The Rinconada and Related Faults in the Southern Coast Ranges, California, and Their Tectonic Significance

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By THOMAS W. DIBBLEE, JR.

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A study of the Rinconada fault and its relation to other nearby major faults and to the tectonics of the southern Coast Ranges

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THE RINCONADA AND RELATED FAULTS IN THE SOUTHERN COAST RANGES, CALIFORNIA, AND THEIR TECTONIC SIGNIFICANCE

By Thomas W. Dibblee, Jr.

ABSTRACT

The Rinconada fault near Santa Margarita, as depicted on the Geologic Map of California, is a northwest-trending high-angle fault about 40 km (26 mi) long that in part separates terranes with different basement complexes. The terrane on the northeast is part of the Salinian block, which is composed of a Mesozoic and older crystalline basement complex of plutonic and metamorphic rocks, overlain unconformably by a thick Upper Cretaceous and lower Tertiary marine sedimentary sequence. In contrast, the terrane on the southwest is part of the Coastal block, composed of a basement complex of Franciscan eugeosynclinal rocks overlain depositionally or tectonically by a thick Cretacecus marine sedimentary sequence. These blocks are separated by the Sur-Nacimiento fault zone to the northwest.

Southeastward from Santa Margarita the Rinconada fault extends continuously into a fault formerly thought to be the Nacimiento fault across the Cuyama River gorge to intersect the Big Pine fault in the San Rafael Mountains. Northwestward, the Rinconada fault passes concealed near Paso Robles into high-angle faults, locally called the San Marcos and Espinosa faults, nearly to Reliz Canyon west of King City, and is within the Salinian block. All these alined faults are now mapped as parts of a major fault 250 km (160 mi) long. The name Rinconada is applied to the entire fault. It is 3 km (2 mi) from the alined Reliz fault to the northwest along the northeastern base of Sierra de Salinas.

The Rinconada fault, as herein defined, is nearly parallel to and is located about 34 km (22 mi) southwest of the San Andreas fault. Southeastward from Santa Margarita the Rinconada fault presumably coincides with the southwestern boundary of the Salinian block, but northwestward from that town it extends into this block.

The Coastal and Salinian blocks were juxtaposed along the Sur-Nacimiento fault zone, possibly by subduction, probably in Late Cretaceous or possibly early Tertiary time. The Rinconada-Reliz fault zone formed largely within the Salinian block in late Cenozoic time, although the southern part of the Rinconada fault followed the former Sur-Nacimiento fault zone. The Rinconada-Reliz fault zone is not presently active.

Major movement on the Rinconada fault is interpreted to have been right lateral strike slip. This is suggested by numerous severely compressed drag folds in the sedimentary rocks along and near the fault and the persistent slightly more east-west trend of their axes as compared to the northwest trend of the fault. This movement is also suggested by displaced stratigraphic units; those of late Miocene and early Pliocene ages are about 18 km (11 mi) apart near Paso Robles, and those of Late Cretaceous and early Tertiary age nearly 60 km (40 mi) apart.

Movement on the Reliz fault is in part right lateral, as suggested by structural relations similar to those along the Rinconada fault, and in part vertical, having elevated the southwest block to form the Sierra de Salinas uplift.

The northern part of the strip within the Salinian block east of the Rinconada-Reliz fault zone reacted to stress during late Cenozoic time as a rigid block of crystalline basement that was tilted slightly southwestward from an axis adjacent to the San Andreas fault to form the Gabilan uplift and Salinas Valley. The southern part of this east strip, where the basement complex deepens southward under a thick sedimentary cover, was compressed to form the La Panza, Caliente, and Sierra Madre Ranges.

In contrast, the strip that includes part of the Salinian and Coastal blocks west of the Rinconada-Reliz fault zone yielded to stress during late Cenozoic time as a series of parallel compressive uplifts and is deformed throughout to form the San Rafael and Santa Lucia Mountains and related hills. The northern part of this west strip, despite its rigid crystalline basement, was upheaved by severe compression to form the high northern Santa Lucia Mountains. The crustal shortening involved in this part, compared to nearly none on the east strip, presumably has absorbed the large amount of right-lateral movement on the fault zone as it dies out northwestward near Salinas.

The Rinconada fault and other geologic features were probably displaced about 14 km (9 mi) by left slip on the east-trending Big Pine fault. The Pine Mountain fault north of Sespe Creek may be the reactivated displaced counterpart of the Rinconada fault south of the Big Pine fault.

INTRODUCTION

LOCATION OF THE RINCONADA FAULT

Mapping of the regional geology of the southern Coast Ranges of California within 46 km (30 mi) west of the San Andreas fault has revealed the presence of a major high-angle fault, traceable for some 250 km (160 mi) or possibly 290 km (190 mi), nearly parallel to and about 34 km (22 mi) southwest of the San Andreas fault (fig. 1). Various segments of this parallel major fault have been mapped at different times, by different workers, who did not recognize their continuity, and so each segment was designated by a local name.

The present investigation reveals that all or most of these segments are parts of a nearly continuous single major fault, designated herein as the Rinconada fault extending from the San Rafael Mountains on the southeast into the hills west of King City. The physiographic features of this and associated major faults are shown in figure 2.

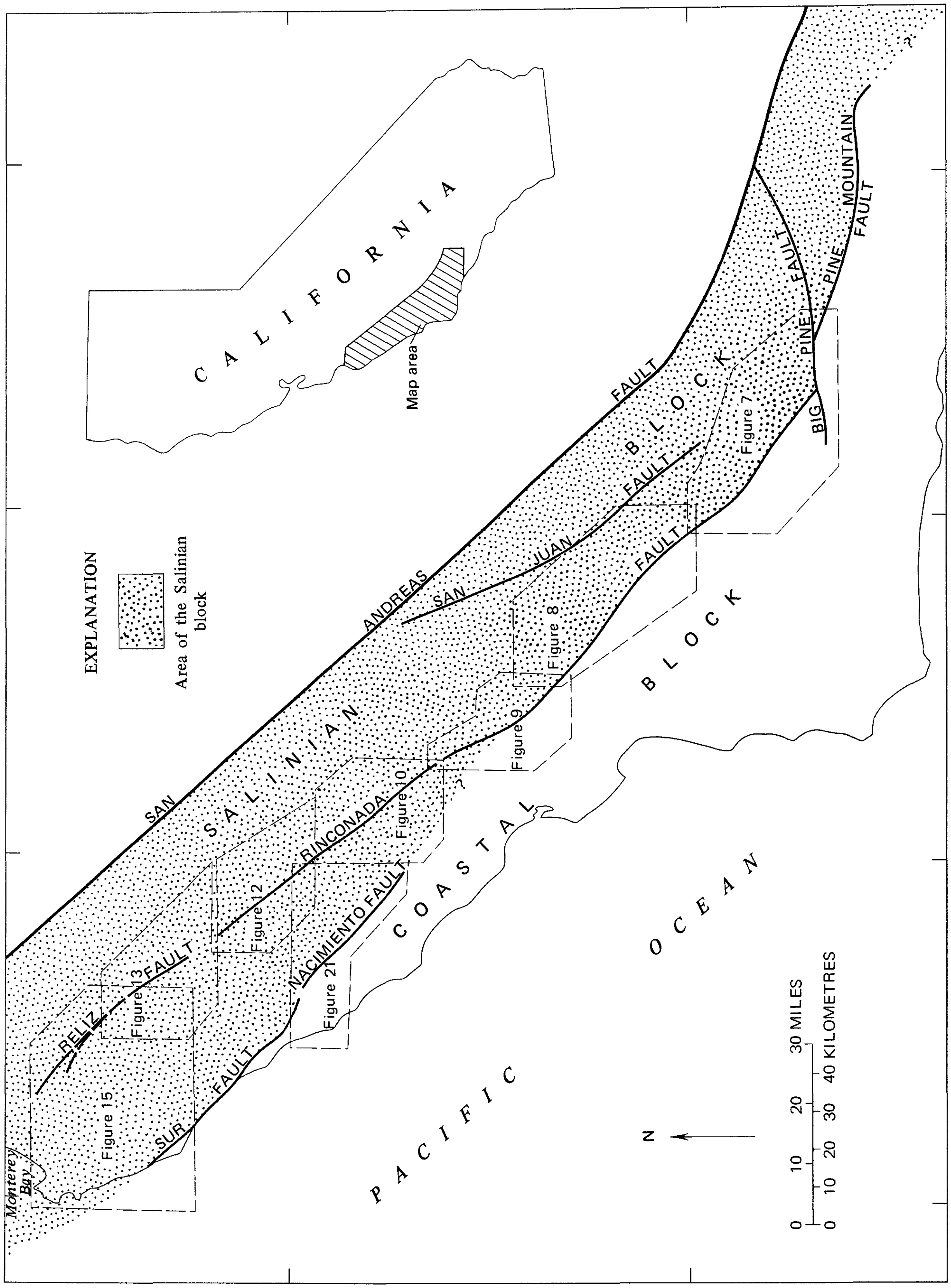

FIGURE 1.—Positions of the Rinconada and Reliz faults relative to the Salinian block and the San Andreas fault. Dashed outlines indicate locations of areas of figures 7, 8, 9, 10, 12, 13, 15, and 21 showing geology along Rinconada and Reliz faults.

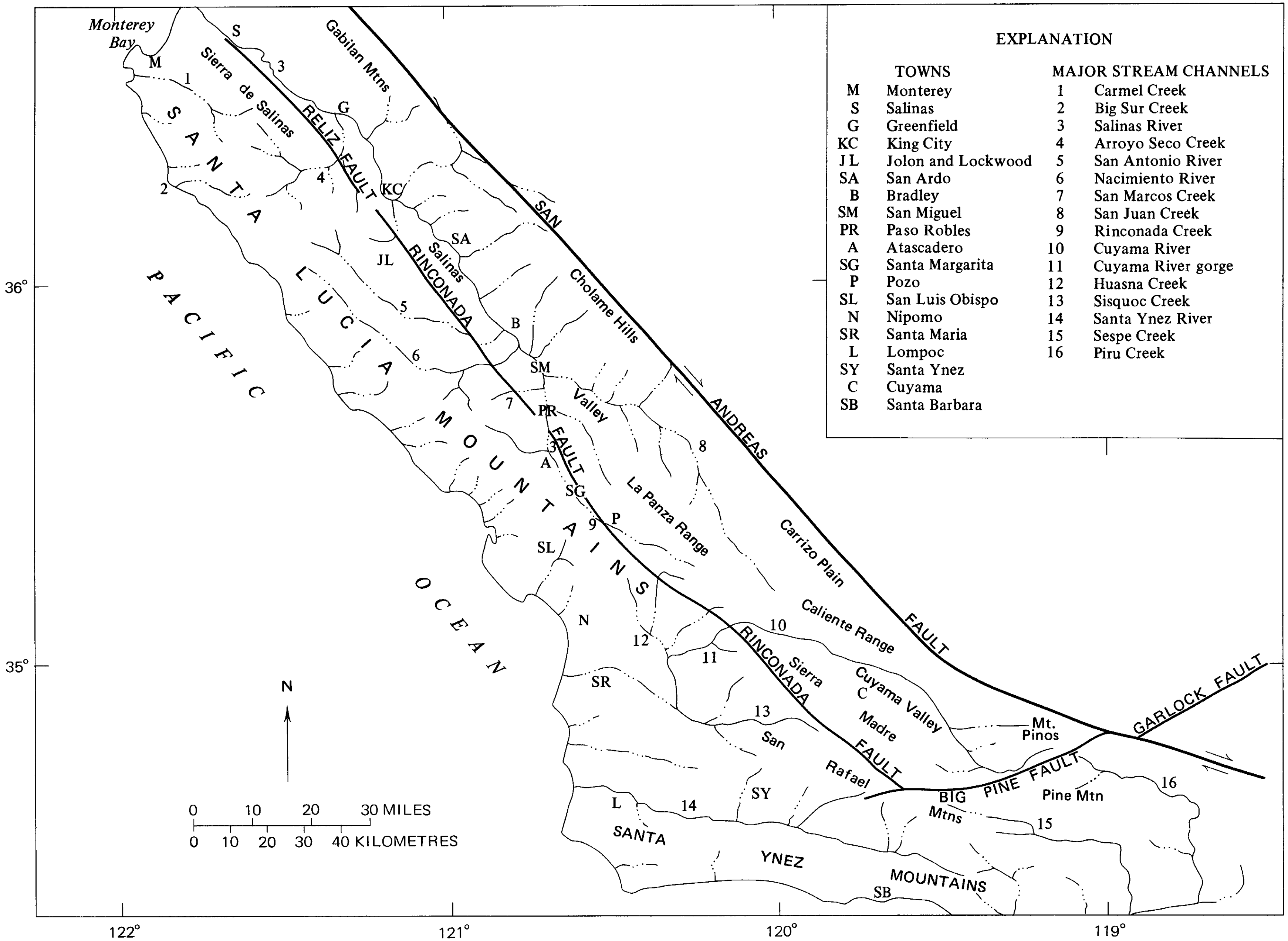

FIGURE 2.—Physiographic features and drainages along and near the Rinconada and Reliz faults.

PURPOSE AND SCOPE

The purpose of this report is to provide data that suggest (1) the continuity of the Rinconada fault as herein designated; (2) the direction, magnitude, and time of movement; (3) the relation of this fault to other nearby major faults and to folding; (4) the relation of this fault to tectonics of the southern Coast Ranges; and (5) the relation of this fault to the physiography and drainage of this area.

This report is based on geologic mapping in the southern Coast Ranges southwest of the San Andreas fault since 1965 for the U.S. Geological Survey as part of its National Earthquake Research Project. The geology of the area southeastward from Paso Robles is largely from Dibblee (1972a, 1972b, 1974a, 1974c); Vedder (1970); Vedder, Gower, Clifton, and Durham (1967); Vedder and Brown (1968); Hall and Corbató (1967); Page (1970a, 1970b); and Vedder, Dibblee, and Brown (1974). The geology of the area from Paso Robles to Monterey Bay was modified from mapping by Trask (1926); Fiedler (1944); Reiche (1937); Bowen (1965); Gilbert (1971 thesis); Durham (1963, 1964, 1965a, 1966, 1968a, 1968b, 1970); Compton (1966a, 1966b, and unpublished data); Page (1970a, 1970b, 1972); Gilbert and Dickinson (1970); and from additional mapping, remapping, and field checking (Dibblee, 1971, 1974b).

This report is a more comprehensive description of the geology, movements, and tectonic analysis of this important fault zone first recognized and discussed in a preliminary paper (Dibblee, 1972a).

ACKNOWLEDGMENTS

I am indebted to B. M. Page, Stanford University, for loan of his detailed field mapping north of San Luis Obispo; E. M. Hart, California Division of Mines and Geology, for his detailed mapping of the Atascadero–Santa Margarita area; and C. A. Hall, University of California, Los Angeles, for his detailed mapping of the Morro Bay–Cambria area northwest of San Luis Obispo. Discussions with these workers, and also with R. R. Thorup of Monterey and O. E. Bowen of Corralitos, have been very helpful. I acknowledge T. H. Nilsen and J. G. Vedder of the U.S. Geological Survey for critical review of the manuscript.

MAJOR GEOLOGIC RELATIONS OF THE RINCONADA FAULT

NOMENCLATURE AND DEFINITION

The Rinconada fault is depicted on the geologic map of California (Jennings, 1959) as a northwest-trending fault extending from the head of Rinconada Creek near Santa Margarita for 40 km (25 mi) northwest toward Paso Robles (figs. 2, 3*A*). This fault is nearly vertical and in the vicinity of Rinconada Creek separates an area in which Mesozoic granitic basement is extensively exposed in the northern La Panza Range on the northeast from an area in which Mesozoic Franciscan basement is widespread in the southern Santa Lucia Mountains on the southwest. As depicted thereon (Jennings, 1959), and verified by mapping I have done, the Rinconada fault is continuous southeastward into the fault formerly thought to be the southeast extension of the Nacimiento fault that crosses Cuyama River gorge to intersect the Big Pine fault in the San Rafael Mountains 150 km (90 mi) southeast of Santa Margarita (fig. 3*A*), and so both are parts of one major high-angle fault (figs. 1, 2).

Mapping northwestward from Paso Robles indicates that the San Marcos and Espinosa faults depicted on the Geologic Map of California (Jennings 1959; Jennings and Strand, 1958) are also parts of a major high-angle fault and are alined and probably continuous with the Rinconada fault (fig. 3*A*). This condition suggests that all three of these segments also may be parts of one major fault, although the part near Paso Robles between the Rinconada and San Marcos segments is concealed for about 5 km (3 mi).

I conclude that the Nacimiento fault across Cuyama River gorge, the Rinconada, San Marcos, and Espinosa faults (fig. 3*A*) are local segments of one continuous major high-angle fault traceable for some 250 km (160 mi) within the southern Coast Ranges of California (fig. 1). In order to simplify this complex nomenclature, it is proposed to apply one name to this combined major fault as shown in figure 3*B* as well as in figures 1 and 2. The local names shown in figure 3*A* are retained for the segments, but the fault as a whole is herein designated as the Rinconada fault. The name Rinconada is adopted because the segment shown as Rinconada fault (Jennings, 1959) is the one along which the crystalline basement and Franciscan basement are almost adjacent at the surface. This segment is designated as the type segment.

The Rinconada fault is defined herein as a high-angle fault that extends from its intersection with the Big Pine fault near Big Pine Mountain in the San Rafael Mountains northwestward for some 250 km (160 mi) to a point where its surface trace dies out in the hills 11 km (7 mi) west of King City (fig. 3*B*). Relative vertical displacements are upward on one side along some parts and on the opposite side along others. These may be only apparent or oblique slip; the major component may be strike slip.

There are few places where this fault is clearly exposed, but its type locality is designated at the low pass near the Rinconada mine, a mercury mine located

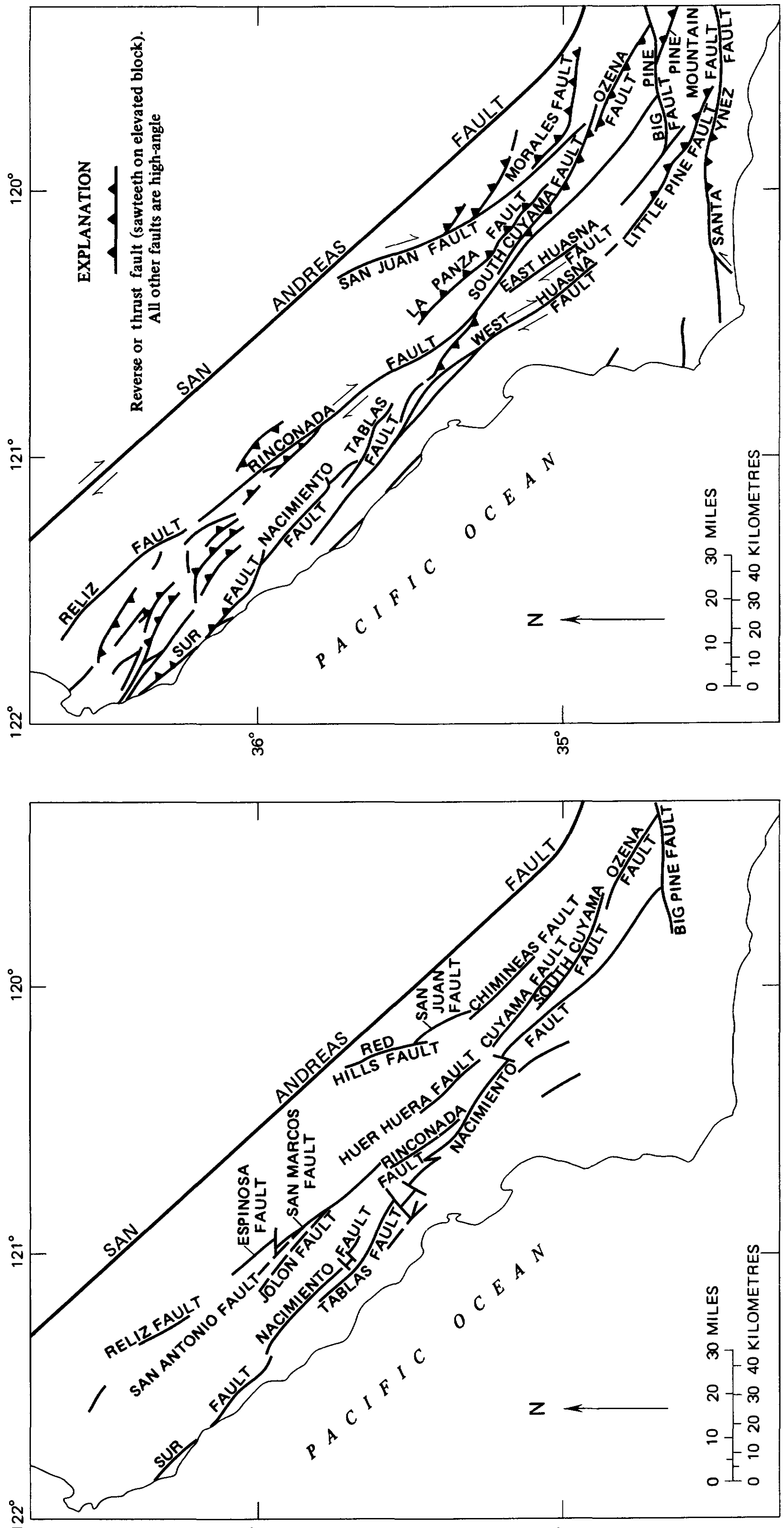

FIGURE 3.—Nomenclature of some major faults in part of southern Coast Ranges. *A*, As shown on Geologic Map of California (Jennings and Strand, 1958, 1969; Jennings, 1959). *B*, Major faults recognized and nomenclature proposed in this report.

about 17 km (10 mi) southeast of Santa Margarita (figs. 2, 9).

About 3 km (2 mi) northwest of the point where the Rinconada fault dies out west of King City, the Reliz fault (figs. 2, 3*B*) is directly alined with it and extends along the base of the steep northeast front of Sierra de Salinas of the northern Santa Lucia Mountains for about 46 km (30 mi), then dies out northwestward (figs. 1, 3*A*, 3*B*).

The Rinconada and Reliz faults together form a zone some 300 km (190 mi) long, herein designated as the Rinconada-Reliz fault zone. As shown in figures 1, 2, and 3*B*, this zone is nearly parallel to the San Andreas fault to the northeast. This parallelism, together with evidence of strike-slip movements, suggests that this zone is part of the San Andreas fault system.

REGIONAL RELATIONS

Southeastward from Santa Margarita the Rinconada fault as defined herein presumably forms the southwestern boundary of the Salinian block (Salinia of Reed, 1933, p. 12, 30), which has a crystalline basement complex of plutonic and metamorphic rocks (fig. 1). The block on the southwest, designated by Reed (1933, p. 30) as the Central Franciscan area, will be herein referred to informally as the Coastal block, which lies west of the Salinian block and has a noncrystalline eugeosynclinal basement complex composed of Franciscan rocks. Northwestward from the Rinconada mine the Rinconada fault veers northward into the Salinian block.

The boundary between the two geologic blocks has long been regarded as the Nacimiento fault zone (Reed, 1933, p. 32; Taliaferro, 1943a, p. 153) or Sur-Nacimiento fault zone (Page, 1970a, 1970b). Accordingly, the name Nacimiento has been applied to more than one mappable fault along this boundary and the faults were thought or presumed to be continuous, at least in the subsurface. The originally named Nacimiento fault was mapped for about 40 km (25 mi) near the Nacimiento River by Taliaferro and his students in the 1930's (Jennings, 1959) and later in more detail by Page (1970a, 1970b). Far to the southeast, the fault along the southwest border of Cuyama Valley was also called the Nacimiento fault by Eaton (1939), Eaton, Grant, and Allen (1941), and Hill, Carlson, and Dibblee (1958). Later it was called the South Cuyama fault (Jennings and Strand, 1969), and the name Nacimiento was applied to the fault a few kilometres southwest that crosses the Cuyama River gorge, on the assumption that this fault (1) forms part of the southwestern boundary of Salinia and (2) extends into the original Nacimiento fault near the Nacimiento River, at least in the subsurface (Dibblee, 1966, p. 64; Jennings, 1959; Jennings and Strand, 1969; Vedder and others, 1967; Vedder and Brown, 1968).

The first of these assumptions is presumably correct, but the second is questionable. The southern Nacimiento fault that crosses Cuyama River gorge is generally interpreted (Jennings, 1959) to extend northwestward from the Rinconada mine (fig. 9) via a complex group of faults and cross-faults along and within the northeast slope of the Santa Lucia Mountains for some 50 km (30 mi) into the original northern Nacimiento fault west of the Nacimiento River (fig. 3A); and it is assumed that this alinement of faults is underlain by the concealed boundary between Franciscan rocks of the Coastal block and the crystalline basement complex of the Salinian block.

However, the faults, including those that involve Franciscan rocks, in the northeastern margin of the Santa Lucia Mountains veer westward to become internal faults in these mountains and in the Coastal block (fig. 4); there is no fault or fault zone that is continuous from Santa Margarita to the northern Nacimiento fault (fig. 4), and the position of the concealed boundary between the basement rocks of the Salinian and Coastal blocks through that area is not known. The two Nacimiento faults are thereby separated by a gap of about 48 km (30 mi; fig. 4).

The southern Nacimiento fault is continuous into the Rinconada fault and is not part of the original northern Nacimiento fault at the surface, even though both Nacimiento faults form parts of the boundary between the Salinian and Coastal blocks. Therefore, if this boundary were once a single fault plane throughout its extent, there may have been no movement on the segment concealed under the Cenozoic sedimentary cover since middle or possibly early Tertiary time.

This boundary between the Salinian block of crystalline basement and the Coastal block of Franciscan basement in this area was designated by Page (1970a, p. 667, fig. 1) as the Sur-Nacimiento fault zone, which "extends southeasterly from Point Sur, crosses the Santa Lucia Range obiquely, and reaches the Transverse Ranges of southern California." This definition is accepted.

In order to avoid confusion, the name Nacimiento should be applied only to the fault originally mapped as the Nacimiento fault near the Nacimiento River (fig. 4). It is illogical and confusing in my opinion to apply this name to any other fault into which that fault cannot be mapped. Therefore, it is incorrect to apply this name to the southern Nacimiento fault southeastward from Santa Margarita. Because that fault is the southeastward extension of the Rinconada fault. I consider it appropriate to apply the name Rinconada to that entire fault.

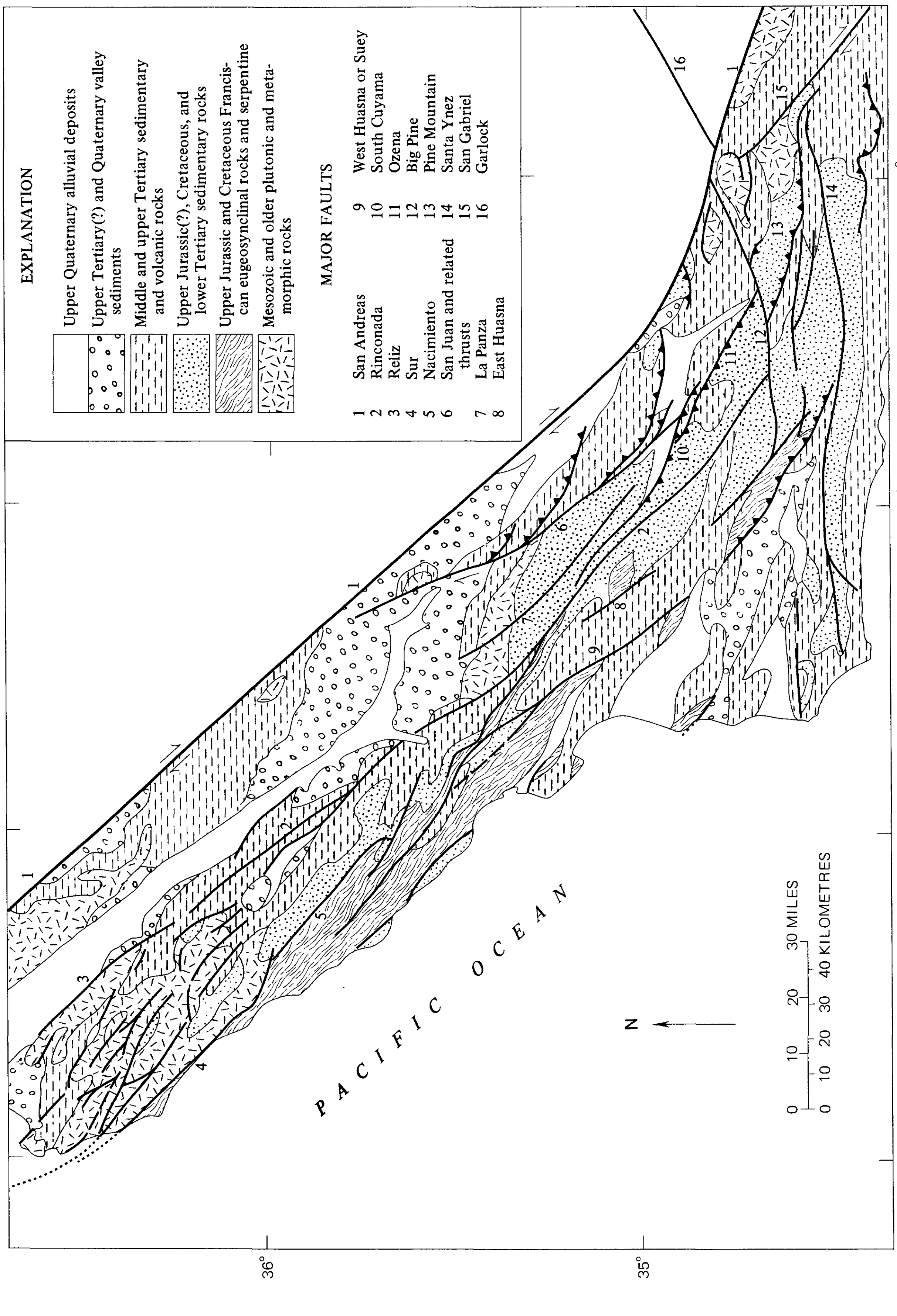

FIGURE 4.—Geologic setting of the Rinconada and Reliz faults.

CONCEALED POSITION OF SOUTHWESTERN BORDER OF THE SALINIAN BLOCK

Between the Santa Margarita area, where Franciscan rocks west of the Rinconada fault are very near the granitic basement of the Salinian block on the east side of this fault, and the northern Santa Lucia Mountains about 25 km (15 mi) west of Jolon, where Franciscan rocks are in contact along the Nacimiento fault with the crystalline basement complex of the Salinian block, the position of the boundary between the Salinian and Franciscan rocks is not known because it is concealed beneath younger sedimentary rocks for a distance of about 100 km (62 mi). This concealed boundary could not be detected by gravity geophysical surveys, owing to lack of density contrast between these two basement complexes (Burch, 1971; Hanna, 1970) and its depth below sedimentary rocks.

Where the boundary between the Franciscan and crystalline basement is exposed in the northern Santa Lucia Mountains along the Nacimiento fault west of Jolon (fig. 21), the fault dips steeply northeast to vertical. On the northeastern block I found that the crystalline basement complex is overlain unconformably by the southward-dipping Upper Cretaceous and lower Tertiary sedimentary sequence. Southeastward this sequence conceals the crystalline basement complex on the Salinian block and is in contact along the fault with Franciscan rocks of the relatively elevated southwestern or Coastal block for 50 km (31 mi).

These conditions suggest, if not indicate, that the concealed boundary of the crystalline basement of the Salinian block with Franciscan rocks of the Coastal block is along the entire northern Nacimiento fault, as generally believed. However, Burch and Durham (1970, p. B13), Burch (1971, p. A12), and Durham (1974, p. 59) suggested that this boundary may be cross-faulted far to the east, to their postulated Jolon fault near the San Antonio River, because of gravity gradients in that area and almost none along the Nacimiento fault. This interpretation, although it cannot be ruled out, is considered improbable.

From the geologic relations described and as shown in figure 21, it is more probable that this concealed boundary continues southeastward along the length of the Nacimiento fault (fig. 1) from the segment along which it is exposed, or along the fault within 2 km (1.3 mi) northeast, because of the following structural evidence: Franciscan and overlying rocks exposed southwest of these faults in the central Santa Lucia Mountains are severly deformed throughout and elevated along these faults against the Upper Cretaceous and lower Tertiary sequence and the middle Tertiary sedimentary sequence of the Nacimiento River area to the northeast, which are much less deformed except adjacent to the fault zone. These conditions suggest that the zone of weakness along which the Santa Lucia Mountains were elevated, including the Nacimiento fault zone, formed presumably along this concealed boundary and that the comparatively less deformed sedimentary sequences to the northeast are probably underlain by the crystalline basement complex that is comparatively more rigid than the Franciscan basement and more resistant to deformation.

There is no structural discordance either at the surface (fig. 21), or in the gravity pattern (Burch, 1971, pl. 1; Hanna, 1970, p. B72), to indicate that the boundary of the basement complex with Franciscan rocks is cross-faulted or deviated from its exposed position along the Nacimiento fault eastward to Lockwood Valley as suggested by Burch and Durham (1970) and Durham (1974). If it is, it would underlie the Upper Cretaceous and lower Tertiary sedimentary sequence, and if it is a fault contact, it would predate that sequence.

It is difficult to interpret the position of this concealed boundary from the geophysical data. Along the Nacimiento fault, including the segment along which the Franciscan and crystalline rocks are in contact at the surface west of Jolon, there is little if any gravity gradient, other than the regional one of progressively decreasing gravity values northeastward as shown by Burch (1971, pl. 1) and Hanna (1970, p. B72–B73). The very slight gradient at the segment along which Franciscan rocks are in contact with the thick Upper Cretaceous and lower Tertiary sedimentary sequence suggests that there is very little density contrast between this sequence, the Franciscan rocks, and the crystalline rocks. Only where one or all of these three rock units are overlain by thick middle and late Cenozoic sedimentary rocks of lower density, such as in the Lockwood Valley area, is there a defined gravity gradient. Burch (1971, p. B12), Hanna (1970, p. B74), and Loney (1970) suggested that the concealed Franciscan—crystalline basement boundary may be slightly east of the Nacimiento fault or that the contact dips northeastward, but it is probably too deep to be detectable in any geophysical pattern.

An airborne magnetometer survey (Hanna, 1970, p. B68–B69) did not definitely detect the position of the concealed Franciscan–crystalline basement boundary, but magnetic variations are locally very strong where Franciscan rocks are exposed, especially over serpentine bodies, and are almost nonexistent eastward to the Rinconada fault. This condition suggests that the concealed boundary is near the easternmost exposures of Franciscan rocks, although Hanna (1970, p. B74) suggested that it may be within 8 km (5 mi) east of these exposures.

Beyond the southeast end of the Nacimiento fault (fig. 10), the position of this concealed boundary is a matter of speculation. Presumably it may continue to extend southeastward (fig. 1), possibly under the syncline axis north of the Las Tablas fault (fig. 10) to join the Rinconada fault near Atascadero (fig. 9).

Southeastward from Santa Margarita the concealed boundary of the crystalline basement of the Salinian block with Franciscan rocks is presumably along the Rinconada fault to and possibly beyond the Big Pine fault (fig. 1), because east of the Rinconada fault the thick Upper Cretaceous and lower Tertiary sedimentary sequence is underlain by the crystalline basement in the La Panza Range (figs. 4, 8, 9) and presumably throughout the extent of this sequence, whereas west of this fault the Cretaceous sedimentary sequence is underlain by Franciscan rocks and is comparatively more intensely deformed.

ROCK UNITS

The rock units of the Salinian and Coastal geologic blocks within the area of figures 1 and 2 are shown in figures 5 and 6. Their areal distribution is shown generalized in figure 4 and in more detail in figures 7, 8, 9, 10, 12, 13, 15, and 21. The basement complexes of the two blocks are totally different. The overlying sedimentary sequences now recognized (Dibblee, 1973) are similar in general but different in detail.

CRYSTALLINE ROCKS

The crystalline basement complex (Dibblee, 1973) of the Salinian block is composed of granitic plutonic rocks that engulf pendants of metamorphic rocks (Wiebe, 1970a, 1970b; Compton, 1966b; Ross, 1972, 1974, 1976). The granitic rocks range in composition from quartz diorite to quartz monzonite, with granodiorite predominant. They locally include small bodies of fine-grained or aplitic alaskite granite, and hornblende diorite or gabbro.

The more widespread plutonic rocks of the Santa Lucia and La Panza Mountains have been radiometrically dated (K–Ar method) at about 70 to 80 m.y. (million years) or Late Cretaceous (Curtis and others, 1958; Evernden and Kistler, 1970). However, it is doubtful that this is the age of emplacement or crystallization of the rocks dated, because the overlying unmetamorphosed sedimentary rocks are also Late Cretaceous, from paleontologic evidence. Compton (1966b, p. 287) and Evernden and Kistler (1970, p. 22) suggested that this may be the age of the earliest uplift since emplacement, or some other postemplacement event, and that the plutons were emplaced probably in mid-Cretaceous time.

The metamorphic rocks are sedimentary rocks regionally metamorphosed under high temperature and pressure. They are older than the plutonic rocks of Mesozoic age that engulf them. Two lithologic units are recognized. The most widespread is micaceous schist to gneiss of great thickness that includes many lenses of marble, hornfels, and feldspathic quartzite. These rocks are intricately intruded by plutonic rocks in most exposures. This metamorphic unit, originally designated the Sur Series by Trask (1926), is extensive in the northern Santa Lucia Mountains from the Big Sur area southeastward (Ross, 1976) and in most exposures dips steeply northeastward. It is present also in the Gabilan Mountains as small scattered pendants (Ross, 1972). It is similar to metasedimentary rocks of Paleozoic and early Mesozoic age in the western Mojave Desert and Tehachapi Mountains (Dibblee, 1967). The less widespread metamorphic unit is more homogeneous and is composed almost entirely of mica-plagioclase-quartz schist. It is injected by plutonic rocks at its margins but not internally. These metamorphic rocks are exposed in much of the Sierra de Salinas, where they dip regionally southwest, and at the south end of the Gabilan Range (Ross, 1972, 1974) just north of Greenfield.

FRANCISCAN ROCKS

Franciscan rocks (the Franciscan Complex of Berkland and others, 1972) form the basement complex of the Coastal block in which these rocks are extensively exposed in the central and southern Santa Lucia and southwestern San Rafael Mountains. This complex is composed of severely deformed slightly metamorphosed eugeosynclinal rocks characteristic of Franciscan rocks as described by Bailey, Irwin and Jones (1964). In the central Santa Lucia Mountains (vicinity of Alder Peak and northwestward, fig. 21) the Franciscan is composed of massive to bedded flyschlike hard graywacke sandstone and minor interbedded micaceous shale. Elsewhere the Franciscan in most places is composed of a melange (mixture) of numerous monolithic fragments of graywacke, greenstone, varicolored layered chert, jasper, and blue glaucophane schist in a pervasively sheared "matrix" of dark claystone. Small intrusions of ultramafic rocks such as pyroxenite and gabbro are locally present. Lenticular sill-like injections of serpentine or serpentinite are common within and at the top of the Franciscan complex, especially in the melange.

SEQUENCE	FORMATION		LITHOLOGY AND THICKNESS	AGE		
Surficial sediments*	Alluvium and older alluvium		0–150 ft	Holocene and late Pleistocene	QUATERNARY	CENOZOIC
Valley sediments*	Paso Robles Formation		Terrestrial gravel 0–1200 ft	Pleistocene and Pliocene ?	QUATERNARY / ?	CENOZOIC
Middle Tertiary sedimentary sequence*	Santa Margarita Formation		Marine sandstone 600–5000 ft	Late Miocene	TERTIARY	CENOZOIC
	Monterey Shale		Marine siliceous shale 600–5000 ft	Late Miocene ? Middle Miocene	TERTIARY	CENOZOIC
		Volcanic rocks	Tuff, dacite, and basalt, 0–2000 ft	? Early Miocene	TERTIARY	CENOZOIC
	Vaqueros Formation		Marine sandstone 0–3200 ft	Early Miocene	TERTIARY	CENOZOIC
	Red beds, conglomerate		Terrestrial deposits 0–600 ft	? Oligocene	TERTIARY	CENOZOIC
Cretaceous (and Upper Jurassic?)+ marine sedimentary sequence	Sandstone, shale, and conglomerate		Marine deposits 10,000± ft	Late Cretaceous	CRETACEOUS	MESOZOIC
	Shale and sandstone		Marine deposits 0–3000 ft	Early Cretaceous (and Late Jurassic ?)+	CRETACEOUS	MESOZOIC
Franciscan Complex	Franciscan rocks‡		Basalt and chert	Cretaceous and Late Jurassic	CRETACEOUS / JURASSIC(?)	MESOZOIC
			Graywacke, shale, chert, and greenstone			

*Regional unconformity at base
‡Injected by serpentine, mafic rocks
+Ages in parentheses apply to only very small part of unit and only local

FIGURE 5.—Major rock units of the Coastal block within area of figures 1, 2 and 4.

SEQUENCE	FORMATION		LITHOLOGY AND THICKNESS	AGE		
Surficial deposits*	Alluvium and older alluvium		0–300 ft	Holocene and late Pleistocene	QUATERNARY	CENOZOIC
Valley sediments*	Paso Robles Formation		Terrestrial gravel, sand, and clay 0–3000 ft	Pleistocene and Pliocene	?	CENOZOIC
Upper Tertiary sedimentary sequence	Morales Formation[x]		Terrestrial gravel, sand, and clay 0–5000 ft	Pliocene	TERTIARY	CENOZOIC
Upper Tertiary sedimentary sequence	Quatal Formation[x]		Terrestrial clay and sand 0–1000 ft	Pliocene	TERTIARY	CENOZOIC
Upper Tertiary sedimentary sequence	Pancho Rico Formation[x]	Upper unit[x]	Marine sandstone 0–700 ft	Early Pliocene	TERTIARY	CENOZOIC
Upper Tertiary sedimentary sequence	Pancho Rico Formation[x]	Lower unit[x]	Marine mudstone, diatomite, and sandstone 0–2000 ft	Early Pliocene	TERTIARY	CENOZOIC
Middle Tertiary sedimentary sequence*‡	Santa Margarita Formation		Marine sandstone 0–2000 ft	Late Miocene	TERTIARY	CENOZOIC
Middle Tertiary sedimentary sequence*‡	Monterey Shale		Marine siliceous shale 0–7000 ft	Late, middle and early‖ Miocene	TERTIARY	CENOZOIC
Middle Tertiary sedimentary sequence*‡	Monterey Shale	Branch Canyon Sandstone†	Marine sandstone 0–3000 ft	Middle Miocene	TERTIARY	CENOZOIC
Middle Tertiary sedimentary sequence*‡	Monterey Shale	Basalt	Flows and dikes	Middle Miocene	TERTIARY	CENOZOIC
Middle Tertiary sedimentary sequence*‡	Vaqueros Formation		Marine sandstone and shale 0–7000 ft	Early Miocene and late Oligocene	TERTIARY	CENOZOIC
Middle Tertiary sedimentary sequence*‡	Simmler and Berry Formations		Terrestrial strata 0–3000 ft	Oligocene	TERTIARY	CENOZOIC
Upper Cretaceous and lower Tertiary marine sedimentary sequence*	Undifferentiated sandstone, shale, and conglomerate		Marine strata 25,000 ft	Eocene, Paleocene, and Late Cretaceous	CRETACEOUS AND TERTIARY	MESOZOIC AND CENOZOIC
Crystalline basement complex	Plutonic rocks		Granite to diorite and gabbro, mainly granodiorite	Cretaceous and older(?)	MESOZOIC	
Crystalline basement complex	Metamorphic rocks		Marble, quartzite, schist, and gneiss	Mesozoic or older		

* Regional unconformity at base
x Unconformity at base along basin margins
† Intertongued with Monterey Shale
‖ Only lowest part in few places of this age
‡ Includes Caliente Formation, easternmost terrestrial equivalent of all marine units of this sequence

FIGURE 6.—Major rock units of the Salinian block within area of figures 1, 2 and 4.

The age of the Franciscan rocks of the Coastal block is inferred to range from latest Jurassic (Tithonian) to early Late Cretaceous (Turonian) by Bailey, Irwin, and Jones (1964). Near Stanley Mountain (fig. 6) these rocks yielded fossils considered diagnostic of Late Jurassic (Tithonian) age (Easton and Imlay, 1955). Shale samples from Franciscan rocks west of the Nacimiento River yielded spores and dinoflagellates inferred to be Early Cretaceous (W. R. Evitt, in Page, 1970a, p. 674, 687).

A predominantly volcanic unit at the top of or above the Franciscan is exposed in two areas: one in the vicinity of Stanley Mountain (fig. 6) as mapped by Hall and Corbató (1967) who included it in the Franciscan, and the other north of San Luis Obispo (fig. 9) as mapped by Fairbanks (1904) and Page (1972). In both areas this unnamed unit is composed of basaltic to andesitic volcanic rocks partly altered to greenstone, as thick as 610 m (2,000 ft), associated intrusive diabase and peridotite partly serpentinized, and an interval up to 92 m (300 ft) thick of light-gray chert, and locally by a little shale and graywacke at the top. This igneous unit is excluded from the Franciscan by Taliaferro (1943a), Gilbert and Dickinson (1970), and Page (1972). It is now regarded as the ophiolite-ultramafic succession of igneous rocks as recognized by Bailey, Blake, and Jones (1970). The age of this volcanic unit is either latest Jurassic or earliest Cretaceous. In both areas this unit may be in fault contact on top of Franciscan rocks or serpentine and is overlain by the lower unit (shale) of the Cretaceous (and Upper Jurassic?) marine sedimentary sequence.

UPPER JURASSIC(?) AND CRETACEOUS MARINE SEDIMENTARY SEQUENCE

In the Coastal block, the Franciscan rocks are overlain by, or in fault contact (Brown, 1968; Page, 1970a, 1970b) with a thick marine sedimentary sequence of shale, sandstone, and local conglomerate, primarily if not entirely of Cretaceous age. Although Taliaferro (1943a, 1944) recognized within this sequence three major units separated by unconformities, only two units (fig. 6) have been mapped by Page (1970a, 1970b, 1972), who referred to this sequence as the "Great Valley-type Mesozoic rocks," Hall and Corbató (1967), and by myself (Dibblee, 1971).

The lower unit of this sequence is as thick as 1,219 m (4,000 ft) and is predominantly dark-gray shale that contains thin interbeds of dark-brown wacke sandstone. This unit was called the Toro Formation by Fairbanks (1904) and Page (1972) in the San Luis Obispo quadrangle; "Knoxville shales" and Marmolejo Formation by Taliaferro (1944) in the Santa Lucia Mountains; Jollo Formation by Hall and Corbató (1966) in the Nipomo quadrangle; and Espada Formation (of Dibblee) by Vedder, Gower, Clifton, and Durham (1976) and Vedder and Brown (1968) in the San Rafael Mountains. Near Stanley Mountain (fig. 8), and also west of Santa Margarita (fig. 9), this unit lies depositionally (unconformably?) on the unnamed volcanic unit at the top of or above Franciscan rocks (Hall and Corbató, 1967; Page, 1972). Near Stanley Mountain and elsewhere the lower unit contains fossils considered diagnostic of Early Cretaceous age (Tiliaferro, 1943a; Easton and Imlay, 1955; Hall and Corbató, 1967; Vedder and Brown, 1968, p. 248). Elsewhere it contains fossils of that age and of inferred Late Jurassic age in a few places.

The upper unit of this sequence consists of interbedded gray micaceous shale, buff arkosic sandstone, and locally dark-gray cobble conglomerate with clasts of granitic rocks, andesitic porphyry, and quartzite. This unit is as thick as 4,572 m (15,000 ft). Shale predominates in the lower part, and sandstone in the middle and upper parts. It is exposed extensively in the San Rafael and Santa Lucia Mountains southwest of the Rinconada fault. In the Santa Lucia Mountains this unit was named the Atascadero Formation by Fairbanks (1904). Taliaferro (1943a, 1944) did not adopt this name but divided this unit in ascending order, into the Jack Creek Formation (mostly shale) and Asuncion Group (mostly sandstone), which he thought were separated by an unconformity. In the Nipomo quadrangle (fig. 8) this unit was named the Carrie Creek Formation by Hall and Corbató (1967). Other workers (Vedder and others, 1967; Vedder and Brown, 1968; Page, 1970a, 1970b) applied no names to this unit. Fossils found in this unit are diagnostic of Late Cretaceous age, as reported by all the authors mentioned above.

In the San Rafael Mountains (fig. 7) the upper unit (unnamed) has a thick basal conglomerate that lies without discordance on the lower unit (Espada Formation of Dibblee, 1966). Near Stanley Mountain (fig. 8), as mapped by Hall and Corbató (1967), the upper unit (Carrie Creek Formation) lies unconformably on the lower unit (Jollo Formation). In the Santa Lucia Mountains the upper unit is either unconformable on both the lower unit and Franciscan rocks (Fairbanks, 1904; Taliaferro, 1943a, 1944) or is thrust presumably westward over them (Page, 1970a, 1970b).

UPPER CRETACEOUS AND LOWER TERTIARY MARINE SEDIMENTARY SEQUENCE

In the Salinian block, the deeply eroded surface of the basement complex on both sides of the Rinconada fault is overlain unconformably by a thick marine clastic sedimentary sequence of Late Cretaceous and early Tertiary age, designated as the Upper Cretaceous and lower Tertiary marine sedimentary sequence (Dibblee, 1973, p. 9–10; 1974a). Because of the scarcity of fossils, continuous deposition, and lithologic similarity, the position of the Cretaceous-Tertiary boundary within this sequence is questionable. This sequence is composed of interbedded light-buff arkosic sandstone, micaceous gray shale, and some cobble conglomerate. The conglomerate is composed of rounded cobbles mostly of hard granitic rocks, porphyritic to aphanitic rhyolite to andesite, and quartzite. This sequence is exposed extensively in the La Panza and Sierra Madre Mountains east of the Rinconada fault, and in the Nacimiento River and San Marcos Creek drainage areas west of this fault, or between this fault and the Nacimiento fault.

East of the Rinconada fault this sequence is estimated to be about 9,144 m (30,000 ft) thick and contains a basal conglomerate as thick as 610 m (2,000 ft), resting on granitic basement in the La Panza Range (Dibblee, 1973, p. 9–10). According to Vedder and Brown (1968) the lowest 1,524 m (5,000 ft) of this sequence just east of this fault yielded fossils diagnostic of Late Cretaceous age, the overlying strata in the La Panza Range yielded fossils of probable Paleocene age, and in the Sierra Madre Mountains, fossils of Eocene age. Taliaferro (1943a, 1944) included exposures of this sequence in the La Panza Range in his Upper Cretaceous Asuncion Formation. Chipping (1972, p. 485, 492) informally called the whole sequence the Sierra Madre sequence.

In the Nacimiento River–San Marcos Creek area west of the Rinconada fault this sequence is at least 2,454 m (8,000 ft) thick and also has a basal conglomerate locally, in places more than 305 m (1,000 ft) thick, on the crystalline rocks in exposures north of the Nacimiento River. Fossils found at a few localities in this sequence are diagnostic of Late Cretaceous age, and at other places of Paleocene age (Taliaferro, 1943a; Durham, 1965a). Taliaferro (1943a, 1944, p. 512–517) mapped the inferred Late Cretaceous part of this sequence as the Asuncion Formation and the inferred Paleocene part as the Dip Creek Formation. However, the position of the Cretaceous-Tertiary boundary within this continuously deposited sequence has not been ascertained, because of the scarcity of fossils, structural complications, and partial cover by younger rock units.

The similarity of this sequence in lithology, stratigraphic relations, and age in the La Panza Range area east of the Rinconada fault and in the Nacimiento River–San Marcos Creek area west of the fault suggests that these two widely separated areas of these rocks on opposite sides of the fault may have been displaced by large right-slip movement on the fault. This is discussed in more detail under "Regional Evidence of Large Strike-Slip Movement on the Rinconada-Reliz Fault Zone."

In the northern Santa Lucia Mountains the crystalline basement complex is overlain unconformably by remnants of this seuqence at a number of places. In the mountains north of the upper Nacimiento River area the largest remnant contains about 1,829 m (6,000 ft) of predominantly sandstone, with sparse fossils of Late Cretaceous age in the lower part and of Paleocene and Eocene age in the upper part (Compton, 1966a, 1966b). Other remnants occur farther northwest adjacent to the Sur and Palo Colorado faults (fig. 15) and are thought to be of Late Cretaceous age (Trask, 1926; Reiche, 1937). Northward in these mountains small remnants (fig. 15) that contain less than 610 m (2,000 ft) of sandstone and shale strata include those of Eocene age in the vicinity of Junipero Serra Peak (Thorup, 1943; Compton, 1966a, 1966b), the southwest side of the Church Creek and Miller Creek faults (Dickinson, 1959), and small ones of Paleocene age near Carmel (Bowen, 1965; Clark and others, 1974). These remnants suggest a gradual northward thinning of the whole sequence probably by wedging out of the lower strata against the basement complex.

MIDDLE TERTIARY SEDIMENTARY SEQUENCE

Throughout both the Salinian and Coastal blocks, the pre-Oligocene rock units are overlain unconformably by the middle Tertiary sedimentary sequence (figs. 5, 6) (Dibblee, 1973). The unconformity at the base of this sequence is of regional extent and indicates that almost the entire region within the area of figures 2 and 4 northward from the Santa Ynez Mountains was affected by a great orogenic episode of uplift and erosion probably during Oligocene time. In the Salinian block, the middle Tertiary sequence rests with great angular discordance upon the beveled surface of the Upper Cretaceous and lower Tertiary marine sedimentary sequence, overlapping it northward onto the crystalline basement complex. On the Coastal block the middle Tertiary sequence rests on the eroded surface of the Upper Jurassic(?) and Cretaceous marine sedimentary sequence and Franciscan rocks, both of which had been severely deformed previously.

The lower or basal unit of the middle Tertiary sedimentary sequence is composed of terrestrial deposits, mostly red to gray sandstone and conglomerate, of inferred Oligocene age. In the Coastal block it is only locally present, mostly southward from Santa Margarita, and is not more than a few tens of metres thick.

In the Salinian block east of the Rinconada fault the basal terrestrial unit is widespread. It crops out in the Caliente Range and underlies the Carrizo Plain, where it is called the Simmler Formation (Hill and others, 1958; Dibblee, 1973), which is as thick as 1,067 m (3,500 ft) and is composed primarily of bedded reddish-gray sandstone. In the La Panza and Sierra Madre Mountains this unit, also called the Simmler Formation, is composed of coarse conglomerate and sandstone derived from the underlying older rocks and is only locally present but is as thick as 914 m (3,000 ft) at the Cuyama River gorge (fig. 8). Northwestward from these areas this unit thins to only a few tens of kilometres of red beds under the Salinas Valley and eventually thins out northward, as indicated from well data.

In the part of the Salinian block west of the Rinconada fault the basal terrestrial unit is absent in outcrop except in the Santa Lucia Mountains west of King City, where it was called the Berry Conglomerate by Thorup (1943), and later the Berry Formation by Durham (1974). It is as thick as 335 m (1,100 ft) and is composed of buff-gray to locally red arkosic sandstone and conglomerate. Small isolated exposures of basal red beds that are either equivalent to or younger than the Berry Formation occur near the Nacimiento River, northwest of the reservoir, and in the northern Santa Lucia Mountains west of Greenfield and south of Carmel.

The presence of the basal terrestrial unit farther north on the west side of the Rinconada-Reliz fault zone than on the east side is somewhat suggestive of right-lateral displacement on this fault zone.

The basal terrestrial unit is overlain by a marine unit of probable late Oligocene to middle Miocene age. It is generally called the Vaqueros Sandstone or Formation where its age is within the Zemorrian and Saucesian Stages, of late Oligocene and early Miocene age. Where the basal terrestrial unit is absent, this marine predominantly sandstone unit forms the basal unit of the middle Tertiary sedimentary sequence and rests unconformably on the pre-Tertiary rocks.

On the Coastal block the basal marine sandstone unit attains a maximum thickness of about 610 m (2,000 ft) in a large syncline in the San Rafael Mountains (fig. 7), where it includes some claystone and ranges in age from the Zemorrian to Relizian Stages, late Oligocene to middle Miocene (Vedder and Brown, 1968). Northward this unit thins to a few tens of metres of sandstone in the Huasna Creek area and southern Santa Lucia Mountains.

On the Salinian block east of the Rinconada fault the lowest marine unit attains its maximum thickness of about 2,134 m (7,000 ft) in the Caliente Range and Carrizo Plain, where it is called the Vaqueros Formation. It is divided into three members and contains faunas diagnostic of the Zemorrian and Saucesian Stages (Vedder, 1970; Dibblee, 1973). In the La Panza Range this unit is about 518 m (1,700 ft) thick, is nearly all sandstone on the northeast flank, and is locally absent on the southwest flank. Northwestward under the Salinas Valley this sandstone thins to only a few tens of metres, and together with the basal terrestrial unit abuts northeastward against the basement complex along an imaginary line that extends east-southeast and northwest from Bradley (fig. 2).

In the Salinian block west of the Rinconada-Reliz fault zone the basal marine sandstone unit is present nearly throughout, although its age may vary. Southward from Arroyo Seco Creek to Lockwood Valley it contains fossils diagnostic of the Zemorrian and Saucesian Stages and is generally called the Vaqueros Formation (Thorup, 1943; Bramlette and Daviess, 1944; Compton, 1966a; Dibblee, 1973; Durham, 1974). From Arroyo Seco Creek to the Nacimiento River it is from 310 (1,000) to 671 m (2,200 ft) thick. Southward from Lockwood Valley to Paso Robles this sandstone is thin in outcrop, generally less than 100 m (300 ft). However, west of the San Antonio Reservoir it is as thick as 800 m (2,400 ft) and contains lenses of granitic boulder conglomerate in the upper part (figs. 10, 21).

In the Santa Lucia Mountains northwest of Arroyo Seco Creek to Monterey the basal marine sandstone unit of the middle Tertiary sedimentary sequence may be younger than the Vaqueros Sandstone to the southeast, but its stratigraphic position above red beds, where present, and below the Monterey Shale is similar.

The middle Tertiary sequence is the only one besides the Franciscan that contains volcanic rocks in this region. The oldest are the dacitic and rhyolitic plugs and dikes in the San Luis Obispo area in the Coastal block and the rhyolitic plugs, dikes, and tuff-breccia (Pinnacles Formation of Andrews, 1936, p. 9–22; Wilson, 1943, p. 217–218) of the Pinnacles area of the Gabilan Range in the Salinian block. Those in the San Luis Obispo area yielded K-Ar radiometric dates between 24 and 26.9 m.y. or Oligocene (Turner and others, 1970b). Those in the Pinnacles area yielded K–Ar dates of about 22 m.y. (Turner and others, 1970a). On the Coastal block rhyolitic tuff-breccia (Obispo Tuff of Bramlette, 1946, p. 22–23; Obispo Formation of Hall and Corbató, 1967, p. 569–570), together with flows of dacitic felsite, basalt, and sills of diabase, is extensive just below the Monterey Shale in the San Luis Obispo-Huasna area and is assigned to the upper Saucesian and Relizian Stages, Miocene by the above authors. The Obispo Formation yielded K–Ar radiometric dates of about 16.5 m.y. or early Relizian (Turner and others, 1970b).

On the Salinian block the middle Tertiary sedimentary sequence contains volcanic rocks in several other areas. East of the Rinconada fault these are flows, sills, and dikes of basalt, mostly in the Miocene part of this sequence, in the Caliente and eastern La Panza Ranges (Dibblee, 1973). West of the Rinconada fault these include flows of basalt near the base of the Monterey Shale a few kilometres west of Paso Robles and flows of basalt and andesite near the top of the basal marine sandstone unit in and near the Carmel Valley in the northern Santa Lucia Mountains.

The Monterey Shale, an unusual marine formation of siliceous and organic shale primarily of middle and late Miocene age, overlies the Vaqueros or basal sandstone unit where present and makes up the major part of the middle Tertiary sedimentary sequence. This distinctive shale formation is present on and once covered nearly the entire Coastal block and most of the Salinian block. On both blocks this formation varies greatly in thickness, indicating that the sea floor upon which it accumulated was undergoing movements.

On the Coastal block the Monterey Shale attains a maximum thickness of about 1,524 m (5,000 ft) in the San Rafael Mountains and Huasna area, but elsewhere to the northwest it is much tinner.

On the Salinian block the Monterey Shale is very thin or locally absent in western Cuyama Valley and southwestern La Panza Range but is very extensive under and west of Salinas Valley (fig. 2), where it is about 914 m (3,000 ft) in average thickness. Eastward under the southern part of this valley it extends nearly to the San Andreas fault, thinning eastward. In the central part from Bradley to Greenfield (fig. 2) it abuts northeastward through strandline sandstones against the basement complex along the King City hinge line described by Gribi (1963). Under this valley northwestward from Greenfield, the Monterey Shale presumably intertongues with arkosic sandstone and terrestrial deposits that likewise abut northeastward against the basement complex, as suggested from logs of several wells and from exposures in the hills southwest of Salinas.

The thickness of the Monterey Shale within the Salinian block varies greatly along both sides of the Rinconada-Reliz fault zone, as indicated from outcrop and well data. On the east side of the Rinconada fault near Bradley, this shale is as much as, if not more than, 2,134 m (7,000 ft) thick but is much thinner west of this fault. On the west side of the Reliz fault in the Arroyo Seco Creek area the Monterey Shale is about 1,829 m (6,000 ft) thick but is much thinner east of this fault. This condition suggests possible displacement of the very thick section, if once continuous, by right slip on the Rinconada-Reliz fault zone.

From the Arroyo Seco Creek area the Monterey Shale extends northwestward as remnants in the northern Santa Lucia Mountains into the Monterey Bay.

In most areas on both blocks the Monterey Shale is composed of two distinct parts, the lower part, of argillaceous to siliceous shale, and the upper part, of hard siliceous shale.

The lower part (Sandholdt Shale of Bramlette and Daviess, 1944; Sandholdt Member of Durham, 1974; Point Sal Formation of Hall and Corbató, 1967) of the Monterey Shale is generally about 610 m (2,000 ft) thick or less and is locally absent. In some areas of the Salinian block the lowest 185 m (600 ft) is claystone (Sandholdt Formation of Thorup, 1943) that contains a microfauna of the upper Saucesian and Relizian Stages. The remainder is composed of thin-bedded fissile organic shale, siliceous shale, and thin carbonate strata and contains a rich microfauna of the Relizian and Luisian Stages, middle Miocene. This part (Saltos and Whiterock Bluff Shale Members of Hill and others, 1958) makes up all the Monterey Shale in the Cuyama Valley and the Caliente and La Panza Ranges east of the Rinconada fault, and the major part west of this fault from Atascadero northwestward to the San Antonio River (fig. 2), suggesting possible right-lateral displacement of this unit of the fault.

The upper part (Hames Member of Durham, 1974) of the Monterey Shale is composed of white-weathering hard platy brittle porcelaneous siliceous shale. It averages about 610 m (2,000 ft) in thickness but in some areas is as thick as 2,029 m (6,000 ft). It contains a microfauna of the Mohnian Stage, late Miocene. East of the Rinconada-Reliz fault zone this part makes up the major part of the Monterey Shale in areas northwestward from the Paso Robles area and in areas northwestward from Lockwood Valley west of this fault zone. Accordingly, the areas in which the thickness of the upper part far exceeds that of the lower part extend farther south on the east side of the Rinconada fault zone than on the west side, suggesting displacement by right slip on the fault.

The upper part of the Monterey Shale presumably grades laterally southeastward and eastward into the Santa Margarita Sandstone in the southern part of the Salinas Valley, on both sides of the Rinconada fault. Farther southeast in the Cuyama Valley, Caliente Range, and Carrizo Plain, the lower part of the Monterey Shale intertongues laterally eastward into the Branch Canyon Sandstone. In those areas that sandstone, together with the overlying Santa Margarita and much of the underlying Vaqueros Formation, intertongue eastward with red beds of the terrestrial Caliente Formation (Hill and others, 1958; Vedder, 1970; Dibblee, 1973) toward the San Andreas fault.

The Santa Margarita Sandstone overlies the Monterey Shale in the southeastern parts of both the Coastal and Salinian block and is composed of white sandstone from 310 (1,000 ft) to 457 m (1,500 ft) in thickness. It contains bioclastic reefs of fossils diagnostic of late Miocene age. East of the Rinconada fault it extends from the Cuyama Valley to the Paso Robles area (fig. 2). West of this fault this sandstone extends about 18 km (11 mi) farther northwest to the San Antonio River, suggesting right-lateral displacement of this sandstone on the fault (fig. 18). The Santa Margarita Sandstone is not definitely known to occur farther northwest except in exposures east of Monterey (Bown, 1965) and possibly in the San Ardo oil field.

UPPER TERTIARY SEDIMENTARY SEQUENCE

With the exception of exposures south of San Luis Obispo and in Santa Barbara County, the upper Tertiary sedimentary sequence is present only on the Salinian block. In the Salinas Valley this sequence is marine, as thick as 610 m (2,000 ft). Its stratigraphy has been interpreted in various ways and is much confused as reviewed by Durham and Addicott (1965, p. A3–A6) because of lack of adequate geologic mapping. On the east side of the Salinas Valley this sequence was casually called the Poncho Rico Formation by Reed (1925, p. 591, 606), and Clark (1929), with no reference to a type section. Later Durham and Addicott (1965, p. A2) formally defined this entire marine sequence as the Pancho Rico Formation and considered the fauna throughout as early Pliocene. However, many other investigators and I recognized two distinctive lithologic units: a lower mudstone unit and an upper sandstone unit, as indicated below and in figure 5.

The lower unit (Santa Margarita or McLure Shale of Taliaferro, 1943a, 1943b; McLure Formation of Kilkenny, 1948, p. 2260; Pancho Rico Formation of Baldwin, 1950; Pancho Rico Shale of Gribi, 1963, p. 18; Pancho Rico Formation of Dibblee, 1971), is a creamy-white fine-grained chalky diatomaceous mudstone about 363 m (1,200 ft) thick. It is widespread northeast of the Salinas River where it is primarily diatomaceous mudstone that rests with a basal sandstone on the basement complex over much of this area. Elsewhere it is conformable, and commonly gradational, on the Monterey Shale. Northwest of Jolon the lower unit is diatomaceous to sandy siltstone. Near and southeast of Jolon, and west and southwest of Bradley, this unit becomes impure chalky diatomite. This diatomite was included in the Monterey Formation by Durham (1965a, 1974) as the Buttle Member, but its lithology and stratigraphic position indicate that it is probably the lower unit of Pancho Rico Formation.

The upper unit (Etchegoin of Taliaferro, 1943b; Jacalitos of Taliaferro, 1943a; Pancho Rico Formation of Kilkenny, 1948, p. 2260; Etchegoin Formation of Gribi, 1963, p. 18; unnamed sandstone of Dibblee, 1971) is composed of yellowish-gray fossiliferous sandstone and is included in the Pancho Rico Formation by Durham and Addicott (1965). It is thickest (about 185 m (600 ft) in Salinas Valley in the vicinity of San Ardo, where it is gradational through interbeds into both the underlying lower unit (of the Pancho Rico Formation) and into the overlying Paso Robles Formation. However, beyond this area, stratigraphic relations change rapidly toward the margins of Salinas Valley. Northward this sandstone unit thins to only a calcareous fossil reef that together with the Paso Robles Formation, laps over the lower unit onto granitic basement north of King City. Eastward this sandstone grades laterally into terrestrial gravel like that of the Paso Robles Formation and unconformably overlaps the lower unit onto the middle Tertiary sedimentary sequence near the San Andreas fault. Southwestward to and beyond the San Antonio River, this sandstone thins to less than 61 m (200 ft) and, together with the Paso Robles Formation, unconformably overlaps diatomite of the lower unit onto the Monterey Shale (fig. 10). This unconformable relation was recognized by Taliaferro (1943b, p. 460), but not by Durham and Addicott (1965).

I mapped and designated the upper unit as an unnamed sandstone (Dibblee, 1971) and excluded it from the Pancho Rico Formation, despite the lower Pliocene fossils it contains, because of the stratigraphic reasons indicated above, and as pointed out by Gribi (1963, p. 16), "it certainly is a recognizable formation." However, because this unit is included in the Pancho Rico Formation by Durham and Addicott (1965, p. A–2) it is herein reluctantly included within that Formation.

In the Carrizo Plain, Caliente Range, and Cuyama Valley, the upper Tertiary sedimentary sequence is all terrestrial (Dibblee, 1973). It is as thick as 1,676 m (5,500 ft) and is composed of two units. A lower unit, the Quatal Formation, of Pliocene age, is about 152 m (500 ft) thick and is mostly claystone, and an upper unit, the Morales Formation, of Pliocene age, is as thick as 1,524 m (5,000 ft) and is interbedded alluvial conglomerate, sandstone, and clay. This sequence rests unconformably on the Santa Margarita Sandstone or on older formations and is overlain unconformably by the Paso Robles Formation.

VALLEY SEDIMENTS

Through the Salinas Valley the upper Tertiary sedimentary sequence is overlain by a widespread severely dissected valley formation as thick as 310 m (2,000 ft) known as the Paso Robles Formation (Fair-

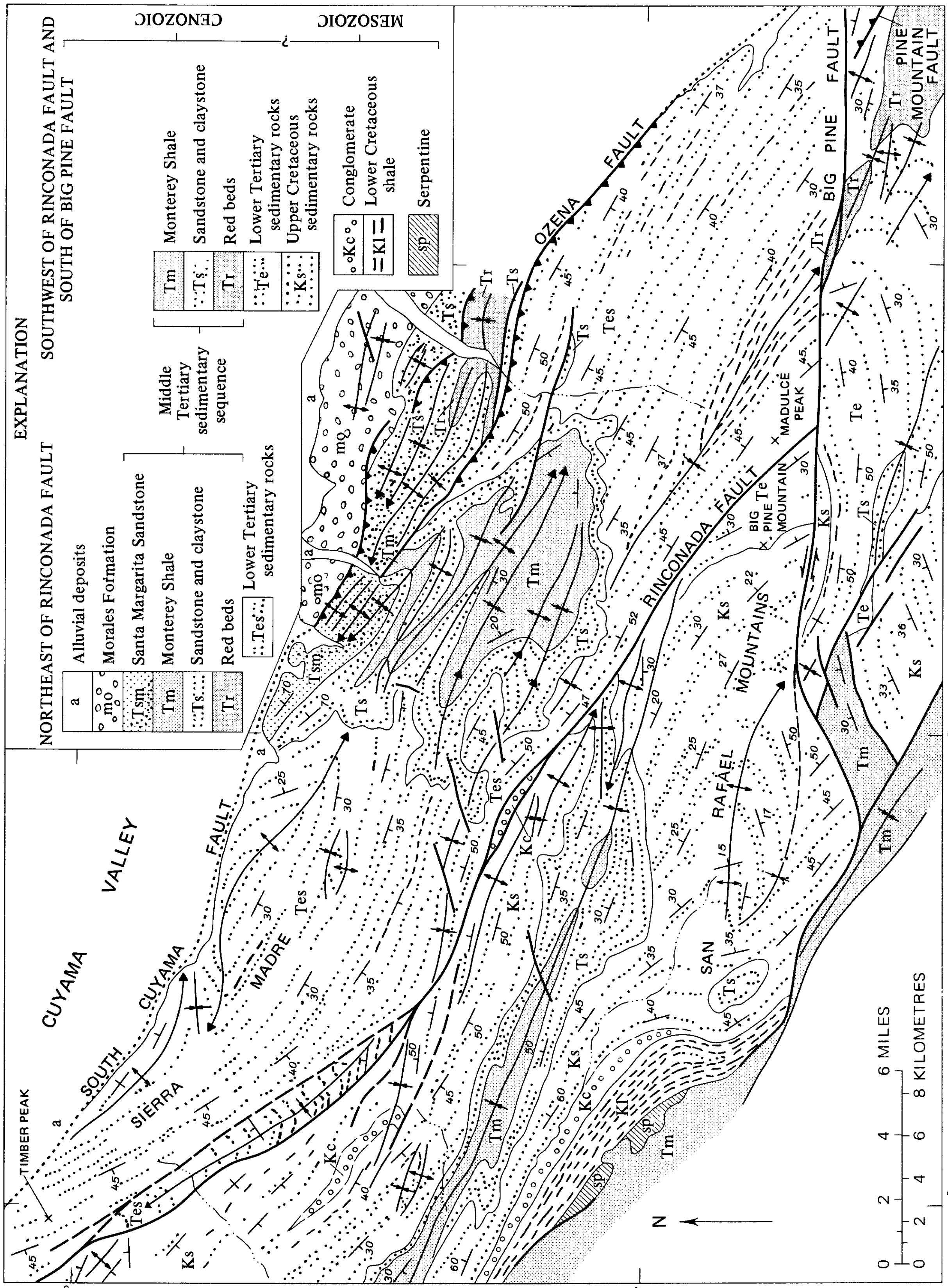

FIGURE 7.—Geology along and near the Rinconada fault (Nacimiento segment) from Big Pine Mountain to Timber Peak (modified from Vedder and Brown, 1968, p. 245).

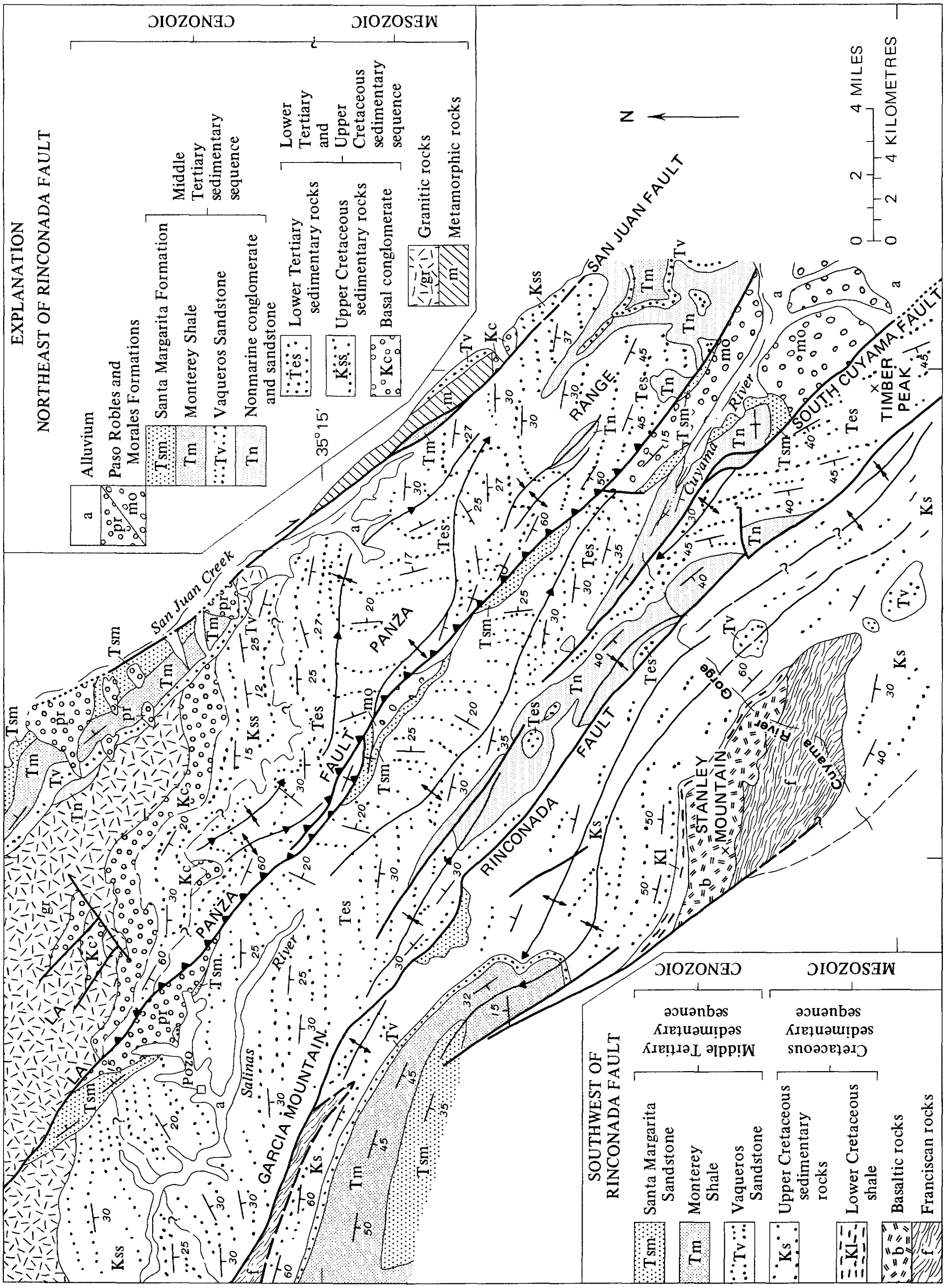

FIGURE 8.—Geology along and near the Rinconada fault (Nacimiento segment) from Timber Peak to Pozo (modified from Vedder and Brown, 1968, p. 244).

banks, 1904; Taliaferro, 1943a,b; Bramlette and Daviess, 1944; Durham, 1965a, 1966, 1974; Galehouse, 1967, Dibblee, 1973). It is composed of weakly indurated pebble-gravel, sand, and clay. A large percentage of the pebbles are derived from the Monterey Shale.

In the central Salinas Valley area near San Ardo and San Miguel, the Paso Robles Formation is conformable on the sandstone unit of the Pancho Rico Formation of Pliocene age. However, along the southwestern margin of this valley from Lockwood Valley southeastward through Paso Robles, Atascadero, and the northeast foothills of the La Panza Range, the Paso Robles Formation is unconformable with great discordance on the middle Tertiary sedimentary sequence and the granitic basement.

The top of the Paso Robles Formation is a surface of deposition. In most areas this is severely dissected or destroyed by erosion, but locally remnants of it are preserved as flat-topped mesas. The Carrizo Plain is in large part the preserved deposition surface of the Paso Robles Formation. West of Carrizo Plain the Paso Robles Formation is exposed as dissected southward-thinning alluvial fans that terminate against granitic basement of the La Panza Range.

The Paso Robles Formation is primarily Pleistocene in age (Dibblee, 1973), but northeast of San Miguel the lowest part intertongues westward with the upper sandstone unit of the Pancho Rico Formation, which contains mollusks assigned an early Pliocene age by Durham and Addicott (1965). A similar relation may occur in the subsurface northward from Atascadero, as suggested by the occurrence near there of Pliocene mollusks at the base of the Paso Robles Formation (Galehouse and Addicott, 1973).

The Paso Robles Formation accumulated as alluvial deposits in the ancestral Salinas Valley when this valley was much more extensive than it is now and was derived from areas to the northeast and southwest that were elevated to form mountains. It was deposited almost entirely on the Salinian block, on which it is widespread, on both sides of the Rinconada-Reliz fault zone. It extends into the Coastal block only in the vicinity of Santa Margarita.

SURFICIAL DEPOSITS

Alluvial deposits of late Pleistocene and Holocene age fill all modern valleys and flood plains of streams. Older alluvium, deposited when this region was somewhat lower than it is now, is dissected into terrace remnants. None are affected by deformation except locally along the San Andreas fault.

SEGMENTS OF THE RINCONADA FAULT

RINCONADA FAULT (NACIMIENTO SEGMENT) FROM SAN RAFAEL MOUNTAINS TO POZO AREA

The southeastern 110 km (70 mi) of the Rinconada fault, or the part heretofore called the Nacimiento fault (Jennings, 1959; Hall and Corbató, 1967; Vedder and others, 1967; Vedder and Brown, 1968), and the related geology are shown in figures 7 and 8. This segment is not to be confused with the original Nacimiento fault west of the Nacimiento River far to the northwest, even though early movements on both faults may have been related. Because this segment (figs. 7, 8), designated as part of the Rinconada fault (Dibblee, 1973, fig. 2), has been previously referred to the Nacimiento fault, it is designated herein the Nacimiento segment of the Rinconada fault.

This segment is interpreted to be the former position of the southeastern part of the Nacimiento fault along which the Salinian and Coastal blocks presumably are in contact. This segment is mapped as part of the Rinconada fault because it is continuous northwestward into the Rinconada fault (Rinconada segment) and not into the Nacimiento fault near and northwest of Atascadero where it is deeply buried and inactive since Miocene time. If the Nacimiento segment of the Rinconada fault was once the southeastern part of the Nacimiento fault as interpreted, that part has been displaced southeastward from the buried position of this fault near Atascadero by right slip on the Rinconada fault.

The Nacimiento segment of the Rinconada fault is generally nearby vertical, but in many places, especially southeast of the Cuyama River gorge, it dips northeast at varying angles at the surface. At one place it dips steeply southwest. This fault is poorly expressed topographically, but the terrain is generally higher on the northeast and in many places, especially southeastward from Cuyama River gorge, rises abruptly from the fault trace. This condition suggests relative upward displacement of the northeastern block, which is further indicated at two places where Miocene strata on the southwest side are against lower Tertiary strata on the northeast (figs. 7, 8). However, this condition may be in part the effect of differential erosion of the southwest block composed largely of intensely deformed weakly resistant Cretaceous clay shale, compared to the northeast block composed of comparatively less deformed, more resistant lower Tertiary sandstone and conglomerate.

Lack of deviation or offsetting of the many stream channels that cross this segment of the fault indicates that no lateral movement occurred along it in late Quaternary time.

If the latest vertical displacement on this segment was relatively upward on the northeast side, then, as interpreted by Vedder and Brown (1968, p. 247, 252), this movement was reversed from earlier movements during which the southwestern block was displaced relatively upward, as indicated by (1) the older or Cretaceous age of the sedimentary rocks on the southwest block with respect to the early Tertiary and Oligocene age of those sedimentary rocks on the northeast block along and throughout this segment and (2) the upward bending of strata of the northeast block adjacent to the fault (fig. 7; fig. 8 northwest of Cuyama River gorge).

If movement was by reversals of vertical displacements, then it must be assumed that strata of Paleocene and early Eocene ages once overlay the Cretaceous strata of the southwest block but were eroded off before middle Eocene time, as suggested by the occurrence of strata of inferred middle Eocene age that lie directly on Upper Cretaceous strata on the southwest block near Big Pine Mountain. The probable total absence of strata of Paleocene and early(?) Eocene age on the southwest block suggests that they were probably never present there, at least not in great thickness.

The juxtaposition of different rocks or rocks of different ages along this segment is difficult to account for by simple vertical movements. As indicated in figures 7 and 8 and in figure 1, this segment follows the old Sur-Nacimiento fault zone along which the crystalline basement complex of the Salinian block was juxtaposed against the Franciscan basement of the Coastal block, either before or during deposition of thick overlying Cretaceous and lower Tertiary sedimentary sequences. The Rinconada fault was active much later, after these strata and the middle Tertiary sedimentary sequence accumulated. These later movements may have been transcurrent, as discussed under "Regional Evidence of Large Strike-Slip Movement on the Rinconada-Reliz Fault Zone."

The only local evidence of strike-slip movement on this segment of the Rinconada fault is the fold pattern adjacent to and near it, especially on the southwest block (figs. 7, 8; Vedder and Brown, 1968, p. 245). The folds in this area trend slightly more westerly than does the fault, and some terminate against it. This pattern, distinct also along other nearly parallel high-angle faults, may be partly the effect of right-lateral drag movements along this fault in the underlying basement complex.

OTHER FAULTS NEAR AND POSSIBLY RELATED TO THE NACIMIENTO SEGMENT OF THE RINCONADA FAULT

The Sierra Madre Mountains were elevated between the Rinconada fault and two southwest-dipping thrust or reverse faults, the South Cuyama and Ozena faults (fig. 7), along the northeastern base of this mountain block. The block was thrust up or elevated along these two faults toward Cuyama Valley in Pleistocene time, and possibly earlier. The range may have been thrust up also on the Rinconada fault to the southwest, although it is not known whether this happened during Pleistocene time or earlier. The South Cuyama and Ozena faults dip toward the Rinconada fault and either splay from it at depth or branch from it near Garcia Mountain (fig. 8). The thrusting movement on these faults, as well as the folding of the thick sedimentary sequences of the mountain block, indicate that severe compression is involved in movements along the Rinconada fault.

The Stanley Mountain area west of the Rinconada fault (fig. 8) was in large part elevated on a fault (East Huasna fault of Hall and Corbató, 1967) just west of this mountain, probably in Pleistocene time. This fault is practically vertical. Movement on the East Huasna fault is up on the northeast and right lateral, as indicated by the northwestward bending of the west-trending rock units and syncline on the east block, nearly parallel to the fault.

The higher part of the La Panza Range was elevated on a northeast-dipping thrust or reverse fault, the La Panza fault (fig. 8), also in Pleistocene time. Although on the map this fault is nearly parallel to the Rinconada fault, it dips northeast away from that fault and is therefore probably unrelated, even though both may have been activated by the same regional stress. There are no offset canyons nor offset geologic contacts to indicate lateral movement on the La Panza fault, although Durham (1974, p. 71) suggested 7 or 8 km (4 or 5 mi) of right-lateral movement on its northwestern part (locally known as the Huer Huero fault, fig. 3*A*), because the contact of the middle Tertiary sequence on granitic basement is farther northwest on the southwest block than on the northeast block. However, this contact is exposed only on the northeast block and is concealed under the Paso Robles Formation on the southwest block within 2 km (1.2 mi) of the fault, and most if not all the apparent offset could be accounted for by the probable westerly strike of this concealed contact southwest of the fault.

The San Juan fault (fig. 8) is a nearly-vertical fault that probably splays southeastward on the west side of the San Andreas fault (figs. 3*B*, 4). Movement may be in large part right lateral, as suggested by the comparatively more easterly trend of the fold axes of the Caliente Range on the east side. This range was elevated by the squeezing up of the middle Tertiary sequence where it is tremendously thick to form several large southwestward-leaning anticlines on northeast-dipping thrust faults that splay eastward from the San Jaun fault (Dibblee, 1974a). These structures appear to be the effect of right-lateral drag movement on the San Juan fault and are probably related more to compressive right-lateral movements on the San Andreas fault than to those on the Rinconada fault.

Although the Red Hills (41 km or 25 mi east of Paso Robles) and the Caliente Range have been elevated northeast of the San Juan fault, little topographic relief is present on the fault. This condition, together with the slightly more easterly trend of the folds and thrust faults of the Caliente Range, suggests that movement on this fault is primarily right lateral. If so, a right slip of some 13 km (8 mi) is suggested by that much offset of the basal conglomerate and contact of the Upper Cretaceous and lower Tertiary marine sedimentary sequence with the crystalline basement along upper San Juan Creek (fig. 8), if this is not the result of relative vertical upward displacement of that sequence.

Schwade, Carlson, and O'Flynn (1958, p. 85) suggested that this contact may be laterally displaced as much as 37 km (23 mi) on this fault zone. Possible additional earlier transcurrent movement is suggested by the difference of the crystalline basement on opposite sides of the fault (fig. 8). Further evidence of strike-slip movement is suggested by the farther northwestward extent on the southwest side of this fault in Cuyama Valley of the Branch Canyon Sandstone that intertongues westward with the Monterey Shale (Dibblee, 1973, fig. 12).

The San Juan fault was active in late Cenozoic time, mostly after deposition of the Santa Margarita Formation and before that of the unconformably overlying Paso Robles Formation. It was recurrently active after deposition of the Paso Robles, but there is no indication of movements during Holocene time.

The Nacimiento segment of the Rinconada fault terminates southeastward against the Big Pine fault (figs. 1, 7), which is a nearly-vertical transverse fault with left-lateral movement (Hill and Dibblee, 1953; Vedder and others, 1974). As suggested by Vedder and Brown (1968, p. 254), the possible offset continuation of the Nacimiento segment may be the Pine Mountain fault (figs. 1, 7). If this fault was once part of the Rinconada fault, it has been displaced about 15 km (9 mi) eastward by that much left slip on the Big Pine fault since Pliocene(?) time. Other geologic features displaced in the same manner are (1) the synclinal structure of the lower Tertiary sedimentary sequence and (2) a distinctive facies within this sequence (Vedder and Brown, 1968; Vedder and others, 1974). The Pine Mountain fault (Jennings and Strand, 1969) is traceable for about 47 km (30 mi) east-southeastward from the Big Pine fault and is a major thrust or reverse fault dipping 33° to 50° northeast, along which the Pine Mountain Range was elevated in Pleistocene time. If the Rinconada and Pine Mountain faults were once continuous and later displaced out of line by the Big Pine fault, the Big Pine fault is younger, or mainly of Quaternary age.

RINCONADA FAULT (RINCONADA SEGMENT) FROM RINCONADA MINE TO PASO ROBLES

The San Luis Obispo folio was the first geologic map published that includes the Rinconada fault; no faults were shown on the map, but a fault (designated years later as the Rinconada fault) was shown on three cross sections and was discussed (Fairbanks, 1904, p. 8). The earliest mention of the Rinconada fault was by Reed (1933, p. 30), presumably from unpublished mapping by N. L. Taliaferro of the northwest-trending fault recognized earlier by Fairbanks (1904) near Santa Margarita. The first published map that shows it as Rinconada fault is the San Luis Obispo sheet of the Geologic Map of California (Jennings, 1959) on which it is about 40 km (26 mi) long. This fault is designated herein as the Rinconada or type segment of the Rinconada fault.

The geology along the Rinconada fault in the vicinity of Santa Margarita and Atascadero is as shown in figure 9. This is the segment along which the granitic basement of the Salinian block and Franciscan basement of the Coastal block are closest at the surface. The Nacimiento segment is continuous into this segment from the southeast.

The Rinconada segment is nowhere well exposed and is poorly expressed topographically. As along the Nacimiento segment, the terrain is generally higher on the northeast. There are no deviated nor offset stream channels, and the Rinconada segment appears to be inactive. However, at a place 5 km (3 mi) east of Atascadero, there is a small trenchlike feature nearly a kilometre (half a mile) long in alluvium that may have been formed by recent movement on this segment.

Near Paso Robles the Rinconada fault is concealed by alluvium deposited by the Salinas River, and so its position there can only be inferred. The Paso Robles Formation nearby is nearly unaffected. The two hot springs at Paso Robles are close to the inferred position of a possible fault that may extend beneath the alluvium as a possible north-trending offshoot of the Rinconada fault (fig. 10).

As shown in figure 8 and partly in figure 9, the pre-middle Tertiary rock units and their structures on op-

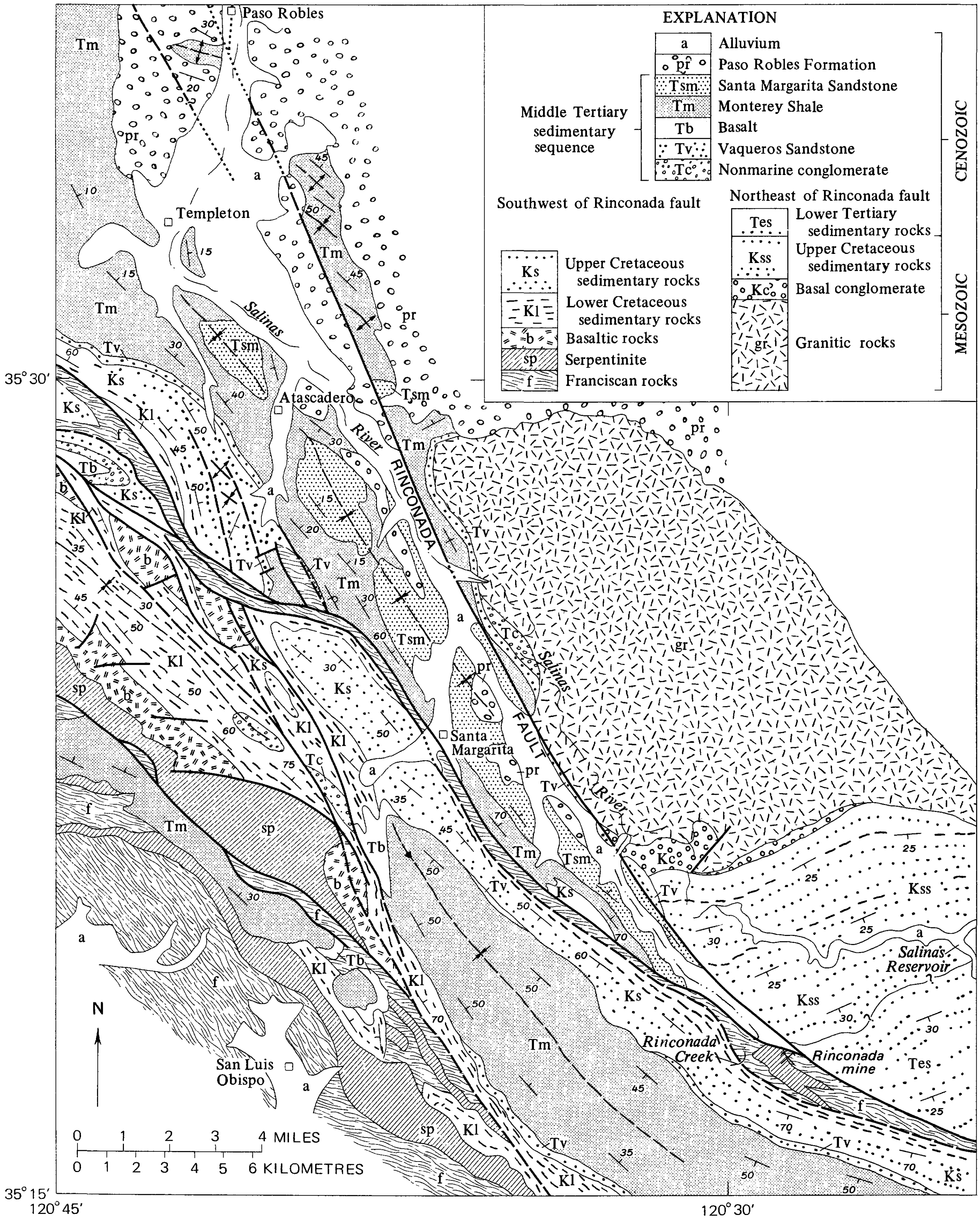

FIGURE 9.—Geology along and near the Rinconada fault (Rinconada segment) from the Rinconada mine to Paso Robles. Geology of parts of area west of Rinconada fault modified from Page (1972) and E. M. Hart (written commun., 1972).

posite sides of this segment of the Rinconada fault are vastly different. This condition indicates this fault was of great magnitude prior to middle Tertiary time. As shown thereon, the pre-middle Tertiary terrane on the east side is one of granite basement overlain unconformably by the very thick Upper Cretaceous and lower Tertiary marine sedimentary sequence that dips southerly and strikes west into the fault and is sharply truncated by it. In contrast, the terrane on the west side is one of Franciscan rocks, serpentine, basaltic rocks, and the Cretaceous marine sedimentary sequence, all severely compressed into structures that trend northwesterly nearly parallel to the Rinconada fault. The Franciscan rocks and serpentine are exposed extensively on the southwest side of the fault at the Rinconada mine, and as two very small slices on the fault 8 and 9.4 km (5 and 6 mi) northwest. All these rocks are close to granitic basement east of the fault. These are the only places along this fault where these contrasting basement rocks are so near each other at the surface, and so there this segment forms the local boundary between the Salinian and Coastal blocks.

The middle Tertiary sedimentary sequence, which is unconformable on all older rocks, is greatly involved in the severe deformation west of the fault. On the east side it is also intensely folded near the fault, even though it lies directly upon rigid granitic basement. If this deformation is the effect of movements on the fault, the fault was active after Miocene time. The Paso Robles Formation, which is unconformable on the Miocene and older rocks, is comparatively much less deformed, indicating comparatively little movement on this segment since deposition of the Paso Robles Formation.

Because of relations as shown in figure 9, it is difficult to determine the character and movement on this segment of the Rinconada fault. The nearly straight trace of this segment through hilly terrain indicates it to be vertical or nearly so. The somewhat higher terrain and relatively older rocks on the northeast side between the Rinconada mine and Templeton suggest relative upward displacement of that side, but southeast of the mine these conditions are reversed. The geologic relations as shown in figure 9 and just summarized cannot be accounted for by mere vertical displacements, especially for the pre-middle Tertiary rocks. These relations can probably be explained only by horizontal juxtaposition along the fault of areas once far apart, suggesting a large amount of strike-slip movement prior to middle Tertiary time and possibly a moderate amount since. If such movements happened, they must have been right lateral, as suggested by the following evidence: (1) More easterly trends of fold axes in all formations as compared with trend of fault, especially in the Monterey Shale adjacent to part of fault southeast of Paso Robles and their truncation by the fault, and (2) sharp truncation of the very thick west-striking south-dipping Upper Cretaceous and lower Tertiary sedimentary sequence and of the underlying granitic rocks by the fault.

Where are the displaced rocks mentioned in item 2 above, on the west side of the fault? In order to answer this question, it is necessary to go far to the northwest to find these rocks. (See section on "Regional Evidence of Large Strike-Slip Movement on the Rinconada-Reliz Fault Zone.")

RINCONADA FAULT (SAN MARCOS SEGMENT) FROM PASO ROBLES TO SAN ANTONIO RESERVOIR

Extensive pioneer mapping by Taliaferro (1943a, 1943b, 1944) and his students in the hills northwest of Paso Robles revealed a northwest-trending fault which he called the San Marcos thrust zone, after San Marcos Creek. It was later called the San Marcos fault (Kilkenny, 1948; Walrond and Gribi, 1963; Jennings, 1959; Page, 1970a). It is designated herein as the San Marcos segment of the Rinconada fault, because from my own mapping I conclude that it is nearly alined with and is probably continuous with the Rinconada segment to the southeast. The San Marcos segment extends from Paso Robles to the San Antonio Reservoir for a distance of about 23 km (15 mi). The geology along this segment, as I have mapped it (Dibblee, 1972b), is as shown in figure 10. This segment is continuous northwestward into that generally known as the Espinosa fault (Jennings, 1959).

The San Marcos segment is a complex zone of faults or strands as shown. Between Paso Robles and San Marcos Creek this segment is composed of one major vertical (?) fault, but northwestward from that creek it is composed generally of two major strands. In most places both are nearly vertical, but within 5 km (3 mi) northwest of San Marcos Creek both dip southwest at indeterminate angles; one strand is well exposed in San Marcos Creek where it dips about 50° southwest in Monterey Shale. Northwest of the Nacimiento River, the northeast strand appears to be vertical. Northwest of the San Antonio Dam, the southwest strand becomes the northeast-dipping San Antonio fault.

With the exception of the granitic basement on the northeast side between Paso Robles and San Marcos Creek, the San Marcos segment of the Rinconada fault at the surface is mainly within the middle Tertiary sedimentary sequence, with some involvement of the Paso Robles Formation. Along and near its strands the Monterey Shale is intensely folded and also severely shattered, brecciated, slickensided, and contorted.

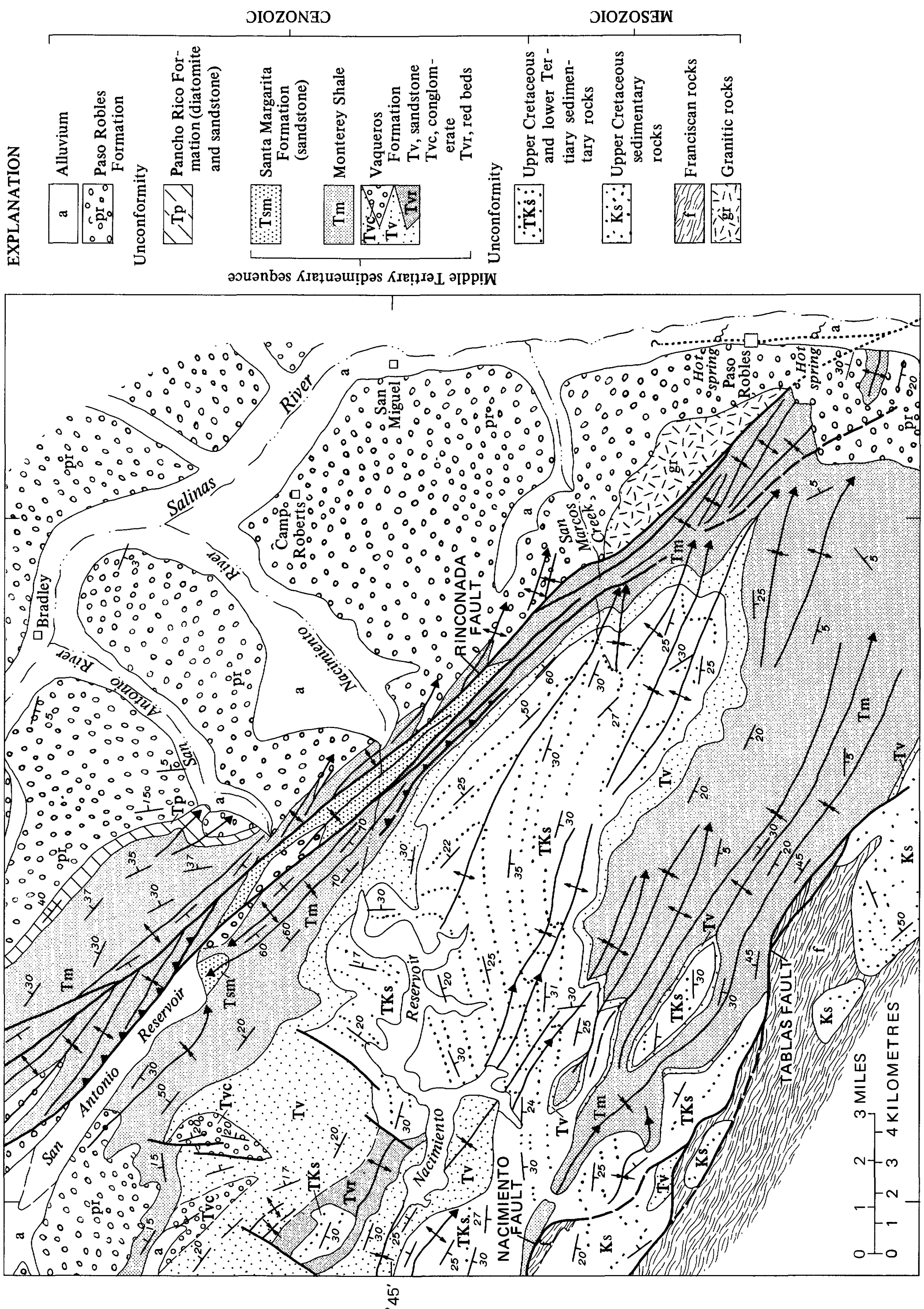

FIGURE 10.—Geology along and near the Rinconada fault (San Marcos segment) from Paso Robles to San Antonio Reservoir.

Evidence of the direction of relative vertical slip or movement on the San Marcos segment of the Rinconada fault is conflicting. Between Paso Robles and San Marcos Creek, as shown in figure 10, granitic basement exposed on the northeast side against the middle Tertiary sedimentary sequence on the southwest side indicates relative uplift of the northeast block. However, the southwest block is topographically higher. Northwest of San Marcos Creek, Miocene strata of the southwest block are in fault contact with the Paso Robles Formation on the topographically lower northeast block. These conditions indicate, if movements were vertical, that the earliest displacement since Miocene time was up on the northeast, then in late Pleistocene time, up on the southwest.

These suggested reversals of vertical displacement may be more apparent than real. Physiographic, structural, and stratigraphic evidences suggest that the dominant movement was strike slip, right lateral, as indicated in the following paragraphs.

Physiographic evidence of right-lateral movement, mainly on the northeast strand, is suggested by the southeastward deflection or partial deflection of the San Antonio and Nacimiento Rivers, San Marcos Creek, and several small intervening channels, where they cross the fault (fig. 11).

Structural evidence of right-lateral movement is suggested by the axial trends of numerous folds along and near the faults as shown in figure 10. A few axes are almost parallel to the faults, but most trend slightly more west than do the faults. Adjacent to the faults, these folds are numerous and tightly compressed, especially in the Monterey Shale. These conditions appear to be the effect of right-lateral drag movement along this fault segment, combined with severe compression.

A large amount of right-lateral displacement on the Rinconada fault is suggested by the presence west of the San Marcos segment of the thick Upper Cretaceous and lower Tertiary marine sedimentary sequence and absence of this sequence east of this segment. Several wells drilled for oil east of it enter granitic basement below the middle Tertiary sedimentary sequence. A well drilled west of it, on a large anticline in the Upper Cretaceous and lower Tertiary marine sedimentary sequence about 3 km (2 mi) southeast of the Nacimiento Reservoir (fig. 10), bottomed in that sequence at a depth of 1,585 m (5,200 ft). This thick sandy sequence may have been displaced from that sequence east of the Rinconada segment (fig. 9), either before or after deposition of the middle Tertiary sedimentary sequence, or in both times.

Post-Miocene lateral displacement is suggested by different stratigraphic relations on opposite sides of this fault segment, especially on the northeast strand. On the northeast side of that strand, a great thickness of the upper part of the Monterey Shale (upper Miocene) is overlain by diatomite of the Pancho Rico Formation, and both these units are overlain unconformably together by the thin marine sandstone of the Pancho Rico Formation (Pliocene) and by the Paso Robles Formation. On the southwest side, the lower part of the Monterey Shale (middle Miocene) is overlain by a thin unit of the upper part (upper Miocene), which in turn is overlain by the Santa Margarita Sandstone, and all these units are overlain unconformably by the Paso Robles Formation which is generally much less deformed than the Miocene units. These adjacent blocks must have been juxtaposed by right slip from areas once separated. This evidence is further discussed under "Regional Evidence of Large Strike-Slip Movement on the Rinconada-Reliz Fault Zone."

RINCONADA FAULT (ESPINOSA SEGMENT) FROM SAN ANTONIO RESERVOIR TO RELIZ CANYON

The San Marcos segment was extended northwestward from San Antonio Creek by Kilkenny (1948). Reconnaissance mapping by the author in the hills on the west side of the Salinas Valley in search of petroleum revealed the presence of a major fault zone alined between the San Marcos and Reliz faults. This was shown by Hill and Dibblee (1953, pl. 1; p. 454–455) as the Reliz Canyon–San Marcos fault, branching southward from the supposed King City fault and interpreted to be among "many important northwest-trending steep faults—parallel to the San Andreas—probably also characterized by right-lateral components of displacement."

On the geologic map of California the northern part (north of San Antonio Reservoir) of the San Marcos fault shown by Hill and Dibblee (1953, pl. 1) is shown as the Espinosa fault (fig. *3A*) by Jennings and Strand (1958) and Jennings (1959).

On a geologic map (scale 1:125,000) of this area compiled by Walrond and Gribi (1963) as well as on a subsurface map by Gribi (1963, p. 26) major northwest-trending faults designated as the Reliz, Espinosa, San Marcos, San Antonio and Jolon faults are shown. The first three mentioned are alined and coincide with the Reliz Canyon–San Marcos fault zone recognized independently by Hill and Dibblee (1953) and are alined with the Rinconada fault to the southeast. Gribi (1963, p. 23) stated that "the Reliz and Espinosa faults are nearly continuous" and "all folds abutting this fault demonstrate drag indicating marked right lateral movement."

The most extensive large-scale mapping to date of the geology of the hills from San Marcos Creek to Ar-

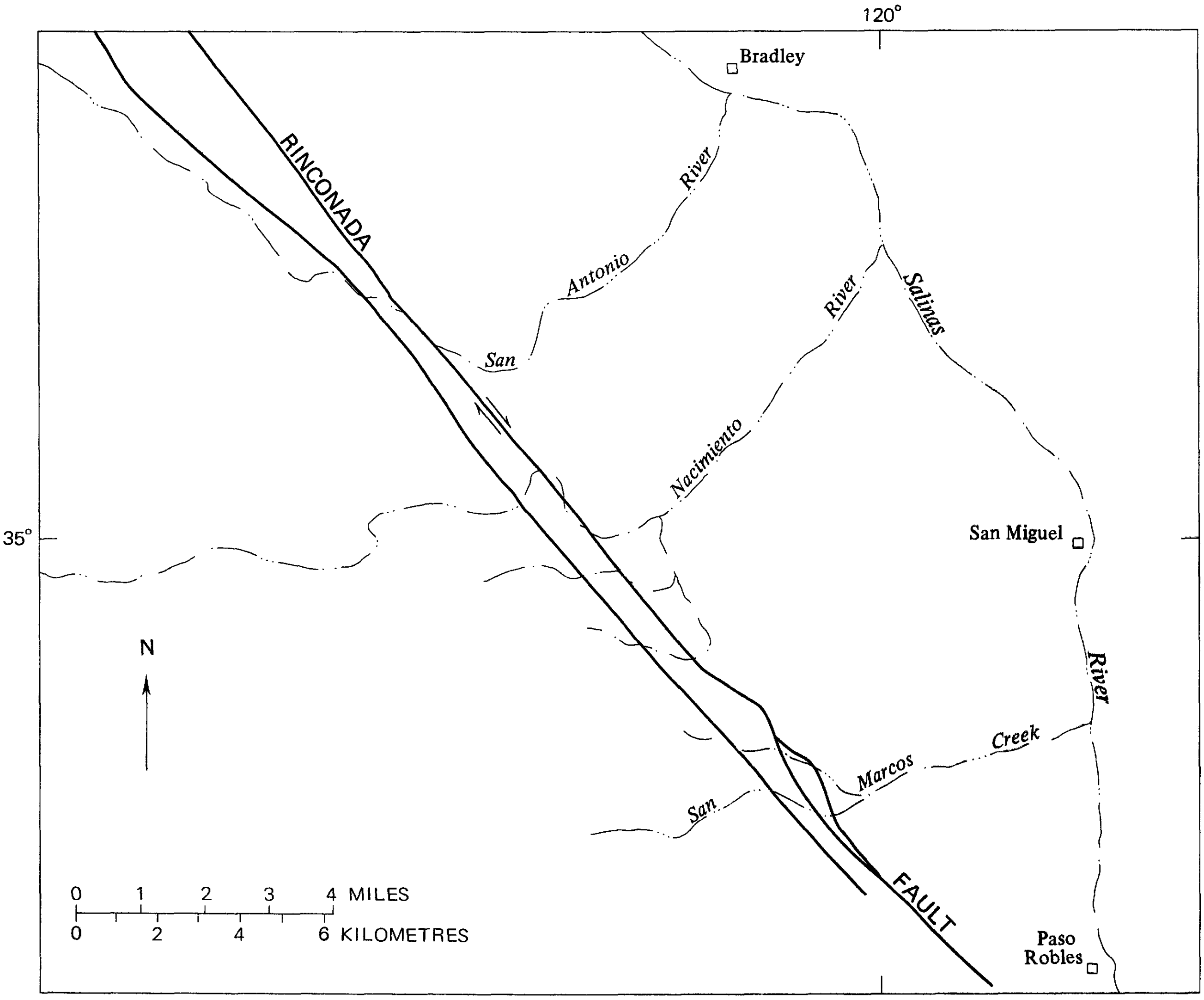

FIGURE 11.—Stream channels deflected possibly by right-lateral movement on the Rinconada fault (San Marcos segment) northwest of Paso Robles. See Bradley and Adelaida, U.S.G.S. 7½-minute quadrangles for topography.

royo Seco Canyon was by Durham (1963, 1966, 1968a, 1968b, 1970). He inferred faults along or near much of the Espinosa, San Antonio, and San Marcos faults mapped independently by Walrond and Gribi (1963), but he applied only the names San Marcos, San Antonio, and Jolon to parts of these. He also inferred numerous other vertical faults, forming a random pattern of intersecting dashed lines through these hills.

On the basis of field checking and additional mapping of the geology of these hills, I conclude that the Espinosa fault shown on the maps mentioned above is continuous with the Rinconada fault (San Marcos segment) to the southeast and thereby designate the Espinosa fault as the Espinosa segment of the Rinconada fault.

The geology of the Espinosa segment of the Rinconada fault is shown in figures 12 and 13. An arbitrary division between the Espinosa segment and the San Marcos segment to the southeast is designated at a point where a minor fault splays off northward east of San Antonio Reservoir (fig. 10). From that point the Espinosa segment extends northwest for 40 km (25 mi), then dies out at the surface in Monroe Canyon about 12 km (7 mi) west of King City.

The Espinosa segment of the Rinconada fault transects the length of the unnamed range of hills, sometimes called San Antonio Hills (Reed, 1933, p. 44; Kilkenny, 1948, p. 2261), between the Salinas and Lockwood Valleys (figs. 10, 12, 13). Along and northwest of San Antonio Reservoir (fig. 10) the southwest strand of the San Marcos segment becomes the San Antonio fault, a northeast-dipping reverse or thrust

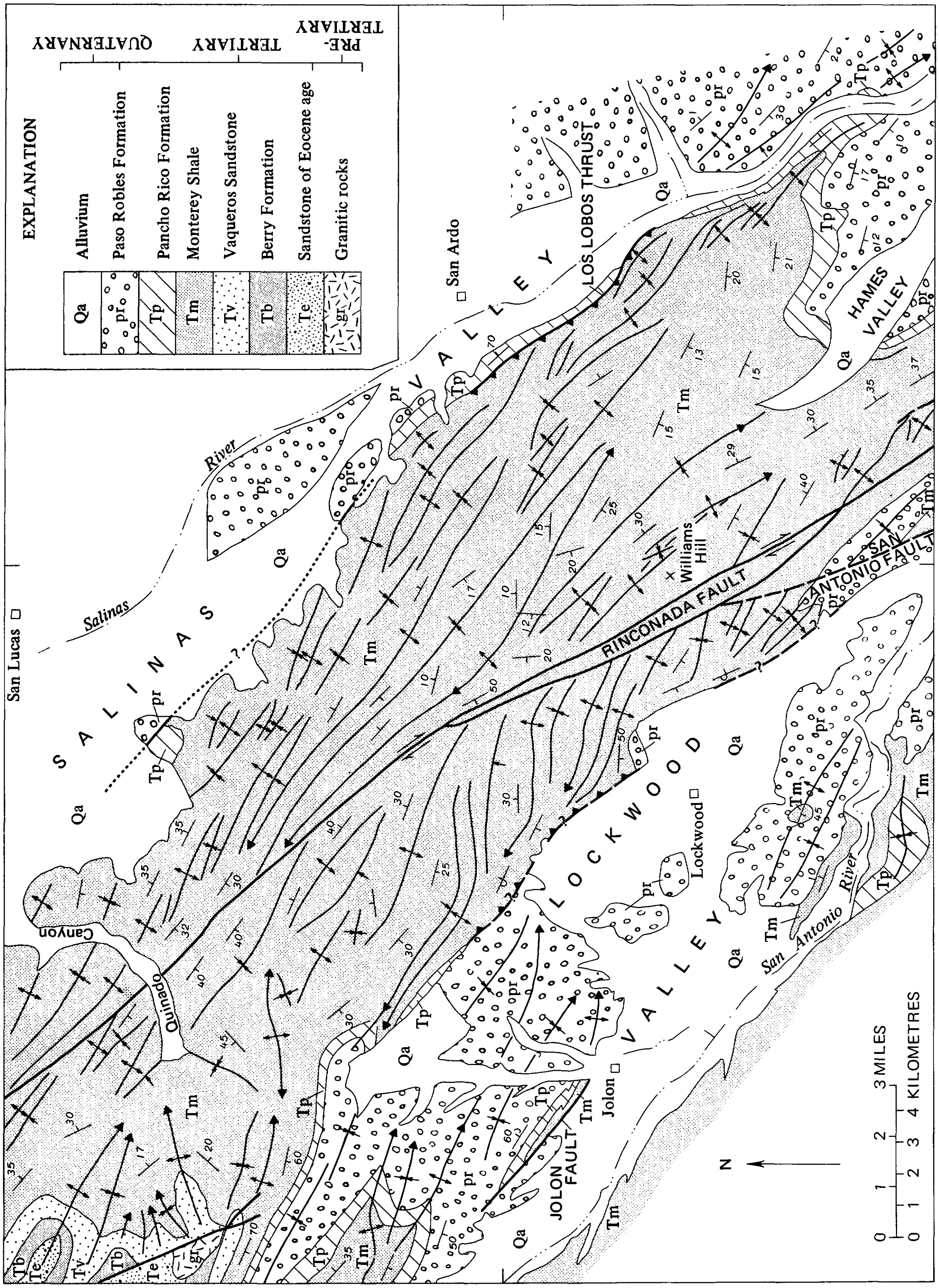

FIGURE 12.—Geology along and near the Rinconada fault (Espinosa segment) between Lockwood and Salinas Valleys.

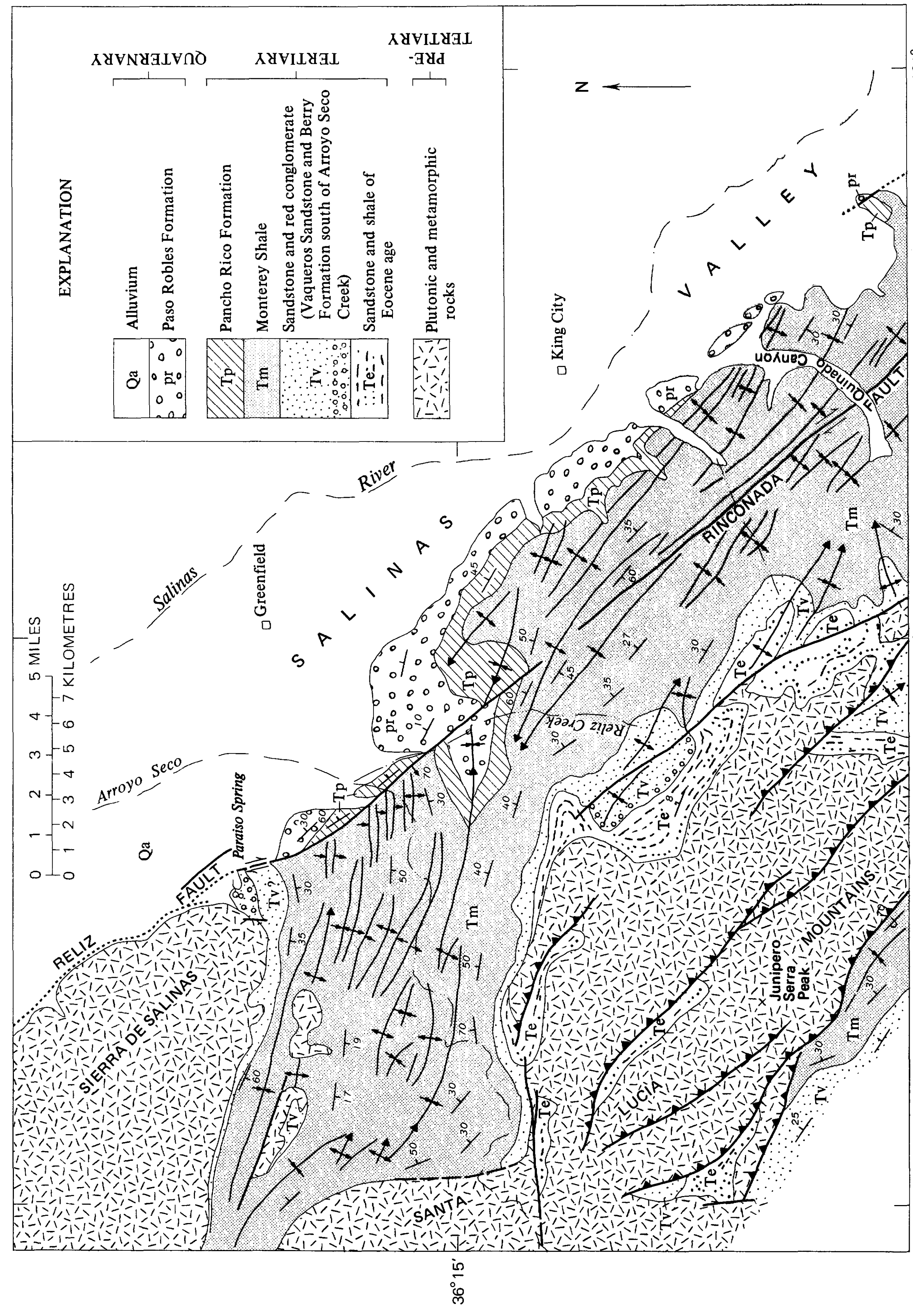

FIGURE 13.—Geology along and near the Rinconada fault (Espinosa segment) and Reliz fault, near King City and Greenfield. Faults near Junipero Serra Peak after Compton (1966a).

fault along which the Monterey Shale on the northeast was elevated against the Paso Robles Formation and older alluvium of Lockwood Valley on the southwest. This fault is traceable for about 19 km (12 mi) northwestward; then it eventually rejoins the southwest strand of the Espinosa segment (fig. 12).

With the exception of the San Antonio fault strand, the Espinosa segment of the Rinconada fault is entirely within the Monterey Shale at the surface, making it difficult to trace. Its course is marked by an alinement of canyons and low divides that forms a trenchlike notch through these hills, especially in the vicinity of Espinosa Canyon. The Monterey Shale along this notch is brecciated, crushed, and contorted.

Because the Espinosa segment is all within Monterey Shale, relative vertical displacements along this segment can be determined only by difference of elevations of the adjacent blocks. Southeastward from Espinosa Canyon, the northeast block is higher, reaching a high point at Williams Hill. Northwestward from that canyon to Quinado Canyon (fig. 12) the southwestern block is slightly higher, and beyond that there is no difference in elevation. These differences in relative elevation may reflect relative vertical displacements on the fault.

The presumed vertical displacements may be only apparent. At Espinosa Canyon and a few kilometres southeastward, several canyons that drain southwest across the fault and its southwest strand are deflected northwestward after crossing it, and northwest of that canyon for a few miles several northeast-draining canyons are deflected southeastward as shown in figure 14. This condition suggests southeastward movement of the northeast block relative to the southwest block, or right-lateral movement, in very late Quaternary time.

Throughout these hills the Cenozoic strata are deformed into numerous tight folds, not only adjacent to the Rinconada fault but along the margins of these hills as well. Indeed, the hills are in large part bounded on both sides either by a thrust fault dipping inward under the hills, or by a zone of upended or intensely folded strata (figs. 12, 13). The Los Lobos thrust south of San Ardo is verified by wells in and near the San Ardo oil field, and it dips southwest at low angles. This and other thrust faults dip toward the Espinosa segment, as do thrusts near other segments of the Rinconada fault to the southeast. These conditions suggest severe compressive movements associated with right-slip movements along the fault.

Structural evidence of right slip along the Espinosa segment of the Rinconada fault, as along the San Marcos segment, consists of the slightly more westerly trend of the folds in the Monterey Shale as compared with that of the fault (figs. 12, 13, 19). None of the folds cross the fault; those adjacent to it veer nearly parallel to it and terminate against or near it. Folding is especially intense between strands of this segment, including the San Antonio fault. This structural pattern must be the drag effect in the thick incompetent Monterey Shale of right-slip movement along the fault in the deeply underlying basement complex.

RELATIONSHIP OF RINCONADA FAULT TO JOLON AND RELATED FAULTS

Published geologic maps (Jennings, 1959; Walrond and Gribi, 1963; Page, 1970a) show the San Marcos fault dividing northwestward into three strands near the San Antonio River (fig. 3*A*). One of these is the San Antonio thrust fault already mentioned. The other is an inferred fault shown as the Jolon fault, projected northwest through Lockwood Valley via the San Antonio River, then through an isolated outcrop of Monterey Shale on the road 3 km (2 mi) south of Lockwood, to a fault traceable for 3 km (2 mi) along the southwest base of a low ridge northwest of Jolon, for a total distance of some 32 km (20 mi).

The only part of this supposed major fault that is mappable by direct field observations is that part within 3 km (2 mi) northwest of Jolon (fig. 12), along which the Monterey Shale on the northeast was displaced upward against the Paso Robles Formation on the southwest. Field evidence suggests that this is a minor northeast-dipping reverse fault that probably curves eastward just north of Jolon and dies out. Only this fault will be referred to as the Jolon fault in this report.

The inferred or projected 32 km (20 mi) segment of the Jolon fault through Lockwood Valley is not mappable by direct field observations. Other than the long straight course of part of the San Antonio River along which the fault is projected, no topographic indications of this fault have been observed on the ground or on aerial photographs. The only suggestion of such a fault is the isolated outcrop of Monterey Shale on the road by Tule Creek 3 km (2 mi) south of Lockwood that protrudes through the unconformably overlying Paso Robles Formation, which appears to be elevated anticlinally. There is no evidence of severe deformation along this projected fault, such as that along the entire course of the Rinconada fault. Deep well data in Lockwood Valley are insufficient to ascertain the existence of such a fault in the subsurface. The gravity data (Burch, 1971) neither affirm nor deny the existence of this supposed major fault projection.

Durham (1968a, p. 40) stated that "the Jolon fault is a major northwest-trending feature of the San Antonio River valley" but did not show it on his maps of that

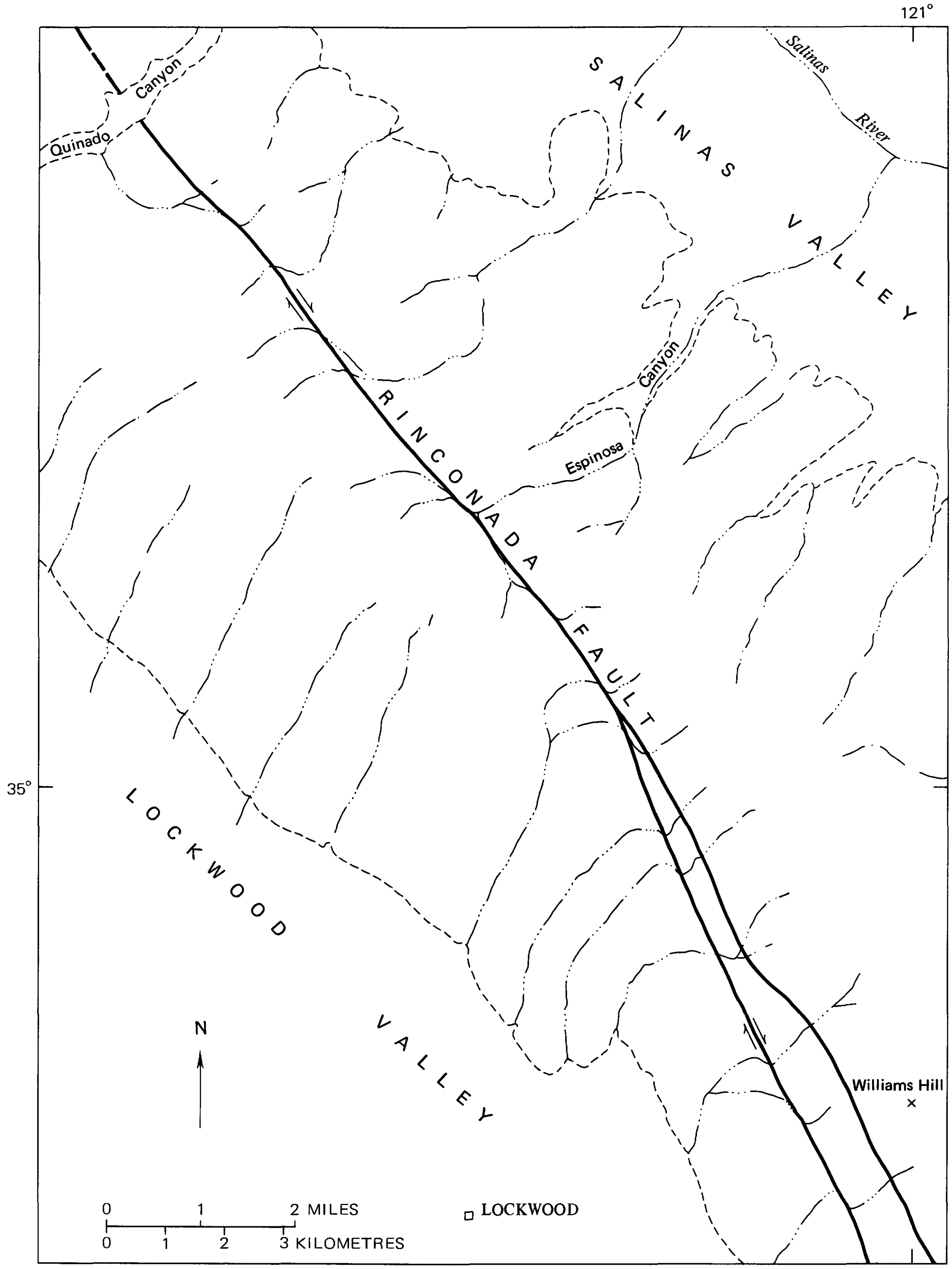

FIGURE 14.—Canyons deflected possibly by right-lateral movement of the Rinconada fault (Espinosa segment) near Lockwood. See Espinosa Canyon and Williams Hill U.S.G.S. 7½-minute quadrangles for topography.

valley (Durham, 1968a, pl. 1; 1965a, pls. 1, 2), although he showed a major fault there (unnamed) on a small-scale map (Durham, 1965b, p. D107). He cited geologic evidence of such a fault as follows (Durham, 1968a, p. 41): "In the San Antonio River Valley near Jolon, the Jolon fault forms the boundary between two distinct stratigraphic sections, one to the northeast in which the Vaqueros Formation lies directly on the pre-Tertiary basement complex, and one to the southwest in which the Vaqueros is preceded by a thick sequence of strata."

This conclusion is inferred from the presence of the "thick sequence of strata" (the Upper Cretaceous and lower Tertiary sedimentary sequence) exposed extensively below the Vaqueros Formation in the hills of the Nacimiento River area to the west and its total absence in all wells drilled to the basement complex in Lockwood Valley. This interpretation implies that the faulting is pre-Vaqueros. These areas are at least 6 km (4 mi) apart, and the pre-Vaqueros rocks are entirely concealed throughout the intervening area and Lockwood Valley. Therefore it is not possible to determine whether the Upper Cretaceous and lower Tertiary sedimentary sequence is in fault or depositional (unconformable) contact with the basement complex where concealed. In the exposed section north of the Nacimiento River, the relation is depositional, with the unconformable contact dipping south (fig. 21). This contact presumably extends south of east concealed under the Vaqueros Formation through the length of Lockwood Valley, possibly under the San Antonio River. If it does, no fault is required.

Part of the San Marcos segment of the Rinconada fault shown herein (fig. 10) is considered by Durham (1968a, p. 41) "to be the southeast extension of the Jolon fault," and accordingly, he showed the northeast strand as the Jolon fault (Durham, 1968a, pls. 1, 2, 3). Because of reasons given above, this interpretation is not accepted.

On his final regional geologic map of the southern Salinas Valley, Durham (1974, p. 58–64, pls. 1, 2) made the following interpretations concerning the Jolon-Rinconada fault: (1) It is a single major fault extending for more the 80 km (50 mi); (2) the Rinconada fault is the principal trace east of the Salinas River (southeast of Paso Robles), and the Jolon fault is the principal trace west of that river (northwest of Paso Robles); (3) the Jolon fault veers somewhat westward through the length of Lockwood Valley; (4) southeastward from Lockwood this fault line may be (as also suggested by Burch and Durham, 1970, p. B13) the boundary between granitic basement of the Salinian block and Franciscan basement of the southwest at depth; (5) the San Marcos fault is "a major secondary element" west of the southern part of the Jolon fault; (6) the Espinosa fault zone is a group of minor faults branching northwestward to the right from the Jolon fault where it crosses the San Antonio River; (7) his Jolon fault extends northwest under the northeast-dipping San Antonio fault and veers westward into Lockwood Valley; and (8) his Bee Rock fault is a low northeast-dipping thrust fault for about 20 km (13 mi) along the base of the Monterey Shale southwest of his San Marcos fault.

Many of these interpretations are questionable. The positions of the Rinconada fault and its northwestern extensions through the southeastern part of the Jolon fault and Espinosa fault segments are generally shown correctly, as well as that of the San Antonio fault (Durham, 1974, pl. 1). However, there is no evidence that the Jolon fault shown extends under the San Antonio fault into Lockwood Valley, and the segment shown through the hills south of Lockwood is not mappable.

I was unable to discover any reliable evidence, either in the field or in the literature, for the Jolon fault as a major fault diverging from the San Marcos fault segment into and through Lockwood Valley. Therefore no major fault is shown through that valley (figs. 3b, 4, 10, 12, 18, 21).

The northeast-dipping San Antonio fault is probably a westerly strand of the Rinconada fault, if it rejoins it to the northwest. The only part of the Bee Rock fault that can be verified in surface exposures is a 5-km (3-mi)-long segment along which tightly folded Monterey Shale (lower part) was thrust southwestward over the northeast-dipping basal clay shale unit of the Monterey Shale southeast of the San Antonio River.

Another major fault supposedly related to the Jolon fault has been inferred under the hills of folded Monterey Shale that border the southwest side of Lockwood Valley, largely from gravity geophysical data (Burch, 1971, p. B13; Durham, 1974, p. 59, their Sam Jones fault). The gravity pattern there is a strong gradient between the extensive gravity high of the Santa Lucia Mountains and the Nacimiento River area and the gravity low of Lockwood Valley and is attributed to a major fault (Burch, 1971, pl. 1, p. B13). However, I could not verify a major fault through these hills. The gravity gradient is parallel to and northeast of the great angular unconformity between the synclinally folded Upper Cretaceous and lower Tertiary sedimentary sequence and the overlying generally northeastward-dipping middle Tertiary sedimentary sequence (fig. 21) of relatively lower density.

From this relationship it is more probable that this gravity gradient is the expression of the northeastward dip of the middle Tertiary sequence, which may be steep at depth where the gradient is strong, into the structural basin that underlies much of Lockwood Valley. Although the exposed low-density Monterey Shale is apparently thin and much folded, the Vaqueros Sandstone dips northeastward and thickens under this shale, as seen in exposures further southeast (fig. 21). This relation, together with the presence of a thick fill of valley sediments under Lockwood Valley, may accentuate the gravity gradient.

GEOPHYSICAL EXPRESSION OF THE RINCONADA FAULT

The Rinconada, San Marcos, and most of the Espinosa segments of the Rinconada fault are strongly expressed by the patterns of gravity and magnetism, as shown by Burch (1971), Burch and Durham (1970), and Hanna (1970), which strongly suggest continuity of this fault alinement at depth. Their gravity maps show that the extensive granitic exposure east of Santa Margarita (fig. 9) and the small one northwest of Paso Robles (fig. 10), both on the northeast side of the Rinconada fault, are expressed as moderate gravity highs and both are separated by a strong gravity gradient along and parallel to the fault from weak gravity lows that express a shallow trough of low-density Cenozoic sedimentary deposits on the southwest side of the fault. The aeromagnetic map (Hanna, 1970) shows a nearly similar expression, of which the two granitic exposures on the northeast side of the fault are expressed as very strong magnetic highs, and both are separated by a strong magnetic gradient along and parallel to the fault from magnetic lows with very little magnetic relief on the southwest side of the fault, owing to the comparative low magnetism of the Cenozoic sedimentary rocks there.

The granitic rock of the small exposure northwest of Paso Robles is indicated by both the gravity and magnetic data (Burch and Durham, 1970, pl. 1; Hanna, 1970, fig. 2) to extend about 3 km (2 mi) southeastward under the Paso Robles Formation, probably to the north-trending fault questionably inferred to pass through the two hot springs in Paso Robles.

Northwestward from San Marcos Creek, the gravity variations become reversed along the Rinconada fault, as shown by Burch and Durham (1970, pl. 1). This strong gravity high produced by the granitic mass exposed south of this creek gives way northwestward to a large gravity low on the northeast side of the fault and south of San Ardo (figs. 10, 18) that apparently expresses a structural basin in which the middle Tertiary sedimentary sequence is more than 3,048 m (10,000 ft) thick. This gravity low is bounded along the Rinconada fault by a steep gradient to an area of relatively higher gravity under eastern Lockwood Valley on the southwest side of the fault. This gravity feature (Lockwood high of Durham, 1974, pl. 3), which has little gravity relief, is the expression of a comparatively thin middle Tertiary sedimentary sequence on granitic basement. The gravity low northeast of the fault is also a magnetic low and is adjacent to a magnetic pattern of almost no relief on the southwest side (Hanna, 1970, fig. 2).

RELIZ FAULT

Southwest of Greenfield (figs. 2, 3*B*, 13) another major fault probably continuous for some 56 km (35 mi) is directly alined northwest of the Rinconada fault. As explained in the following paragraphs, the northern part of this fault has been designated as part of the King City fault and the southern part as the Reliz fault.

KING CITY FAULT

The so-called King City fault has been interpreted in various ways. It was first mentioned by Clark (1929, p. 109–110). He did not define it specifically but showed it on a map as extending southeastward from Monterey Bay along the southwest margin of Salinas Valley past King City, Bradley, and beyond to intersect the San Andreas fault in the Carrizo Plain. It was one of many extensive northwest-trending faults that he hypothesized to explain his fault-block theory of the origin of the Coast Ranges. Reed (1933, p. 43–44) also applied the name King City to his inferred concealed fault. He concluded that southeastward from the base of Sierra de Salinas this fault is largely theoretical, although he indicated there is fair evidence that it may extend as far as Bradley and possibly to San Miguel.

Taliaferro (1943a, p. 158) stated:

"Physiographic evidence for the King City fault is the steep, straight eastern front of the Sierra de Salinas which attains an elevation of over 3,800 feet above the Salinas Valley within 2 miles, and which is cut by sharp steep-walled high-gradient canyons. Alluvial fans, formed at the mouths of these canyons, have coalesced into a continuous apron along the range front, burying practically all direct evidence of faulting."

Concerning the southward extension (later called the Reliz fault) of this fault, he stated (p. 159):

"The Sierra de Salinas and its wide alluvial apron end just north of Arroyo Seco, and a mile east of Paraiso Springs a fault emerges beneath the alluvial apron. This trends due south for about 2 miles and then turns to the southeast, crossing both Arroyo Seco and Reliz Canyon and dying out in Miocene sediments.—This is thought to be a branch of the King City fault, although it may be its southern end.—The King City fault may extend to the southeast along the edge of the valley either as a fault in the bedrock or as a zone of sharp flexing in the Tertiary sediments ***. There is no surface evidence *** that the King City fault extends as far as King City."

Kilkenny (1948, p. 2264–2266) considered the King

City fault to be a zone of southwest-dipping faults through the Salinas Valley, separating the northeastern block, in which the basement surface is shallow and the Miocene sequence is either very thin or absent, from the southwestern block, in which the basement surface is very deep and overlain by a thick Miocene sequence. Kilkenny (1948, p. 2266) concluded that

"the King City fault system is a definitely established feature extending from the Sierra de Salinas to Bradley along the west side of the Salinas River; there were two periods of faulting along the King City line. The first, in Eocene time, created the scarp which underwent periodic rejuvenation in Miocene time; the second, in Pliocene and Pleistocene time, was of a thrust nature in the opposite direction, with some lateral movement in contrast to the early normal faulting and located along the same trend, but not necessarily coincidental with it."

Schwade, Carlson, and O'Flynn (1958, p. 86, fig. 4) accepted Kilkenny's interpretation and inferred the King City fault to extend southeastward via the La Panza fault to the Cuyama Valley.

The numerous wells drilled to develop the San Ardo oil field since its discovery in 1947, and many others drilled in and near the Salinas Valley, provided much data on the subsurface geology of this area, particularly in relation to the King City fault. There is no evidence from the well data of a single present-day fault of mainly vertical movement under this valley southeastward from the base of Sierra de Salinas. Instead, the basement surface slopes southwestward, under this valley, in places rather abruptly, from the Gabilan mesa or shelf to a deeply subsided basin filled with a thick middle Tertiary sedimentary sequence.

This slope trend, formerly interpreted by Kilkenny (1948, p. 2264–2266) as the King City fault, was reinterpreted by Gribi (1963, p. 17, 23) from the well data as the King City hinge line, along which a great thickness of incompetent Monterey Shale abuts northeastward against the rigid basement, has been folded against it by compressive stress, then thrust toward the basement buttress. Gribi (1963) cited as an outstanding example the Los Lobos fault along the foothills west of San Ardo for about 17 km (10 mi) northwestward. However, I suggest that this fault may be related to the Rinconada fault (Espinosa segment) if it splays from it at depth (fig. 18). Gribi (1963) suggested that the King City hinge line may have originated as a basement fault.

The so-called King City fault southeastward from the Sierra de Salinas to Bradley is now generally considered nonexistent and is not shown in the Salinas Valley on geologic maps compiled by Jennings and Strand (1959), Walrond and Gribi (1963), Walrond, Thorup, Gribi, and Rogers (1967), Martin and Emery (1967), nor on maps and sections by Durham (1963, 1964, 1965b, 1966, 1970), although it is mentioned by him (1970, p. 24), nor Dibblee (1971), and none of these authors applied this name to any fault shown.

Gribi (1967, p. 91) and Walrond, Thorup, Gribi, and Rogers (1967) interpreted the fault formerly called the King City fault along the base of Sierra de Salinas as continuous with that mapped as the Reliz thrust by Schombel (1943, p. 462) and designated the combined fault as the Reliz fault. This designation is accepted, as shown in figures *3B*, 4, 13, and 15, even though Jennings (1973) applied the name King City fault to the part along the base of Sierra de Salinas.

RELIZ FAULT IN ARROYO SECO AREA

The Reliz fault of the Arroyo Seco area was defined by Nickell (1931) and Schombel (1943). The geology along this part is as shown in figure 13. This part is considered to be the southeastern segment of the major concealed fault along the base of Sierra de Salinas. The Reliz fault is directly alined with the Rinconada fault to the southeast but is separated from it at the surface by a gap of only about 3 km (2 mi) in Monroe Canyon west of King City.

The Reliz fault is well exposed on the west side of Reliz Canyon and on the north bank of Arroyo Seco (Durham, 1970, p. 25). In both places the fault dips about 70° southwest. With the exception of the syncline across Reliz Canyon, the southwest block is elevated to juxtapose tightly folded Monterey Shale against northeast-dipping Pancho Rico and Paso Robles Formations of the northeast block (fig. 13). Vertical displacement increases northward as successively lower (older) Tertiary units on the southwest side are elevated against the Paso Robles Formation on the northeast side.

A right-lateral component of movement on this segment of the Reliz fault is suggested by the pattern of east-trending fold axes in the Tertiary strata on the southwest side of the fault. The large syncline across Reliz Canyon is displaced slightly right laterally, but the folds in the Monterey Shale to the northwest are terminated against the fault (fig. 13).

The Reliz fault was active primarily after deposition of the Paso Robles Formation, for this formation as well as the underlying strata are truncated by and tilted up by the fault. It is considered presently inactive because there is no indication of movement after deposition of the older alluvium and alluvial fans that cover this segment of the fault. However, 3 km (2 mi) northeast of Paraiso Hot Springs or 10 km (6 mi) west of Greenfield and 1.6 km (1 mi) northeast of the Reliz fault, an old alluvial fan is broken by a small southwest-facing scarp that was undoubtedly formed by faulting.

Paraiso Hot Springs (fig. 13) issue from basal red beds of the middle Tertiary sedimentary sequence in contact with granitic basement just west of the Reliz fault. The hot water presumably rises along or near the fault and breaks through just west of it, possibly on a subsidiary fracture.

RELIZ FAULT AT BASE OF SIERRA DE SALINAS

Near Paraiso Hot Springs the Reliz fault is concealed by alluvial fans. Farther northwest, the base of the steep northeast slope of Sierra de Salinas is undoubtably underlain by a major fault, as postulated by Clark (1929), Reed (1933), Taliaferro (1943a), and Kilkenny (1948), and designated by them as the King City fault. This major fault is considered to be part of the Reliz fault (Walrond and Gribi, 1963; figs. 13, 15 herein).

The Sierra de Salinas is eroded from pre-Tertiary basement complex elevated on the southwest side of this fault. The base of this steep mountain front is moderately straight for a distance of nearly 12 km (20 mi), but the fault trace is almost entirely covered by the upper margins of the northeast-sloping dissected Pleistocene coalescent alluvial fans, some of which extend into canyons of this range. However, about 8 km (5 mi) northwest of Paraiso Hot Springs the alluvial fans have been eroded through to expose the unconformably underlying Paso Rboles Formation on the northeast side of the fault.

Upward vertical displacement of the Sierra de Salinas block on the Reliz fault relative to the valley block on the northeast must be many hundreds of metres, equal to the depth to the top of the buried surface of the basement complex under the valley block adjacent to the fault, plus the present altitude of Sierra de Salinas, plus the amount of basement complex above this altitude removed by erosion. This displacement may be as much as 3,048 m (10,000 ft) or more. Several deep wells drilled for oil in the valley area indicate that the buried surface of the basement complex slopes southwest from its exposures in the Gabilan Range toward the base of Sierra de Salinas. The position of the "trough line" of this buried surface is undetermined but is probably close to, if not at, the Reliz fault. Owing to the concealment of the Reliz fault along the base of Sierra de Salinas, the horizontal component of movement on this segment is not known.

A northeast-southwest gravity profile (Fairborn, 1963) across Salinas Valley about 9 km (6 mi) southeast of Salinas indicates that the buried surface of the basement complex slopes about 10° southwest under the valley from exposures at its northeast margin, to a depth of about 2,438 m (8,000 ft) below sea level at its southwest margin adjacent to the Sierra de Salinas where basement complex rises as high as 610 m (2,000 ft) above sea level. The steep gravity gradient near the mountain front indicates the probable existence of the Reliz (King City) fault with a possible vertical displacement of 3,048 m (10,000 ft) at this line.

Farther northwest, another northeast-southwest gravity profile (Sieck, 1964) across Salinas Valley about 1.3 km (1 mi) northwest of Salinas indicates that the buried basement surface likewise slopes southwestward to a low point of about 1,890 m (3,700 ft) at the southwest margin of the valley, either on a fault or a possible steep northeast flank of an arched basement surface. If the latter is so, the Reliz fault dies out northwestward near this gravity profile line.

The direction and angle of dip of Reliz fault along the base of Sierra de Salinas are not known but are suspected to be southwestward and steep judging from the 70° SW. dip of the part exposed in the Arroyo Seco area.

The alluvial fans that cover the Reliz fault are not broken by the fault, which indicates that it was not active since they were deposited. However, in one small area about 14 km (9 mi) southeast of Salinas there are several northeast-facing scarps in the fans parallel to the fault. These appear to be scarps produced by faulting, but they are more likely former stream-cut banks of the Salinas River.

Near the north end of Sierra de Salinas the Reliz fault splays into several faults, which presumably die out northwestward (fig. 15). Accordingly, the basement complex elevated on these faults becomes concealed under the Cenozoic sediments that flatten northwestward toward Monterey Bay.

POSSIBLE NORTHWESTWARD EXTENSION OF THE RELIZ FAULT

Martin and Emery (1967, fig. 6, p. 2302) postulated that the Reliz fault extends northwestward across Monterey Bay via their Gabilan fault to join the San Gregorio fault (of Branner and others, 1909), with a branch extending northwest to the Ben Lomond fault northwest of Santa Cruz. Ross and Brabb (1973) also suggested that their King City fault may extend across Monterey Bay to join the San Gregorio fault onshore northwest of Santa Cruz, largely on the basis of possible differences in types of plutonic basement rocks on opposite sides of this postulated extension. However, there are no surface indications onshore there of this extension (Branner and others, 1909, p. 9; Brabb, 1970; Clark, 1970; fieldwork by myself in 1948–49).

An acoustical survey of Monterey Bay by Greene (1970) and Greene, Lee, McCullock, and Brabb (1973) showed evidence of several parallel discontinuous local northwest-trending faults and small folds in the Monterey Shale farther west, just north of Monterey (fig.

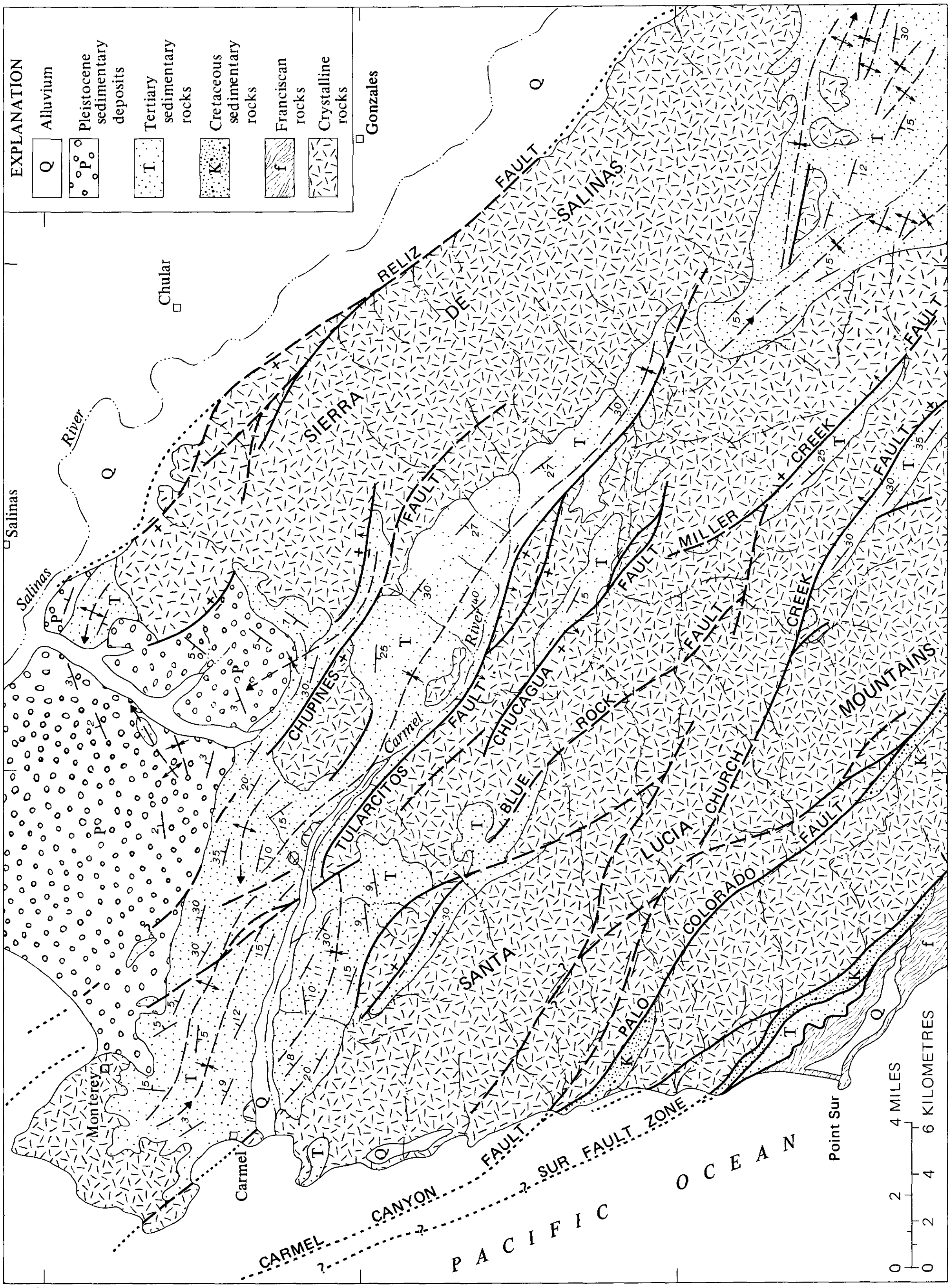

FIGURE 15.—Geology of the northern Santa Lucia Mountains, a segment of the Salinian block elevated on the Reliz fault and many other parallel faults.

22), but none in the bay area underlain by Pliocene and Pleistocene sediments through which the Reliz (or King City) fault has been projected.

REGIONAL EVIDENCE OF LARGE STRIKE-SLIP MOVEMENT ON THE RINCONADA-RELIZ FAULT ZONE

From the data recorded I concluded that movement on the Rinconada fault was predominantly strike slip by which the terrane to the southwest has moved northwestward relative to that on the northeast, with local or apparent relative vertical displacements, and that movement on the Reliz fault was probably oblique slip with the southwestern block elevated and displaced northwestward relative to the northeast block. Right-slip movement is strongly suggested by the severe deformation of the sedimentary rocks into folds with axes that persistently trend slightly more east-west than the faults along nearly the entire course of the Rinconada fault and the part of the Reliz fault that transects those rocks.

MOVEMENTS IN QUATERNARY TIME

There are no indications that the Rinconada and Reliz faults are active presently or were during Holocene time. Evidence of the inferred Holocene movement on the Rinconada fault north of Santa Margarita is slight and inconclusive. Deflection of canyons, possibly by right-lateral movement on the San Marcos and Espinosa segments of this fault, as mentioned, may have happened in very late Pleistocene time, just prior to Holocene time, because there are no breaks in the alluvium. At the west base of Williams Hill there is suggestive evidence that the Monterey Shale was elevated along the east strand of this segment against older alluvium to the southwest. Elsewhere in this area both strands are in places covered by this alluvium.

The Paso Robles Formation, primarily of Pleistocene age, is the youngest formation definitely involved in displacements and deformation along both the Rinconada and Reliz faults. Therefore these faults were active in late Pleistocene time. Along the Rinconada fault, vertical displacements that involve this formation are not large, generally less than a few hundred metres (1,000 ft). Along the Reliz fault north of Arroyo Seco they are greater. The amount of lateral displacement of this formation is not measurable.

MOVEMENTS IN PLIOCENE TIME

The unconformable relation of the Paso Robles Formation (and of the Pliocene upper sandstone unit of the Pancho Rico Formation where present) to the more severely deformed Miocene formations along and near the Rinconada fault suggests that this fault was strongly active in Pliocene time.

A large amount of lateral displacement since early Pliocene time is suggested on the San Marcos segment by differences in the Miocene and Pliocene stratigraphy on opposite sides of that segment. Durham (1965b) pointed out that the northernmost extent of the Santa Margarita Formation and southernmost extent of the Pancho Rico Formation nearly coincide and that both have been displaced about 18 km (11 mi) by right-slip movement on an undesignated northwest-trending fault.

This interpretation of that amount of right-lateral movement is accepted herein, but it applies to the San Marcos segment of the Rinconada fault, as shown in figure 16. On the northeast side of this fault, logs of exploratory wells drilled for oil or gas indicate that the Pancho Rico Formation extends far south of the northern limits of the Santa Margarita Formation. From these relations (fig. 16) it is probable that the San Marcos segment, if not adjacent segments, of the Rinconada fault were active since early Pliocene time with right-lateral movement that amounted to as much as 18 km (11mi). Most of this movement probably preceded deposition of the Paso Robles Formation and possibly the upper sandstone unit of the Pancho Rico Formation.

Additional evidence of right-lateral displacement on the Rinconada fault since deposition of the Monterey Shale is suggested by the areal extent farther northwest of the thick upper part of the Monterey Shale. The absence of the Santa Margarita Sandstone, overlying the Monterey Shale, on the west side of the fault also suggests this displacement.

MOVEMENTS SINCE EARLY MIOCENE TIME

The occurrence of the basal terrestrial unit of the middle Tertiary sedimentary sequence farther northwest on the west side of the Rinconada fault than on the east side could be the result of right-lateral displacement on the Rinconada fault (see "Rock Units"). More data on the subsurface extent of this unit are needed to test this hypothesis.

At Harris Valley about 3 km (2 mi) west of San Antonio Reservoir west of the Rinconada fault, the sandstone of the upper part of the Vaqueros Formation contains several thick lenses of conglomerate composed of unsorted cobbles and boulders almost entirely of granitic detritus (fig. 10). These lenses pinch out southwestward, and their northeastward extent is concealed. They must have been derived from a granitic terrane, despite the fact that the exposed Vaqueros Formation throughout this area is underlain by the

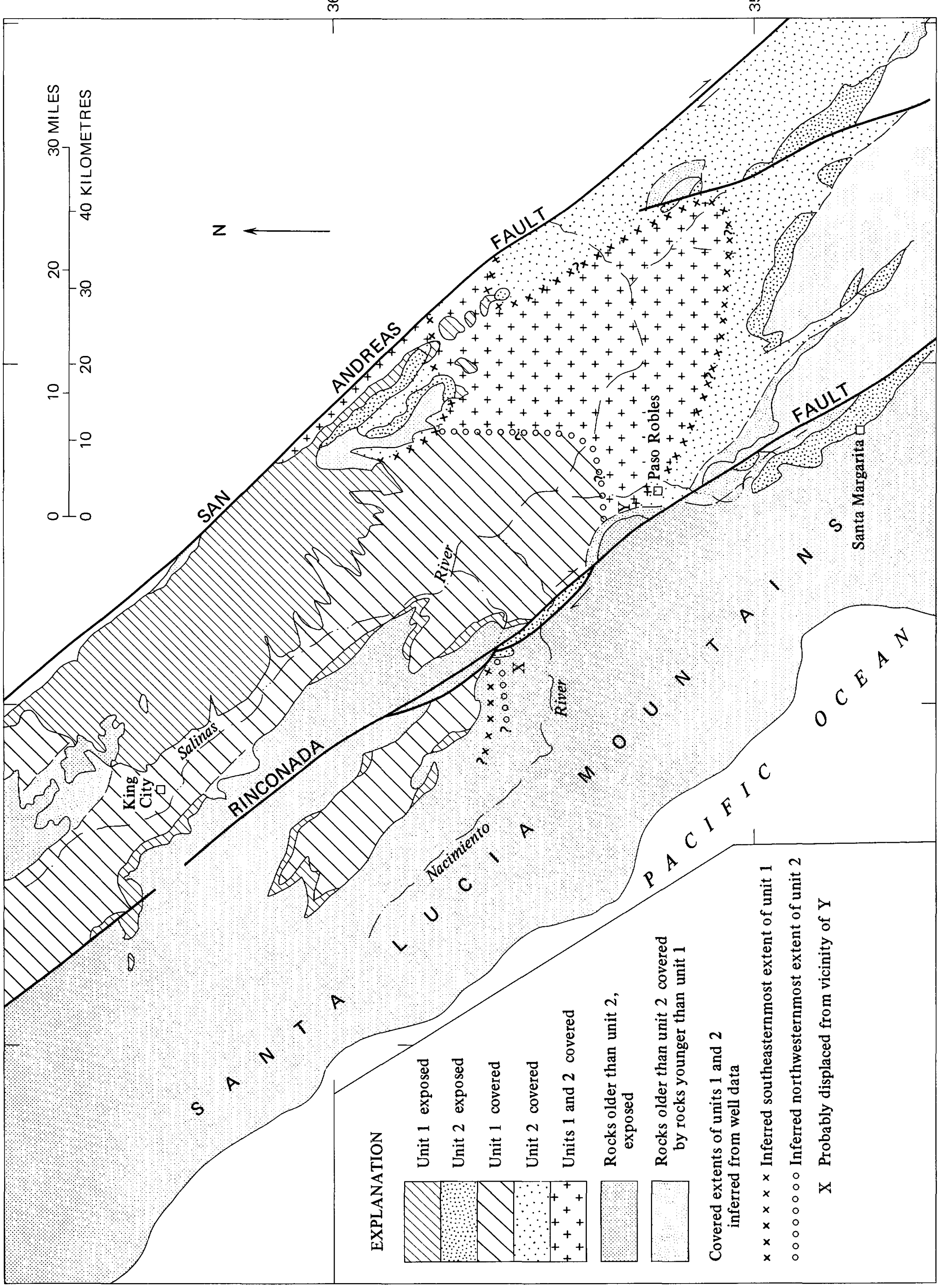

FIGURE 16.—Inferred displacement of lower Pliocene (unit 1, Pancho Rico Formation) and upper Miocene (unit 2, Santa Margarita Formation) by right-lateral strike-slip movement on the Rinconada fault (in part modified after Durham, 1965b).

thick Upper Cretaceous and lower Tertiary marine sedimentary sequence exposed to the west and south. The granitic source area must have been to the northeast, presumably across the Rinconada fault.

According to D. C. Ross (oral commun., 1974) the granitic detritus is subporphyritic granodiorite-quartz monzonite similar to that exposed on the east side of the Rinconada fault northwest of Paso Robles (fig. 10) and exposed extensively in the La Panza Mountain area. This granitic rock may underlie a large part of the Salinas Valley at least as far northwest as San Ardo; therefore, the granitic source area of these clasts could have been anywhere between the La Panza Range and San Ardo northeast of the Rinconada fault. However, the source must have been an area that was undergoing erosion when the Vaqueros Formation was being deposited or an area where this granitic basement is overlain by sediments younger than the Vaqueros. Such an area may be the exposure northwest of Paso Robles, which is overlain by the Paso Robles Formation. If this was the source area of the granitic clasts, it has been shifted some 23 km (15 mi) southeastward on the Rinconada fault since early Miocene time. Another possible source is the large granitic exposure of the La Panza Range area near Santa Margarita, on which the Vaqueros is very thin or locally absent. If this were the source, it has been shifted as much as 56 km (35 mi) southeastward on the Rinconada fault since early Miocene time.

MOVEMENTS IN OLIGOCENE(?) TIME

Movement on the Rinconada fault before deposition of the middle Tertiary sedimentary sequence is suggested from the possibly displaced areal extent of the very thick Upper Cretaceous and lower Tertiary sedimentary sequence that overlies the crystalline basement complex of the Salinian block. As shown in figure 4, and as discussed previously, on the southwest side of the fault this sequence extends as far north as the Nacimiento River area, whereas on the northeast side, it extends no farther north than the La Panza and perhaps the Caliente Range. Deep wells drilled for oil or gas throughout Salinas Valley north of La Panza Range and in the Carrizo Plain enter the crystalline basement directly below the middle Tertiary sedimentary sequence.

These conditions suggest that the basement complex and the overlying thick southward-dipping sedimentary sequence may have been displaced by a large amount of right-slip movement on the Rinconada fault, just prior to or possibly during or after Oligocene time. It is also possible that this could have resulted from relative upward vertical displacement of the northeast block of the fault prior to Oligocene time. However, the granitic basement and the overlying thick sedimentary sequence so extensively exposed in the vicinity of the La Panza Range east of parts of the Nacimiento and Rinconada segments of this fault are abruptly truncated by the fault and have no counterparts directly across it (figs. 8, 9). Instead, the pre-Oligocene rocks exposed west of these segments are Franciscan rocks, overlain by a relatively thin sequence of Cretaceous strata structurally unlike the sequence east of the fault. These conditions cannot be accounted for by vertical displacement, especially if this fault is nearly vertical. The only explanation seems to be that the opposing blocks were juxtaposed by lateral movement along the fault from areas originally far apart.

The westward extensions of the granitic basement complex and overlying thick Upper Cretaceous and lower Tertiary sedimentary sequence of the La Panza Range area on the east side of the Rinconada fault (figs. 8, 9) are probably the same as the granitic and metamorphic basement complex and the overlying thick Upper Cretaceous and lower Tertiary sedimentary sequence exposed in the San Marcos Creek–Nacimiento River area west of the San Marcos and Espinosa segments of the Rinconada fault (figs. 10, 17). Supporting evidence is that in both areas the sedimentary sequence is lithologically identical, has a similar basal cobble conglomerate locally, and dips generally southward off the basement complex into a synclinal structure. All these features seem to be displaced along the fault as much as 60 km (38 mi), suggesting that much right-lateral movement on the Rinconada fault since early Tertiary time. Schwade, Carlson, and O'Flynn (1958, p. 85, fig. 4) recognized evidence of displacement of this magnitude when they concluded that the contact of Cretaceous strata with the granitic basement of the Salinian block exposed in the northern Santa Lucia Mountains and in the La Panza Range was laterally displaced 72 km (45 mi) on the Rinconada fault (which they designated as the San Marcos fault) even though no detailed geologic mapping had been done by that time to demonstrate this interpretation. In addition to the basic geologic mapping to date, detailed geologic and petrologic work may be needed to test this hypothesis.

POSSIBLE MOVEMENTS IN PRE-LATE CRETACEOUS TIME

There is no direct evidence to indicate that the Rinconada or Reliz faults existed prior to deposition of the Upper Cretaceous and lower Tertiary sedimentary sequence.

However, the pre-Upper Cretaceous crystalline basement complex exposed west of both the Rinconada

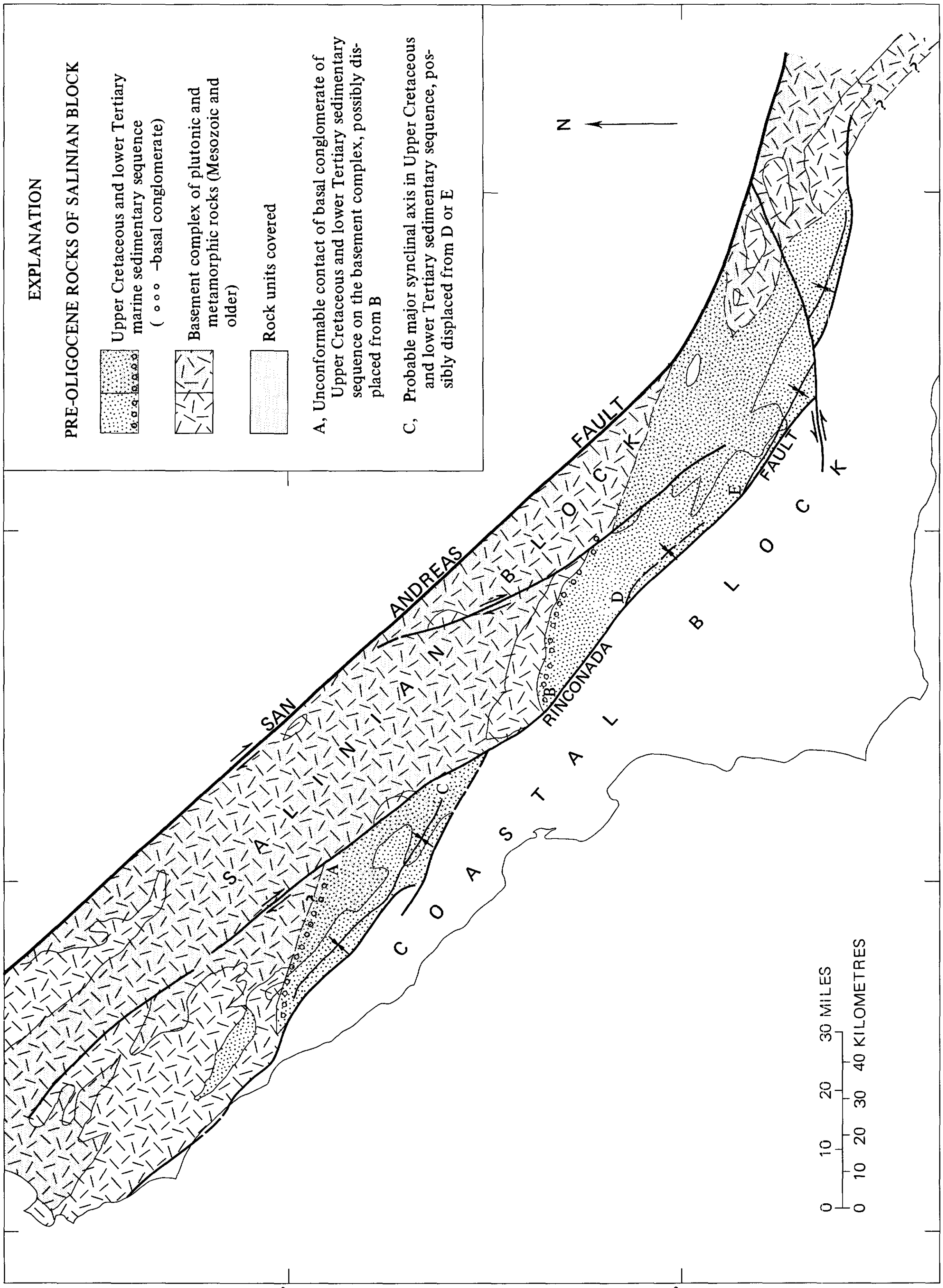

FIGURE 17.—Pre-Oligocene rocks of the Salinian block, possible displaced by right-lateral movement of the Rinconada-Reliz fault zone.

and Reliz faults is composed mostly of metamorphic rocks with the exception of the northern Santa Lucia Mountains where the basement is plutonic, whereas that exposed and struck in many deep wells east of those faults is mostly plutonic. This condition is suggestive of large displacement, either vertical or lateral, on a possible fault zone that may have existed prior to Late Cretaceous time and that evolved into the Rinconada and Reliz fault alinement, as suggested by Nilsen and Clarke (1975, p. 35).

Work on the crystalline basement complex of the Salinian block is in progress (Ross, 1972; 1974).

STRIKE-SLIP MOVEMENT AS SUGGESTED BY CONFIGURATION OF BURIED SURFACE OF BASEMENT COMPLEX

The inferred configuration of the surface of the crystalline basement complex under the sedimentary cover of the central Salinas Valley region is about as shown in figure 18. The positions of contours near wells and basement exposures are deemed moderately accurate but elsewhere are inferred from the geology.

It should be noted that this is one of several alternative contour interpretations, some of which show no displacement on the Rinconada fault zone (Durham, 1974, pl. 3). In my opinion the one shown seems to be the most probable interpretation on the basis of the available data.

As shown in figure 18, the partly exposed basement high near Paso Robles (or possibly the basement exposure of the La Panza Mountains to the southeast) east of the Rinconada fault may have been displaced at least 38 km (25 mi) right laterally on the fault from the buried shallow basement high (Lockwood high of Durham, 1974, p. 13, pl. 3) near Lockwood.

The estimated 3,658-km (12,000-ft)-deep trough west of Bradley on the east side of the Rinconada fault may be displaced by that same amount from the 3,048 km (10,000-ft)-deep trough in the Arroyo Seco area west of the Rinconada-Reliz fault alinement. If this interpretation is correct, these faults are continuous at depth, even though there is a gap between the Rinconada and Reliz faults at the surface.

The inferred continuous southward increase in depth to the basement complex on the west side of the Rinconada fault northwest of Paso Robles (fig. 18) is the effect of the southward slope of the basement surface under the thick regionally southward-dipping Upper Cretaceous and lower Tertiary sedimentary sequence. A similar condition must exist east of this fault southeastward from the La Panza Range (southeast of Paso Robles). Displacement of this southward-sloping basement surface is nearly 60 km (38 mi), in accordance with the offset shown in figure 17.

REGIONAL TECTONICS ALONG AND NEAR THE RINCONADA-RELIZ FAULT ZONE

CONCEPTS OF TECTONIC EVOLVEMENT OF THE COAST RANGES

The tectonic evolvement of the Coast Ranges and intervening valleys to their present form has been interpreted in various ways by geologists who have done or directed extensive geologic work within them. Willis (1925, p. 270–271) interpreted the Coast Ranges as crustal segments elevated primarily by northeastward thrusting on major faults that bound some of the ranges on the northeast and curve southwestward under them to eventually extend under the Pacific Ocean at depth. He interpreted the San Andreas and Sierra Nevada faults as two of these southwest-curving faults. Clark (1929) interpreted the coast ranges and valleys to have been formed as fault blocks bounded by high angle faults, with the elevated blocks forming the ranges and the depressed blocks the valleys, and supposed that each block acted independently. Reed (1933, p. 55–58) questioned Clark's fault-block theory and suggested that the ranges were elevated primarily by folding and then became faulted along one or both margins as deformation progressed. Taliaferro (1943a, p. 157–158) concurred with Reed (1933) that the Coast Ranges, such as the Santa Lucia Mountains, were formed by uplift on one or both sides by compressive folding and eventually by thrusting outward toward the adjacent valley or valleys.

Hill and Dibblee (1953, p. 455) hypothesized that the Coast Range structures are genetically related to the San Andreas and other high-angle faults along which movements have been strike slip during late if not all of Cenozoic time, in accordance with the law of uniformitarianism, with as much as 560 km (350 mi) of cumulative right-lateral movement on the dominating San Andreas fault. They asserted that the folds and accompanying thrust and reverse faults in the Coast and Transverse Ranges are shallow structures generated by strike-slip movements on the deep-seated high-angle faults. Crowell (1952, 1962) independently arrived at similar conclusions regarding large strike-slip movements on the San Andreas, San Gabriel, and other major high-angle faults in southern California.

Christensen (1965, p. 1118–1119) interpreted the Coast Ranges to have been elevated vertically as the result of forceful plutonic intrusions at depth and suggested that the folding and thrust faulting along their margins may be the effect of downward movement of the elevated mountain masses by gravity.

During the last decade many publications have appeared, including those by Crowell (1968), Atwater (1970), and Nilsen and Clarke (1975), that relate tec-

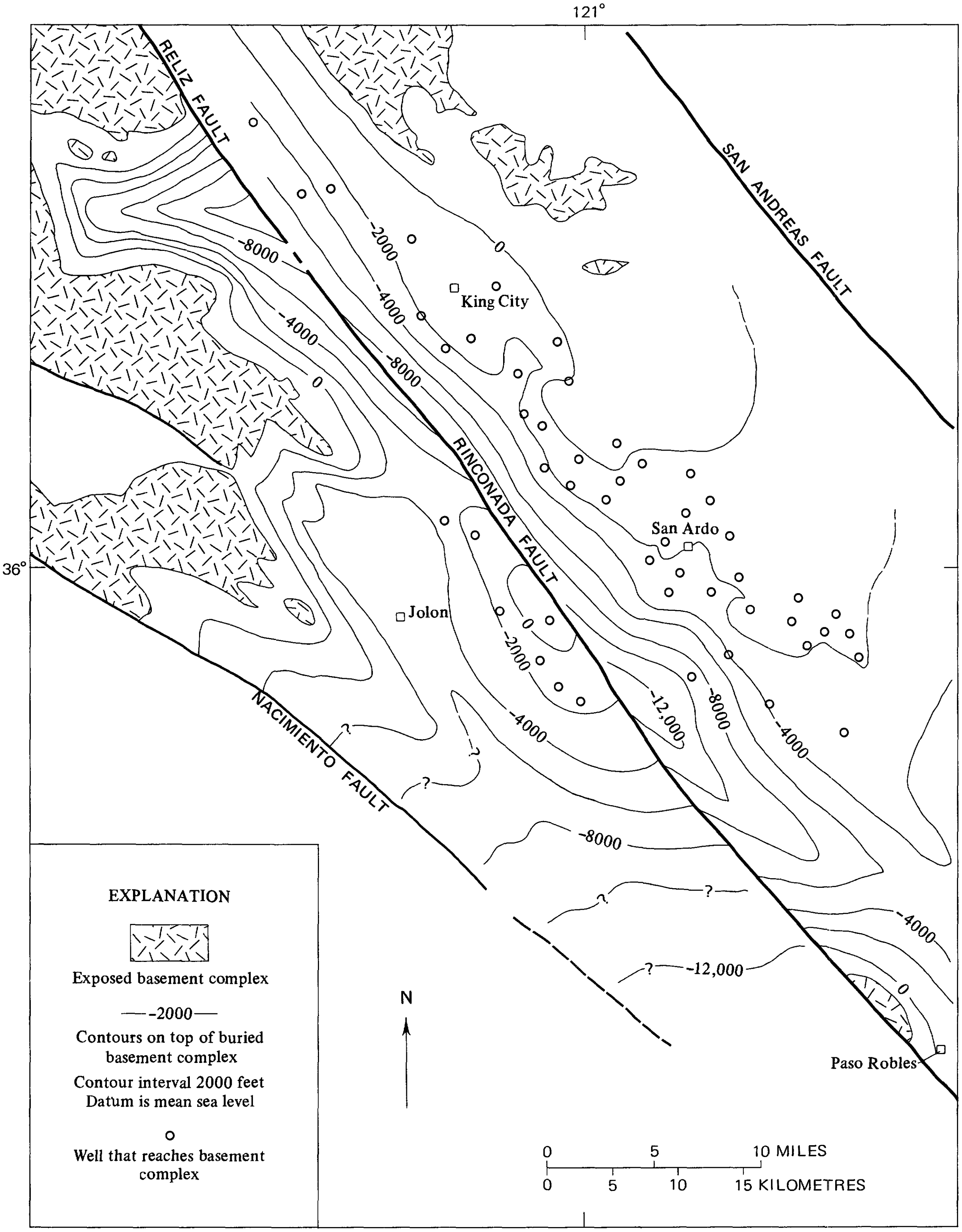

FIGURE 18.—Inferred configuration of buried surface of crystalline basement complex along Rinconada-Reliz fault zone from Paso Robles to Greenfield. In part based on well data from Burch and Durham (1970), Burch (1971), and Durham (1974), and much modified from Gribi (1963, p. 26).

tonics along the San Andreas fault system to the global theory of plate tectonics and continental drift. In so doing, nearly all accept the concept of large cumulative right-lateral movement on the San Andreas fault system and related tectonics advanced by Hill and Dibblee (1953) and Crowell (1962).

From the extensive geologic mapping I have done since 1938 within 50 km (35 mi) of much of the San Andreas fault, including the geologic data presented in the foregoing sections of this report, I conclude that the Coast Ranges have evolved in accordance with the tectonic genesis postulated by Hill and Dibblee (1953) and Crowell (1952, 1962). This concept therefore serves as a basis for the tectonic interpretations presented in this section.

TECTONIC PATTERN

The tectonic pattern along the Rinconada-Reliz fault zone is fairly well defined. The tectonic pattern and upheaval along the Espinosa segment of the Rinconada fault are shown diagramatically in figure 19. This condition is general in varying degrees along the entire course of the Rinconada-Reliz fault zone. The persistent slightly more east-west trend of folds in the sedimentary rocks as compared to the trend of both faults is interpreted to be the drag effect of right-lateral movement on the faults in the underlying basement complex. Thrust and reverse faults that dip inward toward the Rinconada fault from one or both sides probably evolved from large ruptured folds and, together with the intensity of the associated folding, indicate severe compression of one block against the other, or resistance to lateral slip. This resulted in severe squeezing along one or both sides of the Rinconada-Reliz fault zone.

On a regional scale, the major tectonics of the southern Coast Ranges are basically similar to the smaller scale tectonics along the Rinconada-Reliz fault zone. The major tectonic features of the area of figures 1 to 5 are as interpreted in figure 20. All the present uplifts shown were formed during late Cenozoic (primarily Quaternary) time. Throughout this area, in both the Salinian and Coastal block, the axes of major uplifts (except the Gabilan uplift) and the intervening troughs trend slightly west of northwest, as do the thrust faults and fold axes. The consistency of this trend indicates crustal squeezing or shortening normal to this trend from a compressive stress that acted accordingly.

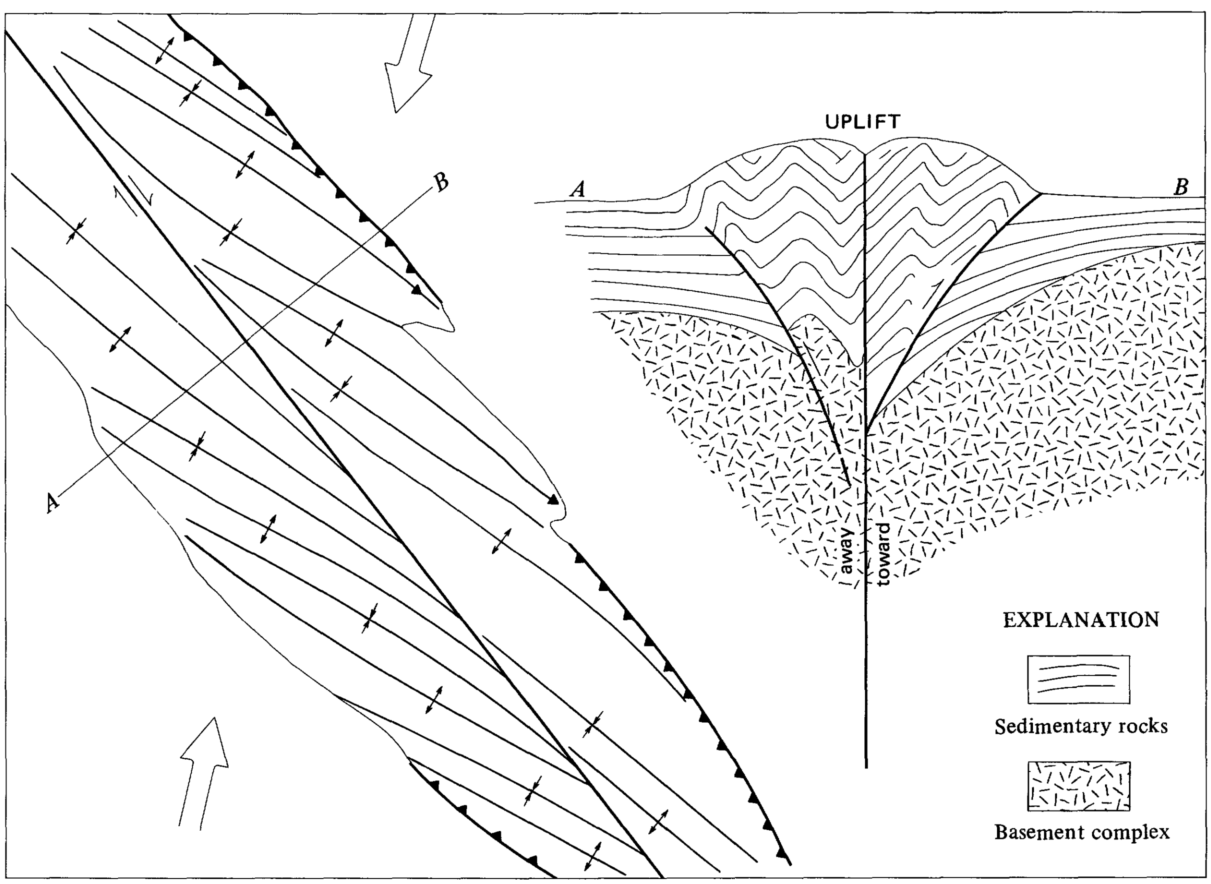

FIGURE 19.—Right-slip tectonics and compressive upheaval along the Espinosa segment of the Rinconada fault.

These parallel structures are contemporaneous with and may be subsidiary to right-lateral movements of blocks on the major faults, such as the San Andreas, Rinconada, Reliz, and other lesser faults shown in figure 20 which trend slightly north of northwest.

The Rinconada-Reliz fault zone divides the region southwest of the San Andreas fault into two geologic blocks of strips, the east strip and the west strip, which differ somewhat structurally and physiographically.

The east strip, wholly within the Salinian block, is structurally and physiographically simple, in general. The northern part is almost unfaulted and includes the major part of the Salinas Valley, which merges eastward into extensive areas of hills and low mountains including the Gabilan Range, which rises to about 650 m (2,000 ft). The east strip becomes increasingly

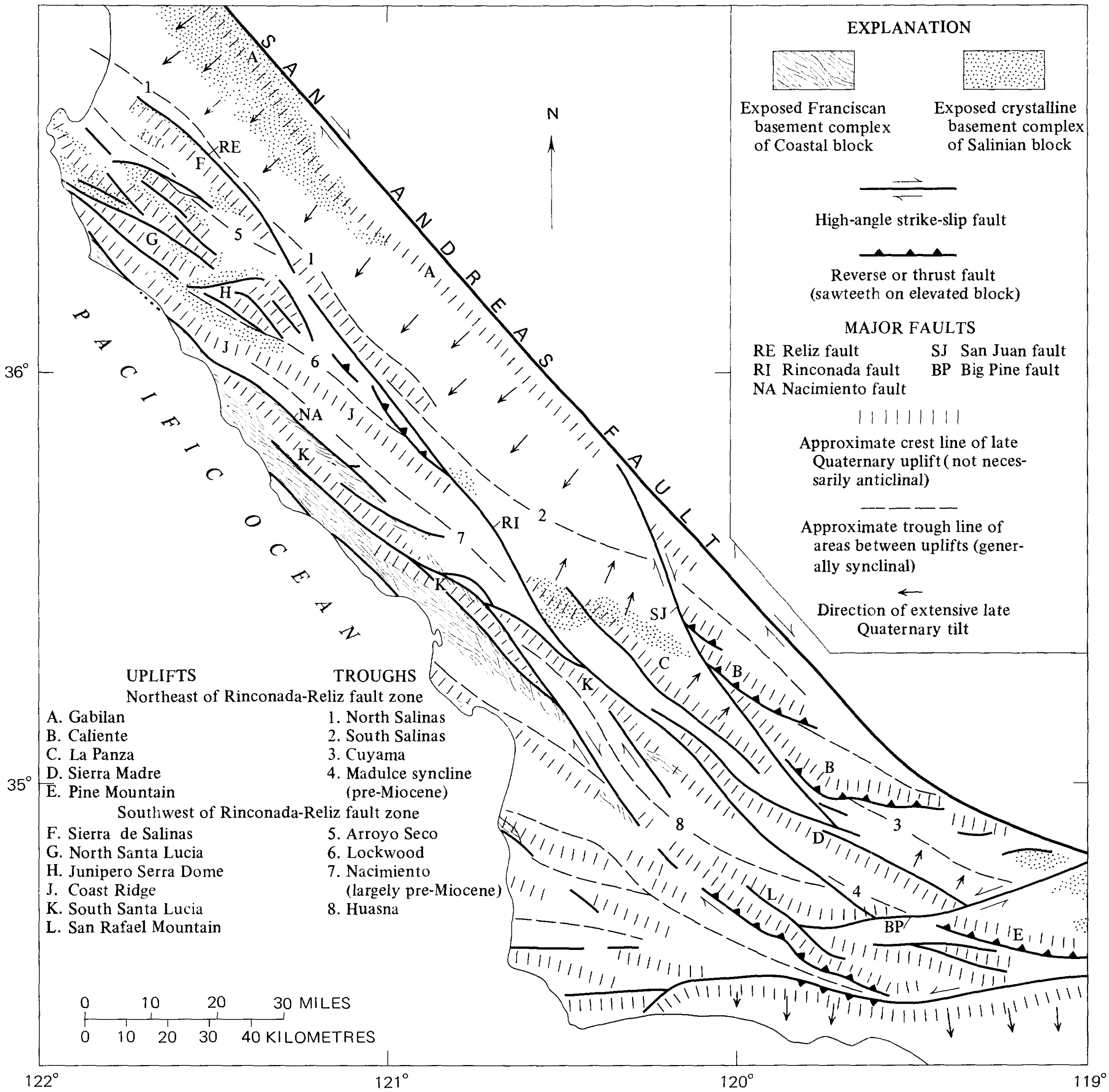

FIGURE 20.—Major tectonic features of the southern Coast Range region in vicinity of the Rinconada-Reliz fault zone.

complex southeastward as parts of it were elevated along faults to form the La Panza and Caliente Ranges, which separate the Carrizo Plain from Cuyama Valley, and the Sierra Madre Range, elevated on faults south of that valley. The Sierra Madre Range, the highest of this strip with altitudes of more than 1,600 m (5,000 ft), is physiographically part of the west strip, but it lies east of the Rinconada fault. The east strip includes Mount Pinos at its easternmost tip with an altitude of 2,600 m (8,000 ft).

In contrast, the west strip, which includes parts of both the Salinian and Coastal blocks, is structurally complex nearly throughout. It is an area of ranges of mountains and hills and includes only a few very small valleys. It is made up largely of the Santa Lucia–San Rafael Mountain belt, which is structurally the most complex and mobile part of the southern Coast Range province west of the San Andreas fault. The northern part of the west strip is elevated along the Reliz fault against the Salinas Valley part of the east strip. The southwest border of the west strip is poorly defined, but it is arbitrarily placed at the southwestern base of the Santa Lucia–San Rafael Mountain belt because this is the only continuous physiographic lineament. Northward this strip terminates at the high northern Santa Lucia Mountains with altitudes of more than 1,600 m (5,000 ft). Southward it terminates either at the high part of the San Rafael Mountains north of the Big Pine fault with altitudes of more than 2,000 m (6,500 ft) or farther southeast at the Santa Ynez fault. This strip thereby attains its greatest altitudes at its northern and southern extremities.

TECTONIC FEATURES OF THE EAST STRIP

The northwestern part of the east strip is made up primarily of the Gabilan uplift (A, fig. 20). This is a stable mass of crystalline basement complex (mostly plutonic) in large part overlain by a thin cover of middle and late Cenozoic sedimentary deposits. This uplift is slightly arched along an axis near the San Andreas fault and is tilted gently southwest toward the Salinas trough (1 and 2, fig. 20). The thin sedimentary cover is generally undeformed, except along the margins where it is folded probably by inferred right-lateral drag on the San Andreas and Rinconada-Reliz fault zones.

In the southeastern part of the east strip the surface of the basement complex deepens southward as the middle and late Cenozoic sedimentary cover thickens. The narrow wedge east of the San Juan fault within this part of the east strip was dragged southward along this fault and compressed into several southward-leaning and southward-thrust large anticlinal folds to form the Caliente Range uplift (B, fig. 20).

The La Panza uplift (C, fig. 20) was formed by arching and northeastward tilt on the northeast-dipping La Panza thrust fault. South of the La Panza and Caliente uplifts the east strip is increasingly deformed southward, as the top of the basement complex deepens even more so under a great thickness of the Upper Cretaceous and lower Tertiary sedimentary sequence, now exposed in the Sierra Madre Mountains where it is synclinally folded adjacent to the Rinconada fault. A long wedge of this thick sequence adjacent to this fault was severely compressed and elevated along the southwest-dipping south Cuyama and Ozena thrust faults toward Cuyama Valley to form the Sierra Madre uplift (D, fig. 20) during late and possibly middle Cenozoic time.

The east-trending Big Pine fault was active in Quaternary time as indicated by left-lateral displacement and deflection of some canyons that cross it (Hill and Dibblee, 1953) and may have been active earlier. Major left-lateral movements on this transverse fault dispalced the Sierra Madre uplift (D, fig. 20), Madulce trough (4, fig. 20), Ozena fault, and possibly the Rinconada fault, all about 14 km (9 mi), indicating that this transverse fault is in large part younger than all those features. The Pine Mountain uplift (E, fig. 20), the probable displaced counterpart of the Sierra Madre uplift, was elevated in Quaternary time on the northeast-dipping Pine Mountain fault. This fault may have been reactivated on an earlier, displaced extension of the Rinconada fault on which there may have been much right-lateral movement in late Tertiary time. Evidence suggesting this movement is the similarity of the Eocene stratigraphy of the Pine Mountains uplift to that of the southeastern part of the Sierra Madre uplift and its dissimilarity to that of the area south of the Pine Mountain fault.

TECTONIC FEATURES OF THE WEST STRIP

The northern part of the west strip is made up of a wedge of the Salinian block that is severely deformed to form the high northern Santa Lucia Mountains from which several major ridges extend southeastward toward the Rinconada-Reliz fault zone. This wedge is the most intensely deformed part of the Salinian block and is composed of four major uplifts and two intervening troughs (F, G, H, I, 5 and 6, fig. 20). The middle Tertiary sedimentary sequence that once covered this area is preserved only as remnants in the troughs, which indicates that the uplifts formed after deposition of this sequence, or in late Cenozoic time.

The Sierra de Salinas uplift (F, fig. 20; fig. 15) was formed largely as a southwest-tilted block of basement complex elevated on the Reliz fault. On its southwest flank it merges through complex structures as shown in figure 20 with the north Santa Lucia uplift.

The Arroyo Seco trough (5, fig. 20; fig. 13) preserves much of the thick middle Tertiary sedimentary sequence that is compressed into a complex synclinal structure that plunges east toward the Reliz fault. This trough might have been displaced on the Rinconada-Reliz fault from the south Salinas trough (2, fig. 20; fig. 18) of the east strip. Northwestward the Arroyo Seco trough once extended into a shallow syncline in Carmel River valley south of Monterey and into Monterey Bay. The middle Tertiary sedimentary sequence of this trough has been severely folded, disrupted by faulting, and involved with the adjacent uplifts to form part of the northern Santa Lucia Mountains during Quaternary time and is now undergoing erosion.

The north Santa Lucia uplift (G, fig. 20; fig. 15) constitutes the major mass of the northern Santa Lucia Mountains. It is in large part bounded on the northeast by the southwest-dipping Tularcitos fault and the Arroyo Seco trough and on the southwest by the northeast-dipping Sur fault zone. Northward it terminates in the granitic mass on the Monterey Peninsula and undersea to the northwest. Southeastward it extends into the Junipero Serra Dome (H, fig. 20). Structurally the north Santa Lucia uplift is primarily a group of subparallel northeast-tilted fault blocks, each elevated on a fault at its southwest border. At least two of these faults (Miller Creek and Church Creek faults, fig. 15) dip steeply northeast; two others to the northwest near the coast seem to deflect canyons right laterally. This uplift was apparently elevated on these internal faults as well as on those that bound it.

The position of the north Santa Lucia uplift, together with the Sierra de Salinas uplift, west of the Reliz fault may be tectonically significant. Because the Reliz fault is at the northwest end of the Rinconada-Reliz fault zone and because this mass of mountains is directly across it from the little disturbed part at Salinas Valley and the Gabilan uplift, it appears that these mountains formed by severe crustal compression or as a pile-up of basement terrane on only the west side of this fault zone as it dies out northwestward. If this is so, the Rinconada-Reliz fault zone acted somewhat as a tear fault between the stable, rigid east strip and the relatively northward moving west strip, and the crustal compression or shortening that formed the mountains on the west side has absorbed the right-lateral movement at the northwest end of its extensive fault zone, as shown in figure 22.

Southeast of Arroyo Seco the north Santa Lucia uplift narrows into a localized mass of high mountains, or the Junipero Serra Dome of Compton (1966a, p. 1367; H, fig. 20). This uplift, which includes the highest peaks of the Santa Lucia Mountains, is structurally similar to the main part of the north Santa Lucia uplift and was elevated as several parallel northeast-tilted blocks on northeast-dipping reverse faults, as mapped by Compton (1966a). Although these elevated blocks and the structure of the metamorphic basement rocks within them trend northwest, the long axis of this mountain uplift trends east-west nearly through its highest peaks. This indicates an overall north-south crustal shortening. The northwest trend of the fault blocks and their somewhat west-east en echelon arrangement suggests a possible right-lateral component of movement on the bounding faults, but proving evidence is lacking. Only the eastermost of these faults shows structural evidence of small right-lateral drag movement (fig. 13).

The position of the Junipero Serra Dome and its fault blocks nearly west of the "gap" between the Rinconada and Reliz faults (figs. 13, 20) suggests that this uplift formed as a secondary crustal compression or pile-up of basement terrane and that the 18 km (11 mi) of right-slip movement on the Rinconada fault during the late Cenozoic time was absorbed by the crustal shortening involved in the Junipero Serra uplift west of the area where the Rinconada fault dies out northwestward. At the "gap," what remains of this strike-slip movement was absorbed by intense folding of the sedimentary rocks.

Lockwood Valley, the largest valley within the west strip, has remained depressed and little deformed relative to the adjacent areas. This valley is structurally a trough, designated as the Lockwood trough (6, fig. 20), in the middle and upper Cenozoic sedimentary sequences, which are underlain directly by the crystalline basement complex, according to well data (fig. 18). The sedimentary sequences are intensely folded along the northern margin of this valley as the result of impingement by the Junipero Serra Dome and by the hills elevated along the Rinconada fault (Espinosa segment, fig. 12), and the sequences are moderately folded along the southwestern margin of this valley. The western extension of the trough has become involved in uplift of the northern Santa Lucia Mountains.

The Lockwood trough separates the Junipero Serra Dome from the south spur of the north Santa Lucia uplift, designated here as the Coast Ridge uplift (J, fig. 20). The Sur-Nacimiento fault zone may be taken as the southwest geologic boundary of this uplift, but it does not form a distinct physiographic boundary with the adjacent south Santa Lucia uplift (K, fig. 20). The Coast Ridge uplift forms a high crest of crystalline basement but decreases rapidly in height southeastward as it passes between the Lockwood and

Nacimiento troughs and as the basement complex becomes covered by the overlying sedimentary rocks of these troughs. The structure of this uplift is complex but appears to be in large part arched. This uplift may have been displaced from the La Panza uplift (C, fig. 20) of the east strip, if originally continuous, on the Rinconada fault.

The Nacimiento trough (7, fig. 20) is a synclinal structure composed of several en echelon axes in the thick Upper Cretaceous and lower Tertiary sedimentary sequence that overlies crystalline basement. It is so named for the conspicuous syncline along much of the upper Nacimiento River (fig. 10, 21). This sequence was deformed and eroded prior to deposition of the unconformably overlying middle Tertiary sedimentary sequence. During late Cenozoic time both sequences were deformed when the Rinconada fault was active and the Nacimiento trough became involved with the adjacent uplifts to form an extensive area of hills. Only the southeastern part of this trough remained somewhat depressed to form the narrow valley through Templeton and Santa Margarita (fig. 9). The synclinal structure in the Upper Cretaceous and lower Tertiary sedimentary sequence might have been displaced as much as 60 km (38 mi) on the Rinconada fault from the Madulce syncline in that sequence (figs. 4, 7, 20) of the east strip, if originally continuous.

The southern part of the west strip is part of the coastal block of Franciscan basement and forms a structurally complex belt of mountains, designated as the Santa Lucia–San Rafael Mountain belt, composed of the central and southern Santa Lucia Mountains, San Rafael Mountains, and intervening lower ranges of hills.

The south Santa Lucia uplift (K, fig. 20) consists of intensely deformed Franciscan rocks and overlying Cretaceous sedimentary rocks squeezed up southwest of the Nacimiento and Las Tables faults and farther south against the Nacimiento trough and the Rinconada fault.

Near San Luis Obispo the south Santa Lucia uplift divides southeastward into two narrow uplifts of hills separated by the Huasna trough (8, fig. 20), a complex synclinal structure in the middle Tertiary sedimentary sequence that unconformably overlies the previously deformed Cretaceous sedimentary sequence and Franciscan rocks. This trough probably formed a valley in early Quaternary time but has since become involved with the adjacent uplifts to form part of the Santa Lucia–San Rafael Mountain belt.

The San Rafael Mountain uplift (L, fig. 20) rises south of the Huasna trough to more than 2,000 m (6,000 ft) against the Big Pine and other faults to the south.

REGIONAL TECTONIC ANALYSIS

The Salinian and Coastal blocks were juxtaposed, presumably by a large amount of movement along a great shear plane, such as the Sur-Nacimiento fault zone. How they juxtaposed is not known. It might have been by a large amount of lateral slip (Curtis and others, 1958). However, Page (1970a, 1970b) postulated that it was by thrusting (subduction) of the oceanic Coastal block northeastward under the Salinian block, which he interpreted as part of the continental plate, in accordance with the plate tectonic theory. This inferred plane of underthrusting was designated as the Coast Ranges subduction zone by Hill (1971, p. 2959). If this postulation is correct, this movement resulted presumably from a direct northeast-southwest compressive stress normal to the subduction zone.

The time of subduction, or whatever mechanism by which these blocks were juxtaposed, was prior to Oligocene time (Page 1970b). As suggested by Hill (1971, p. 2959), it may have been just before or during deposition of the coarse sandy sediments of Late Cretaceous age, because these are the oldest arkosic sediments on both blocks and because they lie unconformably on the basement rocks of the Salinian block and also on the Lower Cretaceous shale unit of the Coastal block near Stanley Mountain (Hall and Corbató, 1967) and possibly in the San Rafael Mountains. In the Santa Lucia Mountains the Upper Cretaceous unit may be unconformable on this shale unit and the Franciscan rocks (Taliaferro, 1944) or may have been, but now in most if not all places is, in fault relation (Brown, 1968; Page, 1970a, 1970b, 1972) possibly by later or continued subduction.

Eventually, the Franciscan rocks of the Coastal block, which presumably were deposited in an offshore trench in Mesozoic time, became squeezed and upheaved against the advancing continental block of crystalline rocks by Oligocene time. During that time, the supposed subduction tectonics, if they were the actual mechanism, were converted to right-lateral strike-slip tectonics on high-angle northwest-trending shear zones such as the San Andreas fault, as suggested by Atwater (1970, p. 3525–3529), along which blocks were carried past each other laterally as well as compressed against each other. These tectonics prevailed throughout middle and late Cenozoic time; they may have started before Oligocene time if the San Andreas fault first formed as a strike-slip fault before that time, as suggested by Wentworth (1968, p. 139–140), Ross (1970, p. 3661–3662), and Clarke and Nilsen (1973, p. 302).

Within the area of figures 1 and 20 west of the San

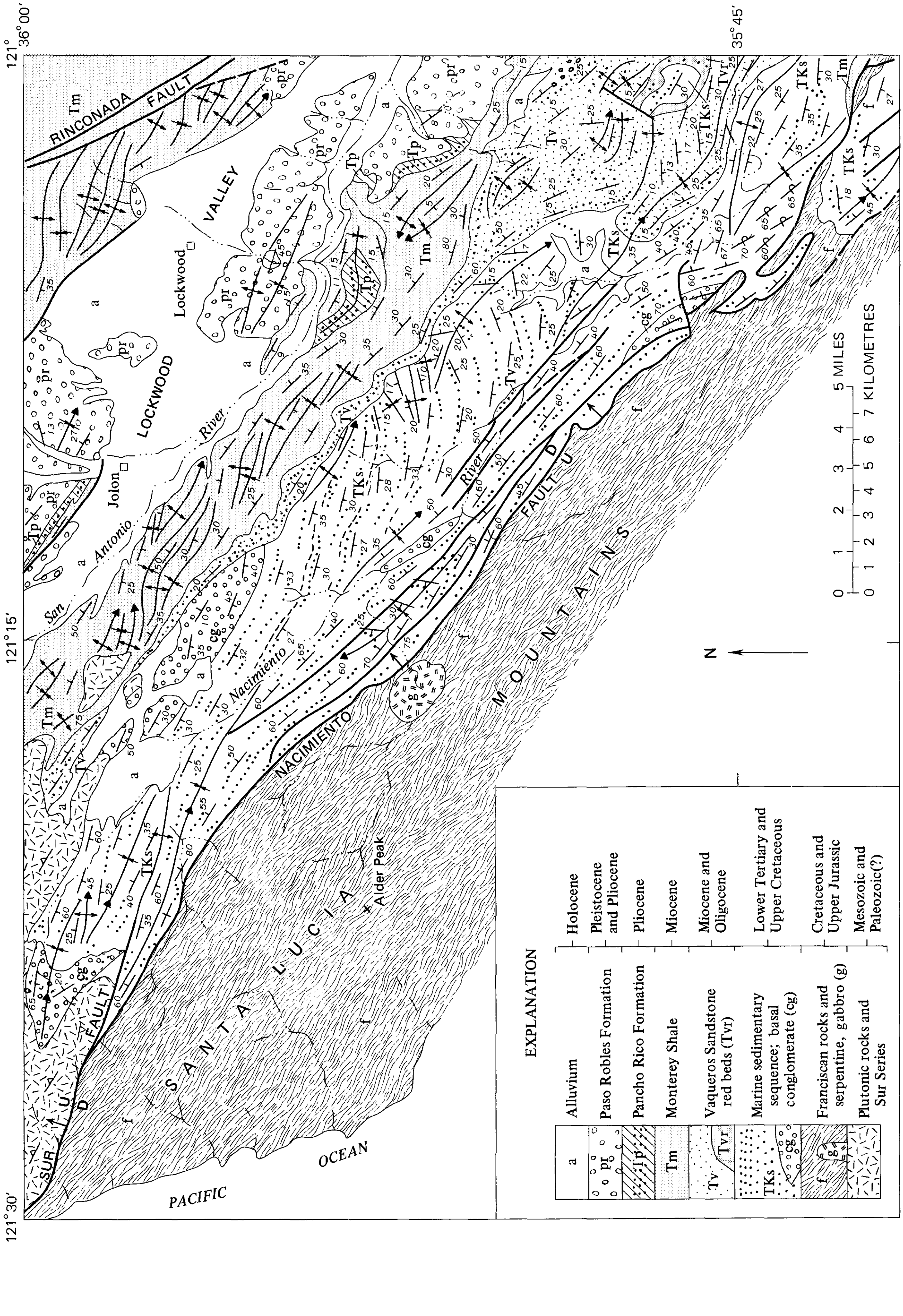

FIGURE 21.—Geology of the upper Nacimiento River area and vicinity (in part modified from Page, 1970a).

Andreas fault, the Rinconada-Reliz fault zone is the largest strike-slip shear zone along which right-lateral movement took place in middle(?) and late Cenozoic time, as indicated by the evidence presented herein. Much of this movement was distributed and taken up by other lesser faults of similar trend, as well as by folding and thrust faulting within this area.

In Cenozoic time right-lateral movements on the southern part of the Rinconada fault followed the old Mesozoic Sur-Nacimiento fault zone or Coast Ranges subduction zone of Hill (1971). In this respect, the Rinconada fault bears the same relation to that zone as the late Cenozoic Newport-Inglewood zone bears to the Mesozoic southern California subduction zone as postulated by Hill (1971, p. 2959).

Since Oligocene time, the Sur-Nacimiento fault zone was apparently inactive northwestward from the Rinconada mine where the Rinconada fault veers northward from that zone, except for small local movements. This inactivity is indicated by the burial of that zone by the middle Tertiary sedimentary sequence between that point and the southeast end of the Nacimiento fault.

The Rinconada-Reliz fault zone is inferred to have formed along the old Mesozoic subduction(?) zone as far northwest as the Rinconada mine and then to have veered away northward into the Salinian block, parallel to the San Andreas fault and slipped laterally in the same manner. Thereby, during late Cenozoic time, the west strip was carreid northward relative to the east strip along the Rinconada-Reliz fault zone.

The east strip of the Salinian block between the San Andreas and Rinconada-Reliz fault zones reacted to stress as a generally rigid mass, compared to the adjacent blocks. The northern part, along which the crystalline basement is exposed in the Gabilan Range and buried under a thin middle and late Cenozoic sedimentary cover elsewhere, resisted deformation and crustal shortening during middle and late Cenozoic time to form a stable area with a surface near sea level. The only deformation of this strip was partial uplift by arching along an axis near the San Andreas fault to form the Gabilan Range (fig. 20).

The southern part of the east strip, where the buried basement surface deepens southward under sedimentary sequences, yielded somewhat to become increasingly deformed southward and was impinged southward against part of the Transverse Ranges. This may account for the intense compressive deformation of the very thick sedimentary sequences of those ranges.

The west strip, in contrast to the east strip, yielded to stress almost throughout its length during the middle and late Cenozoic diastrophism to form the complex series of parallel uplifts along the Santa Lucia–San Rafael mountain belt, as described. The southern part of this strip, that within the Coastal block, is the most intensely deformed part because much of the Franciscan basement is melange with little internal strength. The overlying Cretaceous marine strata are severely shattered and broken, forming poor exposures in contrast to the prominent unshattered exposures of the Upper Cretaceous and lower Tertiary marine sedimentary sequence on the Salinian block.

The northern part of the west strip, even though it is within the Salinian block which has a rigid crystalline basement, is nearly as intensely deformed as the southern part. The northwesternmost part was compressed and upheaved between the Reliz and Sur faults and on a number of reverse faults within it to form the high, rugged northern Santa Lucia Mountains during late Cenozoic time. This upheaval formed by crustal compression or pile-up west of where the Rinconada-Reliz fault zone dies out and involves several kilometres of north-south crustal shortening of the west strip compared to almost none of the east strip across this fault zone. This shortening on only one side of this fault zone thereby presumably absorbed the large right-lateral slip on the Rinconada-Reliz fault zone as it dies out northwestward, as demonstrated in figure 22.

The lowlands and Monterey Bay north of this compressive uplift were only slightly affected by crustal movements and thereby remained compartively stable to form part of the still-depressed North Salinas trough (1, fig. 20).

REGIONAL SIGNIFICANCE OF THE RINCONADA-RELIZ FAULT ZONE

I conclude that the Rinconada-Reliz fault zone is the most extensive late Cenozoic transcurrent fault zone in the southern Coast Ranges west of the San Andreas fault and that the tectonic and physiographic features of the area traversed by the Rinconada-Reliz fault zone

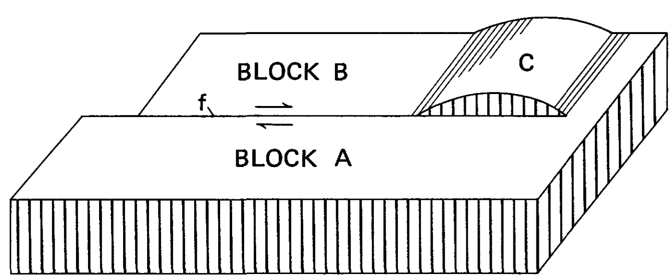

FIGURE 22.—Block diagram illustrating mechanics of conversion of strike-slip movement along a high angle fault into compressive uplift of one block as fault terminates. Block B, which moved to the right along fault (f) relative to block A was compressed and bulged upward at C near end of fault. Northern Santa Lucia Mountains were elevated probably in large part in this manner as the Rinconada-Reliz fault zone dies out northward.

(figs. 2, 20) are probably drag features formed by or controlled in part by northwestward movements of the west strip relative to the east strip of the fault zone, together with right-lateral movements of the more active San Andreas fault. The Rinconada-Reliz fault zone is therefore a major subsidiary or companion fault of the San Andreas, but with a somewhat different history of movement.

The position of the Rinconada fault is en echelon to two other major faults of similar extent, trend, and movement: the San Gregorio fault to the northwest and the San Gabriel fault to the southeast. The en echelon position of the Rinconada-Reliz fault zone between these two major faults and the similar movement history of all of them suggest that all are tectonically related as faults subsidiary to the San Andreas as indicated in the interpretations that follow.

Northwestward the Rinconada-Reliz fault zone dies out probably south of Monterey Bay, but the San Gregorio fault (Branner and others, 1909; Jennings and Burnett, 1961) along the southwestern margin of the Santa Cruz Mountains is nearly parallel to and northwest of the Reliz fault zone but is farther west. The San Gregorio fault had a comparably large amount of right-slip movement, as suggested by dissimilarity of rock units and structures mapped on opposite sides (Brabb, 1970; Clark, 1970; fieldwork by myself in 1948–49). According to recent work by Greene, Lee, McCullock, and Brabb (1973), that fault extends southeastward offshore across subsea Monterey Canyon and onshore into either the Palo Colorado or Sur fault or both (fig. 15), along which its right-slip movement eventually dies out. Consequently, the right-slip movement of the Rinconada-Reliz fault zone must have been transferred through the many large northwest-trending faults in the northern Santa Lucia Mountains to the San Gregorio fault northwestward, and so the right-slip movement on both faults was absorbed in the crustal compression or pile-up that formed these mountains between the extremities of these two en echelon major faults (fig. 23). A small part of this movement was probably absorbed by the many small right-slip faults in Monterey Bay (Greene and others, 1973).

Southeastward the Rinconada fault terminates against the Big Pine fault, but its extension beyond that fault may be the Pine Mountain fault (fig. 4), as suggested previously, even though the Pine Mountain fault is a north-dipping reverse fault on which Pine Mountain was elevated. If the Pine Mountain fault were once part of the Rinconada fault, it may have originally trended southeastward, but since it was displaced by left slip on the Big Pine fault, it probably has been dragged into a more easterly trend by left slip on that fault to become parallel to the more easterly trending part of the San Andreas fault and evolve into a north-dipping reverse fault as the Pine Mountain block was squeezed upward on it. The Pine Mountain fault curves southeastward and dies out near the San Gabriel fault to the east.

The San Gabriel fault extends about 144 km (90 mi) and dips steeply northeast. This fault was active during late Cenozoic time but mostly during Pliocene time, with an inferred maximum cumulative right slip of about 40 km (25 mi) (Crowell, 1952; Dibblee, 1968). It is therefore related to the San Andreas fault, but its history of movement was similar to that of the Rinconada fault. Consequently, the inferred right-lateral movements on both faults may have been absorbed by conversion to compressive vertical movements between or near their extremities to form the Sierra Madre Mountains and Pine Mountain–Alamo Mountain uplift (fig. 24), in much the same way that the northern Santa Lucia Mountain were formed between the Reliz fault and the probable southeastern extension of the San Gregorio fault.

During Quaternary time left slip on the Big Pine fault, which is apparently younger than the Rinconada fault, not only offset the Rinconada fault but also probably impeded or locked right-slip movements on it, and so as stress continued the lateral movements became converted to thrusting movements on the South Cuyama, Ozena, Pine Mountain, and Little Pine faults.

The influence of lateral movements of the blocks or strips bounded by the San Andreas fault, Rinconada–Pine Mountain fault combination, and the San Gabriel fault during late Cenozoic time extended far to the southwest. Assuming that the east strip of the Salinian block, which has a relatively rigid crystalline basement complex, between the San Andreas fault and the Rinconada, Pine Mountain, and San Gabriel faults was stationary relative to the adjacent blocks, the block east of the San Andreas fault was moving relatively southeastward, and the block west of the Rinconada, Pine Mountain, and San Gabriel faults was moving relatively northwestward (fig. 24), or actually northward, against this intervening strip.

The continued irresistable force of these movements caused severe impingement northward against this strip of the Salinian block by the Coastal block which contains the very thick sedimentary accumulations of the Santa Barbara trough that in large part overlie Franciscan basement. This impingement resulted in intense buckling and upthrusting of this thick sedimentary crust to form the San Rafael, the Santa Ynez-Topatopa, and Santa Susana Mountains, and possibly the Santa Monica Mountains. The north-dipping thrust or reverse faults under Frazier Mountain, Pine Mountain, Topatopa Mountains, and the Santa Susana Mountains (fig. 24) may be the effect of counterimpingement from the east strip of the Salinian block, as well as compressive movements along the San Gabriel fault.

Another significant tectonic effect of the Rinconada-Reliz fault zone, together with other major right lateral faults, is their elongation of the Salinian block. Johnson and Normark (1974, p. 11–14) postulated that prior to early Tertiary time the Salinian block, which is part of the borderland of the North American plate, fitted into the 300 km (185 mi) gap between the Sierra Nevada and Peninsular Ranges

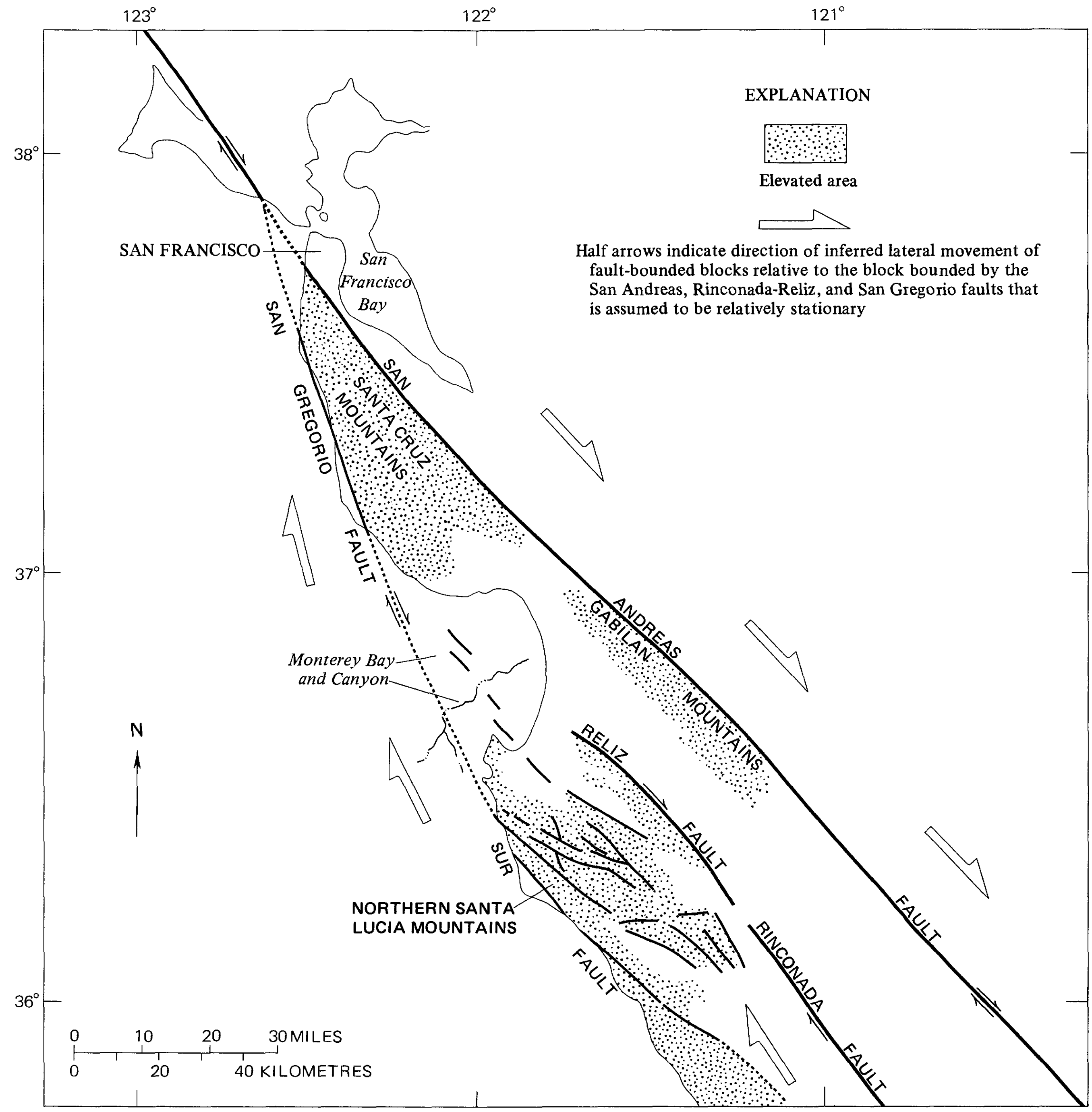

FIGURE 23.—Inferred tectonic movements in vicinity of northern Santa Lucia Mountains showing conversion of right-slip movements near ends of Rinconada-Reliz fault zone and San Gregorio fault into crustal compression and uplift of intervening area to form these mountains.

basement terranes and that it bulged westward; during Neogene time, the Salinian block was displaced northwestward to its present position by right slip on the San Andreas fault and the block has been sliced and elongated to about 600 km (370 mi) or about twice its orginal length by right slip on the Rinconada-Reliz and other major longitudinal faults within this block as it became attached to the relatively northward moving Pacific plate. They also claimed that there is no need for a proto-San Andreas fault within the Salinian block.

These views differ somewhat from those by Nilsen and Clarke (1975, pl, 48–52), who postulated, from their sedimentology studies of early Tertiary strata

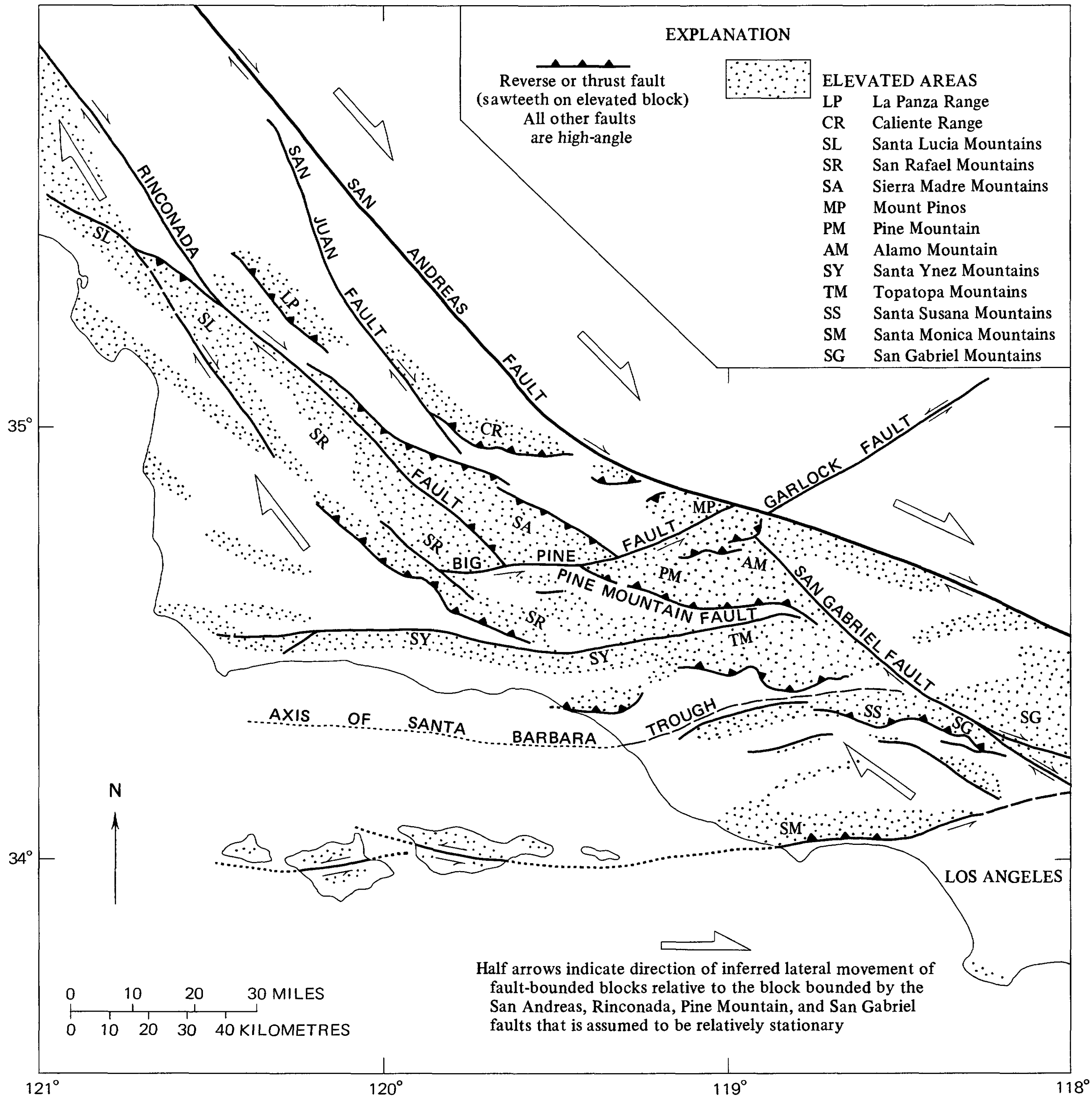

FIGURE 24.—Inferred tectonic movements in vicinity of Sierra Madre Mountains and Pine Mountain, showing inferred conversion of right-slip movements near ends of the Rinconada and San Gabrel faults to crustal compression to form these ranges.

and the comparatively greater displacement of basement rocks of the Salinian block than the lower Tertiary sedimentary rocks, that the Salinian block was displaced northwestward from the continental landmass on a proto-San Andreas fault prior to early Tertiary time; and that clastic sediments were being deposited in early Tertiary time in deep marine basins formed perhaps as rhombochasms between rising source areas within the Salinian block from movements related presumably to right-lateral movements on the proto-San Andreas fault.

Evidence of pre-early Tertiary displacement of the Salinian block presented by Nilsen and Clark (1975) is reasonably convincing. If there is a proto-San Andreas fault in the Salinian block, it is probably close to or at the present San Andreas fault. The slicing or displaçement of at least one large sedimentary basin, the Sierra Madre basin, in the Salinian block during Neogene time by the Rinconada fault is one evidence that the Salinian block has been elongated during Neogene time by faults parallel to the San Andreas as postulated by Johnson and Normark (1974), even though parts of the fault strips have been shortened by compressive movements as indicated.

EFFECT OF RINCONADA-RELIZ FAULT ZONE ON PHYSIOGRAPHY AND DRAINAGE

The physiographic features and drainage of the area of figure 2 evolved directly from the tectonic features (fig. 20) formed in late Cenozoic time. These in turn are genetically related in large part to movements on the Rinconada-Reliz fault zone and related faults. The elevated areas evolved into the present ranges of mountains and hills and are undergoing erosion. The intervening troughs that remained depressed are the valley areas through which the major streams from the elevated areas drain. These conditions indicate that the tectonic features are very young and are still forming.

The mountain ranges uplifted adjacent to or near the Rinconada-Reliz fault zone form one of the major drainage divides of the southern Coast Ranges (fig. 2). Southeastward from the Rinconada mine, the principal divide is formed by the Sierra Madre and La Panza Ranges elevated northeast of the fault. Northwestward from that point, the Santa Lucia Mountains elevated west of the Rinconada-Reliz fault zone from a drainage divide adjacent to the coast for 170 km (110 mi).

The drainage pattern of the two strips opposite the Rinconada-Reliz fault zone are notably different (fig. 2). On the east strip, the major streams such as the Salinas and Cuyama Rivers drain northwestward, and most of their tributaries normally drain directly into them. In contrast, the major streams on the west strip that drain the east slope of the Santa Lucia Mountains, such as the Arroyo Seco, San Antonio, and Nacimiento Rivers, drain southeastward or eastward through structural troughs. Farther south, as this range decreases in height and as the principal drainage divide shifts east of the fault, drainage is normally southwestward to the sea.

The southeastward-draining San Antonio and Nacimiento Rivers are considered by Baldwin (1963) to be remnants of a drainage system in southern Salinas Valley that emptied eastward into San Joaquin Valley. However, I consider this theory improbable because both these streams follow troughs between uplifts of the west strip, and after crossing the Rinconada fault, both turn abruptly northeastward to flow directly to the northwestward-flowing Salinas River, which was established probably either during or after deposition of the Paso Robles Formation.

POSSIBLE SEISMIC ACTIVITY

No earthquakes attributed to the Rinconada or Reliz faults, faults branching from them, or thrust or reverse faults considered related to the Rinconada fault have been recorded during historic time. The area northward from Greenfield has been seismically monitored from 1969 to 1972 (Greene and others, 1973). The results of this work showed numerous minor epicenters in the Gabilan Range just southwest of the San Andreas fault. Only a few with magnitudes up to 4 (Richter scale) were located on or just southwest of the Reliz fault southwest of Gonzales. If these are located accurately, they suggest possible minor activity on this fault. The area of the Rinconada fault has not been monitored.

Compared to the San Andreas fault, the Rinconada and Reliz faults pose little if any seismic hazards and are probably inactive because no trenches, scarps, shutter ridges, or recently offset minor drainage channels in the alluvium or even in the older alluvium have been positively identified along them. The Paso Robles Formation, the youngest geologic unit definitely truncated by the faults, is probably not younger than several hundred thousand or possibly a million years old. Except possibly at a few places, there are no surface indications that either fault has moved since deposition of the older alluvium, which is estimated to be about 50,000 to 500,000 years old.

Suggestive evidence of the latest movements on the Rinconada and Reliz faults are (1) deviation of canyons and stream channels locally on the Rinconada fault (figs. 11, 14) (2) possible fault contact of the Monterey Shale against older alluvium on Rinconada fault near Williams Hill (fig. 13); (3) shallow depression on Rinconada fault 4 km (2½ mi) north of Santa Margarita, due either to fault movement or to former stream erosion; (4) northwest-facing low scarps in older alluvium on Reliz fault southwest of Chualar (fig. 15), due either to vertical fault displacement or to erosion by a former course of the Salinas River; and (5) southwest-facing scarp on older alluvium on a minor fault near Reliz fault east of Paraiso Spring (fig. 15).

Inasmuch as the Rinconada and Reliz faults presumably have been inactive so long, it is not likely that they would generate an earthquake, although the possibility exists. It is possible that some of the related thrust or reverse faults may generate an earthquake because several of these, such as the Los Lobos thrust, San Antonio fault, South Cuyama, Ozena, and Pine Mountain faults, as well as those at the base of the La Panza and Caliente Ranges, are at the base of steep probably actively rising mountain fronts.

The Pine Mountain fault is potentially active because it offsets left laterally some canyons that cross it (Hill and Dibblee, 1953, p. 452) and could generate an earthquake. The Sierra Madre and Pine Mountain areas are potential earthquake areas because these mountains are probably actively rising on the faults that bound them.

Another likely area in which a major earthquake may originate is in the northern Santa Lucia Mountains, because this is an area of rigid basement complex that is being elevated on a number of major faults (fig. 15). Some of these faults may be active and near the coast may offset several canyons in a right-lateral sense. Several of the many minor northwest-trending faults under Monterey Bay are thought to displace the sea floor and, if so, are active (Greene and others, 1973).

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