Tertiary Stratigraphy of the Southeastern San Joaquin Valley, California

GEOLOGICAL SURVEY BULLETIN 1529-J

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By J. ALAN BARTOW *and* KRISTIN McDOUGALL

CONTRIBUTIONS TO STRATIGRAPHY

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Revisions to the Tertiary stratigraphy of the area on the basis of geologic mapping and subsurface stratigraphic studies, including radiometric dating and paleontologic examination of well samples

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By J. ALAN BARTOW AND KRISTIN MCDOUGALL

ABSTRACT

New information derived from geologic mapping and subsurface stratigraphic studies, including radiometric dating of pyroclastic materials and paleontologic examination of well samples, has provided the basis for revisions to the Tertiary stratigraphy of the southeastern San Joaquin Valley. The units discussed in this report are: the Walker Formation (Eocene, Oligocene, and early Miocene), the Bealville Fanglomerate (late Oligocene and early Miocene), the Vedder Sand (Oligocene), the Jewett Sand (early Miocene), the Freeman Silt (early Miocene), the Ilmon Basalt (early? Miocene), the Olcese Sand (early Miocene), the Bena Gravel (Miocene), the Round Mountain Silt (early? and middle Miocene), the Fruitvale Shale of Miller and Bloom (1937) (middle and late Miocene), the "Santa Margarita" Formation (late Miocene), the Chanac Formation (late Miocene), and the Kern River Formation (late Miocene, Pliocene, and early Pleistocene?).

The Walker Formation is the nonmarine equivalent of the "Famoso" sand (Eocene) and the Vedder Sand; south of the Bakersfield arch the upper part of the Walker is equivalent in age to the Jewett Sand and the lower part of the Freeman Silt. The Bealville Fanglomerate is a coarser equivalent of the Walker but not of the Bena Gravel, and is so redefined.

The Bena Gravel is redefined to include a paralic facies in addition to the previously recognized alluvial gravel; the unit is equivalent to the uppermost part of the Freeman Silt, the Olcese Sand, the Round Mountain Silt, and the Fruitvale Shale. The "Santa Margarita" Formation and the nonmarine Chanac Formation are parts of the same transgressive-regressive depositional sequence and are partial age equivalents. The nonmarine Kern River Formation is the youngest Tertiary unit and unconformably overlies older Tertiary strata. The names "Bealville Fanglomerate" and "Ilmon Basalt" are adopted herein.

The Tertiary strata of the southeastern San Joaquin Valley record a major transgression beginning in Eocene time and continuing into the Miocene, followed by a major regression beginning in the late Miocene and extending into the Pleistocene. The transgression was interrupted by relatively minor regressions at the end of Eocene time, near the end of Zemorrian time (earliest Miocene), at the end of Saucesian time (late early Miocene), and near the end of Luisian time (late middle Miocene). The regression was interrupted by two minor transgressions during late Miocene time.

The coarse clastic materials of the Bealville Fanglomerate, the Bena Gravel and Olcese Sand, the Chanac Formation, and the Kern River Formation are considered to be evidence of tectonic activity. The close association of the coarsest part of the Bealville with the Edison fault indicates that this fault was probably active during the late Oligocene and early Miocene. The difference in depositional histories for the areas north and south of the Bakersfield arch suggests that this arch was an important tectonic boundary, particularly during the middle Miocene and later.

INTRODUCTION

Knowledge of the stratigraphy of the southeastern San Joaquin Valley has developed gradually over the period from the early 1900's to the present as the petroleum industry has explored new areas and deeper horizons in the southern San Joaquin basin. The stratigraphic names that generally were first used informally by petroleum geologists have come into common use, and most have been formally adopted. Table 1 summarizes the history of this stratigraphic nomenclature.

The biostratigraphy has developed hand in hand with the rock-stratigraphic nomenclature, owing in part to the large Miocene molluscan fauna that has attracted paleontologists to the area since W. P. Blake, with the Pacific Railroad Survey, first collected fossils there in 1853 (for a review, see Addicott, 1970).

The stratigraphy of the Miocene marine rocks of the area has evolved mostly as part of the larger picture of the Miocene of the west coast, and relatively little information dealing directly with the Tertiary stratigraphy of the southeastern San Joaquin Valley has been published. The literature concerning this area is almost entirely a by-product of stratigraphic studies carried out in conjunction with petroleum exploration and development and thus is concerned primarily with the subsurface stratigraphy and structure.

The purpose of this report is to present new information about the stratigraphy of the southeastern San Joaquin Valley that has been obtained as part of a regional study aimed at providing an overview of Cenozoic tectonics through an understanding of sedimentary-basin development. A geologic map covering the area of this report (fig. 1) was published in preliminary form by Bartow and Doukas (1978); a revised, colored version with cross sections is in press. In this report, Bartow is responsible for interpretations of the stratigraphy based on observations during field mapping and subsurface studies since 1975, and McDougall is responsible for the biostratigraphy based on benthic foraminifers.

Acknowledgments.—We thank the Atlantic Richfield Co., Chevron USA, Inc., and Texaco, Inc., for loaning us the well samples used in our paleontologic studies. We also thank the many other oil companies who provided copies of well logs and other well data that made our subsurface studies possible, and the California Well Sample Repository in Bakersfield, Calif., for their assistance in providing additional material for examination.

STRATIGRAPHY

Addicott (1970) included a discussion of the Tertiary rock-stratigraphic units in the area between the Kern River and Poso Creek in his report on the Miocene gastropods and biostratigraphy of the Kern

TABLE 1.—*Summary of references to principal geologic names in the southeastern San Joaquin Valley, California*

Formation	Original reference	Designation of type section or locality
Kern River Formation	Anderson (1911)[1]	Bartow and Pittman (1983).
Etchegoin Formation	Anderson (1905)	Anderson (1905).
"Santa Margarita" Formation[2]	Merriam (1916)[3]	None.
Chanac Formation	Merriam (1916)	J. P. Buwalda (in Merriam, 1916).
Fruitvale Shale of Miller and Bloom (1937)	Miller and Bloom (1937)	None.
Bena Gravel	Dibblee and Chesterman (1953)	Dibblee and Chesterman (1953).
Round Mountain Silt	Diepenbrock (1933)	Addicott (1970).
Olcese Sand	do	Addicott (1970), after Rogers (1943).
Freeman Silt	Kleinpell (1938)	Addicott (1970).
Jewett Sand	Godde (1928)	Do.
Pyramid Hill Sand Member	Wilson (1935)	Do.
Vedder Sand	Wilhelm and Saunders (1927)	Do.
Walker Formation	do	Dibblee and Chesterman (1953).
Bealville Fanglomerate	Dibblee and Chesterman (1953)	Do.

[1]Anderson (1905, p. 187-188, 191) applied the name "Kern River Beds" to Miocene marine rocks stratigraphically below what was later named the Kern River Group. His description did not include the overlying nonmarine deposits.

[2]First named for exposures near Santa Margarita in the Coast Range 75 km to the west across the San Andreas fault. Quotation marks are used here to indicate that the name is probably misapplied in the southeastern San Joaquin Valley because of uncertainties of correlation with the type locality.

[3]Original reference is Fairbanks (1904), but name was first used in southeastern San Joaquin Valley by Merriam (1916).

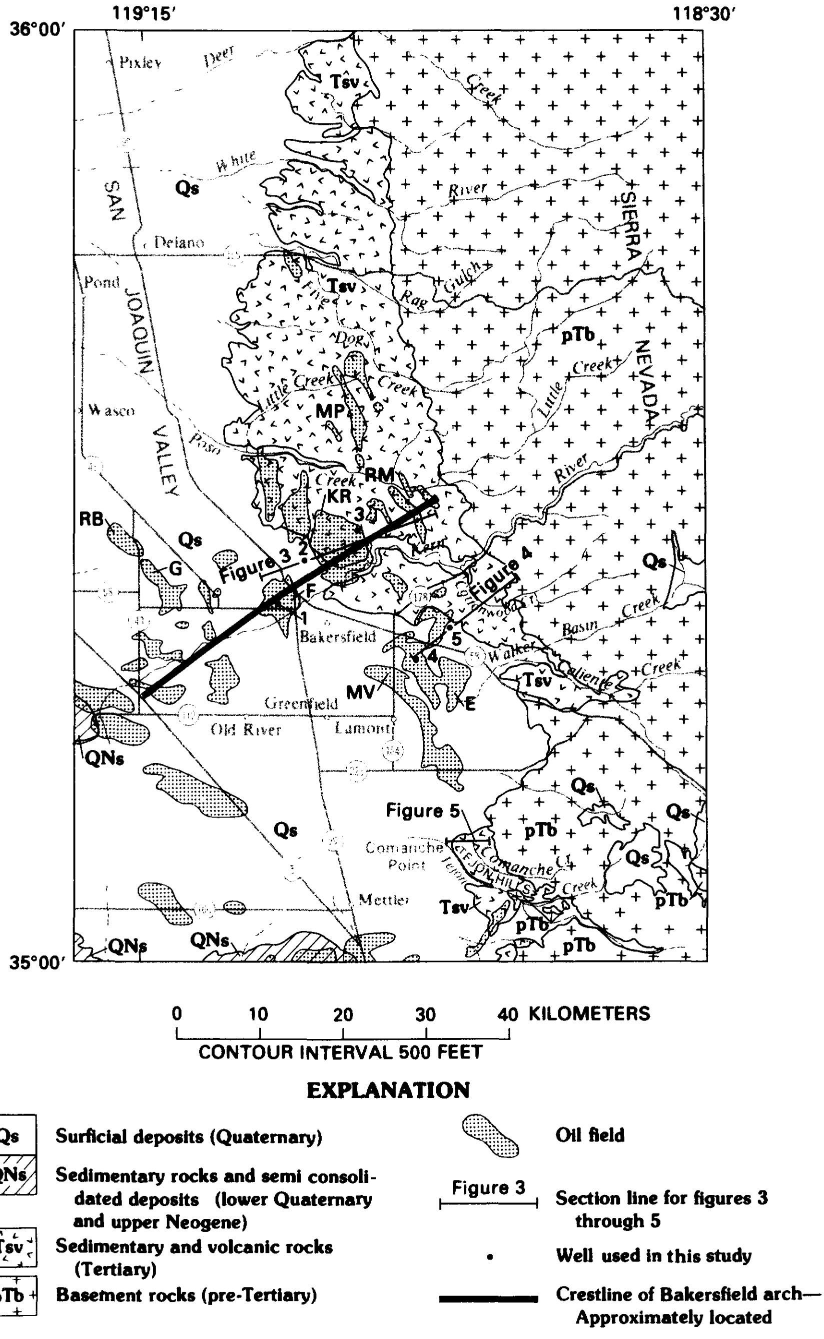

FIGURE 1.—Index map of southeastern San Joaquin Valley, Calif., showing generalized distribution of outcrops of Tertiary strata, lines of section for figures 3 through 5, and geographic names used in text. Wells used for paleontologic study are: (1) Gulf Oil Co. "KCL-B" 45, (2) Chevron USA, Inc., 33-1, (3) Shell Oil Co. "Fuhrman" 1, (4) Jim Riley "Jeppi-Camp" 67-8, and (5) Chevron USA, Inc., 24-35. Letters denote principal oil fields: E, Edison; F, Fruitvale; G, Greeley; KR, Kern River; MP, Mount Poso; MV, Mountain View; RB, Rio Bravo; RM, Round Mountain. Base from U. S. Geological Survey 1:500,000-scale California State Map, south half.

River area. The stratigraphy of that area will, therefore, not be discussed in detail here, except where new information or interpretations can be offered to supplement those provided by Addicott. Several formations, such as the Bealville Fanglomerate (herein adopted), the Bena Gravel, the Chanac Formation, and the Fruitvale Shale of Miller and Bloom (1937), that were not discussed by Addicott (1970) because they do not crop out in the Kern River area or have no bearing on the Miocene biostratigraphy are included here.

Stratigraphic relations of the Tertiary units of the southeastern San Joaquin Valley are shown diagrammatically in figure 2. The Bakersfield arch, a structural salient of Sierran basement rocks, the crest of which approximately coincides with the Kern River, seems to form a boundary between two areas in the southeastern San Joaquin Valley that have had significantly different histories. The sections north and south of the Bakersfield arch are, therefore, diagrammed separately in figure 2.

WALKER FORMATION

A section of nonmarine clayey sandstone, siltstone, and green claystone overlying basement rocks at the base of the Tertiary sequence in the southeastern San Joaquin Valley has traditionally been included within the Walker Formation. This formation was originally named by Wilhelm and Saunders (1927) from three wells in the Mount Poso oil field area, 24 km north of Bakersfield (fig. 1), one of which was subsequently designated (Addicott, 1970) the subsurface reference section for the Walker. A type section on Walker Basin Creek, about 27 km east of Bakersfield, was designated by Dibblee and Chesterman (1953). North of the Bakersfield arch, the Walker is overlain by the Pyramid Hill Sand Member of the Jewett Sand; south of the arch, including the area of the type section, it is unconformably overlain by the Bena Gravel.

The Walker Formation crops out in a more or less continuous strip along the edge of basement outcrops from the Caliente Creek area northward to the White River, and generally does not extend more than 25 to 30 km westward in the subsurface. It is, however, probably continuous in the subsurface with the correlative Tecuya Formation of the San Emigdio Mountains at the south end of the San Joaquin Valley (south of area of fig. 1). The formation is about 550 m thick in the type section; it thickens southeastward to about 900 m and thins northward and westward, and is from 200 to 300 m thick in the Kern River area.

Although no age-diagnostic fossils have been found in the outcrops of the Walker Formation, in the Kern River area the upper part of the formation intertongues basinward with the Zemorrian Vedder Sand, and the lower part intertongues basinward with strata bearing Eocene ("Domengine") brackish-water to marine mollusks. Benthic foraminif-

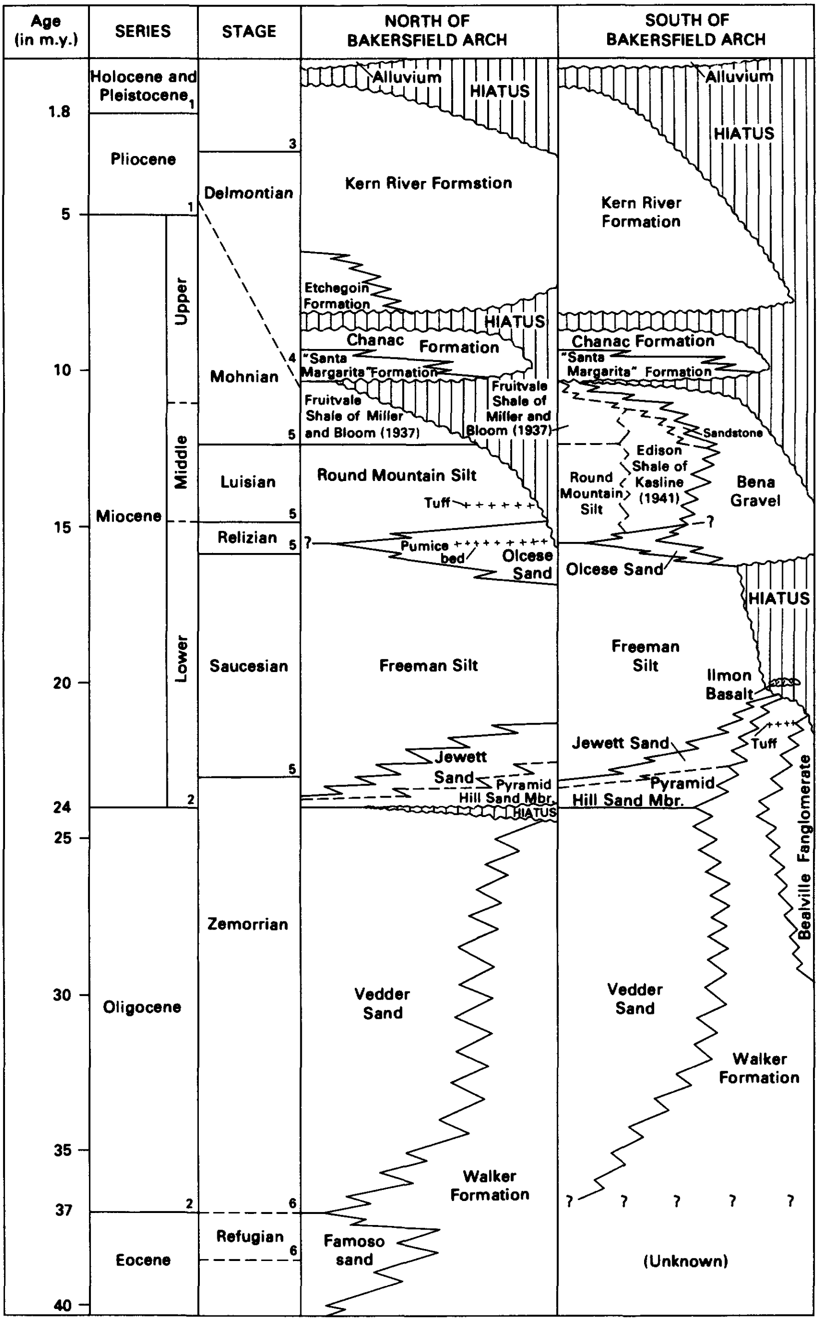

FIGURE 2.—Correlation chart of Tertiary formations in southeastern San Joaquin Valley. Ages of series and stage boundaries are from (1) Van Couvering (1978); (2) Hardenbol and Berggren (1978); (3) Berggren and Van Couvering (1974); (4) Pierce (1970) and Barron (1976); (5) Turner (1970), adjusted for new decay and abundance constants for calculation of K-Ar ages (Steiger and Jäger, 1977); and (6) Brabb and others (1977).

ers are also present in the marine equivalent of the Walker in subsurface sections north of Bakersfield (tables 2, 3). Such diagnostic species as *Cassidulina laevigata*, *Elphidium minutum*, *Uvigerina cocoaensis* species group, and *Valvulineria* cf. *V. willapaensis* indicate a Refugian (late Eocene) age. Stratigraphically higher assemblages are not age diagnostic but are composed of a distinctive inner-shelf assemblage; this assemblage is also recorded as present in the Vedder Sand to the west, where it is mixed with Zemorrian species. Benthic foraminifers from equivalent marine strata suggest an age of late Eocene to Oligocene for the Walker.

A K-Ar age of 21.4 m.y. from a tuff in the type section of the Walker Formation (discussed more fully below in the section entitled "Geochronology") indicates that the top of the Walker in the area south of the Bakersfield arch is within the lower Miocene. In the Kern River area, north of the arch, an unconformity between the Walker and the Jewett Sand of earliest Miocene age (fig. 2) precludes that the Walker of that area is Miocene. The total age range of the Walker, then, is late Eocene to early Miocene (fig. 2).

As Addicott (1970) pointed out, the lithology of arkosic sandstone, conglomerate, and minor green sandy claystone in the type section on Walker Basin Creek differs from that in the area northeast of Bakersfield, where green sandy claystone is the most conspicuous rock type. In either case, where the Walker Formation consists of white anauxite-bearing kaolinitic quartzose sandstone and kaolinitic claystone with scattered quartz grains, it bears a strong resemblance to the Eocene Ione Formation in its type area 350 km to the northwest. Although long-range correlations based on lithologic resemblance are generally questionable, where the lithology may be related to climatic factors (such as a wet tropical or subtropical climate that would cause intense chemical weathering), there may be some validity to the correlation. A tuff bed in the Walker on the White River near the northern end of the Tertiary outcrop belt (fig. 1) is, unfortunately, too badly weathered to date or to correlate chemically. Its weathered condition and its close association with anauxite-bearing quartz-kaolinite sandstone suggests, however, that it may be Eocene.

A few wells drilled for oil in the Wasco-Famoso area, about 30 km northwest of Bakersfield, have penetrated a thick (300-500 m) section of probable nonmarine rocks below Eocene marine strata; this section has yielded pollen that suggest a Late Cretaceous (Maestrichtian) age.[1] The upper part of this section is probably equivalent to the thin Walker Formation that occurs below marine strata of Eocene age in nearby areas, but most of the section should probably be considered a separate unit of Cretaceous age.

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[1]Palynologic age of Mobil-Pan American Petroleum "KCL" 31-15 sidewall cores (R. L. Pierce, Mobil Oil Corp., Los Angeles, unpub. data, 1967). Courtesy of Mobil Oil Corp.

TABLE 2.—*Checklist of foraminifers from the Gulf Oil Co. "KCL-B" 45 well in sec. 22, T. 29 S., R. 27 E.*

[A, abundant (more than 50 specimens); C, common (21-50 specimens); F, few (2-20 specimens); R, rare (1 specimen). Depths shown are those given on samples]

FORMATION	Fruitvale Shale of Miller and Bloom (1937)										Round Mountain Silt					Freeman Silt																							Rio Bravo Sand			Vedder Sand / Famoso Sand			
SERIES	Miocene																																										Oligocene			Eocene
STAGE	Mohnian								?		Luisian					Relizian		Saucesian																		Zemorrian									Refugian
SPECIES / DEPTH (FT)	6090-6095	6095-6101	6101-6111	6111-6121	6230-6236	6236-6240	6246-6256	6256-6266	6266-6569	6822-6832	7166-7176	7176-7180	7186-7192	7202-7212	7456-7466	7659-7663	7663-7673	8394-8404	8404-8414	8614-8624	8634-8639	8639-8642	8802-8808	8808-8811	8825-8835	8835-8842	8842-8850	8850-8858	8863-8866	8866-8872	8872-8875	8877-8886	8886-8894	8894-8899	8899-8906	8906-8911	8911-8914	8914-8917	8917-8923	8923-8943	8943-8953	9420-9423	9423-9429	9429-9432	10282-292
Bolivina marginata Cushman	F	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	F	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina obliqua Barbat and Johnson	F	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Buliminella subfusiformis Cushman	C	--	F	F	--	--	--	--	--	--	F	F	R	C	F	F	F	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	--	A	A	C	--	--	--	--	--	--	--	--
Cyclammina sp.	F	F	--	--	F	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dorothia sp.	F	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerina hootsi Rankin	C	--	A	A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerina peregrina Cushman	F	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina seminuda Cushman	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina cf. B. girardensis Rankin	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nonionella miocenica Cushman	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria araucana (d'Orbigny)	--	F	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Baggina sp.	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina advena striatella Cushman	--	--	--	--	--	--	--	--	--	--	F	F	--	F	R	F	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina imbricata Cushman	--	--	--	--	--	--	--	--	--	--	F	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Siphogenerina transversa Cushman	--	--	--	--	--	--	--	--	--	--	F	--	--	--	F	--	--	--	R	--	C	--	--	F	--	A	A	R	--	--	--	--	--	--	--	--	--	C	--	--	C	--	--	--	--
Valvulineria californica Cushman s.l.	--	--	--	--	--	--	--	--	--	--	C	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cassidulina panzana Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	F	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina smileyi (Kleinpell)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--
Orthomorphina rohri (Cushman & Stainforth)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	F	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pullenia miocenica globula Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerina joaquinensis Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dentalina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fursenkoina californiensis (Cushman)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Globobulimina pacifica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--
Lenticulina simplex (d'Orbigny)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	C	F	--	--	F	--	--	--	--	F	--	--	F	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--
Nonionella costifera (Cushman)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	F	F	F	--	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--
Plectofrondicularia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Suggrundia californica Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Uvigerinella obesa impolita Cushman & Laiming	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	C	C	F	C	--	F	--	--	F	--	C	--	--	--	--	--	--	A	F	A	A	--	--	--	--	--	--	--	--	--
Anomalina glabrata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina advena Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Stilostomella advena (Cushman & Laiming)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Siphogenerina pseudococoaensis Cushman & Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cibicides floridanus (Cushman)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	F	--	--	R	--	F	--	--	--	--	--	--	--	F	--	--	F	F	F	--
Cyclammina cancellata obesa Cushman & Laiming	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	R	--	--	--	--	--	--	--	--	--	--	F	--	F	--	--	--	--	--	F	--	--	--	--	--	--	--
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Pullenia salisburyi Stewart & Stewart	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Cassidulina laevigata d'Orbigny	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--
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Siphogenerina mayi Cushman & Parker	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	A	F	C	--	--	--	--	--	--	--	--
Bulimina carnerosensis Cushman & Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	C	--	F	--	--	--	--	--	--
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Melonis pompilioides (Fitchell & Moll)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--
Uvigerina cocoaensis species group	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F

TABLE 3.—*Checklist of foraminifers from the Shell Oil Co. [Seaboard Oil & Gas Co.] "Fuhrman" 1 well in sec. 28, T. 28 S., R. 28 E.*

[A, abundant (more than 50 specimens); C, common (21-50 specimens); F, few (2-20 specimens); R, rare (1 specimen). Depths shown are those given on core samples]

FORMATION	Round Mountain Silt				Olcese Sand			Freeman Silt																						Vedder Sand / Walker Fm.									Famoso(?) sand											Walker Fm	Basement rocks		
SERIES	Miocene																												Oligocene									Eocene												pre-Tertiary		
STAGE	Luisian				Relizian			Saucesian														Zemorrian																	Refugian														
SPECIES / DEPTH (FT)	1603-1613	1662-1674	1737-1747	1782-1787	1911-1921	1921-1931	2068-2080	3600-3612	3620-3636	3636-3645	3645-3657	4657-3668	3668-3679	3679-3691	3691-3702	3702-3713	3713-3725	3725-3735	3735-3745	3745-3757	3757-3769	3769-3786	3771-3783	3787-3799	3799-3811	3811-3823	3823-3835	3835-3847	3847-3859	4020-4032	4044-4056	4056-4068	4068-4050	4080-4092	4207-4219	4219-4943	4908-4927	4920-4931	4943-4955	4991-5003	5003-5029	5015-5048	5027-5048	5059-5098	5098-5112	5112-5131	5131-5142	5152-5164	5164-5176	5177-5203	5203-5226	5226-5251	5251-5261
Buliminella subfusiformis Cushman	F	F	R	--	--	--	R	--	--	F	--	--	--	--	--	--	--	F	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria sp.	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina advena striatella Cushman & Laiming	--	F	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina imbricata Cushman	--	A	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Epistominella subperuviana (Cushman)	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina miocenica (Chapman)	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina cf. L. reedi (Kleinpell)	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nonionella costifera (Cushman)	--	F	--	--	R	--	--	F	F	F	F	R	--	R	--	F	--	A	--	F	R	--	--	--	F	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerina joaquinensis Kleinpell	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria californica Cushman	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria ornata Cushman	--	F	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Buccella mansfieldi Cushman	--	--	R	--	--	F	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Bathysiphon sp.	--	--	--	--	--	--	--	F	--	--	--	--	F	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina marginata Cushman	--	--	--	--	--	--	--	F	F	F	R	--	R	--	--	C	--	F	F	F	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cassidulina laevigata d'Orbigny	--	--	--	--	--	--	--	C	F	F	F	F	R	--	--	--	--	A	--	A	--	--	--	C	--	--	--	--	--	--	--	C	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--
Cibicides floridanus (Cushman)	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	F	--	--	F	--	--	F	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Dentalina quadrulata Cushman & Laiming	--	--	--	--	--	--	--	F	--	F	R	F	R	F	R	F	--	R	--	R	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Hoeglundina elegans d'Orbigny	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Lenticulina mayi (Cushman & Parker)	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Siphogenerina transversa Cushman	--	--	--	--	--	--	--	A	A	C	F	C	F	--	F	A	--	A	F	A	A	F	--	--	A	F	R	A	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sphaeroidina bulloides d'Orbigny	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

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Uvigerinella obesa impolita Cushman & Laiming	--	--	--	--	--	--	--	C	A	C	F	F	F	C	R	A	--	A	C	A	A	R	R	F	--	--	R	--	--	--	--	--	--	--	--	--	F	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--
Baggina californica Cushman	--	--	--	--	--	--	--	--	F	--	--	--	--	F	--	--	--	R	F	F	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyclammina cancellata obesa Cushman & Laiming	--	--	--	--	--	--	--	--	R	F	--	F	F	F	F	F	--	F	F	C	--	A	--	--	--	F	F	A	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina laimingi (Bandy & Arnal)	--	--	--	--	--	--	--	--	F	R	R	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina subkubinyii (Nuttall)	--	--	--	--	--	--	--	--	F	--	F	R	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Martinotiella patens Cushman and Laiming	--	--	--	--	--	--	--	--	R	F	R	F	F	R	F	F	F	F	F	R	--	F	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Siphogenerina tenua Cushman & Kleinpell	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	F	--	F	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Uvigerinella sparsicostata Cushman & Laiming	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Plectofrondicularia californica Cushman & Stewart	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	F	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Uvigerina hispida Schwager	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A	--	--	F	--	--	--	F	C	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina smileyi (Kleinpell)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Elphidium sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cibicides sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Elphidium minutum (Reuss)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	C	--	--	--	--	--	--	--	R	--	--	--	--	--	--
Uvigerina cocoaensis species group	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--
Valvulineria cf. V. willapaensis Rau	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	F	--	--	--	--	--
Bulimina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--

BEALVILLE FANGLOMERATE

The Bealville Fanglomerate was first named and described by Dibblee and Chesterman (1953) as an unsorted boulder-conglomerate facies of both the Walker Formation and the Bena Gravel. More recent fieldwork, however, has demonstrated that whereas the Bealville intertongues westward with the lithologically similar but finer grained Walker, a clear lithologic distinction exists between the Bealville and the Bena. Both the Bealville and the Walker are characterized by their relatively common greenish-gray clayey matrix, whereas the matrix of the Bena Gravel is typically sandy, and gray to orange brown in color. Also, the sorting and rounding of clasts is better in the Bena than in the Bealville conglomerate beds.

The Bealville Fanglomerate, then, is an unsorted granitic rubble that unconformably overlies granitic basement and intertongues westward with the Walker Formation. It is unconformably overlain by the Bena Gravel.

The Bealville Fanglomerate is restricted to a relatively small area in the vicinity of Caliente Creek south of the Kern River, although lithologically similar rocks are present in the Tecuya Formation farther to the south (Nilson and others, 1973). At its type section south of Caliente Creek, the Bealville is more than 2,100 m thick (Dibblee and Chesterman, 1953).

Although the part of the Bealville Fanglomerate below the Bena Gravel was considered by Dibblee and Chesterman (1953) to be Oligocene, the upper part is presumably early Miocene because of the intertonguing between the Bealville and the tuff-bearing part of the Walker Formation and because of the occurrence of what may be the same tuff in the Bealville. The name "Bealville Fanglomerate" is here adopted as defined above; its age is regarded as late Oligocene and early Miocene.

VEDDER SAND

The Vedder Sand is principally a subsurface unit that is widespread in the southeastern San Joaquin Valley (Richardson, 1966) and may reach a thickness of more than 300 m locally. It crops out in a narrow belt north of Poso Creek, where it is composed principally of light-gray well-sorted fine- to medium-grained sandstone, locally cemented with silica. The thickness in outcrop ranges from 0 to about 80 m. It conformably overlies the Walker Formation and in the subsurface is the lateral equivalent of the upper part of the Walker (fig. 3). The Vedder is unconformably overlain by the Jewett Sand (or the undivided Freeman-Jewett silt of some authors) along the east margin of the basin, north of the Bakersfield arch, but south of the Bakersfield arch and farther west in the deeper parts of the basin they may be conformable.

Diagnostic microfossils from subsurface sections of the Vedder Sand support a Zemorrian age (fig. 2; tables 2-5; Ferguson, 1943; Beck, 1952; Rudel, 1965), and the unit is here considered to be restricted to the Oligocene. Along the east margin of the basin, benthic-foraminiferal assemblages contain *Cassidulina laevigata*, *Cibicides floridanus*, *Gyroidina soldanii*, and *Nonionella costifera*. These species indicate an age no older than Zemorrian and possibly as young as Saucesian. Transported shelf species are commonly associated with these assemblages. A similar shelf assemblage, though probably not transported, occurs in the Vedder near its base or where it interfingers with

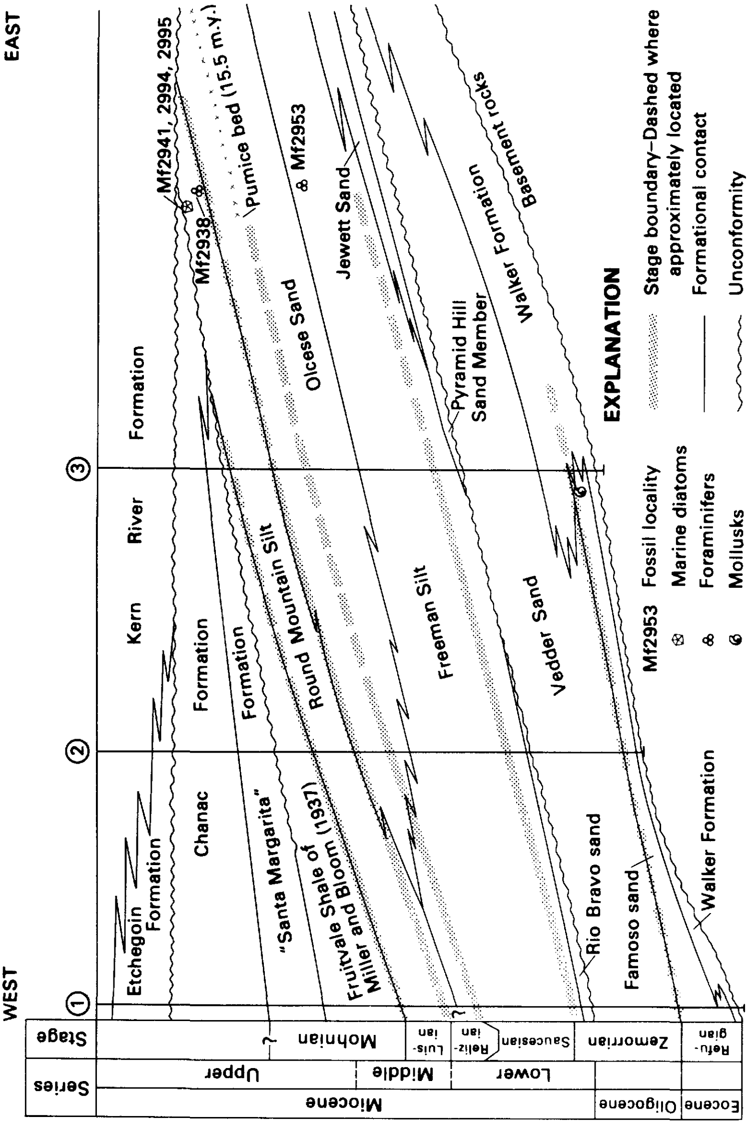

FIGURE 3.—Diagrammatic cross section of Kern River area, showing stratigraphic relations of Tertiary formations north of Bakersfield arch and approximate position of age control. Not to scale, although biostratigraphic boundaries are in correct positions relative to formational boundaries. Numbered vertical lines indicate wells (see fig. 1) from which samples were studied, projected into line of section.

TABLE 4.—*Checklist of foraminifers from the Chevron USA, Inc.*

[A, abundant (more than 50 specimens); C, common (21-50 specimens); F, few (2-20

FORMATION	Fruitvale Shale of Miller and Bloom (1937)										Round Mountain Silt											Olcese Sand					
SERIES	Miocene																										
STAGE										?	Luisian														Relizian		
SPECIES / DEPTH (FT)	3240-3280	3280-3300	3300-3320	3320-40	3340-60	3360-80	3380-3420	3420-40	3440-60	3540-60	3560-80	3580-3600	3600-20	3640-60	3660-80	3680-3700	3700-20	3720-40	3740-60	3840-60	3940-60	4060-80	4040-60	4080-4100	4100-20	4120-40	4140-60
Nonionella costifera (Cushman)	--	--	--	--	--	--	--	--	--	--	R	R	F	--	F	F	F	R	--	--	--	--	--	--	F	F	F
Valvulineria spp.	--	--	--	--	--	--	--	--	--	--	A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina advena striatella Cushman	--	--	--	--	--	--	--	--	--	--	--	R	--	F	F	F	F	F	--	--	F	--	--	--	F	--	--
Buliminella subfusiformis Cushman	--	--	--	--	--	--	--	--	--	--	--	R	F	F	F	F	F	F	--	--	C	--	F	--	F	F	F
Uvigerinella californica Cushman	--	--	--	--	--	--	--	--	--	--	--	F	F	--	F	--	--	--	--	--	F	F	--	--	--	--	F
Uvigerinella obesa Cushman	--	--	--	--	--	--	--	--	--	--	--	F	--	C	F	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria ornata Cushman	--	--	--	--	--	--	--	--	--	--	--	A	A	F	F	--	F	F	F	F	F	F	F	F	F	F	R
Gyroidina soldanii d'Orbigny	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Baggina californica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	F	F	--	F	R	--	--	--	--	--	F	--	--	--
Siphogenerina transversa Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	F	R	R	--	R	--	--	F	--	R	F	A	A	F
Valvulineria californica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	C	A	F	F	C	C	F	C	--	F	F	F	F	F
Bolivina marginata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	R	--	--	--	--	--	F
Lenticulina simplex (d'Orbigny)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	R	R	--	F	F	--	F	--	--	--
Stilostomella adolphina (d'Orbigny)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina imbricata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	R	F	--	--	F	--	--	--	R	F	--
Uvigerinella obesa impolita Cushman & Laiming	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	F	F	F	--	F	F	F	F	F	--	F
Epistominella subperuviana Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	--	--	--	F	--
Trifarina occidentalis (Cushman)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--
Dorothia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--
Marginulina beali (Cushman)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--
Cassidulina laevigata d'Orbigny	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	F	F	F	F
Hanzawaia crassiseptus (Cushman & Laiming)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--	R
Hanzawaia relizensis (Kleinpell)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	F
Lenticulina convergens (Bornemann)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	F	F
Bolivina advena Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--
Nonionella incisa (Cushman)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	--
Quinqueloculina cf. Q. goodspeedi Hanna & Hanna	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F	F
Bolivina spp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
Buccella mansfieldi Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R
Lenticulina inornata (d'Orbigny)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
Textularia shivelyi Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	A
Anomalina glabrata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Globobulimina pacifica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina spp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerinella sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria miocenica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Buliminella curta Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Melonis pompilioides (Fitchel & Moll)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyclammina cancellata obesa Cushman & Laiming	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyclammina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fursenkoina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina mayi (Cushman & Parker)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Praeglobobulimina pupoides (d'Orbigny)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Praeglobobulimina ovata (d'Orbigny)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Reophax sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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[Standard Oil of California], 33-1 well in sec. 1, T. 29 S., R. 27 E.

specimens); R, rare (1 specimen). Depths shown are those as given on ditch samples]

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the nonmarine Walker Formation. Farther west in the deeper parts of the basin, common to abundant specimens of *Siphogenerina nodifera* appear in the faunas and restrict these assemblages to the late Zemorrian Stage of Kleinpell (1938).

JEWETT SAND AND FREEMAN SILT

The Jewett Sand is a unit of silty sand to sandy shale that overlies the Vedder Sand or the Walker Formation, and the Freeman Silt is a siltstone unit that gradationally overlies or intertongues with the Jewett and intertongues with the overlying Olcese Sand (Addicott, 1970). The Pyramid Hill Sand of Wilson (1935), formerly considered a separate formation, was reduced in rank by Addicott (1970) to a member (the Pyramid Hill Sand Member) of the Jewett Sand. The composite thickness of the two units is about 300 m in the Kern River area.

Basinward from the vicinity of the Round Mountain oil field (fig. 1), where the Jewett Sand and the Pyramid Hill Sand Member are best developed (Park and others, 1963, pl. 6), the Jewett Sand thins by facies change to siltstone, and the Freeman Silt correspondingly thickens. In subsurface work, where the Jewett Sand is thin or absent, the interval between the Olcese Sand (or the Round Mountain Silt where the Olcese is absent) and the Vedder Sand is commonly referred to as the Freeman-Jewett Silt (of local usage). We prefer, however, to restrict the name "Jewett" to the sandstone facies, and use the name "Freeman" for all of the siltstone facies (fig. 3).

Although the Freeman Silt and the Jewett Sand can ordinarily be differentiated in subsurface correlations on the basis of their electric-log character, the two formations are generally difficult or impossible to differentiate in outcrop because of the fine-grained texture of the Jewett Sand. Toward the north end of the Tertiary outcrop belt (fig. 1), the Freeman Silt becomes thinner and sandier, and consistent differentiation of the Freeman from the overlying Olcese Sand and the underlying Jewett Sand becomes nearly impossible. Neither the Freeman Silt nor the Jewett Sand crops out south of the Kern River, although both units or equivalent strata are present in the subsurface at the south end of the valley.

The basal part of the Pyramid Hill Sand Member of the Jewett Sand is a fossiliferous calcareous pebbly sandstone, informally called the grit zone, that unconformably overlies the Walker Formation or the Vedder Sand. The contact is locally channeled, and a slight angular discordance is evident. Basinward, particularly in the vicinity of the Rio Bravo and Greeley oil fields (fig. 1), this basal grit zone occurs in the Rio Bravo sand, an informal unit that is the local equivalent of the Pyramid Hill Sand Member. The relations of the Rio Bravo sand to the underlying Vedder Sand are uncertain. The data of Bandy and Arnal (1969, fig. 2, table 5) imply continuous deep-water sedimentation across the contact, but the presence of shallow-water mollusks (mostly

TABLE 5.—*Checklist of foraminifers from Chevron USA, Inc. [Standard Oil of California], 24–35 well in sec. 35, T. 29 S., R. 29 E.*

[A, abundant (more than 50 specimens); C, common (21-50 specimens); F, few (2-20 specimens); R, rare (1 specimen). Depths shown are those given on ditch samples]

FORMATION		"Santa Margarita" Formation	Edison Shale of Kasline (1941)																				
SERIES	Miocene																						
STAGE	?		Luisian (Relizian not differentiated)																				
SPECIES / DEPTH (FT)	2200	2620	2640	2708	2720	2740	2760	2780	2800	2820	2860	2900	2940	2980	3020	3060	3100	3140	3180	3220	3260	3300	3340
Bulimella curta Cushman	--	--	R	--	--	--	--	--	--	--	--	R	F	--	R	--	--	--	--	--	--	--	--
Valvulineria californica Cushman	--	--	R	R	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	R
Gyroidina rosaformis (Cushman & Kleinpell)	--	--	--	R	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	F
Cassidulina panzana Kleinpell	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gyroidina soldanii d'Orbigny	--	--	--	--	F	R	R	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--
Bolivina advena striatella Cushman	--	--	--	--	--	--	R	--	--	--	--	F	--	--	--	--	--	R	R	--	--	--	--
Uvigerina spp.	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--
Bolivina advena ornata Cushman	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria miocenica Cushman	--	--	--	--	--	--	--	--	--	R	--	--	R-	--	--	--	--	--	--	--	--	--	--
Pullenia miocenica Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--
Anomalina salinasensis Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--
Valvulineria spp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--
Haplophragmoides sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--
Bolivina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerinella obesa Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerinella obesa impolita Cushman & Laiming	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
?Bolivina floridana Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria ornata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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Anomalina glabrata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina imbricata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Buliminella subfusiformis Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerinella californica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina advena Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nonionella miocenica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dentalina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nonionella costifera (Cushman)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nonionella incisa (Cushman)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pullenia salisburyi Stewart & Stewart	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quinqueloculina cf. Q. goodspeedi Hanna & Hanna	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Globobulimina pacifica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Globobulimina globosa (Hantken)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina marginata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina tumida Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina californica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trochammina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Praeglobobulimina pupoides (d'Orbigny)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
?Gaudryina triangularis Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Epistominella subperuviana Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Martinotiella patens Cushman & Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cibicides sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina mayi (Cushman & Parker)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyclammina pacifica Beck	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Siphogenerina mayi Cushman & Parker	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyclammina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fursenkoina hobsoni (Beck)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cassidulinoides californiensis Bramlette	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nodosaria longiscata d'Orbigny	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Buliminella elegantissima (d'Orbigny)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cibicides fletcheri Galloway & Wissler	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
?Eggerella subconica Parr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Textularia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

oysters) in the Rio Bravo sand suggests very shallow water conditions during its deposition. Although the presence of an unconformity at the Rio Bravo-Vedder contact, like that at the Pyramid Hill-Walker contact, cannot be demonstrated, the marked shallowing of the San Joaquin basin indicated by the presence of the Rio Bravo sand suggests that an unconformity could be present locally.

Both the Jewett Sand and the Freeman Silt were considered to be lower Saucesian (Ferguson, 1943; Beck, 1952; Rudel, 1965). Although

TABLE 5.—*Checklist of foraminifers from Chevron USA, Inc. [Standard*

FORMATION	Edison Shale of Kasline (1941)																							
SERIES	Miocene																							
STAGE	Luisian (Relizian not differentiated)																							
SPECIES / DEPTH (FT)	3380	3420	3460	3500	3540	3580	3620	3660	3700	3720	3740	3760	3780	3800	3820	3840	3860	3880	3900	3940	3980	4000	4040	4080
Bulimella curta Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--
Valvulineria californica Cushman	--	R	R	--	--	R	--	--	R	R	F	R	--	--	R	--	--	--	--	--	--	--	--	--
Gyroidina rosaformis (Cushman & Kleinpell)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cassidulina panzana Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gyroidina soldanii d'Orbigny	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	R	--	--	F	--	--
Bolivina advena striatella Cushman	R	R	R	--	--	--	--	--	R	R	--	R	--	--	--	--	--	--	--	--	--	--	R	--
Uvigerina spp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina advena ornata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria miocenica Cushman	F	R	F	--	F	R	F	--	--	R	R	--	R	--	--	--	--	--	R	R	--	--	F	--
Pullenia miocenica Kleinpell	--	--	--	--	--	--	--	--	--	--	R	--	--	--	R	--	--	--	--	--	--	--	--	--
Anomalina salinasensis Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria spp.	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Haplophragmoides sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina sp.	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerinella obesa Cushman	--	R	F	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerinella obesa impolita Cushman & Laiming	--	R	--	--	--	--	--	--	R	--	F	--	--	--	--	--	--	--	--	--	--	--	--	--
?Bolivina floridana Cushman	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Valvulineria ornata Cushman	--	--	--	--	R	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerinella spp.	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Anomalina glabrata Cushman	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	R	--	--	--	--	--	--
Bolivina imbricata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Buliminella subfusiformis Cushman	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--
Uvigerinella californica Cushman	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina advena Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	R	--	--	--	--	--	--
Nonionella miocenica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	R	--	--	--	--	--
Dentalina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nonionella costifera (Cushman)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nonionella incisa (Cushman)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pullenia salisburyi Stewart & Stewart	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Quinqueloculina cf. Q. goodspeedi Hanna & Hanna																								
Globobulimina pacifica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Globobulimina globosa (Hantken)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina marginata Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina tumida Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bolivina californica Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trochammina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Praeglobobulimina pupoides (d'Orbigny)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
?Gaudryina triangularis Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Epistominella subperuviana Cushman	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Martinotiella patens Cushman & Kleinpell	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cibicides sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lenticulina mayi (Cushman & Parker)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyclammina pacifica Beck	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Siphogenerina mayi Cushman & Parker	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyclammina sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Fursenkoina hobsoni (Beck)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cassidulinoides californiensis Bramlette	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nodosaria longiscata d'Orbigny	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Buliminella elegantissima (d'Orbigny)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cibicides fletcheri Galloway & Wissler	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
?Eggerella subconica Parr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
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the lower part of the Jewett Sand in outcrop is a shallow-water facies that does not carry a diagnostic foraminiferal fauna, the equivalent deeper water facies farther west in the subsurface is Zemorrian. The presence of diagnostic Zemorrian benthic foraminifers, including *Bulimina carnerosensis*, *Cibicides floridanus*, and the lowest occurrences of *Siphogenerina mayi* and *Uvigerinella obesa impolita* (tables 2-6), indicate that the Zemorrian-Saucesian boundary occurs within the lower part of the Freeman Silt and that the unconformity at the base of the Pyramid Hill Sand Member may be at or very close to the Oligocene-Miocene boundary (fig. 2).

Oil of California], 24–35 well in sec. 35, T. 29 S., R. 29 E.—Continued

Edison Shale of Kasline (1941)									Olcese(?) Sand					Freeman Silt										Jewett Sand						Vedder Sand							Walker Fm.	
Miocene																														Oligocene								
Luisian (Relizian not differentiated)										Saucesian					Zemorrian																							
4100	4140	4180	4200	4240	4280	4300	4340	4380	4400	4440	4480	4500	4520	4540	4560	4580	4600	4620	4625-35	4635-45	4663-72	4672-82	4720	4735-44	4744-50	4750-60	4835	4875	4915	4955	4995	5035	5075	5115	5155	5195	5235	5255
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Saucesian benthic foraminifers are common throughout most of the Freeman Silt in subsurface sections. Characteristic of these assemblages are *Bulimina inflata alligata, Dentalina quadrulata, Hanzawaia crassiseptus, Plectofrondicularia californica, Siphogenerina transversa, Uvigerinella obesa,* and *U. obesa impolita* (tables 2-7). Both Saucesian and Zemorrian assemblages indicate that the Freeman Silt was deposited in deep water, probably at lower middle bathyal depths (1,500-2,000 m).

In most subsurface sections the Saucesian assemblages appear to end abruptly because of the influx of transported shelf species, or in some places because of sample gaps. Farther west in the deepest part of the basin, diagnostic Saucesian benthic foraminifers disappear below the Freeman-Round Mountain Silt contact, and long-ranging Miocene species and transported shelf species appear that are most commonly associated with the middle and late Miocene (table 2). Although distinctly Relizian or younger species have not been identified in the uppermost part of the Freeman Silt, this interval is probably Relizian (fig. 2). The Freeman Silt, then, is early Miocene. On the basis of new evidence for a late Zemorrian-early Saucesian age of the Jewett Sand and the lower part of the Freeman Silt, and on the early Miocene age of the upper part of the Walker Formation reported here, we infer that the Jewett and the lower part of the Freeman are equivalent to the upper part of the Walker Formation south of the Bakersfield arch, even though the Jewett unconformably overlies the Walker in the Kern River area to the north of the arch (fig. 2).

ILMON BASALT

The Ilmon Basalt is a thin flow unit that lies above the Walker Formation and below the Bena Gravel in the vicinity of Caliente Creek. Dibblee and Chesterman (1953), who first named and described the unit, believed that the Ilmon and the Walker were conformable. However, although the two formations are apparently concordant, more probably there was a hiatus, however small, between the deposition of the Walker Formation and the time when the basalt flowed over its surface. The Ilmon is unconformably overlain by the Bena Gravel, as evidenced by its limited and discontinuous distribution.

The name "Ilmon Basalt" is here adopted as redefined above; lower Walker Basin Creek at its confluence with Caliente Canyon is designated as the type locality. Although the age and source of the Ilmon are not known, the unit is presumably early Miocene on the basis of its stratigraphic position (fig. 2) and may correlate with Miocene basalts northeast of Tehachapi.

OLCESE SAND

The Olcese Sand was defined by Ferguson (1941), although the name was first used by Diepenbrock (1933). The unit is dominantly a sandstone, with some interbedded siltstone and local pebbly sandstone or conglomerate. It reaches a thickness of 300 to 360 m in the vicinity of the Round Mountain oil field, which is its type area. In outcrop, the middle part is probably nonmarine, although the upper and lower parts are marine and abundantly fossiliferous in some areas (Addicott, 1970); farther basinward, the Olcese is wholly marine. Abrupt changes in benthic-foraminiferal faunas suggest an unconformity within the Olcese and near the Saucesian-Relizian boundary. The unit intertongues basinward with the underlying Freeman Silt and the overlying Round

Mountain Silt, and apparently pinches out completely within a few kilometers of the outcrop at the deep south end of the basin (fig. 4), although the Olcese extends more than 20 km westward from the outcrop in the area north of the Kern River (fig. 3).

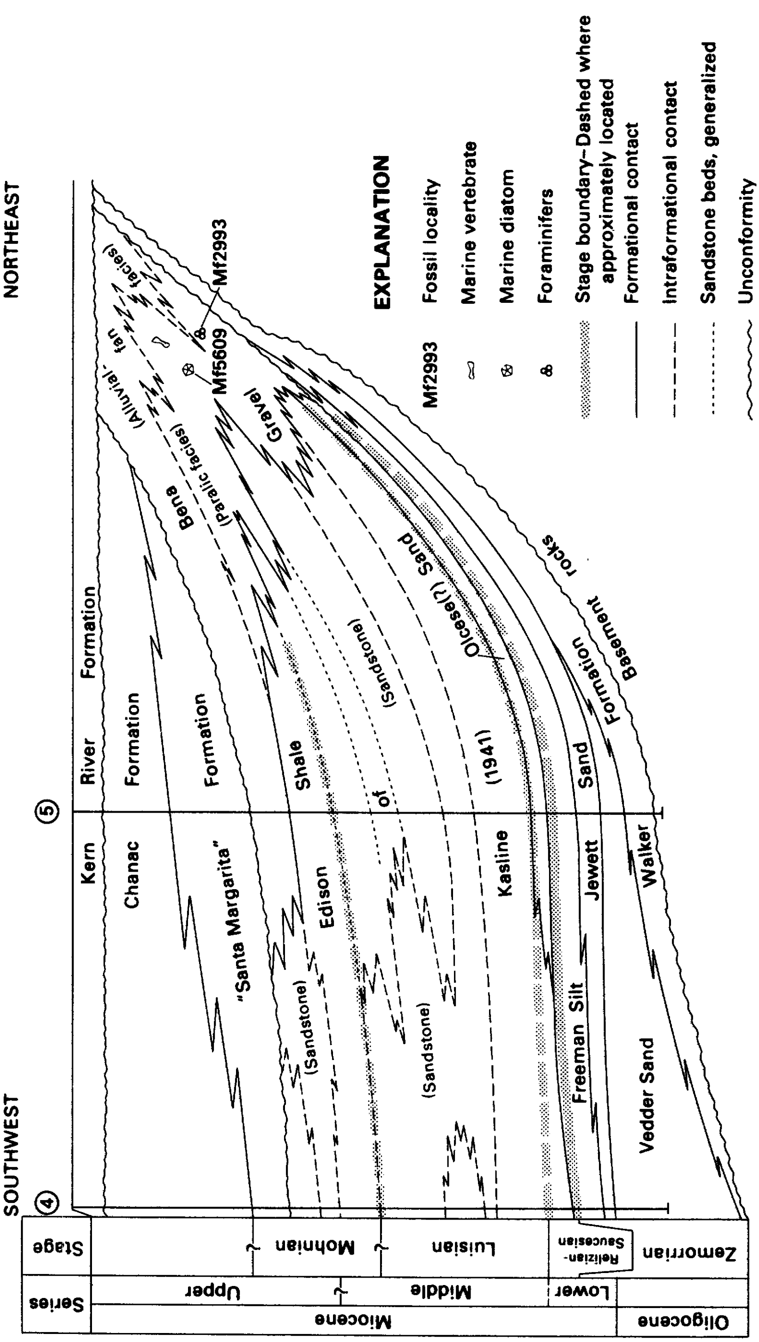

FIGURE 4.—Diagrammatic cross section of Cottonwood Creek area, showing stratigraphic relations of Tertiary formations south of Bakersfield arch and approximate position of age control. Not to scale, but biostratigraphic boundaries are in correct positions relative to formational boundaries. Numbered vertical lines (see fig. 1) indicate wells from which samples were studied.

South of the Kern River, the outcrops of Olcese sand rest unconformably on the Walker Formation, and farther south in the Tejon Hills, fossiliferous sandstone of the Olcese rests directly on basement rocks (fig. 5). A boulder conglomerate at the north end of the outcrops in the Tejon Hills is a lateral equivalent of the Olcese and may be partly or wholly nonmarine (Bartow and Dibblee, 1981).

Ferguson (1941) regarded the Olcese Sand as late Saucesian to early Relizian, although Beck (1952) placed it entirely within the Saucesian. The long-ranging Miocene species *Buccella mansfieldi*, *Nonionella costifera*, *N. incisa*, and *Quinqueloculina* cf. *Q. goodspeedi* characterize the Olcese Sand (tables 3-6). The only age-diagnostic species found in the Olcese Sand is *Marginulina beali*, which indicates

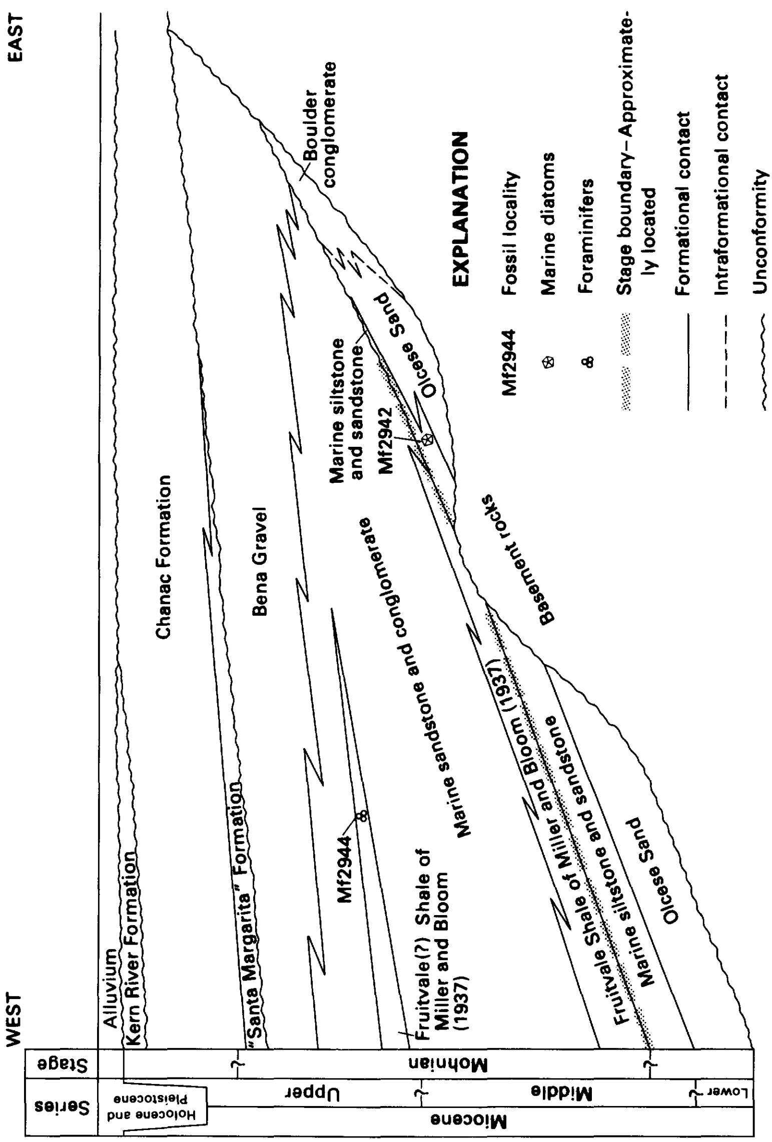

FIGURE 5.—Diagrammatic cross section of Tejon Hills area, showing stratigraphic relations of Tertiary formations and approximate position of age control. Not to scale, but biostratigraphic boundaries are inferred to be in correct positions relative to formational boundaries.

an age of Relizian or Luisian. Appearance of the assemblage including *M. beali* in the upper part of the Freeman Silt farther west implies lateral equivalency of the two formations. Although a Relizian fauna is not well represented in the Olcese, this formation is here considered Saucesian and Relizian, that is, early Miocene (fig. 2).

Addicott (1970, p. 18) described a crossbedded sandstone containing abundant pumice grains and pebbles that occurs near the middle of the unit. This pumiceous sandstone, first observed by W. P. Blake in 1853, provides a marker bed to which the fossils that he collected in Ocoya (Poso) Creek can be related (Blake, 1857, p. 167; pl. 1, sec. 3). It can be traced northward to where it is overlapped by the Kern River Formation. Pumice pebbles from this sandstone have been dated by K-Ar and fission-track methods, and the best age is considered to be 15.5 m.y. These results, which place the pumice bed near the Saucesian-Relizian boundary, are discussed more fully in the section below entitled "Geochronology."

BENA GRAVEL

The Bena Gravel was originally defined as "* * * a series of terrestrial gravels of lower and middle Miocene age lying conformably above the Walker formation and Ilmon basalt and unconformably below the Kern River gravels in lower Caliente Canyon" (Dibblee and Chesterman, 1953, p. 38). In the vicinity of Cottonwood Creek, several kilometers northwest of the Caliente Canyon area, Dibblee and Chesterman (1953, p. 38) reported the presence of a thin unit consisting of thin-bedded punky shale containing laminae of silty sand. This unit, which they called the Freeman-Jewett Shale, was believed to occur conformably between the Bena Gravel and the Walker Formation. A later map (Dibblee and others, 1965) covering the Cottonwood Creek area shows the Freeman Silt, the Olcese Sand, and the Round Mountain Silt between the Bena and the Walker and intertonguing at the top with the Bena.

The heterogeneous lithology of the sequence between the Bena Gravel (as originally defined by Dibblee and Chesterman, 1953) and the Walker Formation, which consists of coarse sandstone and conglomerate closely associated with laminated claystone and siltstone, diverges from the typical lithologies of the Freeman Silt, the Olcese Sand, and the Round Mountain Silt in the area north of the Kern River. This sequence contains plant material in places, and it contains freshwater diatoms in a claystone at the base that was mapped as the Freeman Silt by Dibblee and others (1965). There are also rare occurrences of oysters and barnacles (Hackel, 1965, p. 29), marine-mammal bones, diatoms, and foraminifers (figs. 4, 6). The conglomerate interbeds are lithologically identical to the nonmarine Bena Gravel, and much of the sandstone, siltstone, and claystone occurs in fining-upward sequences a few meters thick, including at least one fossil soil (measured section unit 21), that are best interpreted as fluvial cycles. The whole sequence

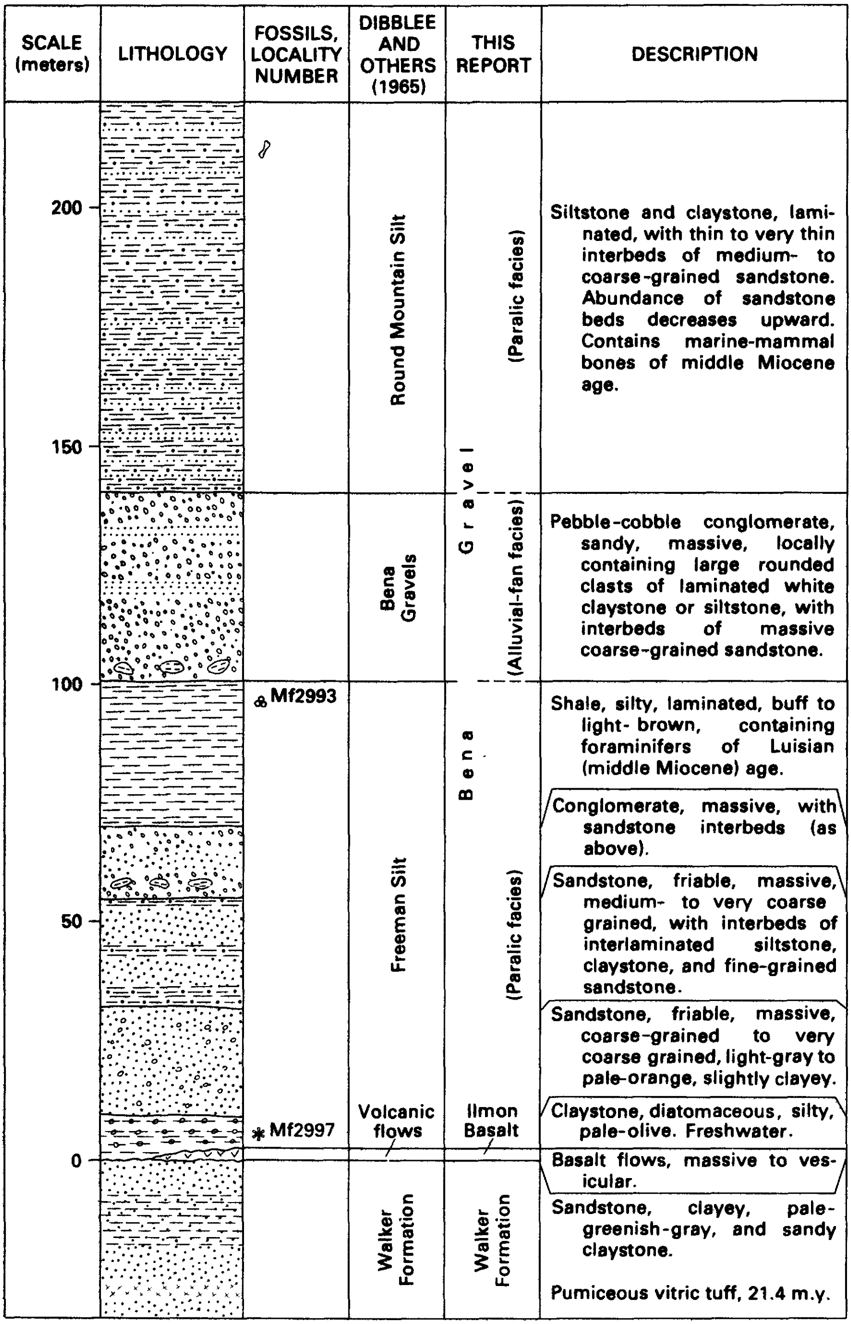

FIGURE 6.—Columnar section of lower part of the Bena Gravel south of Cottonwood Creek, showing position of age control.

MEASURED SECTION OF THE PARALIC FACIES OF THE BENA GRAVEL

[From roadcuts along Breckenridge Road in sec. 16, T. 29 S., R. 30 E., Mount Diablo base and meridian]

	Thickness (m)
Bena Gravel (part):	
42. Claystone and silty claystone, laminated, light-olive-gray, containing common gypsum veins. Higher beds not exposed	7.0+
41. Sandstone, pebbly, coarse-grained to very coarse grained, massive, including thin sandy pebble-conglomerate lens near base, and concentration of dense laminated limestone boulders in upper part. Scour surface at base	9.0
40. Claystone, silty, pale-olive; sandy in lower part	1.0
39. Sandstone, pebbly, medium- to coarse-grained and coarse-grained to very coarse grained, friable, yellowish-gray; contains large-scale crossbedding locally. Fines upward to fine- to medium-grained clayey sandstone and grades into overlying unit; scour surface at base	10.0
38. Claystone, sandy claystone, and clayey fine-grained to very fine grained sandstone; pale-olive to yellowish-gray	6.5
37. Sandstone, pebbly, coarse-grained to very coarse grained friable; grades upward into medium to coarse sand. Poorly exposed	6.0?
36. Sandstone, calcareous, coarse-grained to very coarse grained pebbly, and medium- to coarse-grained; large-scale crossbedding locally includes pebble-conglomerate lens near middle of unit; scour surface at base	12.0
35. Sandstone and siltstone, very fine grained, clayey, laminated, pale-olive (locally stained dark yellowish orange); grades upward into silty claystone	1.0
34. Sandstone, pebbly, coarse-grained to very coarse grained, including thin interbeds of medium- to coarse-grained sandstone, and laminated siltstone with calcareous concretions	1.5
33. Pebble conglomerate, friable, with coarse-grained sandstone matrix; fines upward and grades into overlying unit	3.5
Covered interval	
32. Siltstone and silty sandstone, laminated, grayish-orange and pale-yellowish-brown, with thin interbeds of light-gray to light-olive claystone and thin lenses of medium-grained sandstone; weathers to very fissile shale. Claystone contains fish remains and marine diatoms	4.0+
31. Sandstone and conglomerate, with clasts of laminated white claystone in sandstone. Poorly exposed	2.0
Fault and covered interval	
30. Conglomerate, sandy, containing rounded pebbles and cobbles, with a few boulders of laminated white claystone near base. Fills channels in underlying unit	3.5+
29. Sandstone, coarse-grained, friable, containing abundant claystone pebbles throughout and laminated white claystone boulders at top	1.8
28. Conglomerate, sandy, containing rounded pebbles and cobbles; crudely bedded, with thin interbeds of pebbly sandstone	2.7
27. Sandstone, thin- to medium-bedded, friable, light-gray to yellowish-orange; grain sizes range from fine to very coarse and pebbly	5.0
26. Conglomerate, sandy, massive, dark-yellowish-orange, containing rounded pebbles and cobbles; scour surface at base with a few centimeters of relief	3.0

MEASURED SECTION OF THE PARALIC FACIES OF THE BENA GRAVEL—Continued

	Thickness (m)
25. Interlaminated siltstone, claystone, and fine-grained sandstone, light-gray to grayish-yellow	0.3
24. Sandstone, coarse-grained to very coarse grained, friable, light-gray; poorly sorted grayish-orange conglomeratic sandstone at base; Contains large isolated clasts of laminated siltstone and poorly sorted conglomerate bed near base; includes eroded and truncated interbeds of interlaminated claystone, siltstone, and very fine grained sandstone in lower part, with scattered small claystone clasts in upper part	17.0
23. Sandstone, pebbly, clayey, pale-olive; contains clasts of very clayey greenish-gray sandstone at base. Fines upward to clayey fine-grained to very fine grained sandstone at top	2.7
22. Claystone, pale-greenish-yellow to grayish-yellow; becomes silty to sandy near top	1.5
21. Eroded fossil soil, sandy, yellowish-gray to dusky-yellow in lower part, mottled-yellowish-orange toward top, and dark-yellowish-orange in upper few centimeters; clay content increases upward. Contains root(?) molds throughout; mostly massive but blocky structure in upper 30 cm	1.5
20. Sandstone, pebbly, medium- to coarse-grained, grayish-orange; becomes clayey in upper part. Fills erosional relief of 20 to 30 cm on underlying unit	3.6
19. Claystone, light-grayish-olive; becomes sandy upward and grades into pale-olive sandy claystone to clayey very fine grained sandstone	3.0
Fault	
18. Sandstone, clayey, very fine grained	1.0+
17. Conglomerate, containing rounded pebbles and cobbles, with coarse-grained sandstone matrix	2.8
Fault	
16. Conglomerate (as above), containing large white claystone boulders at base; fines upward	2.0
15. Sandstone, pebbly, coarse-grained to very coarse grained, very pale orange to grayish-orange	1.0+
Fault and covered interval	
14. Pebble conglomerate, sandy, crudely stratified; contains scattered large cobbles	3.0+
13. Sandstone, coarse-grained to very coarse grained, friable, massive, light-gray to very-pale-orange; includes thin bands of pebbles and cobbles	3.0
12. Claystone, silty, pale-olive	1.5
Fault	
11. Sandstone, pebbly, grading upward into sandy conglomerate; fills channels in underlying sandstone	5.5
10. Sandstone, clayey, very fine grained	1.0+
Fault	
9. Pebble conglomerate, sandy, light-gray to pale-orange, crudely stratified	11.5
8. Sandstone, very coarse grained, pebbly, friable, massive, light-gray	4.5
7. Sandstone, medium-grained, massive, very pale orange; contains pebble- and cobble-sized clasts of siltstone and claystone	1.5
6. Conglomerate, sandy, massive, poorly sorted, light-gray to very pale orange	2.0

MEASURED SECTION OF THE PARALIC FACIES OF THE BENA GRAVEL—Continued

	Thickness (m)
Fault	
5. Interlaminated siltstone and very fine grained sandstone, pale-olive to yellowish-gray	1.0
4. Sandstone, medium- to coarse-grained, light-gray; grades upward into overlying unit	2.5
3. Pebble conglomerate; contains boulders of dense pale-olive limestone with scattered pebbles	1.3
2. Sandstone, coarse-grained to very coarse grained, massive, pale-yellowish-orange; contains scattered pebbles, and pebble- to boulder-size clasts of pale-olive siltstone. Grades upward into sandy pebble conglomerate	6.0
Fault	
1. Claystone, laminated, light- through grayish-olive to locally dark gray, includes few very thin interbeds of very fine grained yellowish-gray calcareous sandstone near top and a thin dense microcrystalline limestone at top	2.0
Total exposed thickness	162.2+

between the Bena Gravel (of Dibblee and Chesterman, 1953) and the Walker Formation probably represents a complex of freshwater, brackish-water, and marine environments equivalent to the deeper water marine facies represented by the uppermost part of the Freeman Silt, the Olcese Sand, the Round Mountain Silt, and the Fruitvale Shale of Miller and Bloom (1937) in the deeper parts of the basin. Because of the intertonguing of this sequence with the Bena Gravel at the top and the inclusion of conglomerate interbeds or lenses lithologically identical to the Bena throughout, we here include this sequence within the Bena Gravel as a paralic facies distinct from both the alluvial-fan facies characteristic of the remainder of the Bena and the fully marine facies to the southwest.

The Bena Gravel changes facies within a short distance northward into the Olcese Sand and the Round Mountain Silt, and southwestward into the Edison Shale of Kasline (1941) (fig. 4). The Edison Shale, which is recognized in the subsurface of the Edison oil field (fig. 1) a few kilometers southwest of outcrops of the Bena, probably represents a transitional facies between the Bena and the normal marine facies (Round Mountain Silt and the Fruitvale Shale of Miller and Bloom, 1937).

The absence of the Freeman Silt and the Jewett Sand in outcrops south of the Kern River, where the Olcese Sand rests directly on the Walker Formation (Dibblee and others, 1965; Bartow, 1981), strongly suggests that, despite the statement of Dibblee and Chesterman (1953) to the contrary, an unconformity exists between the Bena Gravel and the underlying Walker Formation or Ilmon Basalt. The presence of this unconformity is supported by the strong lithologic contrast between the Bena Gravel and the Walker Formation (as discussed above) where the two formations are in contact.

The Bena Gravel is restricted to the area south of the Kern River and is about 760 m thick at the type locality south of Caliente Creek (Dibblee and Chesterman, 1953). In the vicinity of Cottonwood Creek, about 750 m of nonmarine conglomerate and sandstone overlies more than 200 m of the paralic facies.

Nonmarine sandstone, conglomerate, and mudstone unconformably below the "Santa Margarita" or Chanac Formation in the Tejon Hills were included within the Bena Gravel by Dibblee and Warne (1970), although these strata were originally mapped as the Santa Margarita Formation by Hoots (1930). These rocks, as much as 250 m thick, are lithologically similar to the type Bena Gravel but are equivalent to only the upper, late Miocene part (fig. 5).

Age diagnostic fossils have been found at a few localities in the Bena Gravel. The paralic facies in the area between Cottonwood Creek and Caliente Creek has yielded foraminifers of Luisian age and seal bones[2] (figs. 4 and 6). Marine diatoms of middle Miocene age (table 8) were found in the measured section of the paralic facies (unit 32).

The Bena Gravel in the Tejon Hills contains nonmarine mammals of Savage's (1955) Cerrotejonian Stage (early Clarendonian [late Miocene]). The Bena conformably overlies a marine sandstone containing a tongue of the Mohnian Fruitvale Shale of Miller and Bloom (1937), and unconformably underlies the "Santa Margarita" Formation containing a late Miocene molluscan fauna (fig. 5). The age of the Bena, then, is late early Miocene(?), middle Miocene, and late Miocene.

ROUND MOUNTAIN SILT

Diepenbrock (1933) first used the name "Round Mountain Silt" for an interval of diatomite, siltstone, and sandstone in a well in the Mount Poso area. Its boundaries were redefined by Addicott (1970) to make them more consistent with current usage. The unit conformably overlies the Olcese Sand and is unconformably overlain by the "Santa Margarita" or Chanac Formation in the Kern River area (fig. 3). In the subsurface to the west, the Round Mountain Silt, generally 120 to 180 m thick, is conformably overlain by the Fruitvale Shale of Miller and Bloom (1937). The Round Mountain reaches a thickness of more than 400 m locally south of the Kern River.

A unit composed mostly of fine-grained micaceous sandstone with thin interbeds of laminated siltstone and claystone crops out in the

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[2]Identified as *Allodesmus kernensis* (Lusian and Mohnian) by C. A. Repenning. This species is best known from the bone bed in the Round Mountain Silt.

TABLE 6.—*Checklist of foraminifers from Jim Riley [Standard Oil of California], "Jeppi-Camp" 67–8 well in sec. 8, T. 30 S., R. 29 E.*

[F, few (2-20 specimens); R, rare (1 specimen). Depths shown are those given on ditch samples]

FORMATION	Round Mountain Silt				Freeman Silt / Olcese(?) Sand		
SERIES	Miocene						
STAGE	Saucesian					Zemorrian	
SPECIES / DEPTH (FT)	5500	5520	5540	5560	5580	5600	5620
Cibicides floridanus (Cushman)	F	--	R	--	--	--	--
Epistominella pacifica (Cushman)	F	R	--	--	--	F	F
Globobulimina pacifica Cushman	F	R	F	R	--	R	--
Plectofrondicularia californica Cushman & Stewart	R	R	--	--	--	--	--
Praeglobobulimina pupoides (d'Orbigny)	R	--	--	--	--	--	--
Oridorsalis umbonatus (Reuss)	R	--	--	--	--	--	--
?*Bolivina advena striatella* Cushman	--	R	--	--	--	--	--
Gyroidina soldanii d'Orbigny	--	R	R	--	--	--	--
Haplophragmoides sp.	--	R	--	--	--	--	--
Nonionella costifera (Cushman)	--	F	--	--	--	F	--
Nonionella cf. *N. incisa* (Cushman)	--	R	--	--	--	--	--
Bolivina marginata Cushman	--	--	R	--	--	R	--
Lenticulina simplex (d'Orbigny)	--	--	R	--	--	--	--
Uvigerinella obesa Cushman	--	--	F	--	--	--	--
Uvigerinella obesa impolita Cushman & Laiming	--	--	F	R	--	R	F
Siphogenerina mayi Cushman & Parker	--	--	--	R	--	--	--
Bolivina sp.	--	--	--	--	--	R	--
Cibicides americanus (Cushman)	--	--	--	--	--	R	--
Marginulina exima Neugeboren	--	--	--	--	--	R	--
Cassidulina monicana Cushman and Kleinpell	--	--	--	--	--	--	R
Cassidulina californiensis Bramlette	--	--	--	--	--	--	R
Gaudryina triangularis Cushman	--	--	--	--	--	--	R
Lenticulina colorata (Stache)	--	--	--	--	--	--	R
Siphogenerina transversa Cushman	--	--	--	--	--	--	R
Trochammina sp.	--	--	--	--	--	--	R
Uvigerina joaquinensis Kleinpell	--	--	--	--	--	--	F

TABLE 7.—*Checklist of foraminifers from outcrops of Miocene strata in the southeastern San Joaquin Valley, California*

[X, present. Units sampled at various localities: Mf2938, Round Mountain Silt; Mf2953, Freeman Silt; Mf2993, Bena Gravel (paralic facies); Mf2944, Fruitvale(?) Shale]

SERIES	Miocene			
STAGE	Saucesian	Luisian		Mohnian
SPECIES / LOCALITY	mf2953	mf2938	mf2993	mf2944
Bolivina advena Cushman	X	X	X	--
Boldia cf. B. hodgei (Cushman & Schenck)	X	--	--	--
Elphidium sp.	X	--	--	--
Epistominella ramonensis Cushman & Kleinpell	--	--	--	--
Fursenkoina californiensis (Cushman)	X	--	--	--
Globobulimina ovula (d'Orbigny)	X	--	--	--
Globocassidulina margareta (Karrer)	X	--	X	--
Gyroidina orbicularis planata Cushman	X	--	--	--
Gyroidina soldanii d'Orbigny	X	--	--	--
Lagena sp.	X	--	--	--
Lagena sulcata Walker & Jacob	X	--	--	--
Lenticulina simplex (d'Orbigny)	X	--	--	--
Marginulina dubia Neugeboren	X	--	--	--
Nonionella costifera (Cushman)	X	X	--	--
Nonionella incisa (Cushman)	X	X	--	--
Nonionella miocenica Cushman	X	--	--	--
Planulina appressa Kleinpell	X	--	--	--
Plectofrondicularia californiensis (Cushman)	X	--	--	--
Uvigerinella obesa Cushman	X	X	X	--
Uvigerinella obesa impolita Cushman & Laiming	--	X	--	--
Valvulineria californica Cushman	--	X	--	--
Valvulineria ornata	--	X	X	--
Bolivina conica Cushman	--	--	X	--
Buliminella curta Cushman	--	--	X	--
Buliminella subfusiformis Cushman	--	--	X	--
Buliminella sp.	--	--	X	--
Bulimina montereyana Kleinpell	--	--	--	X
Bulimina montereyana delmontensis Kleinpell	--	--	--	X
Bulimina pseudoaffinis Kleinpell	--	--	--	X
Epistominella gyroidinaformis (Cushman & Goudkoff)	--	--	--	X
Hopkinsina magnifica Bramlette	--	--	--	X
Uvigerina hootsi Rankin	--	--	--	X

TABLE 8.—*Checklist of marine diatoms from outcrops of Miocene strata in the southeastern San Joaquin Valley, California*

[Data from J. A. Barron (written communs., 1976, 1980). X, present; ?, uncertain. Units sampled at various localities: Mf2941, Mf2994, and Mf2995, Round Mountain Silt; Mf2942, unnamed siltstone and sandstone in Tejon Hills; Mf5609, Bena Gravel (paralic facies)]

SERIES	Miocene				
	Middle				
ZONE/SUBZONE	Denticulopsis lauta zone (Barron, 1981)				
	a				b
SPECIES / LOCALITY	Mf2941	Mf2942	Mf2994	Mf2995	Mf5609
Actinocyclus ingens Rattray	X	X	X	X	X
Actinoptychus kernensis Hanna	X	--	--	--	--
Actinoptychus thumii Schmidt	X	--	--	--	--
Coscinodiscus endoi Kanaya	--	--	X	?	--
Coscinodiscus marginatus Ehrenberg	--	X	--	--	--
Cussia praepalecea (Schrader) Schrader	X	--	--	--	--
Cussia sp.	--	--	--	--	X
Cymatosira andersoni Hanna	X	--	--	--	--
Delphineis sp. of D. penelliptica Andrews	--	--	--	--	X
Denticulopsis hyalina (Schrader) Simonsen	--	--	--	--	X
Denticulopsis lauta (Bailey) Simonsen	X	--	X	X	X
Denticulopsis norwegica (Schrader) Simonsen	--	--	--	--	X
Glyphodiscus stellatus Greville	--	X	--	--	--
Hemiaulus polymorphus Grunow	--	X	--	--	--
Mediaria splendida Shesukova-Poretzkaya	--	--	X	--	X
Melosira sulcata (Ehrenberg) Kutzing	--	X	--	--	--
Opephora schwartzii? (Grunow) Petit	--	X	--	--	--
Rhaphoneis angustata Pantocsek	--	--	X	--	--
Rhaphoneis miocenica Schrader	X	--	X	X	--
Rhaphoneis obesa Hanna	X	--	X	X	--
Rhaphoneis parilis Hanna	--	--	--	X	--
Rhaphoneis cf. R. parilis Hanna	--	--	--	X	--
Stephanopyxis sp.	--	X	--	X	--
Synedra jouseana Sheshukova-Poretzkava	--	--	--	X	X
Triceratium condecorum Brightwell	X	--	--	X	--

Tejon Hills (Bartow and Dibblee, 1981). This unit, which is probably correlative with the Round Mountain Silt, lies conformably on the Olcese Sand and appears to be disconformably overlain by an upper Miocene marine sandstone (fig. 5). The siltstone-sandstone unit contains middle Miocene diatoms (table 8).

The Round Mountain Silt has been considered Relizian to Saucesian (Ferguson, 1941; Rudel, 1965) or latest Saucesian to Luisian (Beck, 1952). These age assignments are too old for most of the unit. An outcrop sample (loc. Mf2938, table 7), about 45 m above the base of the Round Mountain in the area just southeast of the Round Mountain oil field (fig. 1), contains a Luisian benthic-foraminiferal fauna. In subsurface sections, the Round Mountain is characterized by the distinctive "*Valv. cal.* flood" (*Valvulineria californica*), which is generally considered to be synonymous with the Luisian Stage. Benthic-foraminiferal faunas in the subsurface sections include such restricted or diagnostic Luisian species as *Bolivina advena striatella*, *B. imbricata*, *Cassidulina panzana*, *Siphogenerina branneri*, *Uvigerina joaquinensis*, *Valvulineria californica* s.l., and *V. ornata* (tables 2-4). These faunas support a Luisian age for the Round Mountain Silt, although unsampled intervals may contain Relizian faunas. Diatoms from outcrop samples in the upper part of the unit (table 8) are assigned to the *Denticulopsis lauta* zone, which is correlative with the Luisian Stage. The age of the Round Mountain, therefore, is early(?) and middle Miocene (fig. 2).

FRUITVALE SHALE OF MILLER AND BLOOM (1937)

The name "Fruitvale Shale" was apparently used informally in subsurface correlations in the southern San Joaquin Valley for several years before being introduced into the literature by Miller and Bloom in 1937. As first used, the unit consisted of dark poorly sorted carbonaceous silt of late Miocene age below the "Santa Margarita" Formation.

The Fruitvale Shale is Mohnian (late middle and late Miocene) (fig. 2; Beck, 1952). The only known outcrops that might be identified as the Fruitvale Shale are at Comanche Point, about 30 km southeast of Bakersfield, where a small area of silty claystone has yielded an early to middle Mohnian foraminiferal fauna (sample Mf2944, table 7), although that outcrop is probably only a tongue of the Fruitvale in a thick upper Miocene marine sandstone (fig. 5). Benthic foraminifers from subsurface sections compose an early to middle Mohnian assemblage characterized by such age-diagnostic species as *Bolivina girardensis*, *B. obliqua*, *Uvigerina hootsi*, and *U. peregrina* (table 2).

"SANTA MARGARITA" AND CHANAC FORMATIONS

Merriam (1916) introduced the names "Santa Margarita" and "Chanac" for the outcrops of upper Miocene strata in the Tejon Hills area. The original description of the nonmarine Chanac by J. P. Buwalda (in Merriam, 1916, p. 113-114) did not include a stratigraphic section or a map, and so there is some uncertainty about which beds he intended to include in the formation. Hoots (1930) provided a map and a more complete description of the Chanac Formation, and it is his usage that has been followed by subsequent workers. As used by Hoots, the Chanac is easily differentiated from underlying units because of its prevailing brown color.

The "Santa Margarita" Formation is a marine sandstone that conformably underlies the nonmarine Chanac. Subsurface correlations indicate that the lower part of the Chanac is the lateral equivalent of the "Santa Margarita." The "Santa Margarita," as mapped in the Tejon Hills by Hoots (1930), included an extensive area of nonmarine sandstone, claystone, and conglomerate below the fossiliferous marine sandstone. As noted above, Dibblee and Warne (1970) referred these nonmarine strata to the Bena Gravel.

Previous workers (see Hoots, 1930, and Ferguson, 1941) have generally agreed that an unconformity exists at the base of the "Santa Margarita" Formation, although in the Tejon Hills area there is uncertainty about the position of the base of the "Santa Margarita." In the area east of Comanche Creek, a unit of coarse-grained marine sandstone and conglomerate abruptly overlies generally finer grained older units (fig. 5) and appears to overlap most or all of the older section (Bartow and Dibblee, 1981). Part of this apparent overlap is due to rapid thinning of the older units by facies change, and no angular discordance is apparent at the contact. The field evidence favors only a local unconformity.

An angular unconformity can be seen west of lower Comanche Creek, where the "Santa Margarita" Formation, represented by a unit of thin white sandstone conformably below the buff to brown Chanac Formation, overlies light- and greenish-gray sandstone and claystone of the Bena Gravel. The presence of an unconformity in this part of the section is supported by evidence from vertebrate paleontology. Two vertebrate assemblages occur in the Tejon Hills (Drescher, 1942; Savage, 1955)—one at the base of the Chanac Formation, and one in the uppermost part of the Bena Gravel (Santa Margarita Formation of Hoots, 1930). According to Drescher (1942, p. 7), the "striking differences" that distinguish the faunas, which are as close as 15 m apart stratigraphically, suggest a break in deposition between the two units. The "Santa Margarita" Formation in this area, then, is restricted to the thin white marine sandstone that lies below the Chanac and unconformably above the lower nonmarine unit now called the Bena Gravel.

A thin white sandstone and conglomeratic sandstone in the Kern River area that unconformably overlies the Round Mountain Silt and is unconformably overlain by the Kern River Formation was mapped as the "Santa Margarita" Formation by Dibblee and others (1965). Alhough marine fossils are abundant in the "Santa Margarita" at Comnche Point (B. L. Clark, in Merriam, 1916, p. 115; Hoots, 1930), they have not been found in the thin unit in the Kern River area (Addicott, 1970). Because of the absence of fossils and the poor sorting of the sand and gravel, this unit was questionably referred to the Chanac by Bartow and Doukas (1978). Although marine "Santa Margarita" sandstone is present only a few kilometers downdip to the west, "Chanac" is probably a more appropriate name for the outcrops of this unit (fig. 3).

Most information on the age of the "Santa Margarita" and Chanac Formations comes from the Tejon Hills outcrops, where both formations are fossiliferous. The sandstone beds of the "Santa Margarita" bear late Miocene marine mollusks (B. L. Clark, in Merriam, 1916, p. 115; Hoots, 1930), and continental vertebrates have been found at the base of the Chanac; these vertebrates are of the Montediablan Stage (late Clarendonian age) of Savage (1955). Late Miocene marine megafossils are also common in the "Santa Margarita" in the subsurface (Addicott, 1970).

In summary, the "Santa Margarita" and Chanac Formations are considered to be different facies of the same upper Miocene depositional sequence (fig. 2) that, in outcrop, unconformably overlies older Miocene strata. The "Santa Margarita," however, apparently becomes conformable with the underlying Fruitvale Shale of Miller and Bloom (1937) in the subsurface to the west. The "Santa Margarita" is no more than 15 to 20 m thick in outcrop at Comanche Point but reaches a thickness of more than 200 m in the subsurface. The Chanac is from 90 to more than 300 m thick in the Tejon Hills (Hoots, 1930) but no more than 30 m thick in the Kern River area. The thickness of the Chanac is indeterminate in the subsurface because of the difficulty in differentiating the Chanac from the Kern River Formation.

KERN RIVER FORMATION

The Kern River Formation is the youngest Tertiary unit in the southeastern San Joaquin Valley. It unconformably overlies older Tertiary strata and laps onto pre-Tertiary basement rocks about 50 km north of Bakersfield. The lower part of the nonmarine Kern River intertongues westward with the marine Etchegoin Formation, and the upper part of the Kern River is equivalent to the San Joaquin and Tulare Formations of the west side of the valley. The Kern River, now considered to be late Miocene, Pliocene, and early Pleistocene(?), is discussed in more detail by Bartow and Pittman (1983).

GEOCHRONOLOGY

The geochronology of Miocene strata in California is based on the dating of Kleinpell's (1938) benthic-foraminiferal stages by Turner (1970). The stage boundaries shown in figure 2 have been adjusted slightly to conform to the K-Ar ages recalculated according to new decay and abundance constants (Steiger and Jäger, 1977). The ages for the Zemorrian-Saucesian boundary (originally 22.5, now 23 m.y.) and the Saucesian-Relizian boundary (originally 15.3, now 15.7 m.y.), which are most critical to this discussion, were the least ambiguous of Turner's results. Recent correlation of the California benthic stages with the European stages by means of a deep-sea planktonic biochronology (Poore and others, 1981) suggests that the California stage boundaries may need to be revised. These new correlations, however, have not yet been reconciled with the chronology derived from the dating of rocks within the province. Evidence of the time-transgressiveness of benthic assemblages is also accumulating (for example, Brabb and others, 1977, fig. 2; Crouch and Bukry, 1979); but regardless of where correlations of the benthic stages may eventually lead, there is presently no direct evidence to contradict Turner's age determinations for the stage boundaries in the San Joaquin basin.

The Tertiary section in the southeastern San Joaquin Valley contains several tuff beds that might provide additional age control for the associated sedimentary rocks and their contained faunas. Samples from a thin vitric tuff in the Round Mountain Silt, a thick ash-flow tuff in the type section of the Walker Formation, and pumice pebbles from the pumiceous sandstone in the Olcese Sand were collected for radiometric dating.

WALKER FORMATION

A thick pumiceous rhyolite tuff occurs about 365 m below the top of the type section of the Walker Formation in Walker Basin Creek. The outcrop consists of a massive ash-flow unit, about 3 m thick, that was apparently confined to a channel, and an overlying much thicker water-laid tuff that is interbedded with sedimentary rocks of the Walker Formation. Both units were sampled, and the petrology of the samples, together with trace- and minor-element chemistry of the glass fractions, was determined by neutron-activation analysis of cleaned glass separates (A. M. Sarna-Wojcicki, written commun., 1979). The results indicate that the two units are virtually identical in composition. Plagioclase from the ash-flow unit was dated by the K-Ar method at 21.4 m.y. (field No. GV75-2, table 9).

Evidence that the Jewett Sand and the lower part of the Freeman Silt are partly Zemorrian, that is, older than 23 m.y., indicates that the upper part of the Walker Formation south of the Bakersfield arch must be partly equivalent to the Jewett and the lower part of the Freeman. This would be the case even if the tuff were actually 1 m.y. older, which would be more than the probable error (± 0.6 m.y.) of the K-Ar age. Additional dates from the tuff might refine this age somewhat but would probably not greatly change the relations shown in figure 2.

OLCESE SAND

The abrupt appearance of a high concentration of pumice pebbles and grains in the pumiceous sandstone zone of the Olcese Sand

TABLE 9.—*Analytical data for K-Ar age determinations*

[Field No. GV74-1, tuff in the Round Mountain Silt; field No. GV75-13, pumice pebbles from the Olcese Sand; field No. GV75-2, tuff in the Walker Formation. Potassium determinations by J. Tillman, J. Christie, and M. Cremer; argon determinations and age calculations by A. Berry, E. Sims, and J. Von Essen. ^{40}K decay constants: $\lambda_{\beta}=4.962\times10^{-10}$ yr^{-1}, $\lambda_{\varepsilon}+\lambda_{\varepsilon}'=0.581\times10^{-10}$ yr^{-1}, and $^{40}K/K=1.167\times10^{-4}$ mol/mol]

Field No.	Mineral	K_2O (wt pct)	$^{40}Ar_{rad}$ (10^{-12} mol/g)	$^{40}Ar_{rad}$ / $^{40}Ar_{total}$	Calculated age (m.y.)
GV74-1	Biotite---------	8.955	804.2	0.86	61.3±1.8
	Plagioclase-----	.449	28.20	.70	43.1±1.3
GV75-13	Sanidine--------	10.125	318.9	.80	21.8±0.6
	Plagioclase-----	1.000	27.50	.59	19.0±0.8
GV75-2	Plagioclase-----	.506	15.61	.49	21.4±0.6

suggests that the pumice was transported and deposited very soon after eruption. An age for the pumice should be close to, but no younger than, that of the containing sediment.

Feldspar (plagioclase and sanidine) and zircon crystals separated from large pumice pebbles, which had first been cleaned of adhering sediment, were dated by the K-Ar and fission-track methods, respectively. The results, summarized in tables 9 and 10 (field No. GV75-13), show an age spread of 6.3 m.y. that appears to span the stratigraphically determined age of the pumice-bearing sediment.

Where K-Ar ages are older than a fission-track age for the same unit, the best explanation is that the sample contained an admixture of older material. The feldspar concentrates, then, would be composites of crystals of different ages, and the resulting K-Ar age would fall somewhere between the oldest and youngest. The zircon concentrate would also contain older crystals, but because the crystals were examined and counted individually, the older population can be eliminated from the age calculation. The fission-track age of 15.5 m.y. was based on six zircon grains; however, a seventh zircon that was counted had an age of 28.2 m.y. which indicates the presence of older material in the sample. The best of these three ages, then, is the fission-track age of 15.5 m.y., which is very close to the stratigraphically determined age of the pumice bed. The older contained material could be either detrital grains that had worked deeply into the porous pumice, or a separate population of pumice pebbles from an older deposit in the source area. The fact that the sanidine K-Ar age is the oldest argues against detrital-grain contamination because detrital sanidine is rare in the Kern River area.

ROUND MOUNTAIN SILT

A thin fine-grained vitric tuff, about 45 m above the base of the Round Mountain Silt and within 1 m of Luisian locality Mf2938 (fig. 3),

TABLE 10.—*Analytical data for fission-track age determinations*

[Field No. GV74-1, tuff in the Round Mountain Silt (5 zircons counted); field No. GV75-13, pumice pebbles from the Olcese Sand (6 zircons counted). Age determinations by C. E. Meyer and C. W. Naeser, respectively]

Field No.	U (ppm)	Spontaneous tracks		Induced tracks		Neutron flux	Calculated age (m.y.)
		Density ($10^6/cm^2$)	No.	Density ($10^6/cm^2$)	No.		
GV74-1	216	3.34	947	6.50	922	1.35	41.4±1.9
GV75-13	210	1.78	527	5.15	763	.732	15.5±1.7

was dated by both the K-Ar and fission-track methods. The resulting K-Ar ages of 43.1 and 61.3 m.y. from plagioclase and biotite, respectively (field No. GV74-1, table 9), were judged to be too old by a factor of 3, most probably because of the inclusion of detrital minerals derived from the Sierra Nevada batholith.

The fission-track age of 41.4 ± 1.9 m.y. from the zircons (field No. GV74-1, table 10) oddly coincides with the plagioclase K-Ar age. Because this fission-track date is derived from individual grains, it cannot reflect a mixing of old and young populations, as is the case with the K-Ar ages. Nor is it likely that the zircons were derived from 41-m.y.-old igneous rocks, because this age falls within the early Cenozoic magmatic null period (Snyder and others, 1976), although the existence of an Eocene tuff, now altered or removed by erosion, cannot be discounted. Bentonite and other volcanic detritus have been recognized in Eocene strata elsewhere in central California. Another possible explanation is that older (approx 41 m.y.) zircons in rocks of the vent area were thermally reset at 41 m.y., or partially reset at some later time, and then still later became accidental constituents of the middle Miocene ash.

SUMMARY

Radiometric dating of pyroclastic material from Tertiary rocks in the southeastern San Joaquin Valley has produced mixed results. Despite a few questionable age, these results are, on the whole, encouraging because they represent only single-sample dating of what are relatively complex deposits.

The best material for dating came from the tuff in the Walker Formation, and we consider the age of 21.4 m.y. to be reasonably accurate for this tuff, even though a single sample provides no means for assessing possible areal or stratigraphic variations in composition within the massive ash-flow unit. The best agreement with an age inferred from stratigraphic position is provided by the pumice bed in the Olcese Sand. Although each pebble is, in effect, a separate sample, the fission-track dating technique affords a means of discriminating between older and younger material, and the age of 15.5 m.y. is probably accurate for the pumice that was deposited a short time later in the Olcese Sand. A worst case is illustrated by the tuff in the Round Mountain Silt. A thin tuff in a marine siltstone should always be suspect, even if is looks pure, because of the strong probability of inmixing of a small amounts of detrital minerals by bioturbation.

These results, though of some usefulness to San Joaquin Valley stratigraphy, should be considered preliminary. Careful multiple sampling, exacting mineral-separation procedures, and replicate analyses should refine the ages reported here and remove any remaining ambiguities.

DISCUSSION

BASIN HISTORY

The Tertiary strata of the southeastern San Joaquin Valley record a major transgression, beginning in Eocene time and continuing into the Miocene, that was punctuated by relatively minor regressions at the end of Eocene time (as evidenced by a small tongue of the nonmarine Walker Formation overlying a probable lagoonal facies of the late Eocene age; fig. 3), near the end of Zemorrian time, and at the end of Saucesian time (the Olcese Sand). Evidence from benthic foraminifers also suggests a regression near the end of Luisian time. A major and relatively rapid regression began in late Miocene time and continued into the Pleistocene, with only two minor marine transgressions ("Santa Margarita" and Etchegoin Formations).

The Paleogene formations, such as the Vedder Sand and the Walker Formation, are relatively thin, considering the timespan that they represent. Their thinness, together with their widespread distribution and relatively uniform lithology, suggests a period of relative stability. However, the coarse Bealville Fanglomerate is evidence of some tectonic activity near the end of the Paleogene. Increased tectonic activity, beginning near the end of Saucesian time, produced the coarse clastic materials of the Bena Gravel, the Olcese Sand, and the Chanac and Kern River Formations, and was responsible for the major regression beginning in late Miocene time.

DISTRIBUTION OF COARSE CLASTIC MATERIALS

The Bealville Fanglomerate and the Bena Gravel are presently restricted to the southeast margin of the San Joaquin Valley south of the Bakersfield arch. The Bealville is, in addition, restricted to the area north of the east-west-trending Edison fault (which separates Tertiary and basement rocks south of Caliente Creek) and intertongues northward or northwestward with the finer grained Walker Formation. This relation, together with evidence that the coarse angular blocks in the Bealville were derived from upthrown basement rocks south of the fault (Dibblee and Chesterman, 1953, p. 50), indicates that the Edison fault was active during the time of Bealville deposition, that is, in the late Oligocene and early Miocene.

The Bena Gravel is related to this increased tectonic activity, mostly in middle Miocene time. The coarse clastic materials probably reflect uplift of the Sierra Nevada concurrent with faulting and subsidence in the southern part of the basin. The Bena Gravel, including both alluvial-fan and paralic facies, seems to represent a fan delta that formed at the steep east margin of the basin in response to this tectonic activity. The close juxtaposition of dissimilar facies in the Bena and its rapid transition southwestward into the Edison Shale of Kasline (1941) (fig. 4) contrast with the relatively simple stratigraphy without the rapid facies changes shown by equivalent-age strata north of the Bakersfield arch. This difference suggests that the Bakersfield arch was, by middle or possibly late early Miocene time, beginning to become an important boundary between the deep south end of the basin and a relatively more stable shelf area to the north.

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