

THE RUSSELL FAULT; AN EARLY STRIKE-SLIP FAULT OF THE CALIFORNIA COAST RANGES

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ABSTRACT

The subsurface Russell fault is a controlling structure for oil fields in the Cuyama basin. It was preceded by the Simmler Formation, as young as 23 Ma, which was deposited in extensional basins bounded by north-facing ancestors of the La Panza and Ozena faults. Right-lateral strike slip on the Russell fault began with the Soda Lake Shale, which includes the Zemorrian-Saucesian microfaunal boundary dated at about 23 Ma. The Soda Lake Shale and Painted Rock Sandstone were deposited in west-trending, right-stepping troughs as most of the right slip on the Russell fault was accumulated; pre-Vaqueros geology is offset 26-29 km, but Vaqueros isopachs only 3.7 km. Coeval subsidiary faults in younger Miocene strata near the Russell fault also respond to distributed right-lateral shear. The Russell fault is overlain unconformably by the Morales Formation, as old as 4 + 1 Ma. North of Russell Ranch oil field, the Russell fault bifurcates into a west branch that joins the Chimeneas fault and an east branch that is overridden by the Big Spring reverse fault. To the southeast, the Russell fault may continue as the Ozena fault and be offset across the Big Pine fault. Right slip began 23 Ma, 6-7 million years after the predicted time of first contact of the Pacific and North American plates. Slip rates were 6.5-7 mm/yr in the period 23-19 Ma and 0.25 mm/yr in the period 19-4 Ma; the sudden decrease in slip rate occurred as the basin deepened for the Monterey Formation. The relation of Soda Lake Shale basins to coeval strike slip on the Russell fault suggests that a reconstruction of the early Miocene strike-slip tectonics of the southeastern Coast Range may permit exploration for other hidden Soda Lake Shale basins elsewhere.

INTRODUCTION

Exploration in the southern Coast Ranges of California by geologists of Richfield Oil Corporation led not only to the discovery of oil in the Cuyama basin in 1948 (Schwade and others, 1958) but also to the recognition that the San Andreas fault underwent right-lateral strike slip measured in hundreds of kilometers (Hill and Dibblee, 1953). Most of the oil occurs close to the Russell fault, a structure known only from the subsurface because it is covered by the Pliocene-Pleistocene Morales Formation or by the Whiterock thrust. Much of the extensive subsurface data base acquired during oil exploration and development is now in the public domain, and it has resulted in biostratigraphic papers by Lago (1981, 1984, 1986) and master's theses by Calhoun (1986), Nevins (1983), Schwing (1984), and Spitz (1986) of Oregon State University. These theses present evidence that the Russell fault is a right-lateral strike-slip fault that began to accumulate displacement as the early Miocene Soda

Lake Shale was deposited and completed its displacement prior to the deposition of the Morales Formation. This paper summarizes that evidence and speculates on the role of the Russell fault in the early history of the San Andreas fault system.

GEOLOGIC SETTING

The Cuyama basin is part of the Salinian block, bounded on the northeast by the San Andreas fault and on the southwest by the Rinconada fault and Sur-Nacimiento fault (Figure 1). Granitic basement characterizes the Salinian block, whereas Franciscan Formation, Jurassic ophiolite, and late Mesozoic forearc deposits characterize the Coast Ranges northeast of the San Andreas fault and southwest of the Rinconada fault. The Salinian block is terminated on the southeast by the Big Pine fault, which separates the northwest-trending Coast Ranges from the west-trending Transverse Ranges.

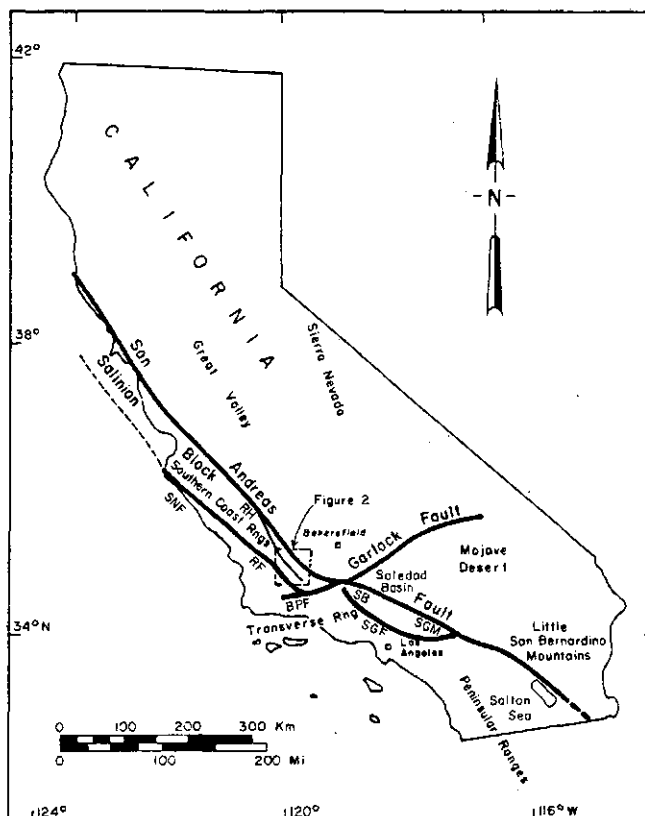
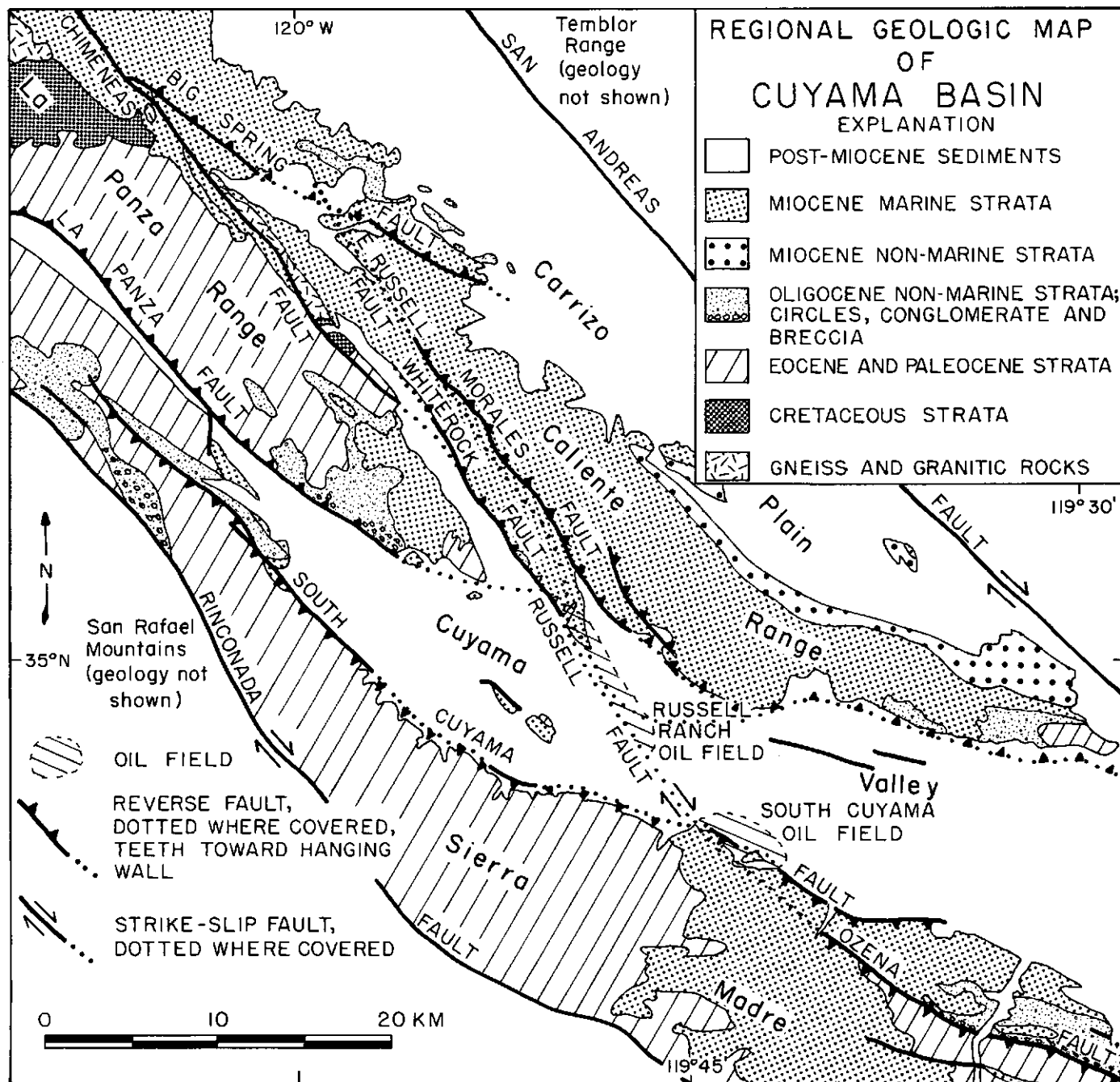


Figure 1. Index map of southeastern Salinian block showing major structures discussed in text. BPF, Big Pine fault; RF, Rinconada fault; RH, Red Hills; SB, Soledad basin; SGF, San Gabriel fault; SGM, San Gabriel Mountains; SNF, Sur-Nacimiento fault.

Crystalline basement underlies strata as old as late Campanian (Howell and others, 1977; Vedder, 1977) and includes gneiss of Barrett Ridge and quartz monzonite of the La Panza Range; these contrasting basement rocks are separated by the Chimeneas fault (Ross, 1972, 1978). Ross (1977) suggested that the Barrett Ridge gneiss may be related to a heterogeneous assemblage of crystalline rocks in the San Gabriel Mountains as old as Precambrian and intruded by plutons as young as Cretaceous. The Barrett Ridge gneiss has been dated as 1.7 Ga by Mattinson (1983) and Mattinson and James (1985), and scattered plutons intruding the gneiss are 75-80 Ma (Mattinson and James, 1985). The quartz monzonite of the La Panza Range was dated as 106-120 Ma by Rb-Sr and U-Pb (Kistler and others, 1973; Compton, 1966), but Mattinson and James (1985)



consider this pluton to be 80-90 Ma. K-Ar ages as young as 80 Ma may reflect cooling associated with uplift (Ross, 1972, 1978; Kistler and others, 1973); cooling ages of plutons in this region are only 1 to 4 m.y. younger than emplacement ages (Mattinson, 1983; Mattinson and James, 1985). If these two basement terranes have been juxtaposed by faulting, this event must predate the deposition of Upper Cretaceous conglomerate which lies on both quartz monzonite and gneiss. Alternately, the Chimeneas fault follows an older intrusive contact between quartz monzonite and gneiss. The alternate hypothesis is supported by the presence of rare inclusions of gneiss in the southeastern corner of the exposures of La Panza quartz monzonite (Joseph and others, 1982; Ross, 1984) and granitic rocks at the southern end of Barrett Ridge.

The basement is overlain unconformably by Upper Cretaceous to Eocene strata, with age control derived largely from a southward-dipping homocline in the La Panza Range (Chipping, 1972; Howell and others, 1977). The Sierra Madre is underlain by Eocene strata, and neither Upper Cretaceous strata nor basement rocks are known from there (Chipping, 1972). Pre-Oligocene strata of the Cuyama basin have been known as the "Cretaceous of Cuyama Valley" (Hill and others, 1958), but these strata may be as young as Eocene, similar to the rocks of the Sierra Madre to the south. Beneath the Caliente Range, well data show that the pre-Oligocene strata overlie crystalline rocks similar to those at Barrett Ridge and apparently dip south, as the Cretaceous-Eocene rocks do in the La Panza Range. Paleocene strata of the Pattiway Formation crop out in the eastern Caliente Range and the Cuyama Badlands farther southeast. The correlation of these strata to those of the Cuyama basin and Sierra Madre is unclear.

A major diagenetic break separates Eocene rocks from the Simmler Formation: nonmarine redbeds and rare interbedded mafic volcanics of late Oligocene (and possibly locally early Miocene) age (Bartow, 1974) that accumulated in an east-trending set of fault-angle depressions that, when right slip on the San Andreas and associated faults is removed, extend from the La Panza Range to the ranges north of the Salton Sea (Bohannon, 1975; Spitz, 1986). The Simmler rests on all older units of the Salinian block, including the gneiss of Barrett Ridge. The Ozena and La Panza faults were active during Simmler deposition, based on the presence of scarp-derived colluvial breccias and alluvial-fan deposits close to these faults (Ballance and others, 1983; Vedder, 1968).

The Cuyama basin itself began with deposition of the transgressive Quail Canyon Sandstone of Oligocene age followed by the deep-water Soda Lake Shale (Hill and others, 1958; Cross, 1962; Dickinson and others, 1987) and the shallow-marine Painted Rock Sandstone of Saucian age (Figure 3). These three marine units comprise the Vaqueros Formation, and where the Soda Lake Shale is not developed, the Quail Canyon and Painted Rock sandstones cannot be differentiated. Renewed deepening of the basin was reflected in deposition of Monterey Formation (Saltos Shale Member and Whiterock Bluff Shale Member) (Lagoe, 1984, 1985) followed by the Santa Margarita Formation of late Miocene age. The Miocene sequence shallows eastward toward the San Andreas fault (Clifton, 1981) to the shallow-marine Branch Canyon Formation and the nonmarine Caliente Formation, and the interfingering of facies permits

correlation of vertebrate, molluscan, and microfossil assemblages (Repenning and Vedder, 1961; Vedder, 1973). The Pliocene and Pleistocene are completely nonmarine and include the Quatal, Morales, and Paso Robles formations (Hill and others, 1958; Dibblee, 1973b, 1982).

Miocene depositional patterns were strongly influenced by the coeval NW-trending Rinconada fault (Dibblee, 1976), Russell fault and its northern extension, the Chimeneas fault (Calhoun, 1986), and possibly the San Andreas fault (Huffman, 1972). These patterns did not reflect modern topography: lower and middle Miocene sandstone, claystone, and siliceous shale are found in the Hurricane Deck area of the San Rafael Mountains (Vedder and Brown, 1968), and middle Miocene marine strata cover much of the higher parts of the Sierra Madre (Dibblee, 1973a, b; Fritsche, 1969). In the Pliocene and Pleistocene, the modern topography developed along with north- and south-dipping reverse faults. Part of the Cuyama Valley is a broad lowland with a Transverse Ranges trend between the Caliente Range, thrust southward on the Whiterock and Morales faults, and the Sierra Madre, thrust northward on the South Cuyama and Ozena faults.

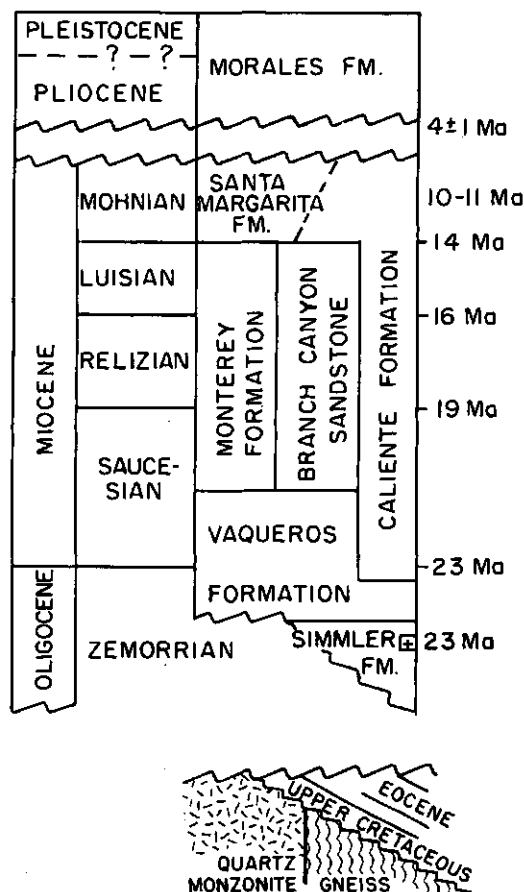


Figure 3. Stratigraphy and age of rocks adjacent to Russell fault.

A. VAQUEROS SUBCROP MAP

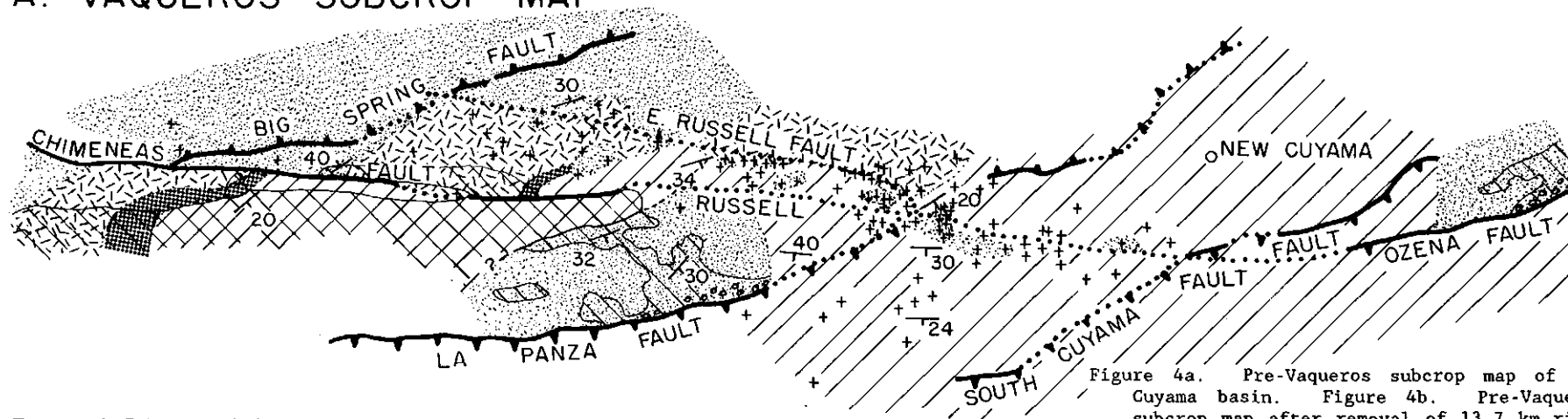
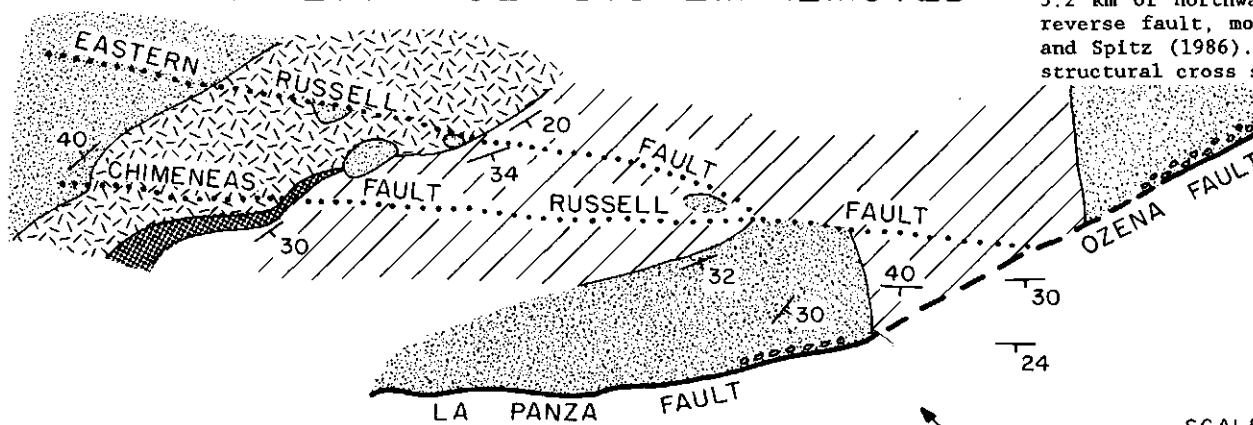
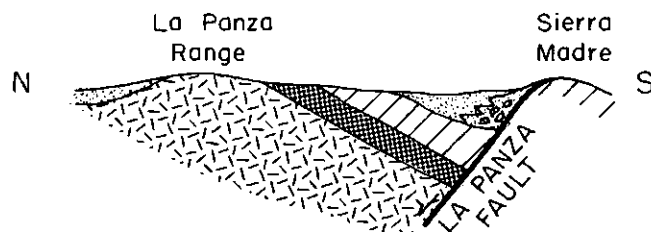


Figure 4a. Pre-Vaqueros subcrop map of the Cuyama basin. Figure 4b. Pre-Vaqueros subcrop map after removal of 13.7 km right slip on the Russell-Chimineas fault, 13.7 km right slip on the eastern Russell fault, and 3.2 km of northward transport on the Ozena reverse fault, modified from Calhoun (1986) and Spitz (1986). Figure 4c. Pre-Vaqueros structural cross section, not to scale.

B. VAQUEROS SUBCROP MAP STRIKE SLIP ON RUSSELL FAULT SYSTEM REMOVED



C. DIAGRAMMATIC PRE-VAQUEROS CROSS SECTION



- OUTCROP CONTROL
- WELL CONTROL
- WELL WITH DIPMETER

- OLIGOCENE NON-MARINE STRATA; CIRCLES, CONGLOMERATE AND BRECCIA
- EOCENE AND PALEOCENE STRATA
- CRETACEOUS STRATA
- GNEISS AND GRANITIC ROCKS

OFFSETS ACROSS THE RUSSELL FAULT

Pre-Vaqueros Subcrop Map

Calhoun (1986) and Spitz (1986) constructed a geologic map of formations underlying the Vaqueros Formation (Figure 4a). North of the Cuyama Valley, the Russell fault divides in the subsurface into a western strand (called here the Russell fault) that reaches the surface and continues on the west side of Barrett Ridge as the Chimeneas fault, and an eastern strand (called here the eastern Russell fault) that never reaches the surface but instead is overridden by the younger Big Spring reverse fault. Cross (1962) called the eastern strand the Russell fault, and he extended it northward to a junction with the San Juan fault north of Barrett Ridge. Calhoun (1986) showed that the eastern Russell and the Russell-Chimeneas faults join north of Russell Ranch oil field to become the Russell fault of the Russell Ranch and South Cuyama oil fields.

West of the Chimeneas fault, the La Panza quartz monzonite is overlain on the south by a south-dipping homocline of Upper Cretaceous and early Tertiary strata and on the north by Simmler Formation. Schwade and others (1958) showed that the quartz monzonite-Cretaceous contact is offset 22.5 km (14 miles) across the Russell fault and associated faults (possibly including the eastern Russell fault), and Bartow suggested 13 to 14.5 km (8 to 9 miles) right slip based on offset of both the quartz monzonite-Simmler contact and the contact between quartz monzonite and Upper Cretaceous strata. Calhoun (1986), using a more extensive data base, corroborated Bartow's estimate of 13 to 14.5 km offset on the Chimeneas fault, but she found an additional 13 to 14.5 km offset on the eastern Russell fault, giving 26 to 29 km offset on both faults and on the Russell fault south of the junction of the Russell-Chimeneas and eastern Russell faults.

Figure 4b is a palinspastic pre-Vaqueros subcrop map removing 13.7 km right slip on the Russell-Chimeneas fault, 13.7 km right slip on the eastern Russell fault, and 3.2 km of northward transport on the late Cenozoic Ozena reverse fault at the northern margin of the Sierra Madre (Calhoun, 1986; Spitz, 1986). In addition to lining up the contacts between basement and Simmler and between basement and pre-Oligocene strata, this restoration places the La Panza fault on trend with the Ozena fault. These faults had different late Cenozoic histories: the La Panza is a north-dipping reverse fault, and the Ozena is a south-dipping reverse fault. But during the time of Simmler deposition, they were both north-dipping normal faults. Eocene rocks from the south side of the La Panza fault were incorporated in scarp-derived breccias and alluvial-fan deposits in the Simmler Formation north of the fault (Ballance and others, 1983). North of the Ozena fault, the Simmler Formation (Caliente Formation of Vedder, 1968) contains breccias derived from the Eocene, of the Sierra Madre immediately south of the Ozena fault (Vedder, 1968; Blake, 1982). We believe that the ancestral La Panza and Ozena were part of the same normal fault that was itself part of a system of east-trending fault-angle depressions (Bohannon, 1975) that were subsequently disrupted by the Russell fault, as shown here, as well as by the San Gabriel and San Andreas faults, as shown by Bohannon (1975). The restored normal fault is parallel to the basement ridge exposed at that time to the north, and uplift of this ridge

must have accompanied subsidence and southward tilting of the Simmler fault-angle depression immediately north of the combined La Panza and Ozena faults (Figure 4c).

The Russell fault system could not have originated before the Vaqueros was deposited, because the Simmler and its bordering coeval faults show the full displacement across the Russell fault system (excluding a possible pre-Upper Cretaceous offset in the basement, discussed above). The Simmler is as young as an interbedded basalt flow dated by Ballance and others (1983) as 22.9 ± 0.7 to 23.4 ± 0.8 Ma. The Zemorrian-Saucesian boundary in the overlying Vaqueros Formation (Soda Lake Shale) is 23.1 Ma (Obradovich and Naeser, 1981; Turner, 1970), and the Soda Lake Shale is affected by right slip on the Russell fault, as is shown below. Accordingly, the Russell fault began to move about 23 Ma.

Vaqueros Isopachs

The Vaqueros Formation consists of the Quail Canyon Sandstone, the overlying Soda Lake Shale, and the Painted Rock Sandstone. The basal Quail Canyon Sandstone rests conformably on the Simmler Formation (Bartow, 1974) and fills in a surface of moderate relief eroded in Eocene strata (Schwing, 1984). The transition from nonmarine Simmler to marine Quail Canyon may be due to a eustatic rise in sea level, but the overlying Soda Lake Shale and Painted Rock Sandstone clearly respond to a syndepositional syncline that strikes 45 counterclockwise from the Russell fault north of the South Cuyama field (Figure 5). En echelon, syndepositional troughs in the Vaqueros were first suggested by Schwade and others (1958, p. 83, 87). Shallow-marine sandstone is overlain abruptly by bathyal mudstone interbedded with turbidites that either pond against the top of the Quail Canyon Sandstone or lens out to mudstone upstructure toward the South Cuyama oil field (Figure 6). The overlying Painted Rock Sandstone also thickens toward the axis of this syncline. The syncline dies out eastward away from the Russell fault (B. Ellis, in prep.). Farther north, in Russell Ranch oil field, a second syncline also trends counterclockwise to the Russell fault (Figure 5), although this is not as well constrained by isopachs as the syncline farther south. The orientation of these broad, en echelon folds counterclockwise to the Russell fault and the disappearance of the southern syncline eastward away from the fault suggest that the folds accompanied right-lateral strike slip on the Russell fault, a pattern of folding developed during the early stages of wrench faulting (Wilcox and others, 1973).

The southern syncline intersects the Russell fault at the southern end of the Russell Ranch oil field, and its continuation is offset 3.7 km right laterally across the Russell fault on the basis of unusually thick Vaqueros in two wells west of the central part of the Russell Ranch field (Figure 5). Other piercing-point offsets farther north cannot be documented because of structural complications and extensive post-Vaqueros erosion. The contact between the Painted Rock Sandstone and the overlying Saltos Shale is within the Saucesian Microfaunal Stage, and Lagoe (1985) estimated the age of this contact as 19 Ma. This indicates that most of the right slip on the Russell fault took place as the Vaqueros was being deposited, a period of about 4 million years.

Monterey-Branch Canyon Facies Offset

Following deposition of the Vaqueros, the Cuyama basin subsided again to receive the Saltos Shale and Whiterock Bluff Shale, both part of the Monterey Formation. The Monterey shallows eastward to the shallow-marine Branch Canyon Sandstone. The

Monterey-Branch Canyon facies boundary intersects the Russell fault in the Russell Ranch oil field, where Nevins (1983) showed that the easternmost limit of predominantly Monterey Formation is offset right laterally about 3 km (Figure 7). Another lens of Branch Canyon Sandstone lies west of this boundary, and this, too, is offset right laterally.

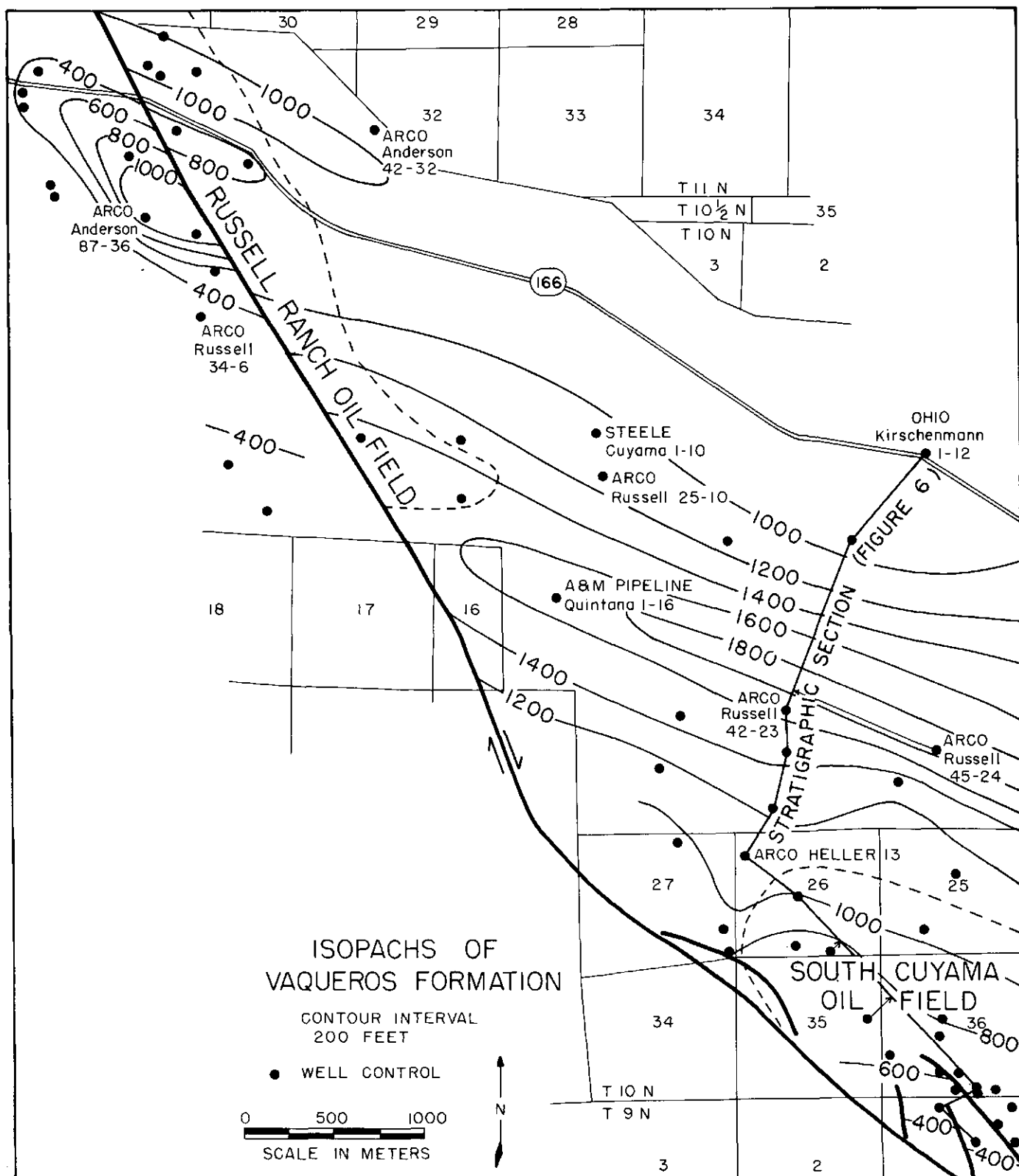


Figure 5. Isopach map of Vaqueros Formation at South Cuyama and Russell Ranch oil fields.

The age of the Monterey Formation in the area of offset is about 14-18 Ma (Lagoe, 1984).

In the South Cuyama oil field, a tongue of shallow-marine sandstone similar to the Branch Canyon Formation thins westward and lenses out into Monterey Formation (Schwing, 1982). The 200- and 250-foot isopachs of this sandstone are offset right laterally about 1.6 km across splay faults that are part of the Russell fault system. However, these isopachs cannot be traced across the main strand of the Russell fault, and so this offset is a minimum figure.

Schwing (1982) found that small-displacement growth faults formed during deposition of the Monterey, Branch Canyon, and overlying Santa Margarita formations show offsets of these formations that are consistent with their trend: right-lateral strike slip for faults parallel to the Russell fault, and normal slip for north-trending faults. This is consistent with a wrench-faulting regime and is similar to the pattern developed in Miocene and Pliocene strata in the Los Angeles basin deposited over the right-lateral Newport-Inglewood fault (Yeats, 1973).

Failure to Offset Morales Formation

The Russell fault is overlain unconformably by the Morales Formation, indicating that all displacement was completed prior to deposition of the Morales. The ages of the Morales and underlying

Santa Margarita formations are poorly constrained. Lagoe (1984) considers the Santa Margarita to be at least as young as 11 Ma, and Hemphillian vertebrates in the pre-Morales Caliente Formation are about 10 Ma (Evernden and others, 1964; Obradovich and Naeser, 1981). The Morales contains a vertebrate fauna suggestive of a Blancan age (James, 1963) and is generally considered as Pliocene to early Pleistocene. East of the Cuyama basin, the Morales is overlain with angular unconformity by gravels of the Paso Robles Formation which are themselves deformed (Dibblee, 1982 and unpublished mapping). Yeats (1978) showed that subsidence rates in Neogene basins clustered about the big bend in the San Andreas fault (including the Cuyama basin) accelerated about 4 ± 1 Ma. Because the Morales Formation is the oldest formation to respond to the modern topographic configuration of the Cuyama Valley, we suggest that the Morales began to be deposited about the time of acceleration of basin subsidence.

DISCUSSION

Slip Rates on Russell Fault

Figure 8 is a plot of slip on the Russell fault system vs. age of piercing-point offsets. Most of the displacement occurred during deposition of the Vaqueros 23-19 Ma at a slip rate of 6.5-7 mm/yr. Subsequent displacement occurred at an average rate of 0.25 mm/yr, and no displacement occurred after the Miocene. The Simmler Formation was deposited

Figure 6. Stratigraphic Correlation Section for the Vaqueros Formation

(For location of line of section, see Figure 5.)

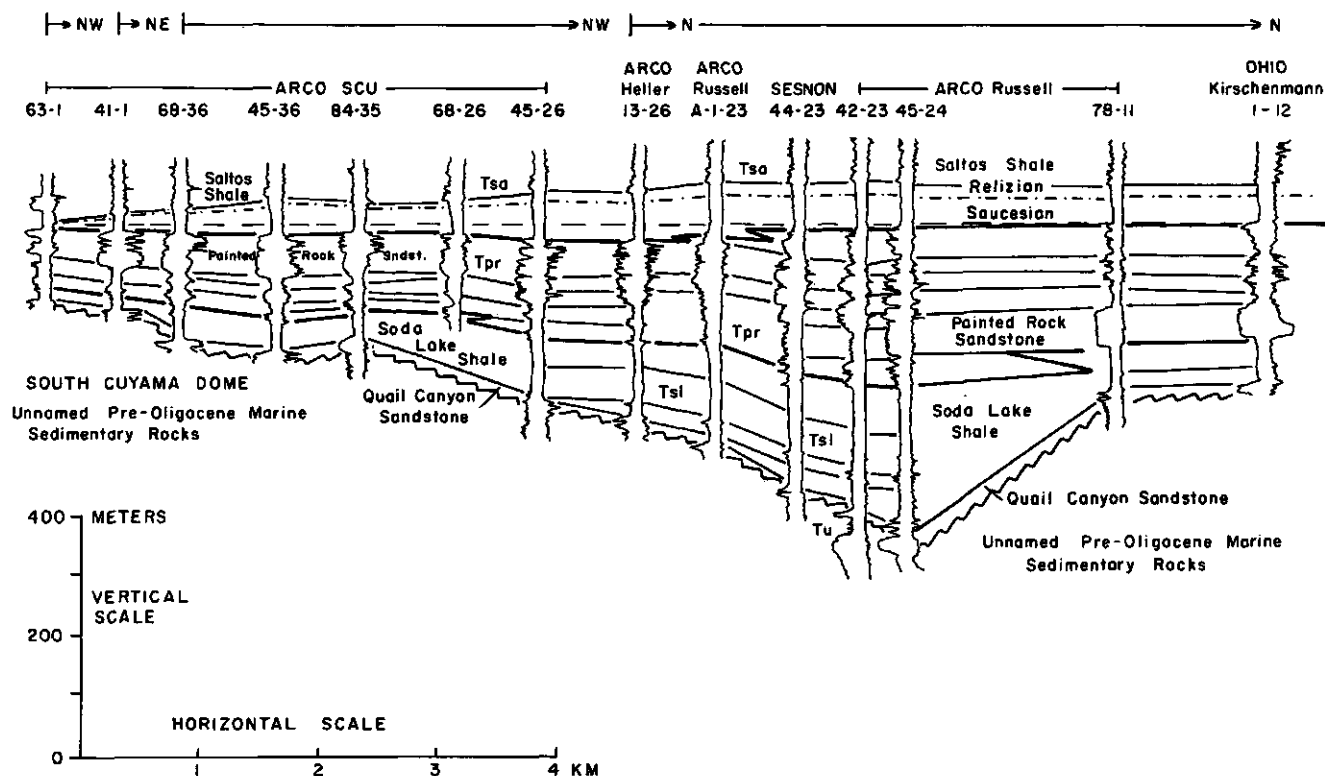
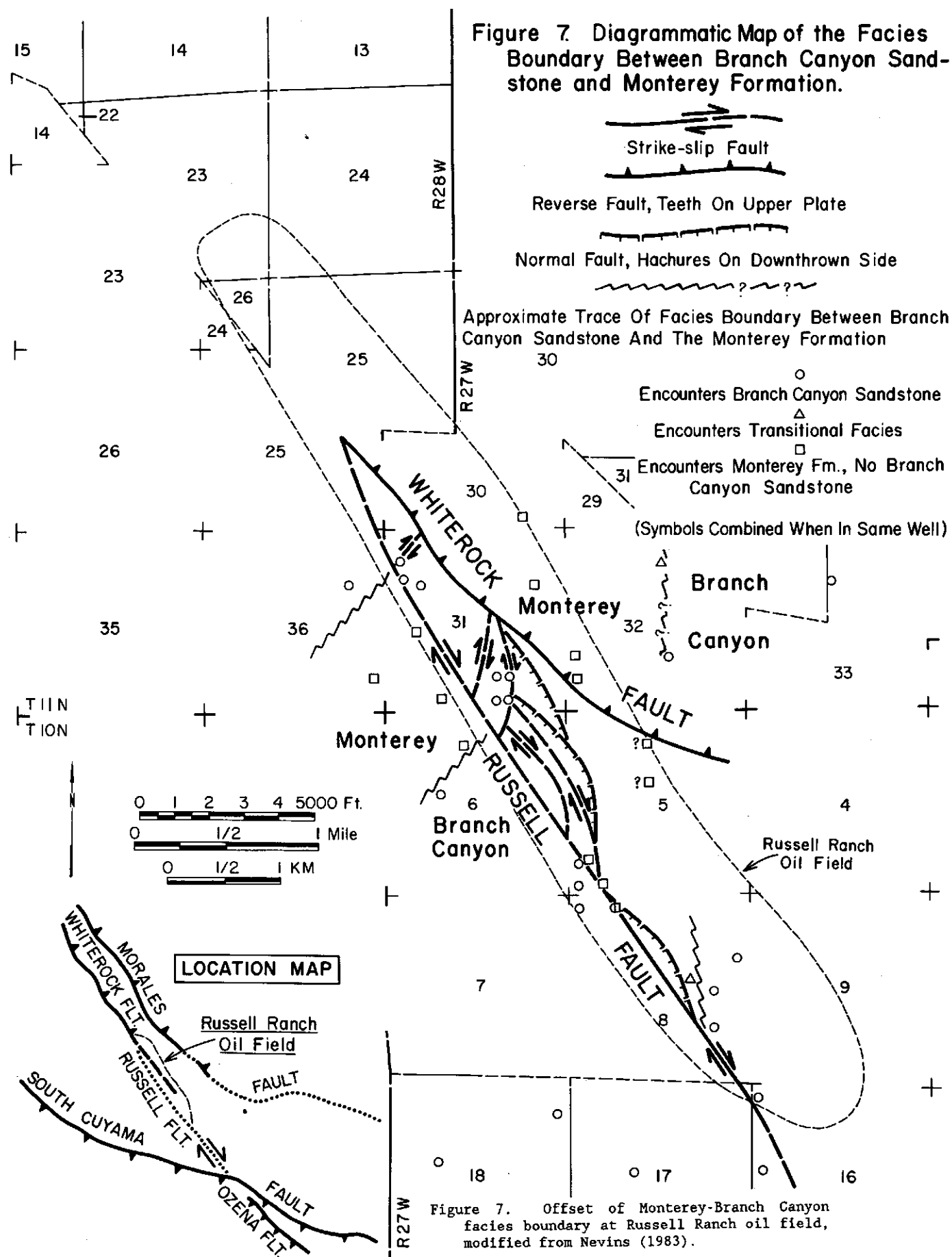


Figure 6. Stratigraphic sections of Vaqueros Formation from South Cuyama oil field northeastward toward Caliente Range, from Schwing (1984).



during a time of NE-SW crustal extension of the North American plate (Yeats, 1987). The Pacific-North American plate boundary jumped inland about 23 Ma, and one strand of this boundary formed the Russell fault. Because the early Miocene slip rate on the Russell fault is only a fraction of the slip rate between the Pacific and North American plates, there must have been other strands active at the same time, possibly including the San Andreas fault to the east.

The sudden decrease in slip rate about 19 Ma coincides with the tectonic subsidence of the Cuyama basin to receive the Monterey Formation. The Russell fault no longer served as a major part of the plate boundary, and the low slip rate represents nothing more than continued yielding of a NW-trending zone of weakness in a regime of simple shear throughout the southern Coast Range, with the main plate boundary presumably at the San Andreas fault. During the last few million years, displacement on the Russell fault ceased altogether, possibly because the orientation of the maximum principal compressive stress may have shifted from N-S to NE-SW, the orientation it has today (Zoback and others, 1987).

The age of initiation of strike slip in the southern Coast Range, 23 Ma, is not predicted by the time the Pacific and North American plates came into contact, 29-30 Ma (Atwater, 1970; Atwater and Molnar, 1973; Engebretson, 1983; Crowell, 1987).

Slip between 29 and 23 Ma could have taken place at the continental margin and not be recorded. Alternately, the thin remnants of the disappearing Farallon plate may have caused an unstable, shifting ridge configuration causing the ridge to hang offshore (Tennyson, 1986), much as the ridges at the north end of the Juan de Fuca plate do today off Vancouver Island (Riddihough and others, 1983).

Relation to Other Coeval Faults

It is assumed that the San Andreas fault east of the Cuyama basin was active during Vaqueros deposition. Simmler fault-angle depressions of the eastern Cuyama area are offset across the San Gabriel fault (then the main strand of the San Andreas) to the Vasquez Formation of the Soledad basin (Bohannon, 1975), but the timing of this offset has not been established.

Dibblee (1976) suggested that the contact between basement rocks and the south-dipping homocline of Upper Cretaceous and lower Tertiary strata may be displaced as much as 60 km across the Rinconada fault (cf. Schwade and others, 1958). However, Graham (1978) showed that the basement could not be displaced more than 43 km (see discussion by Ross, 1984). Dibblee also suggested that the source area for a cobble conglomerate in the upper part of the Vaqueros formation may be displaced 23 km across the Rinconada fault; if so, then the Rinconada fault underwent large displacement at the same time that the Russell fault

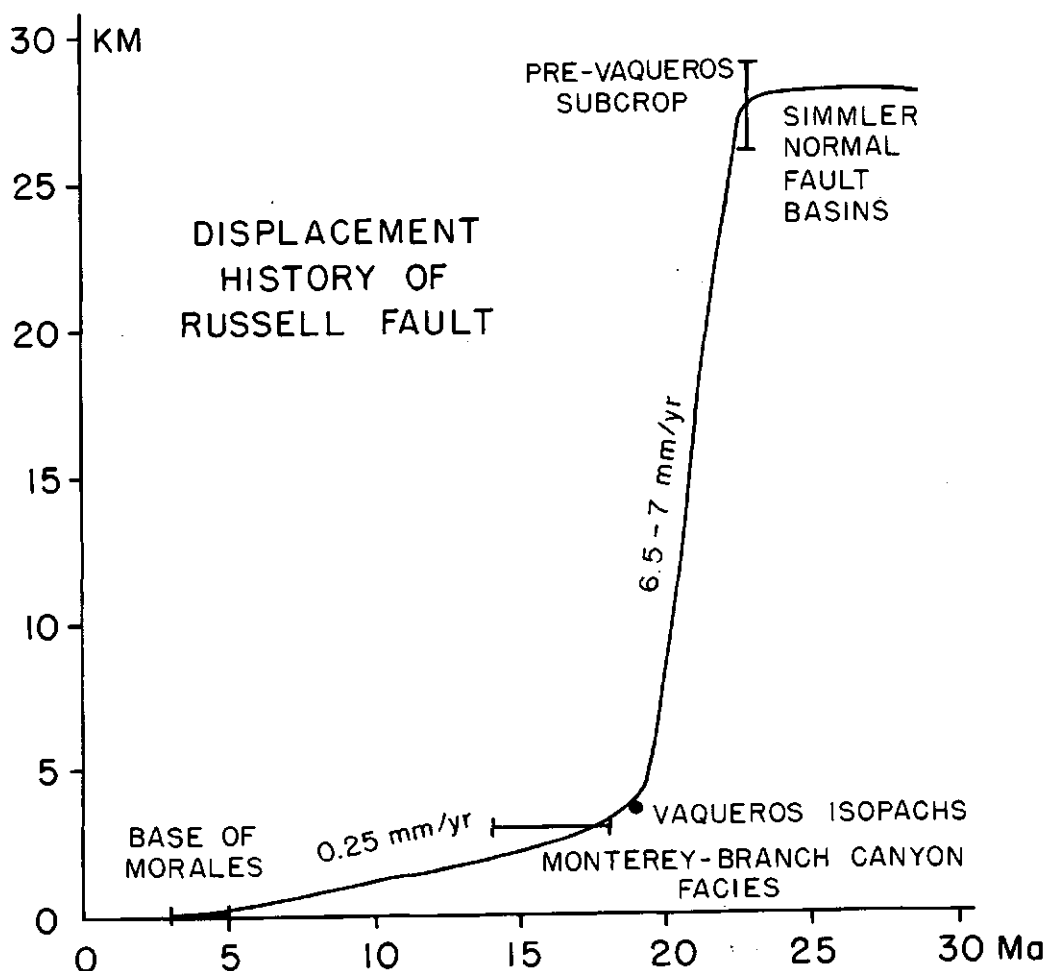


Figure 8. Displacement of Russell fault vs. time, showing slip rates.

did. The Rinconada may have undergone much more post-Vaqueros displacement than the Russell fault did, because the northernmost extent of the Miocene Santa Margarita Formation and the southernmost extent of the Pliocene Pancho Rico Formation are both offset about 18 km across the Rinconada fault (Durham, 1965; Dibblee, 1976). However, Yaldezian and others (1983) found that a marine Miocene submarine fan could not have been displaced more than 6 km across the Rinconada fault, suggesting that it underwent most of its displacement about the same time that the Russell fault did.

Southeast Continuation of Russell Fault

The Russell fault is traced to the southern margin of the Cuyama Valley southeast of South Cuyama oil field where it is cut off by the younger South Cuyama reverse fault. It is not found to the

south in the Sierra Madre where strongly folded Monterey Formation and Branch Canyon Sandstone rest on Eocene marine strata (Dibblee, 1973a). A displacement of 26-29 km should be recognizable if the Russell fault extended into the Sierra Madre, so the fault must lie farther east.

The Ozena fault, the eastern boundary fault of the Sierra Madre, lies on trend with the Russell fault (Figure 2). This fault has already been shown to have a schizophrenic history: normal displacement down to the north during Simmler deposition (Blake, 1982) and reverse displacement down to the north, bringing Eocene rocks over Oligocene to Pliocene nonmarine strata of the Cuyama basin and Cuyama Badlands (Vedder and others, 1973; Dibblee, 1982). We suggest a third phase to the history of the Ozena fault: right-lateral strike slip during the time of deposition of the Vaqueros Formation. We offer no evidence to support this claim because the Ozena would follow the trace of the Simmler normal fault, whereas the normal fault is offset by the Russell fault farther northwest. But there is no evidence to refute this claim either, and we believe that displacement on the Russell fault is too large for the fault to die out at the edge of the Cuyama Valley. A test of this hypothesis would be a match of marine Eocene strata in the southeastern Sierra Madre as subdivided by Chipping (1972) with marine Eocene strata known to be present in the subsurface east of the Ozena fault (Dibblee, 1982).

Dibblee (1982) suggested that the Ozena is offset by the Big Pine fault to the San Guillermo fault (Vedder and others, 1973), which also brings Eocene marine strata on the southwest against nonmarine rocks on the northeast. The San Guillermo fault dies out to the southeast in the Caliente Formation, which could have been deposited after the accumulation of most of the right slip on the Russell fault.

The Russell-Ozena fault could be offset by the Big Pine fault to the San Gabriel fault, but this is less likely because right slip on the San Gabriel fault probably began 12-14 Ma (Crowell, 1982) and is thus younger than large-scale displacement on the Russell fault.

Smith (1977) proposed 175 km of right-lateral offset in late Oligocene to middle Miocene time along the San Juan and Chimineas fault and offset continuations in the Soledad basin and in southeastern California northeast of Salton Sea. A principal line of evidence is his conclusion that an Oligocene megabreccia in Soledad basin was derived from the La Panza Range. This large-displacement fault did not continue southeast to the Russell and Ozena faults, but instead followed a trace subsequently occupied by the younger Morales reverse fault. This interpretation would deny the correlation of the La Panza and Ozena normal faults and the La Panza and Barrett basement ridges across the Russell fault system. It does account for the contrast in basement rock type across the Chimineas fault, but does not accept the correlation of the Cretaceous conglomerate overlying La Panza basement west of this fault and Barrett Ridge gneiss east of the fault. Ross (1984) has difficulty reconciling the basement rocks with Smith's proposed large-displacement fault.

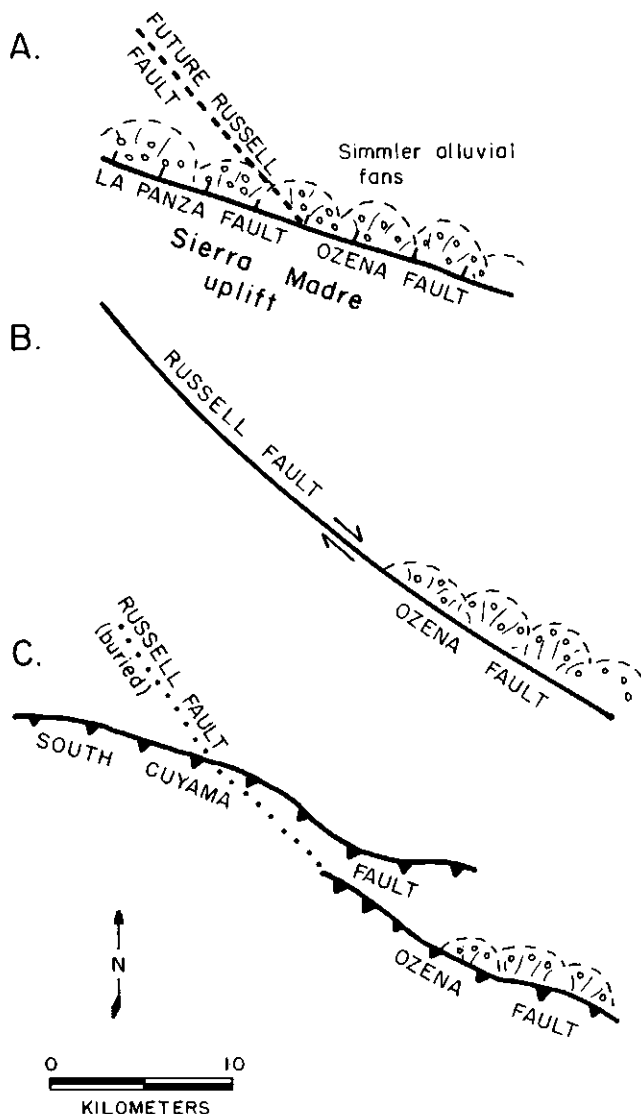


Figure 9. Three faces of Eve: The schizophrenic Ozena fault. a. Oligocene normal fault, down to north during deposition of Simmler Formation. b. Oligocene-early Miocene right-lateral strike-slip fault during deposition of Vaqueros Formation. c. Quaternary reverse fault, down to north.

Early Miocene Strike-Slip Faults and Vaqueros Exploration

We have shown that thick local accumulations of Vaqueros strata, including deep-water sediments of Soda Lake Shale facies, are controlled by coeval strike slip on the adjacent Russell fault. If the Soda Lake Shale is a source rock for Cuyama oil, then it is worthwhile to search for other hidden Soda Lake Shale basins by reconstructing the early Miocene tectonic picture of the southern Coast Ranges. Other Soda Lake basins may lie adjacent to the Chimeneas and San Juan faults northward to their intersection with the San Andreas fault. North of the Cuyama Badlands, a narrow belt of Soda Lake Shale is found adjacent to the San Andreas fault (G. Freitag, in prep.), and this may suggest that the San Andreas fault was active there during the time of Soda Lake deposition.

CONCLUSIONS

The Russell fault bifurcates northward into a western strand that continues farther northwest as the Chimeneas and San Juan faults and an eastern strand, the eastern Russell fault, that has not been traced north of the Big Spring reverse fault, but probably rejoins the San Juan fault farther northwest. A basement ridge overlain by Oligocene Simmler redbeds on the north and by Cretaceous-Eocene marine strata on the south is offset 26-29 km right laterally along both of these faults. The La Panza fault was a normal fault active during Simmler deposition, and if the same offset is applied to the main Russell fault, this fault lines up with the Ozena fault which had a similar Oligocene history. Vaqueros isopachs are offset 3.7 km, and the facies boundary between Monterey Formation and Branch Canyon Sandstone is offset 3 km. The base of the Morales Formation is not cut by the fault. This indicates no right slip prior to 23 Ma, a slip rate of 6.5-7 mm/yr in the period 23-19 Ma, 0.25 mm/yr in the period 19-4 Ma, and no right slip subsequently. Slip beginning at 23 Ma, the earliest documented for the San Andreas system, is 6 to 7 million years later than the predicted first contact between the Pacific and North American plates, possibly because the ridge became unstable and lagged offshore for several million years as the northern end of the Juan de Fuca ridge does today.

The Russell fault is believed to continue southeast as the Ozena fault, which results in a history of contrasting movement on that fault: Oligocene normal faulting, early Miocene right-lateral strike-slip faulting, and younger reverse faulting.

Deep-water Vaqueros troughs, including the Soda Lake Shale, a potential oil-source rock, are believed to be controlled by wrench faulting. Recognition of early Miocene strike-slip faults may lead to future exploration targets related to previously-hidden Vaqueros basins containing Soda Lake Shale.

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