The Kern River Formation, Southeastern San Joaquin Valley, California

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By J. ALAN BARTOW *and* GARDNER M. PITTMAN

CONTRIBUTIONS TO STRATIGRAPHY

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CONTENTS

ILLUSTRATIONS

CONTRIBUTIONS TO STRATIGRAPHY

THE KERN RIVER FORMATION, SOUTHEASTERN SAN JOAQUIN VALLEY, CALIFORNIA

By J. ALAN BARTOW and GARDNER M. PITTMAN[1]

ABSTRACT

The nonmarine sedimentary deposits overlying marine Miocene strata in the Kern River area of the southeastern San Joaquin Valley were named the Kern River Group by Anderson (1911). This group was later subdivided by Diepenbrock (1933) into the Chanac, Kern River, and Etchegoin Formations. Diepenbrock's (1933) name, Kern River Formation, is herein adopted and type and composite reference sections are designated. The names Kern River Group and Kern River Series are herein abandoned.

The Kern River Formation crops out in a crescent-shaped belt about 80 km (50 mi) long and up to 20 km (12 mi) wide; it reaches its maximum thickness of 800 m (2,600 ft) in the subsurface west of the outcrop. The formation consists mostly of poorly sorted fluvial sandstone and conglomerate with interbeds of siltstone or mudstone and becomes finer grained northward and westward. Two oil-producing zones occur in the lower part of the formation in the Kern River oil field located over a structural salient produced by the southwest-plunging Bakersfield arch.

The Kern River Formation, or its basinward marine partial equivalent, the Etchegoin Formation, unconformably overlies the Chanac Formation. The Kern River is unconformably overlain by Pleistocene alluvium. The Kern River is considered to be late Miocene, Pliocene, and early Pleistocene(?) in age on the basis of contained mammals and its relations to adjacent dated formations.

INTRODUCTION

The name Kern River Group was first applied by Anderson (1911, p. 90, 95–96) to the nonmarine gravels, sands and clays unconformably overlying the marine Miocene rocks in the Kern River area of the southeastern San Joaquin Valley, California.[2] As originally defined by Anderson, the unit probably included beds that are now commonly referred to the "Santa Margarita"[3] or Chanac Formations. Since then

[1]Getty Oil Co., Ventura, Calif.

[2]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. The description did not include the overlying nonmarine deposits.

[3]Quotes are used here to indicate that the name Santa Margarita is probably misapplied in the southeastern San Joaquin Valley because of the uncertainties of correlation with the type locality west of the San Andreas fault.

the name has been used in a variety of ways (fig. 1). Subsurface evidence from wells drilled after Anderson's definition indicated the presence of a wedge of marine Etchegoin Formation within the Kern River Group. This marine wedge was used by Diepenbrock (1933) to subdivide the nonmarine Kern River Series into an upper unit called the Kern River Formation and a lower unit referred to the Chanac Formation with the wedge of Etchegoin in the middle. Thus the name Kern River was used by Diepenbrock for both a unit of group rank and for a formation within that group. Use of the name Kern River by various authors without specifying whether formation or group was intended has probably contributed to confusion over the age and stratigraphic relations of the formation.

Regional mapping in the San Joaquin Valley since 1974, with an emphasis on late Cenozoic tectonics and sedimentation, has focused new attention on the Kern River Formation and its significance in the history of the San Joaquin basin. We here adopt the name Kern River Formation of Diepenbrock (1933) and abandon the names Kern River Group and Kern River Series.

ACKNOWLEDGMENTS

The authors gratefully recognize the contributions of many individuals, in particular Claudia Owen for her assistance in the field, and the personnel of Getty Oil Co. We wish to thank the management of Getty Oil for the release of proprietary subsurface information and permission for Gardner Pittman, the junior author, to participate in publishing this paper.

KERN RIVER FORMATION

The Kern River Formation crops out in a roughly crescent-shaped belt, about 20 km (12 mi) wide at its widest point, from Caliente Creek on the south to the vicinity of Terra Bella on the north, a distance of about 80 km (50 mi) (fig. 2). In cross section, the formation forms a westward-thickening wedge that has a thickness of about 450–500 m (1,475–1,600 ft) near the west edge of the outcrop belt. In the subsurface farther west, it reaches a maximum thickness of 800 m (2,600 ft). It thins northward, appearing to be about 150 m (500 ft) thick near Richgrove (Klausing and Lohman, 1964, fig. 124.2).

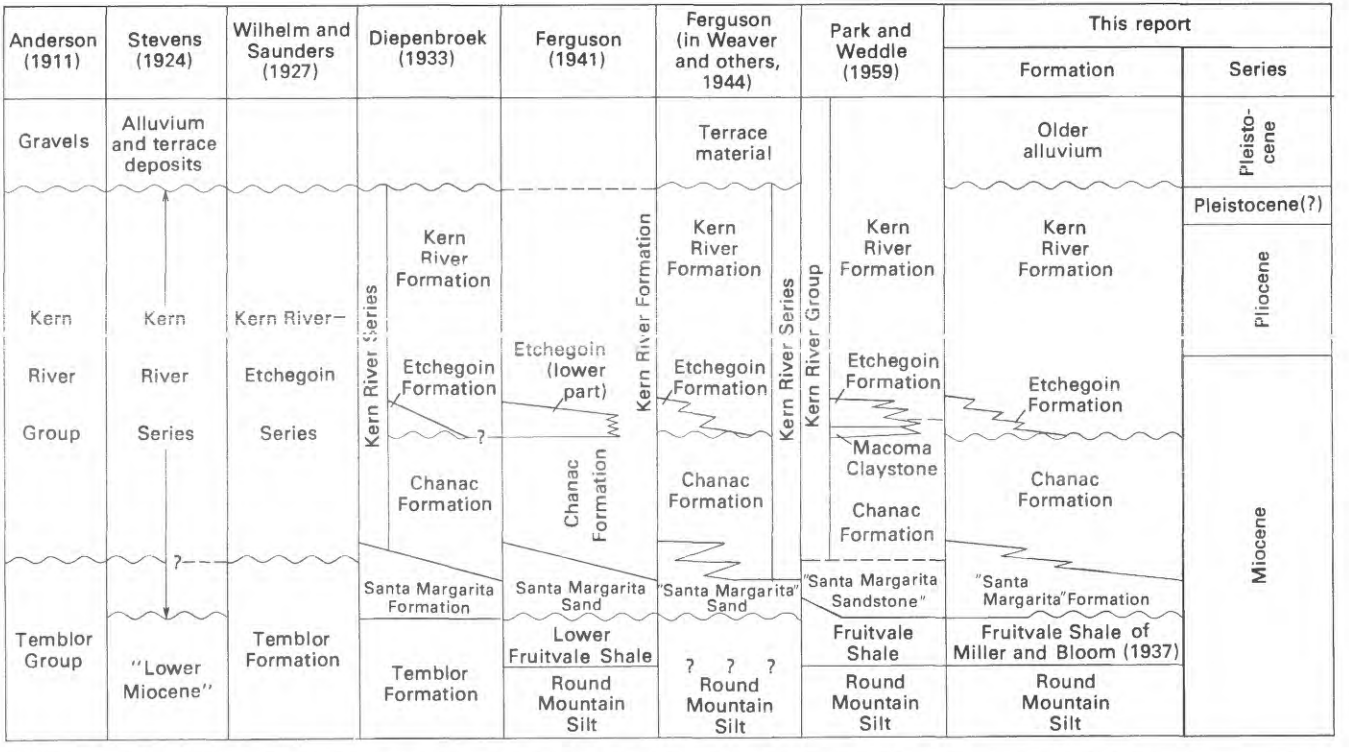

FIGURE 1.—Development of stratigraphic nomenclature for late Cenozoic rock-stratigraphic units in the southeastern San Joaquin Valley, California.

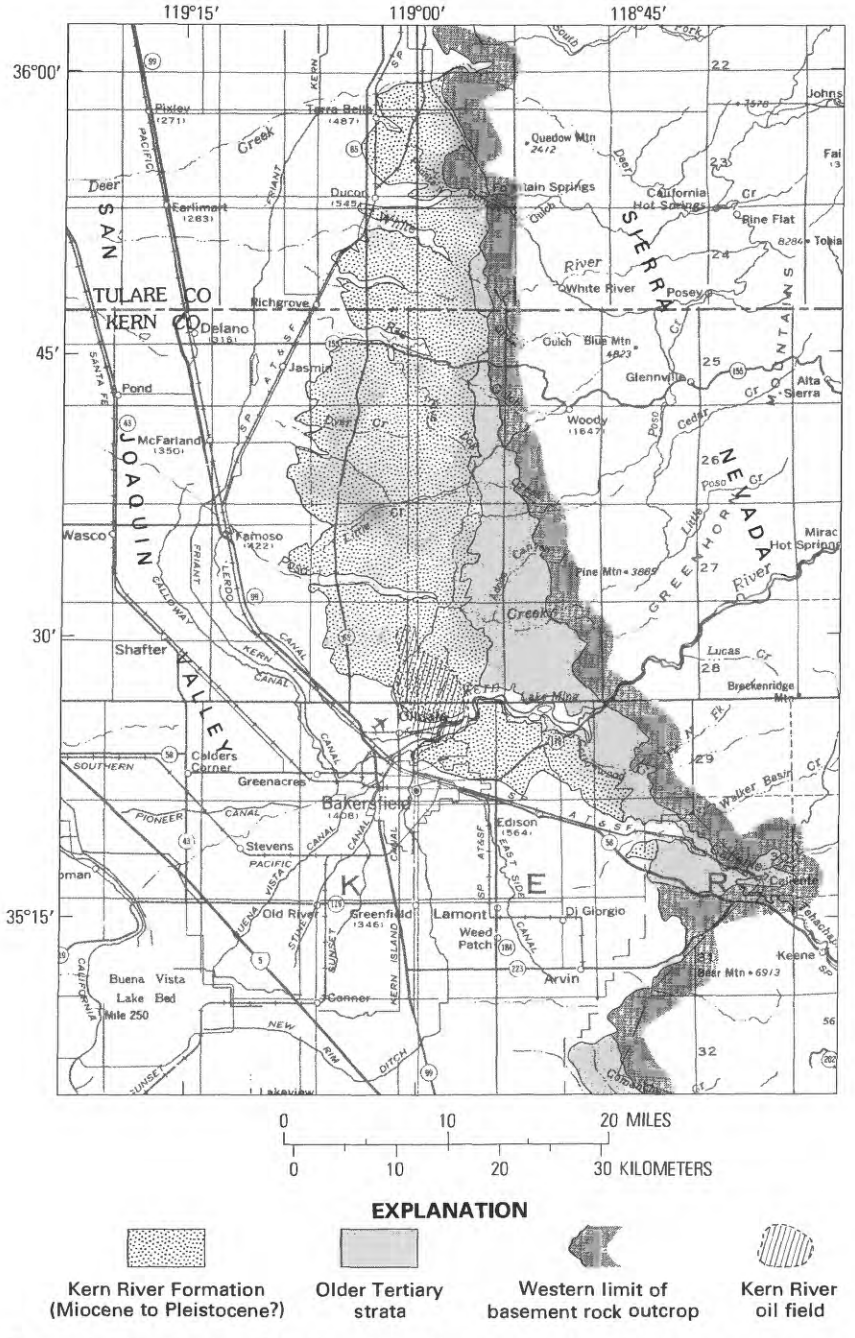

FIGURE 2.—Distribution of the Kern River Formation in the southeastern San Joaquin Valley, California. Unpatterned areas are underlain by Quaternary sediments younger than the Kern River Formation. Base from U.S. Geological Survey, State of California, 1970, original scale 1:1,000,000.

LITHOLOGY

Where it crops out, the Kern River Formation consists mostly of pale-yellow to light-brown sandstone and conglomerate with interbeds of greenish-gray or greenish-brown siltstone and mudstone. Drab colors predominate, but red-brown mudstone can be seen locally in outcrop. The deposits are generally poorly sorted and crudely bedded, although medium- and large-scale trough crossbedding is common. The sediments were deposited in a fluvial environment, probably braided river channels for the most part. Some of the thicker siltstone or mudstone interbeds may represent the deposits in small ephemeral lakes or ponds.

The Kern River Formation is coarsest in its easternmost exposures, generally the area south of the Kern River. In this area, it is composed of cobble conglomerate with boulders near the base and pebbly sandstone. The best exposures of the formation are in the bluffs on the south side of the Kern River westward from the vicinity of Kern River State Park (fig. 3). Here the predominant lithology is coarse-grained sandstone with lenses of sandy conglomerate and pebbly sandstone. The conglomerate clasts are smaller here than in the easternmost exposures, and a few lenses of siltstone or silty very fine grained sandstone are present. Farther north and west, conglomerate becomes a minor constituent and medium- to coarse-grained sandstone interbedded with greenish-gray siltstone or mudstone predominates. Thin calcareous layers occur sporadically in both outcrop and subsurface sections. Their distribution is very irregular, and they seldom exceed 0.5 m (1.5 ft) in thickness.

The sandstone is composed predominantly of clear to slightly milky, highly angular to slightly rounded quartz grains along with many grains of white to pink feldspar in various stages of alteration, commonly to kaolinite. The accessory heavy minerals are mainly euhedral grains of gold colored to brown biotite along with minor amounts of hornblende, garnet, and pyrite. All of these components have been described in both surface samples and subsurface cores. This suite of minerals indicates the source to be the granitic rocks of the Sierra Nevada located to the northeast.

A thin (1–3 m or 3–10 ft) but conspicuous ledge-forming unit composed of clayey sandstone occurs near the base of the Kern River Formation in the vicinity of Poso Creek and northward as far as the White River. This unit, which exhibits a crude irregular layering, rare siliciclastic pisoliths, and vugs and tubules lined with clay or silica, grades downward by decrease in clay content into friable coarse-grained sandstone. The unit was interpreted as a sandy tuff by Hackel and Krammes (1958, p. 14–15). Although it is locally tuffaceous, it is here reinterpreted as a diagenetically modified part of a paleosol within the Kern River Formation.

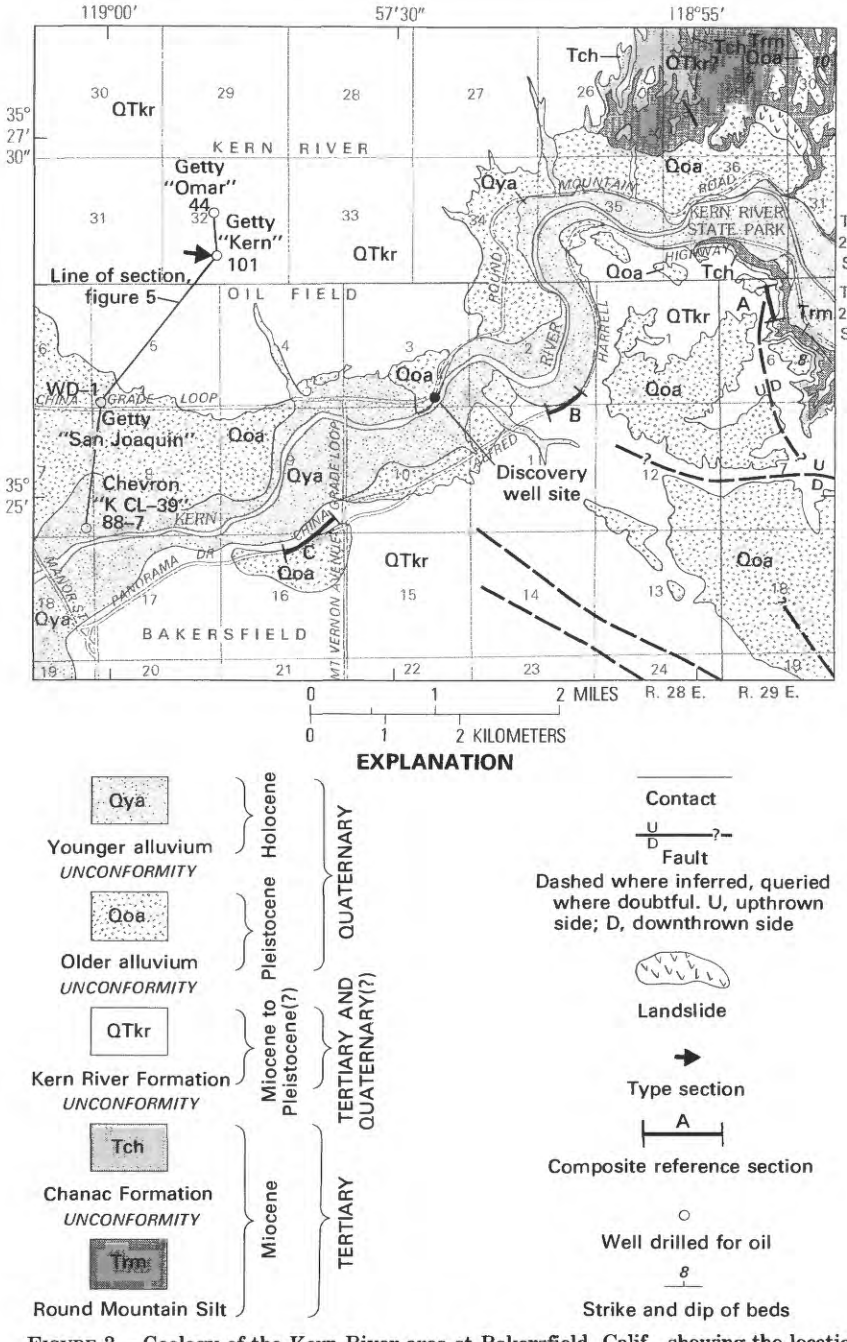

FIGURE 3.—Geology of the Kern River area at Bakersfield, Calif., showing the location of the type section and reference section (measured sections A, B, and C) of the Kern River Formation.

TYPE SECTION

The excellent exposures of Kern River Formation in the Kern River bluffs at Bakersfield have been generally, if informally, accepted as the type area of the formation. No more than 60–65 m (200–215 ft) of section are exposed at any one location in the bluffs south of the river, but the Kern River oil field immediately across the Kern River to the north (fig. 2) has a great many wells that penetrate the formation. Because oil is produced from sands in the lower part of the Kern River, the formation has been frequently cored in the Kern River field. One of these wells, the Getty Oil "Kern" 101, in the SE¼SW¼ sec. 32., T. 28 S., R. 28 E. (fig. 3) is here designated the type section of the Kern River Formation (pl. 1). This well was cored continuously from 106.8 m (350 ft), within the formation, to 375.8 m (1,232 ft), below the base of the formation, and provides the most complete section available. Unfortunately, no core material was retained from this well for reexamination. Approximate restoration of the post-Kern River erosion surface at this well site indicates about 64 m (210 ft) of erosion. The cored interval, then, represents approximately the lower two-thirds of the original thickness of the formation at this location.

In order to provide additional, easily available lithologic information about the Kern River Formation, sections were measured at three locations (fig. 3) along the bluffs south of the Kern River. The relative stratigraphic position of these sections is shown diagrammatically on figure 4. The measured sections, though too short to overlap stratigraphically, are positioned to provide some lighologic information about the upper part as well as additional information about the lower and middle parts of the formation. These sections are here designated as a composite reference section.

The lithology of the formation as described in the type section well cores (pl. 1) is, with a few minor exceptions, essentially the same as the lithology in the outcrop composite reference section. Fine-grained units in the cores were usually described as claystone or silty claystone. These units are probably mudstone or clayey very fine grained sandstone, as in the outcrop sections. The apparent color difference, blue in subsurface samples, green in outcrop, is thought to result from the presence of drilling fluid filtrate in the core samples when they were described. The cores also suggest a lower proportion of sandstone than is actually present due to the loss of friable sand during core recovery.

Although it is impossible to make a precise correlation from subsurface to outcrop sections, it is probable, on the basis of similarity of lithology and stratigraphic position, that the interval from 244 to 282

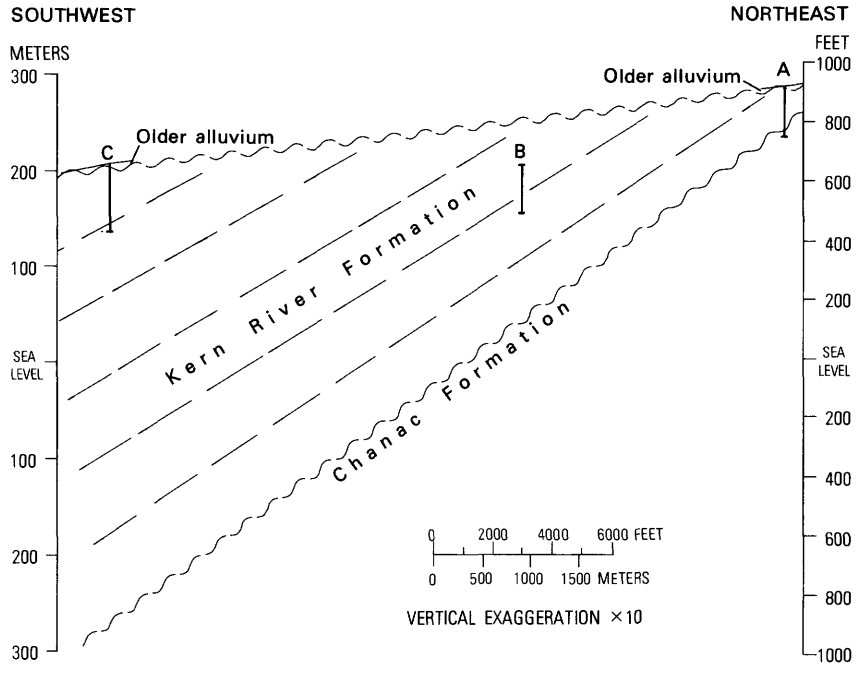

FIGURE 4.—Diagrammatic section showing the relative stratigraphic position of the composite reference section (measured sections A, B, and C) of the Kern River Formation. Locations of measured sections shown on figure 3.

m (800 to 925 ft) in the type section is approximately equivalent to the interval including units 5 through 7 of measured section B.

OIL SANDS

The hydrocarbon-bearing intervals in the nonmarine Kern River Formation are composed of a sequence of fine to very coarse grained, predominantly quartz sand lentils that are at places conglomeratic or clayey. The oil sands are separated by silty and muddy interbeds that show various degrees of induration from plastic to firmly compacted sandy siltstones and mudstones. The oil is trapped in the sand beds by their lentiform structure and tar seals. The oil accumulation in the Kern River oil field has a lens shape with a homoclinal southwestward plunge of 3° to 6° across a structural salient where the Bakersfield arch intersects the uplifted Sierra Nevada.

The producing interval in the Kern River Formation of the Kern River oil field has been divided into two zones separated by a number of water-bearing sand lentils. The lower producing zone is called the China Grade zone; the upper is the Kern River zone. The China Grade

zone produces only in the south end of the field between 300 and 550 m (1,000 and 1,800 ft) depth. The Kern River zone is productive throughout the field between 75 and 425 m (250 and 1,400 ft). Some of these oil sands crop out along the Kern River bluff near the Discovery Well Monument and along the Round Mountain Road in sec. 3, T. 29 S., R. 28 E. (Latta, 1949, p. 167–186). These outcrops show the varied environmental conditions under which the Kern River Formation was deposited. Excellent examples of crossbedding and other aspects of the fluvial depositional environment can be observed here. The outcropping oil sands are stratigraphically correlative with oil-bearing sands from about 181 m (595 ft) to 220 m (720 ft) in the type-section well (Kern 101) near the middle of the overall oil-bearing interval. The outcropping sands and sands in the type-section well are not considered to be the same beds, but are approximate time equivalents and have similar sediments derived from the same source and deposited under the same environmental conditions. Many cores from wells in the field are lithologically comparable to these outcrops.

Detailed subsurface correlations based on electric log characteristics suggest that the two producing zones are separated by a local disconformity, but the sand lentils are very similar lithologically and both were deposited in a nonmarine environment. No single bed in the Kern River Formation extends across the entire dimensions of the Kern River oil field. This lack of continuity makes correlating the oil sands very uncertain, although the field limits are well defined and the field is developed on approximately 2.5-acre spacing (that is, approximately one well per hectare. Because of the absence of field-wide marker beds and a low total salt content in the connate formation fluids that make electrical-survey interpretation very difficult, correlating the subsurface oil sands to the surface oil sands is often impossible.

The descriptions of core material from the Kern River Formation reveal the presence of organic material such as very thin layers of lignite, flora imprints, and bird bones. Therefore, some of the oil may have been generated indigenously, but most of the oil has migrated updip from older marine beds in the San Joaquin basin as overburden pressure increased with continuous deposition in that area. The oil-producing sands are, therefore, concentrated at or near the base of the Kern River Formation. Analysis of the oil sand cores from the typical well shows the producing interval to be variably oil saturated (Bursell and Pitman, 1975), owing to variation in clay content, degree of calcareous cementation, and gravity of the oil in the different sand lentil. The lower gravity oil occurs in the stratigraphically deeper producing lentils.

STRATIGRAPHIC RELATIONS

The unconformity between the Kern River Group of Anderson (1911) and the marine Miocene strata was recognized early in the development of regional stratigraphy. Anderson (1911, p. 96) mentioned the northward truncation of progressively older Miocene strata by the base of the Kern River Group. Since that time, there has been much uncertainty about where the unconformities are located in the Tertiary section (fig. 1), perhaps because it was not always clear whether the name Kern River referred to the group or the formation. Diepenbrock (1933, p. 12) contributed to the confusion by making apparently contradictory statements about the nature of the contact at the base of the Kern River Series (or Chanac Formation). He did, however, present evidence (1933, p. 12) indicating an unconformity at the base of the Etchegoin Formation, at least locally. This unconformity has been accepted by most workers. There is also general agreement that the Kern River and Etchegoin Formations are conformable and that the wedge of marine Etchegoin is the basinward equivalent of the basal part of the Kern River Formation (fig. 5). A fossiliferous marine siltstone or claystone at the base of the Etchegoin, informally called the Macoma claystone, is readily distinguished from the sandstone of the overlying Kern River and underlying Chanac Formations on the basis of electric-log character. The siltstone grades eastward into a thin marine sandstone (fig. 5), but is still generally recognizable on electric logs.

There is less general agreement on the nature of the contact between the Kern River and Chanac Formations updip from the pinchout of the Etchegoin. The stratigraphic relations of the Kern River and Chanac are most clearly seen in a roadcut on State Highway 178 about 19 km (12 mi) east of Bakersfield. Near the west end of the cut, light gray sandstone and cobble conglomerate of the Chanac Formation (mapped as Santa Margarita sand by Dibblee and others, 1965) is overlain by the Kern River Formation, here consisting of brown sand and gravel with boulders at the base. The abrupt color change and the presence of boulders concentrated at the contact suggest an unconformity. The contact can be followed northwestward by means of the abrupt color change nearly to Poso Creek, where the Chanac is apparently overlapped by the Kern River (Bartow and Doukas, 1978). The progressive northward overlap of the older Miocene section north of Poso Creek substantiates the presence of an unconformity.

The stratigraphic relations of the Chanac and Kern River Formations are more obscure in the subsurface. The color difference is not apparent, and the similarity of their lithology and electric-log character makes the two formations virtually impossible to discriminate. Local petroleum geologists generally use the term "Kern River-

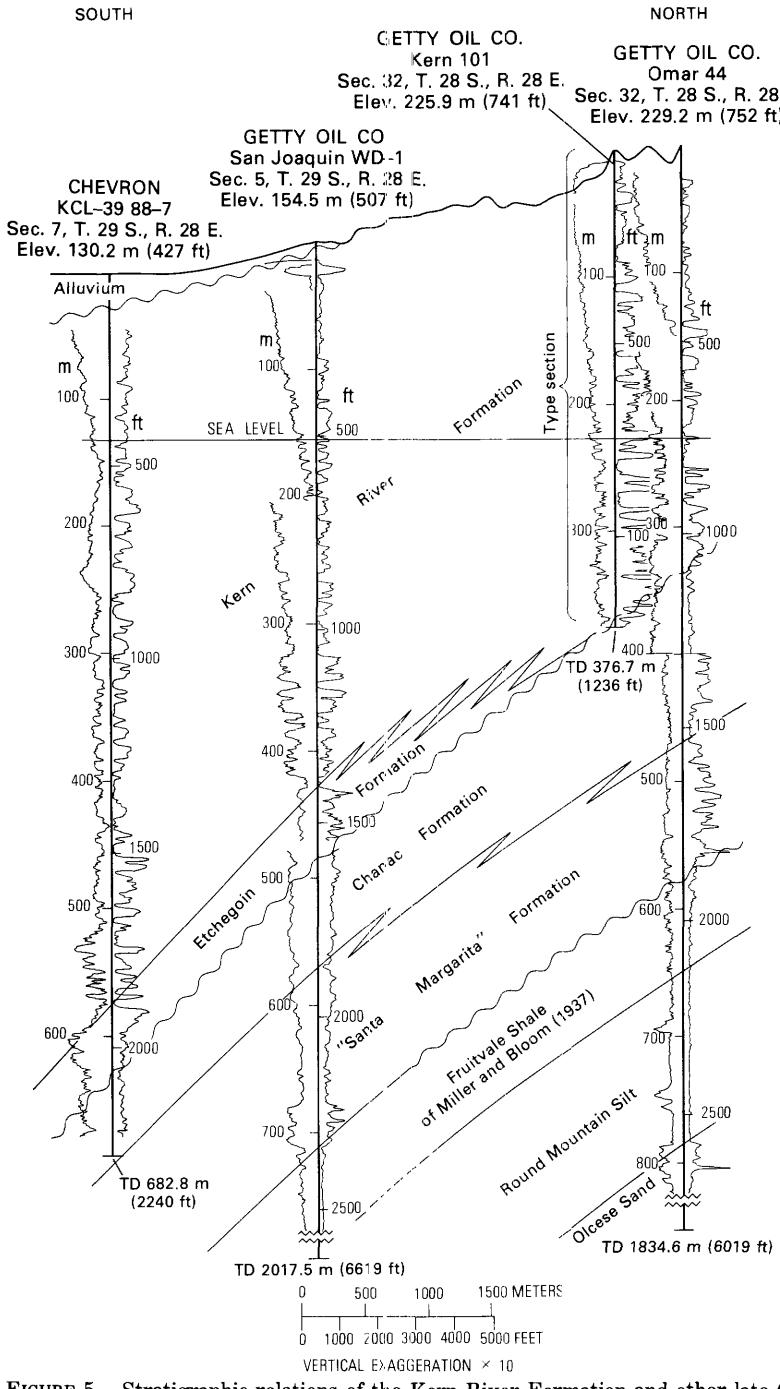

FIGURE 5.—Stratigraphic relations of the Kern River Formation and other late Cenozoic units in the area of the type section of the Kern River Formation. Location of cross section shown on figure 3.

Chanac undifferentiated" in areas where the Etchegoin Formation is not present.

The top of the Kern River Formation is deeply eroded; more than 60 m (200 ft) appears to have been removed in the area of the type section and the relief on the bluffs south of the Kern River is at least 135 m (450 ft). The formation is locally overlain unconformably by Pleistocene alluvial gravels that are easily distinguished from the Kern River Formation by their less deeply weathered pebbles and unconsolidated sand matrix. At the western edge of its outcrop belt, the Kern River is distinguished from younger Quaternary deposits principally on geomorphic criteria. The younger deposits underlie terraces and flood plains along streams, and the Kern River underlies the gently rolling surface of the interfluve areas.

In summary, we believe that the Kern River Formation unconformably overlies the Chanac Formation and conformably overlies and interfingers with its basinward marine equivalent, the Etchegoin Formation. The Kern River is in turn unconformably overlain by Pleistocene alluvium.

AGE AND CORRELATION

The Kern River Formation, though a coarse-grained fluvial unit, has yielded vertebrate fossils. Mammalian remains from several localities near the base of the formation were considered by Savage, Downs, and Poe (1954, p. 53) to be of early Hemphillian age. The Hemphillian is now considered to be late late Miocene to early Pliocene (Repenning and Tedford, 1977, table 1). The fauna from the Kern River is probably correlative with an early Hemphillian fauna from the Mehrten Formation near Knights Ferry on the Stanislaus River, about 300 km (190 mi) northwest (Hugh Wagner, written commun., 1980). The Mehrten fauna occurs within a few meters of a tuff dated at 8.2 m.y. and is thus late Miocene in age.

The wedge of marine Etchegoin Formation separating the Kern River and Chanac Formations contains abundant fossils. Gale (in Preston, 1931, p. 16) listed a molluscan fauna from this unit that he correlated with the upper part of the now obsolete Jacalitos Formation on the west side of the San Joaquin Valley. Later, Ferguson (1941) correlated the marine wedge with the lower part of the Etchegoin Formation on the west side of the valley on the basis of benthic foraminifers. Neither correlation provides very precise age control because of the commonly time transgressive nature of shallow-water benthic faunas, but both place the wedge of Etchegoin, and consequently the basal part of the Kern River Formation, in the latest Miocene.

The upper age limit of the Kern River Formation is less well known

but is probably within the Pleistocene. It can be reasonably inferred that it spans the Pliocene. The age range, then, is latest Miocene to Pleistocene (?).

Basinward, the Kern River Formation grades laterally into the marine Miocene and Pliocene Etchegoin and Pliocene San Joaquin Formations of the central part of San Joaquin Valley. The upper part of the Kern River is probably equivalent to the nonmarine Pliocene and Pleistocene Tulare Formation of the west side of the San Joaquin Valley.

Tentative correlations with the northeastern San Joaquin Valley suggest that the Kern River Formation is equivalent to the part of the Mehrten Formation above the 9 m.y. old Table Mountain Latite and to the Laguna Formation. The uppermost part of the Kern River may be equivalent to the early Pleistocene Turlock Lake Formation. Further work on the Quaternary stratigraphy of the southern San Joaquin Valley may clarify the age and correlation of the upper part of the Kern River.

COMPOSITE REFERENCE SECTION

(See figures 3 and 4 for location and stratigraphic position.)

Measured section A

[E½NE¼NW¼ sec. 6, T. 29 S., R. 29 E., Mt. Diablo Base and Meridian]

	Thickness	
	Meters	*Feet*
Older alluvium:		
2. Soil, gravelly, brown	1.5	5.0
1. Gravel, sandy, yellowish orange	2.0	6.6
Total thickness of older alluvium	3.5	11.6
Unconformity		
Kern River Formation (part):		
19. Sandstone, fine- to medium-grained, well sorted, brown	3.1	10.2
18. Sandstone, coarse- to very coarse grained, pebbly, poorly sorted, arkosic, friable, grayish-orange	1.7	5.6
17. Mudstone clast conglomerate, sandy; olive-gray mudstone boulders in coarse-grained sandstone	1.0	3.3
16. Sandstone, same as unit 18, but calcareous in lower part	1.3	4.3
15. Sandstone, medium-grained, clayey, gray; grades up into brown sandy mudstone	0.9	2.9
14. Sandstone, same as unit 18, but grades up into brown clayey sandstone at top	1.3	4.3
13. Conglomerate and interbedded sandstone. Conglomerate, sandy, yellowish-orange; thin lenses. Sandstone, same as unit 18	1.0	3.3
12. Sandstone, coarse- to very coarse grained, pebbly, friable; conglomeratic at base; contains very thin conglomerate bed in lower part and several thin calcareous sandstone layers	6.7	22.0
11. Sandstone, coarse- to very coarse grained, crossbedded, grayish-orange; contains very thin conglomerate bed in upper part; becomes slightly clayey at top	3.1	10.2

	Thickness Meters	Feet
Kern River Formation (part)—Continued		
10. Conglomeratic sandstone, coarse- to very coarse grained friable, grayish-orange	1.6	5.2
9. Sandstone, same as unit 18	1.4	4.6
8. Conglomeratic sandstone, same as unit 10	3.0	9.8
7. Sandstone, same as unit 18, but slightly calcareous locally	1.4	4.6
6. Sandstone, coarse- to very coarse grained, conglomeratic (cobbles and boulders)	1.5	4.9
5. Conglomeratic sandstone, same as unit 10, but with thin calcareous layer near middle	1.6	5.2
4. Sandstone, medium- to coarse-grained, calcareous; contains scattered pebbles and cobbles	1.7	5.6
3. Conglomeratic sandstone, same as unit 10	2.8	9.2
2. Sandstone, medium-grained, well-sorted, grayish-orange; grades up into brown fine-grained sandstone	0.4	1.3
1. Sandstone, coarse- to very coarse grained conglomeratic, poorly sorted, arkosic, friable, grayish-orange; slightly calcareous locally; contains pebbles, cobbles, and boulders to 38 cm of granitic rocks, metamorphic rocks, and deeply weathered volcanic rocks; clast size decreases upward	3.1	10.2
Total thickness of Kern River Formation	38.6	126.7
Disconformity		
Chanac Formation (part):		
4. Siltstone and claystone, sandy, pale olive; grades up into grayish-olive and pale-olive claystone, weathered to brownish orange at top; secondary gypsum coating fractures	2.2	7.2
3. Sandstone, medium- to coarse-grained, yellowish-gray; becomes clayey near top and grades to overlying unit	1.6	5.2
2. Sandstone, medium- to coarse-grained, clayey, yellowish-gray; clay content increases upward; grades into pale-olive siltstone and sandy claystone	3.5	1.5
1. Sandstone, medium- to coarse-grained, friable, light-gray; thin calcareous layer near top; few invertebrate(?) burrows; lower beds poorly exposed and not measured	3.0+	9.8+
Total exposed thickness of Chanac Formation	10.3+	23.7+

Measured Section B

[Roadcut on Alfred Harrell Highway; S½SE¼SE¼ sec. 2, and NE¼NW¼NE¼ sec. 11, T. 29 S., R. 29 E., Mt. Diablo Base and Meridian]

	Thickness Meters	Feet
Kern River Formation (part):		
9. Sandstone, coarse- to very coarse grained, pebbly, arkosic, friable, pale yellowish-orange and light-gray, crossbedded; contains lenses of sandy conglomerate; fills large channel several meters deep; higher beds not exposed	22.5	73.8
8. Sandstone, coarse- to very coarse grained, pebbly, poorly sorted, light-gray and yellowish-orange, friable, crossbedded	1.5	4.9
7. Mudstone clast conglomerate, sandy, very pale orange to light-gray and dark yellowish-orange; olive-gray mudstone pebbles and cobbles in very coarse pebbly sand matrix	0.7	2.3

	Thickness Meters	Feet
Kern River Formation (part)—Continued		
6. Sandstone, coarse- to very coarse grained; yellowish-orange; pebbly at base; grades up through medium- to coarse-grained sandstone to olive-brown very fine grained sandstone and grayish-olive sandy claystone at top; orange and brown mottling in upper 1.5 m; fills local small channels in underlying unit	3.3	10.8
5. Sandstone and clayey sandstone. Sandstone, very fine grained, light-gray to light olive-gray. Clayey sandstone, very fined grained, dusky-yellow to olive brown. Slightly calcareous locally; massive in lower part to crudely thin-bedded near top	4.0	13.1
4. Sandstone, medium- and coarse-grained, light-brown; pebbly in lower part; boulders of yellowish-orange mudstone near base; calcareous locally; large-scale low-angle crossbedding in lower part; becomes less pebbly and better sorted upward; grades into clayey sandstone in upper 50 cm	7.5	24.6
3. Sandstone, medium- to coarse-grained, well-sorted, grayish-orange and yellowish-gray crossbedded; contains lenses of pebbly sandstone with mudstone clasts	3.0	9.8
2. Sandstone, coarse- to very coarse grained, friable, grayish-orange; local brown and orange mottled mudstone at top	2.8	9.2
1. Sandstone, coarse- to very coarse grained conglomeratic, friable, grayish-orange; contains boulders of sandstone and light-olive mudstone; grades into overlying unit; lower beds not exposed	1.7	5.6
Total exposed thickness of Kern River Formation	47.0	154.1

Measured Section C

[Roadcut on China Grade Loop; SW¼SE¼SE¼ sec. 9, and N½NW¼NE¼ sec. 16, T. 29 S., R. 28 E., Mt. Diablo Base and Meridian]

	Thickness Meters	Feet
Older alluvium:		
2. Sand, very coarse, pale-yellowish-orange, crossbedded; grades up into sandy pebble gravel	1.0+	3.3+
1. Gravel, yellowish-orange; pebbles and cobbles with coarse sand matrix; fills erosional relief of as much as 3 m on underlying Kern River Formation	7.5	24.6
Total thickness of older alluvium	8.5	27.9
Unconformity		
Kern River Formation (part):		
9. Conglomeratic sandstone, coarse- to very coarse grained, arkosic, very pale orange; locally becomes sand gravel; contains thin lenses of laminated coarse-grained sandstone	3.0	9.8
8. Sandstone, coarse- to very coarse grained, very pale orange, crossbedded; contains thin pebble bands and lenses of pebbly sandstone	12.0	39.4
7. Conglomerate, sandy, friable, very pale orange; contains lenses of coarse- to very coarse grained sandstone; grades into overlying unit	4.5	14.8
6. Sandstone, coarse- to very coarse grained, pebbly, friable, very pale orange to yellowish-orange, crossbedded; contains conglomeratic sandstone lenses in lower part and sandy conglomerate lenses in upper part; conglomerate lenses increase near top and unit grades into overlying unit	20.5	67.3

	Thickness	
	Meters	*Feet*
Kern River Formation (part)—Continued		
5. Sandstone, coarse-grained; grades up into laminated very fine grained sandstone; fills channel with concentration of yellowish-gray mudstone boulders at base	1.5	4.9
4. Sandstone, coarse- to very coarse grained, pebbly, friable, very pale orange to yellowish-orange, crossbedded; contains lenses of gravelly sandstone and sandy conglomerate	5.0	16.4
3. Sandstone, coarse- to very coarse grained, pebbly, friable, very pale orange; large-scale crossbedding in lower part with gravel concentrations along foresets; local thin greenish-gray sandy mudstone at top	2.5	8.2
2. Partly covered; exposed sandstone same as unit 4	3.5	11.5
1. Sandstone, same as unit 4, but contains siltstone boulders near base; lower beds not exposed	9.0	29.5
Total exposed thickness Kern River Formation	61.5	201.8

REFERENCES CITED

Anderson, F. M., 1905, A stratigraphic study in the Mount Diablo Range of California: California Academy Sciences Proceedings, 3d ser., v. 2, no. 2, p. 155–248.

Anderson, F. M., 1911, The Neocene deposits of the Kern River, California, and the Temblor basin: California Academy of Sciences Proceedings, 4th ser., v. 3, no. 3, p. 73–148.

Bartow, J. A., and Doukas, M. P., 1978, Preliminary geologic map of the southeastern border of the San Joaquin Valley, California: U.S. Geological Survey Miscellaneous Field Studies Map MF–944, scale 1:125,000.

Bursell, C. G., and Pittman, G. M., 1975, Performance of steam displacement in the Kern River Field: Society of Petroleum Engineers of AIME Transactions, v. 259, p. 997–1004.

Dibblee, T. W., Jr., Bruer, W. G., Hackel, Otto, and Warne, A. H., 1965, Geologic Map of the southeastern San Joaquin Valley, *in* Hackel, Otto, Chairman, Geology of southeastern San Joaquin Valley, California, Kern River to Grapevine Canyon: American Association of Petroleum Geologists, Pacific Section, April 3, 1965, Guidebook, scale about 1:48,000.

Diepenbrock, Alex, 1933, Mount Poso oil field: California Division of Oil and Gas Summary of Operations—California Oil Fields, v. 19, no. 2, p. 5–35.

Ferguson, G. C., 1941 [1943], Correlation of oil field formations on east side of San Joaquin Valley, *in* Geologic formations and economic development of the oil and gas fields of California: California Division of Mines and Geology Bulletin 118, p. 239–246.

Hackel, Otto, and Krammes, K. F., 1958, Stratigraphy, *in* Round Mountain area: San Joaquin Geological Society Spring Field Trip Guidebook, May 17, 1958, p. 10–11, 14–15.

Klausing, R. L., and Lohman, K. E., 1964, Upper Pliocene marine strata on the east side of the San Joaquin Valley, California: U.S. Geological Survey Professional Paper 475–D, p. D14–D17.

Latta, F. F., 1949, Black gold in the San Joaquin: Caldwell, Idaho, Caxton Printers, 344 p.

Miller, R. H., and Bloom, C. V., 1937, Mountain View oil field: California Division of Oil and Gas Summary of Operations—California Oil Fields, v. 22, no.4, p. 5–36.

Park, W. H., and Weddle, J. R., 1959, Correlation study of southern San Joaquin Valley: California Division of Oil and Gas Summary of Operations—California Oil Fields, v. 45, no. 1, p. 33–34.

Preston, H. M., 1931, Report on Fruitvale oil field: California Division of Oil and Gas Summary of Operations—California Oil Fields, v. 16, no. 4, p. 1–24.

Repenning, C. A., and Tedford, R. H., 1977, Otarioid seals of the Neogene: U.S. Geological Survey Professional Paper 992, 93 p.

Savage, D. E., Downs, Theodore, and Poe, O. J., 1954, Cenozoic land life of southern California, Chap. 3 *in* Jahns, R. H., ed., Geology of southern California: California Division of Mines and Geology Bulletin 170, p. 43–58.

Stevens, J. B., 1924, A comparative study of the San Joaquin Valley oil fields: American Association of Petroleum Geologists Bulletin, v. 8, p. 29–40.

Weaver, C. E., and others, 1944, Correlation of the marine Cenozoic formations of western North America: Geological Society of America Bulletin, v. 55, p. 569–598.

Wilhelm, V. H., and Saunders, L. W., 1927, Report on the Mount Poso oil field: California Division of Oil and Gas Summary of Operations—California Oil Fields, v. 12, no. 7, p. 5–12.

Wood, H. E., and others, 1941, Nomenclature and correlation of the North American Tertiary: Geological Society of America Bulletin, v. 52, p. 1–48.

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