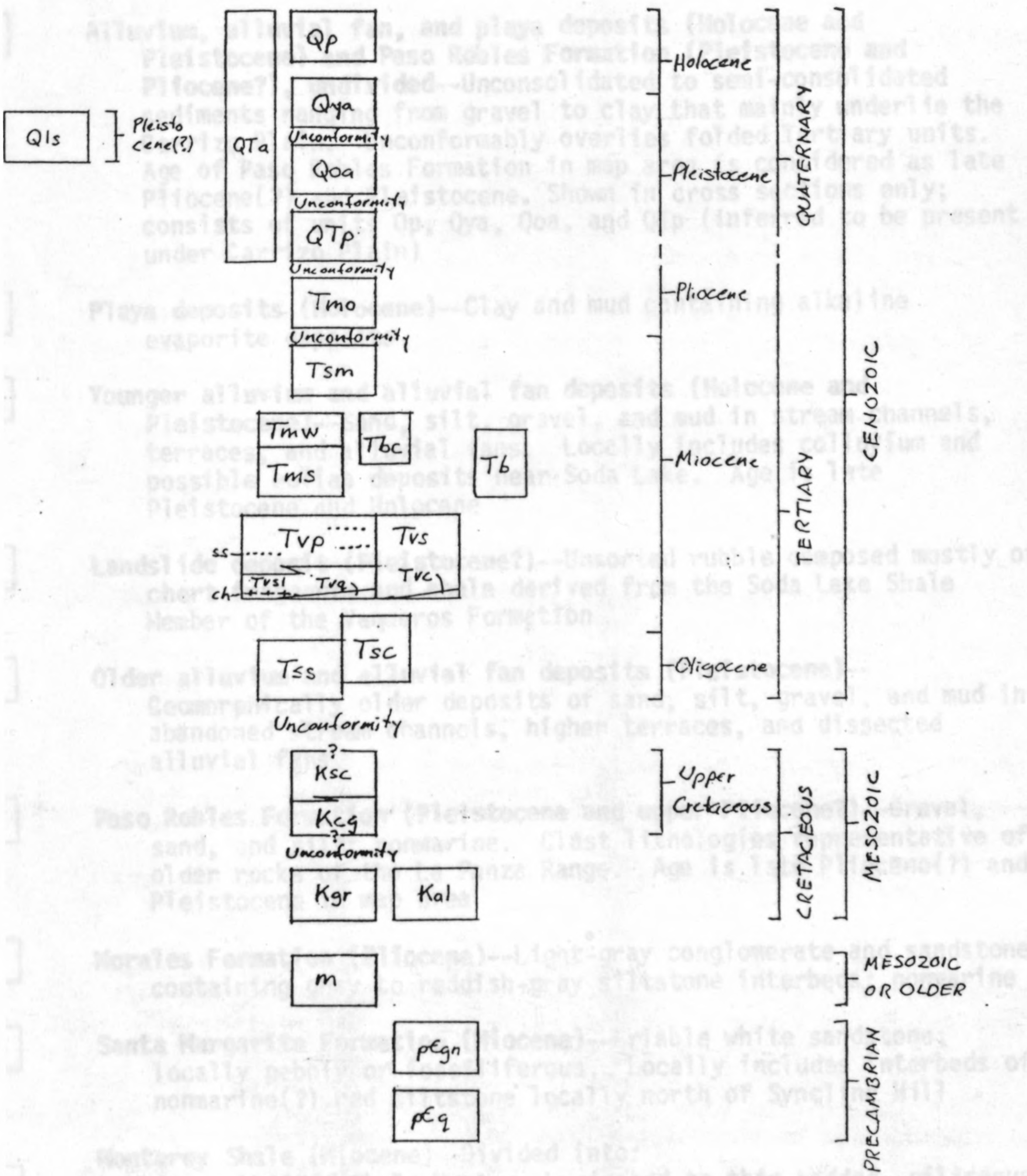
CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qta **Alluvium, alluvial fan, and playa deposits (Holocene and Pleistocene) and Paso Robles Formation (Pleistocene and Pliocene?), undivided**--Unconsolidated to semi-consolidated sediments ranging from gravel to clay that mainly underlie the Carrizo Plain. Unconformably overlies folded Tertiary units. Age of Paso Robles Formation in map area is considered as late Pliocene(?) and Pleistocene. Shown in cross sections only; consists of units Qp, Qya, Qoa, and QTp (inferred to be present under Carrizo Plain)

Qp **Playa deposits (Holocene)**--Clay and mud containing alkaline evaporite deposits

Qya **Younger alluvium and alluvial fan deposits (Holocene and Pleistocene)**--Sand, silt, gravel, and mud in stream channels, terraces, and alluvial fans. Locally includes colluvium and possible eolian deposits near Soda Lake. Age is late Pleistocene and Holocene

Qls **Landslide deposit (Pleistocene?)**--Unsorted rubble composed mostly of chert fragments and shale derived from the Soda Lake Shale Member of the Vaqueros Formation

Qoa **Older alluvium and alluvial fan deposits (Pleistocene)**--Geomorphically older deposits of sand, silt, gravel, and mud in abandoned stream channels, higher terraces, and dissected alluvial fans

QTp **Paso Robles Formation (Pleistocene and upper Pliocene?)**--Gravel, sand, and silt; nonmarine. Clast lithologies representative of older rocks of the La Panza Range. Age is late Pliocene(?) and Pleistocene in map area

Tmo **Morales Formation (Pliocene)**--Light-gray conglomerate and sandstone containing gray to reddish-gray siltstone interbeds; nonmarine

Tsm **Santa Margarita Formation (Miocene)**--Friable white sandstone; locally pebbly or fossiliferous. Locally includes interbeds of nonmarine(?) red siltstone locally north of Syncline Hill

Monterey Shale (Miocene)--Divided into:

Tmw **Whiterock Bluff Shale Member**--Laminated to thin-bedded, siliceous shale, cherty shale, diatomaceous shale, and minor calcareous shale. Contains Relizian(?) and Luisian foraminifers

Tms **Saltos Shale Member**--Soft-weathering, calcareous or siliceous mudstone and shale; includes minor interbedded sandstone. Contains Relizian foraminifers

Tbc **Branch Canyon Sandstone (Miocene)**--Light-gray to brown sandstone and calcareous sandstone; locally fossiliferous. Intertongues with the Monterey Shale

Tb

Basaltic rocks (Miocene)--Black fine-grained basalt, basaltic agglomerate, and lithic tuff; locally includes shallow dikes and sills

Vaqueros Formation (Miocene)--Divided into:

Tvp

Painted Rock Sandstone Member--Thick-bedded, locally crossbedded, very coarse to medium-grained sandstone and conglomeratic sandstone interbedded with sandy siltstone and silty fine-grained sandstone. Coarser grained sandstone crops out as prominent lenticular bodies (ss). Upper part of unit has thinner, more regular bedding and contains fossiliferous concretionary layers. Contains Saucesian and Relizian foraminifers and mollusks of the "Vaqueros" and "Temblor" (provincial molluscan) Stages of Addicott (1972)

Tvs

Sandstone--Poorly bedded to massive, locally crossbedded, fine- to medium-grained sandstone; locally fossiliferous. Lower part commonly pebbly or conglomeratic. Contains mollusks of the "Vaqueros" and "Temblor" (provincial molluscan) Stages of Addicott (1972)

Tvsl

Soda Lake Shale Member--Hard dark-gray to brown siltstone and platy shale containing thin turbidite sandstone beds and occassional layers of dolomite concretions. Includes a thin unit of bedded chert (ch) in lower part. Contains Saucesian foraminifers

Tvq

Quail Canyon(?) Sandstone Member--Light-gray calcareous sandstone, and minor interbeds of dark-gray siltstone. Shown in cross sections only

Tvc

Claystone--Poorly exposed claystone containing thin platy limestone beds

Simmler Formation (Miocene and Oligocene)--Divided into:

Tsc

Conglomerate and sandstone facies (Miocene and Oligocene)--West of Chimineas fault: gray and grayish-red, clayey, coarse-grained, pebbly sandstone containing scattered cobbles and boulders of granite; nonmarine. East of Chimineas fault: red-brown to grayish-red, poorly sorted, muddy to sandy conglomerate or breccia and lenses of gray, pebbly sandstone to sandy breccia; nonmarine. Clasts mostly gneissic rocks but also include quartzite and rare volcanic porphyries. Age is Oligocene and early Miocene

Tss

Sandstone facies (Oligocene)--Light-gray, fine- to medium-grained sandstone and subordinate gray to grayish-red siltstone interbeds; locally crossbedded; nonmarine

Marine sedimentary rocks (Upper Cretaceous)--Divided into:

Ksc

Sandstone, siltstone, and conglomerate--Thick sequence of lenticular sandstone and interbedded siltstone; locally contains lenses of conglomerate or conglomeratic sandstone. Contains Maestrichtian(?) mollusks near Deadman Flat

Kcg — **Conglomerate**--Pebble and cobble conglomerate and minor sandstone interbeds; clasts composed of quartzite, granitic rocks, gneiss, volcanic porphyries, and minor schist, in order of decreasing abundance. Grades upward into unit Ksc. Chiefly nonmarine in lower part

Kgr — **Granitic rocks (Cretaceous)**--Gray medium-grained granite and granodiorite

Kal — **Alaskite (Cretaceous)**--Light-gray to pinkish-gray, medium-grained alaskite

m — **Marble (Mesozoic or older)**--White crystalline marble occuring in fault horses along Chimineas fault

pЄgn — **Gneiss (Precambrian)**--Banded quartzo-feldspathic to biotite-rich gneiss; locally contains augen gneiss

pЄq — **Quartzite (Precambrian)**--Gray, dense, crudely layered quartzite or quartz schist

Contact

Fault--Dashed where indefinite or inferred; dotted where concealed; queried where inferred from subsurface evidence. Bar and ball on downthrown side; crosses where intruded by dike. In cross sections, arrows indicate direction of relative movement (where two directions are shown by double-headed arrow, larger arrow indicates most recent movement); A, movement away from observer; T, movement toward observer

Thrust fault--Dashed where indefinite; dotted where concealed; queried where inferred. Sawteeth on upper plate

Fold axes--Showing approximate location of crestline and direction of plunge; dotted where concealed

Anticline

Syncline

Overturned syncline--showing dip of limbs

Strike and dip of beds

44 **Inclined**

Vertical

75 **Overturned**

Landslide--Arrows show inferred direction of movement

Well--Number refers to table 1

Well penetrating basement rocks above Big Spring thrust fault

Well penetrating a thrust or reverse fault but not reaching basement rocks

Well penetrating basement rocks structurally below all thrust faults

Table 1. Wells On Cross Sections

Well No	Company and Well Name	Location
	Section A-A'	
1	Shell Oil Co. "Ferguson" 87X-14	Sec. 14, T. 30 S., R. 17 E.
2	Shell Oil Co. "Ferguson" 41-13	Sec. 13, T. 30 S., R. 17 E.
3	Shell Oil Co. "McDonald Estate" 28-30	Sec. 30, T. 29 S., R. 18 E.
4	Continental Oil Co. "Cavanaugh" 1	Sec. 32, T. 29 S., R. 18 E.
	Section B-B'	
5	R.K. Cross "Grayson-Owen" 38-3	Sec. 3, T. 31 S., R. 18 E.
6	Signal Oil and Gas Co. "Signal-Grayson-Owen" 46-34	Sec. 34, T. 30 S., R. 18 E.
7	C.L. & E. Corp. "Grayson-Owen" 1-35	Sec. 35, T. 30 S., R. 18 E.
	Section C-C'	
8	R.K. Cross "Grayson-Owen" 38-19	Sec. 19, T. 31 S., R. 19 E.
9	Bell Petroleum Co. "Grayson-Owen" 53-19	Sec. 19, T. 31 S., R. 19 E.
10	Texas Crude Oil Co. "Grayson-Owen" 67-18	Sec. 18, T. 31 S., R. 19 E.
11	Texas "Grayson-Owen" 5	Sec. 18, T. 31 S., R. 19 E.
	Section D-D'	
12	Texaco "Santa Margarita Land & Cattle Two" 1	Sec. 5, T. 32 S., R. 19 E.
13	Signal Oil and Gas Co. "SMLC-Arnold" 1	Sec. 4, T. 32 S., R. 19 E.
14	Exxon "Arnold" 2	Sec. 33, T. 31 S., R. 19 E.
15	Exxon "Arnold" 1	Sec. 33, T. 31 S., R. 19 E.
16	R.K. Cross "Chimineas-Arnold" 52-34	Sec. 34, T. 31 S., R. 19 E.
17	Elmer Von Glahn "Soda Lake" 1	Sec. 12, T. 31 S., R. 19 E.

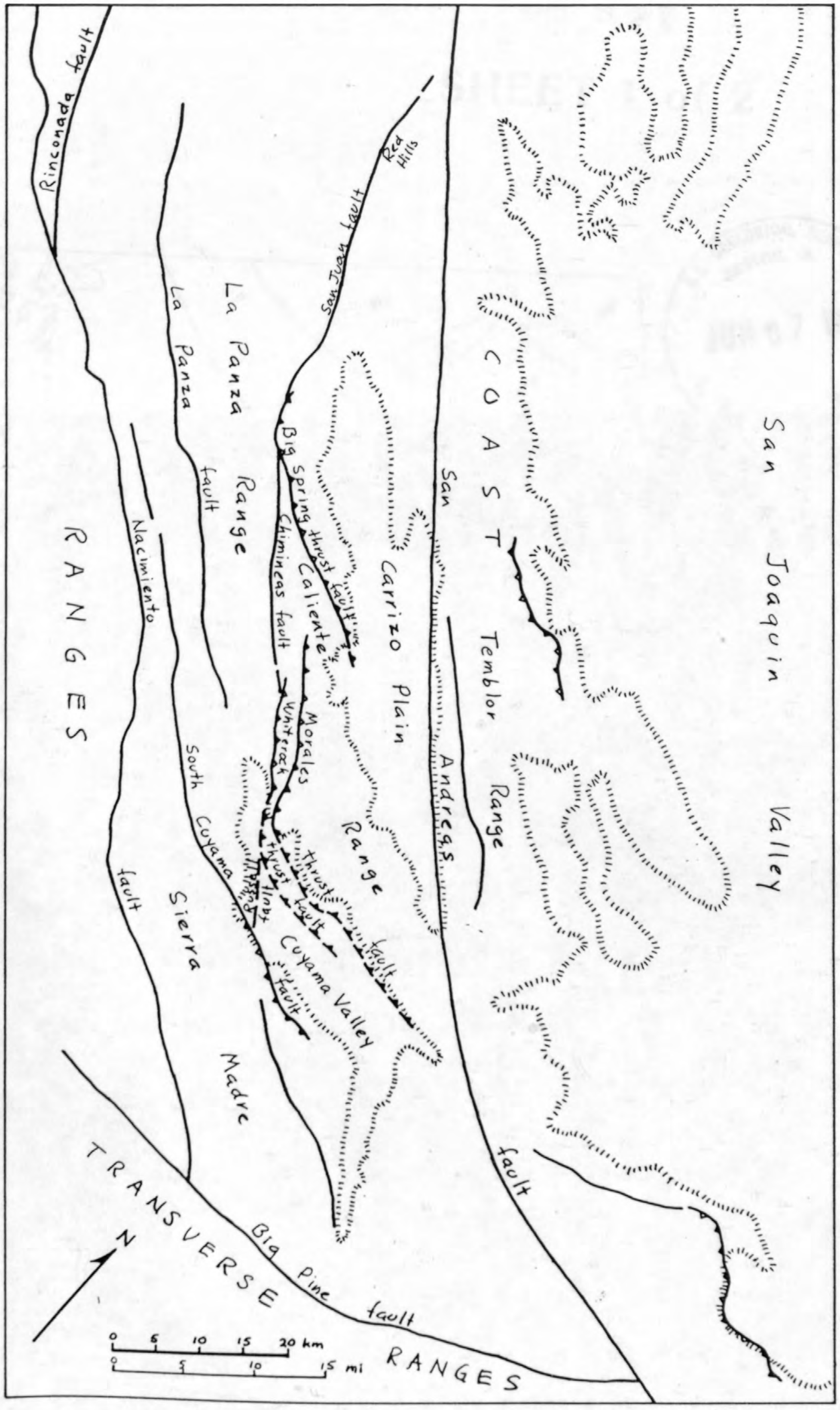


Figure 1.--Index map for the region surrounding the Caliente Range.