Geology and Oil Resources of the Western Puente Hills Area, Southern California

GEOLOGICAL SURVEY PROFESSIONAL PAPER 420-C

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By R. F. YERKES

GEOLOGY OF THE EASTERN LOS ANGELES BASIN, SOUTHERN CALIFORNIA

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A study of the stratigraphy, structure, and oil resources of the La Habra and Whittier quadrangles

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By R. F. Yerkes

ABSTRACT

The western Puente Hills area south of lat 34°00′ includes the La Habra and Whittier 7½-minute quadrangles; the area extends from about 12 to 30 miles east of downtown Los Angeles, in the northeast part of the Los Angeles basin. The north-dipping Whittier fault zone trends about N. 65° W. across the northeast quarter of the area, dividing it into the northern Puente Hills to the northeast and the west-trending La Habra Valley and Coyote Hills to the southwest.

The Puente Hills are underlain by an aggregate of about 16,600 feet of Cenozoic rocks which overlie a Mesozoic basement of granitoid plutonic rocks that contain a large pendant of foliated greenschist. The exposed section of the hills consists of about 13,000 feet of marine clastic sedimentary rocks: 8,900 feet assigned to the four members—La Vida at base, Soquel, Yorba, and Sycamore Canyon—of the upper Miocene Puente Formation and 4,100 feet assigned to the lower and upper members of the Fernando Formation.

The total known stratigraphic section south of the Whittier fault zone aggregates at least 27,500 feet of Cenozoic rocks, of which about 9,500 feet is exposed: 900 feet of marine clastic sedimentary rocks of the Sycamore Canyon Member of the Puente Formation, 6,800 feet of marine clastic sedimentary rocks of the Fernando Formation, and 1,800 feet of marine lower Pleistocene and nonmarine upper Pleistocene and younger deposits.

Structural relief at the basement surface across the Whittier fault zone is about 12,000 feet. Vertical stratigraphic separation across the north-dipping fault zone ranges from 2,000 or 3,000 feet at its distal ends (at the westernmost and southernmost margins of the hills) to about 14,000 feet at the central part of its trace (near the east edge of the present map). In addition, some degree of right-lateral movement is indicated by such evidence as a wide band of "right handed" en echelon folds that extends along the edge of the upthrown block, mapped beds that are truncated by the fault in a manner seeming to require right-lateral slip, and several large drainages that are deflected to the right as much as 5,000 feet along the fault zone. The available surface and subsurface data of the Puente Hills yield a probable, but not unique, solution of about 15,000 feet of cumulative right-oblique slip on the fault zone, north block up and eastward relative to the south block, with the rake of slip varying along the length of the fault. The fault zone dates back to at least late Miocene time, when it served as a conduit for intrusions and may have controlled deposition of sand lenses; much of the movement, however, is late Pleistocene or younger in age, as indicated by tilted, locally overturned La Habra beds and faulted old alluvium.

The Norwalk fault is a largely buried, north-dipping reverse fault that trends east-west along the south margin of the Coyote Hills, where it locally forms a faultline scarp. Apparent vertical stratigraphic separation does not exceed 1,000 feet at the base of the Pliocene Series, and displacement apparently dies out upward.

Several separate anticlinal culminations occur along the Coyote Hills trend, between the west center and the edge of the map area. Folding and faulting along this trend began in late Miocene time and was concentrated in its central part, where deformation also persisted the longest.

The Puente Hills appear to be a remnant of a once-extensive upland surface, greatly dissected by streams that headed north and east of the hills but are now beheaded; their canyons are now occupied by small misfit streams, such as Brea and Tonner, that have greatly incised their broad canyon floors. During much of late Pleistocene time, alluvial material accumulated to great thicknesses south of the Puente Hills, overlapping the site of the Coyote Hills onto the central plain to the south. As much as 2,000 feet of these deposits is transected by erosion that breached the Coyote Hills during and after their uplift. This erosion formed an extensive surface of low relief by late Quaternary time, then warped during uplift of the Coyote Hills and dissected by such antecedent streams as Brea and Coyote Creeks. South of the Coyote Hills these creeks have been sharply deflected by westward encroachment, from southeast of the map area, of the Santa Ana River alluvial fan and southward encroachment of the San Gabriel River fan; the deflections occur in the area where the two fans merge on the inland margin of the central plain.

Oil has been produced from fields along the Whittier fault zone since 1880, when the Puente Hills field, in the east part of the map area, was discovered on the basis of oil seeps. Most of the oil from the mapped area comes from stratigraphic or structural traps in the downthrown block of the Whittier fault zone and along the Coyote Hills trend; at the end of 1967 fields in the mapped area had a cumulative production of 1,183 million barrels, about 85 percent of that for the Puente Hills and about 21 percent of that for the Los Angeles basin. Estimated reserves

of these fields on January 1, 1968, were 86.8 million barrels, about 4 percent of the reserves for the basin. About 73 percent of the oil recovered from the mapped area has come from the lower Fernando, about 26 percent from the Puente Formation, and the remainder from the Topanga Formation. Recent production additions have come entirely from deeper pool discoveries in established fields. Despite several such developments and extensive secondary recovery programs in several of the fields, annual production of fields in the mapped area declined by nearly 2 million barrels between 1961 and 1966. Water production in 1968 exceeded that of oil in all but one field; at most fields water exceeded oil by ratios of more than 2 to 1, and at two fields, by more than 10 to 1. Detailed records of 442 exploratory and selected producing wells drilled before June 30, 1968, are tabulated and used as a basis of the detailed geologic sections.

INTRODUCTION

LOCATION AND PURPOSE

The Puente Hills extend between 12 and 42 miles east-southeast of downtown Los Angeles, in parts of Los Angeles, Orange, San Bernardino, and Riverside Counties. Together with the San Jose Hills to the north, the Puente Hills are triangular in plan, with their long side—their fault-controlled southwest margin—trending about N. 65° W. and bounding the northeast margin of the central plain of the Los Angeles basin (fig. 1). This report describes the geologic and oil resources of the western part of the hills, west of long

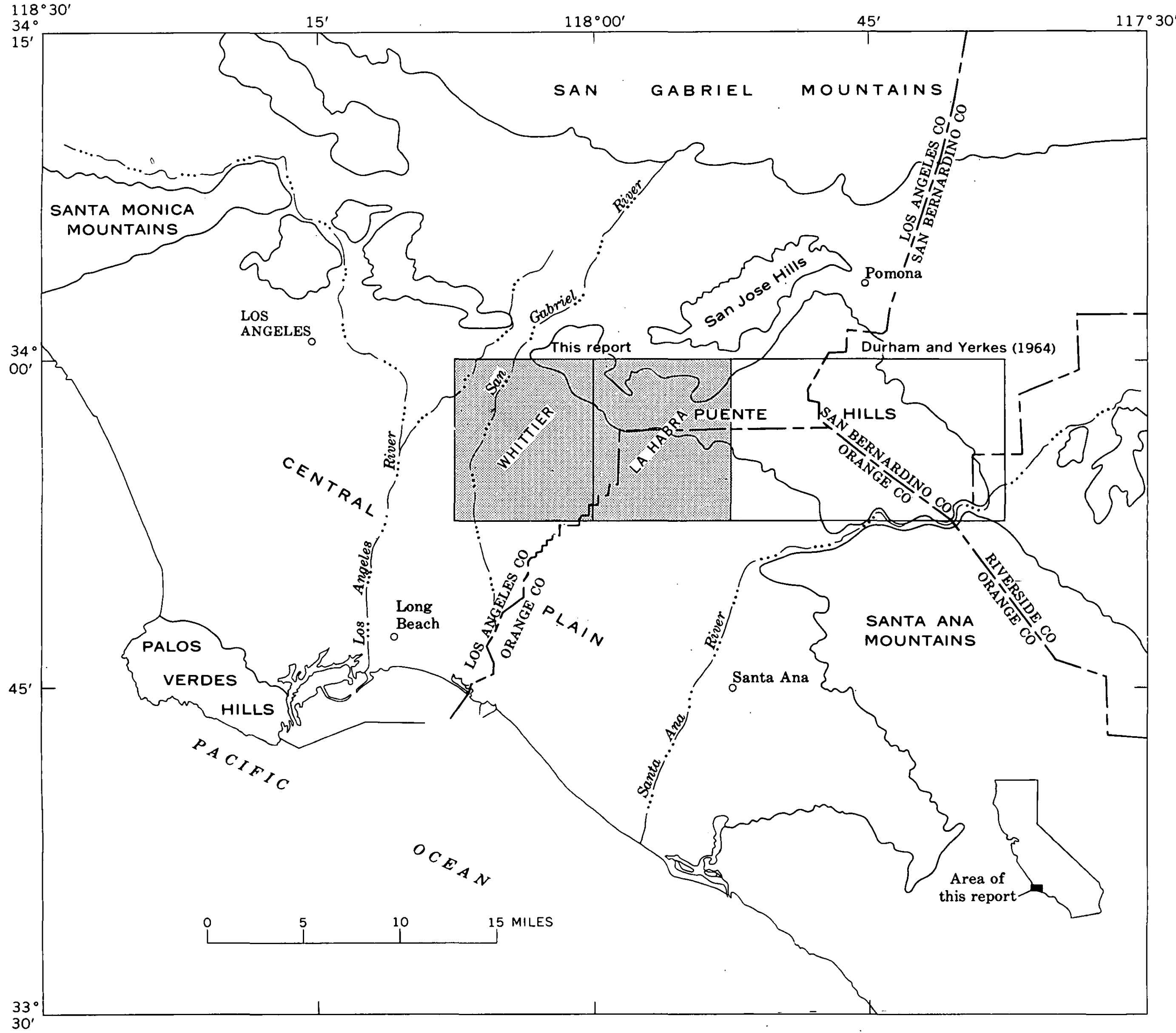

FIGURE 1.—Index map of Los Angeles basin area showing location of the western Puente Hills area.

117°52½′ and south of lat 34°00′, and is based on a geologic map and on structure sections of the La Habra and Whittier 7½-minute quadrangles (pls. 1, 2, 4). The eastern part of the hills south of lat 34°00′ was described in Professional Paper 420–B (Durham and Yerkes, 1964); an introduction to the geology of the Los Angeles basin was given in Professional Paper 420–A (Yerkes and others, 1965).

This study is part of the Geological Survey's investigation of the Los Angeles basin, one of California's most prolific oil-producing areas. Most of the oil produced in the basin comes from upper Miocene and lower Pliocene strata, which, although concealed in most oil fields as well as in the central part of the basin, are exceptionally well exposed in the Puente Hills. This report describes the thick late Cenozoic (post-Eocene) sequence in the western part of the hills; this sequence includes the important Whittier fault zone in the area where surface and abundant subsurface data make it one of the best kown of southern California's major faults. The report also contains basic data on the several oil fields, indicates correlations of the oil-bearing strata with the exposed section, reviews the history of petroleum exploration in the area, includes an annotated list of all known exploratory wells drilled before June 30, 1968, and summarizes the occurrence of oil and gas.

PREVIOUS WORK

References to the geology of the Puente Hills date from last century (chiefly in publications of the California Mining Bureau; see Durham and Yerkes, 1964), but systematic investigations began with that of G. H. Eldridge (Eldridge and Arnold, 1907). Eldridge (pl. 10; planimetric map at scale 1:62,500) first mapped the distribution and general structure of the major stratigraphic units as part of his study of the oil fields in the Whittier-Olinda area and introduced a stratigraphic nomenclature. He was also probably the first to recognize the economic significance of the Puente "anticline," along which several oil fields were being developed, and suspected that it was the locus of a major fault (as illustrated in his structure sections; Eldridge and Arnold, 1907, pl. 11). His descriptions of the structure of the oil fields are remarkably detailed.

English (1926) mapped the Whittier fault zone (at 1:62,500) as part of his geologic map of the Puente Hills–San Jose Hills–Santa Ana Mountains area in the northeast Los Angeles basin.

Woodring (1938) published a small basin-wide geologic map on which the central cores of the Coyote Hills were depicted as lower Pleistocene.

A planimetric geologic map (at 1 inch to about 1 mile) of the Puente and San Jose Hills north of the Whittier fault zone and east of long 117° 57½′ by Woodford, Shelton, and Moran (1945) includes detailed structure sections utilizing surface exposures and exploratory wells and a brief description of the stratigraphy and the structure and of the foraminiferal faunas. Woodford, Moran, and Shelton (1946) described the composition and provenance of the Miocene conglomerates that underlie much of the same area. Daviess and Woodford (1949) presented a detailed (1:12,000) geologic map of the western Puente Hills north of the Whittier fault zone and west of about long 117° 55′; this map summarizes the stratigraphy and micropaleontology, incorporates considerable subsurface data in numerous structure sections, and delineates some of the overturned folds along the Whittier fault zone. The basement configuration map of the western Los Angeles basin by Schoellhamer and Woodford (1951) includes a structure section (at 1:125,000) through the western Puente Hills and contains the first published report on the greenchist that underlies a part of the Brea-Olinda oil field area. Kundert (1952) mapped (at 1:24,000) and described the geology of the southwestern part of the hills south of the Whittier fault zone. Selected reports from an extensive literature on the subsurface geology of the several oil fields are cited where appropriate.

METHODS AND ACKNOWLEDGMENTS

The La Habra and Whittier quadrangles were mapped during the years 1957 to 1959 at 1:12,000 using the same vertical aerial photographs (1949) that served as photogrammetric control for compiling the topographic quadrangles; more recent photography was used in selected areas to locate more accurately the numerous artificial exposures, especially those in the oil fields, that were made after 1949.

An effort was made to verify identifications and incorporate into the faunal lists (tables 1, 2) significant earlier microfossil and megafossil collections, including some that have not been previously published. Although the Cenozoic epochs of the Pacific coast have not been satisfactorily correlated with those of Europe, the classification proposed by Weaver and others (1944) and Durham (1954) and the division of the "Miocene" of Kleinpell (1938) are adopted herein, as they were for Professional Papers 420–A and B, because of their great practical value for local and regional correlation purposes.

Fieldwork was greatly aided by the cooperation of landowners and also by the local management of oil companies that operate the several oil fields in the area. Many of these same companies and numerous individual operators furnished indispensable records on several hundred selected exploratory and producing wells and

furnished accessory subsurface data. Geologists employed by many of these operators were especially kind in discussing interpretations of the subsurface data.

Mollusks collected during fieldwork were identified by J. G. Vedder and W. O. Addicott, of the U.S. Geological Survey, who also assisted in some of the collecting. Foraminifera were identified and then assembled into the distribution-abundance chart by Patsy B. Smith, of the U.S. Geological Survey. T. H. McCulloh, then of the University of California at Riverside, and D. B. McIntyre and A. K. Baird, of Pomona College, aided in field interpretation of some of the structural features. The Geology Department of Pomona College furnished office, library, and laboratory facilities during the period of fieldwork. F. B. Leighton, then of Whittier College, cooperated in field identification of landslides.

STRATIGRAPHY

The northeastern part of the Los Angeles basin, including the San Jose and Puente Hills, is underlain by upper Cenozoic sedimentary (chiefly Puente Formation) and volcanic rocks which rest unconformably on a Mesozoic basement of schist and granitoid plutonic rocks (pl. 3). These plutonic basement rocks are locally exposed at the northern tip of the Puente Hills near Pomona (fig. 1); the schists are not exposed, but are known from well cores in the Brea-Olinda oil field.

ROCKS OF THE BASEMENT COMPLEX

UNNAMED GREENSCHIST

The oldest rock known in the northeastern Los Angeles basin is the unnamed greenschist of the Puente Hills oil field area (Schoellhamer and Woodford, 1951). It underlies the oil field at depths greater than 3,360 feet subsea in the upthrown block of the Whittier fault for a distance of about 2½ miles parallel to the fault and 2,500 to 4,000 feet north of the fault's surface trace (secs. 34, 35, 36, T. 2 S., R. 10 W.; fig. 2). This area coincides with one of the structural highs of the Puente Hills.

All samples of the greenschist from eight wells are very similar, varying only slightly in texture and accessory minerals. The rock is commonly crudely banded subparallel to foliation, which in one well dips 14°; the bands are as thick as 5 millimeters and consist of alternating light (albite-calcite) and dark (chlorite-epidote-magnetite) assemblages. One sample from a depth of 6,443–6,453 feet in the Shell Oil Co. well Menchego 6 shows well-developed striae or lineation on the foliation surface. Composition is approximately 40 percent albite-oligoclase, 15 percent chlorite, 15 percent epidote, 20 percent calcite, actinolite (found only in samples from the Shell Menchego 6), and magnetite. Albite-oligoclase ($An_{10\pm5}$) occurs in all samples as well-formed laths with albite twinning, and albite occurs as

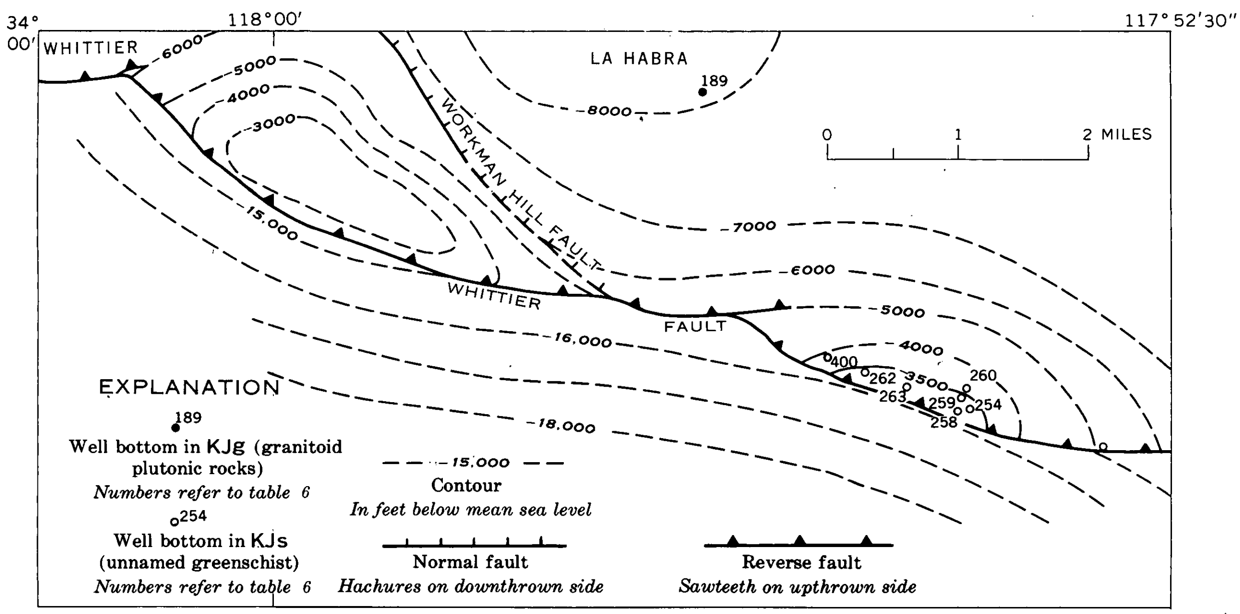

FIGURE 2.—Generalized contour map of the basement rock surface in northern part of map area showing location of wells known to bottom in basement rocks and major faults that cut basement rocks (modified from Yerkes and others, 1965, fig. 2).

aggregates of shapeless untwinned grains that contain abundant microlites, commonly oriented subparallel to the foliation.

The chlorite occurs as fibrous bundles, is pleochroic, has a refractive index of 1.6±0.003 (J. E. Schoellhamer, written commun., 1949), and has a brown to lavender anomalous interference color; it is probably prochlorite. Epidote is yellow green and nonpleochroic, has high birefringence and relief, and is probably pistacite; $2V_X$ is about 85°. Calcite is common to abundant in all samples as scattered grains and continuous layers or "veinlets"; sharply terminated crystals of magnetite are common in all samples, and actinolite and sphene are present in some (Shell Oil Co. well Menchego 6). Quartz in minute amount has been reported in a sample from a depth of 4,636–4,649 feet in Shell Oil Co. well Puente A-3 (J. E. Schoellhamer, written commun., 1949), but was not found during this study.

This assemblage albite-chlorite-epidote-calcite-actinolite is characteristic of the greenschist facies and indicates a relatively low temperature and moderate pressure of dynamothermal metamorphism. The texture, mineralogy, and common presence of "igneous" plagioclase as well as "metamorphic" albite suggest derivation from basic or andesitic volcanic rocks; the foliation and penetrative lineation may be attributed to dislocation metamorphism associated with movement along the Whittier fault zone.

Schoellhamer and Woodford (1951) first described the schist on the basis of cores from one well (Shell Oil Co. well Puente A-3) as "Catalina-like schist [of the western Los Angeles basin] * * * perhaps more nearly identical with the Pelona Schist of the [northern San Gabriel Mountains]." They recognized, however, that the Puente Hills schist possesses neither the "crinkly" schistosity nor the distinctive minerals typical of the glaucophane schist facies that distinguishes the Catalina; nor does it contain the abundant quartz-mica (muscovite or biotite) assemblages that characterize much of the Pelona. As later suggested by Woodford (1960, p. 407) on the basis of more samples from additional wells, the Puente Hills schist may best be correlated with the Santiago Peak Volcanics of the west flank of the Santa Ana Mountains. The Santiago Peak Volcanics is a sequence of deeply weathered and locally metamorphosed (to greenschist facies) andesitic volcanics that unconformably overlie the Late Jurassic (Callovian) and older metasedimentary core of the range and are intruded by pre-Turonian granitoid plutonic rocks of the Southern California batholith. (See Yerkes and others, 1965, p. 23.)

The Puente Hills greenschist is inferred to be an isolated pendant in a terrane of chiefly batholithic rocks that are believed to underlie the entire Puente Hills–San Jose Hills area northeast of the Whittier fault. On the basis of geologic association, relative age, structural position, texture, and composition, the greenschist is tentatively correlated with the Santiago Peak Volcanics of the Santa Ana Mountains.

GRANITOID PLUTONIC ROCKS

Granitoid plutonic rocks (biotite-quartz diorite and grandodiorite) are exposed at the northern tips of the Puente and San Jose Hills north of the map area, are present at the bottom of several wells in the San Jose and eastern Puente Hills (Yerkes and others, 1965, fig. 5), and are probably (as based on electric log and cuttings) at the bottom of the Morton and Sons well Rowland Estate 3-1 in sec. 16, T. 2 S., R. 10 W., in the north-central part of the map area (well 189, section *D–D′*). Similar rocks underlie much of the Puente Hills and San Gabriel Valley. A core of biotite-quartz diorite from the bottom of a 12,000-foot well near the center of sec. 21, T. 1S., R. 11 W., just 5 miles north of the map area, has a radiometric age of 153±3 million years (potassium-argon determination, Geochron Laboratories).

SUPERJACENT ROCKS

EOCENE TO MIOCENE SERIES

Rocks of the basement complex are unconformably overlain throughout the mapped area by strata assigned to either the upper Eocene to lower Miocene Sespe and Vaqueros Formations undifferentiated or to the middle Miocene Topanga Formation; older strata may locally underline the Sespe-Vaqueros along the Coyote Hills trend. Neither the Sespe-Vaqueros nor the Topanga is exposed in the map area; however, both are exposed near the Whittier fault zone in the southeastern Puente Hills (Durham and Yerkes, 1964, pl. 1), and both are widespread in the subsurface of the eastern part of the hills and adjoining parts of the Los Angeles basin (Yerkes and others, 1965, figs. 8, 9). Nomenclature of these units is reviewed by Durham and Yerkes (1964, p. 7–8).

Distinctive red mudstones, sandstones, and pebbly sandstones of the undifferentiated Sespe and Vaqueros Formations are known from wells in the Turnbull oil field (section *C–C′*, pl. 2) and from several wells along the Coyote Hills trend (section *A–A′*, pl. 1), where thicknesses as great as 1,700 feet have been penetrated.

MIOCENE SERIES

The middle Miocene rocks of the Los Angeles basin have been divided into two partly coextensive sequences on the basis of age (Yerkes and others, 1965, p. 30). The lower sequence, of early middle Miocene age, is probably not present in the map area. The upper sequence, of late middle Miocene age, contains a widespread and locally thick accumulation of volcanic rocks at or near its base, which is an erosional unconformity in the Puente Hills area. Where the volcanic rocks are exposed in the San Jose Hills, they overlie plutonic basement rocks and consist of subaerial to shallow marine flows, flow breccias, tuffs, and tuff-breccias, chiefly of andesitic composition. (See Shelton, 1946; Durham and Yerkes, 1964, p. 10–11.) The volcanic rocks locally attain a thickness of 3,500 feet in the San Jose Hills. In the northern part of the map area, they rest unconformably on plutonic basement rocks (section *D–D′*, pl. 2), but everywhere to the south they are interbedded with middle Miocene sedimentary rocks (sections *A–A′*, *C–C′*; pls. 1, 2). Thicknesses attain 1,000 feet in both areas (sections *A–A′*, *C–C′*, *D–D′*, pls. 1, 2).

In the map area marine clastic rocks of the Topanga Formation are interbedded with or overlie both the volcanic rocks and older sedimentary and basement rocks; these marine rocks consist of foraminiferal siltstone, silty sandstone, pebbly sandstone, and conglomerate. Detritus in the conglomerates, which has been traced to basement sources to the north and east, was deposited at or near the northeast margin of the late middle Miocene sea. (See Woodford and others, 1946; Yerkes and others, 1965, fig. 9.)

Thickness of the middle Miocene sedimentary rocks exceeds 1,600 feet in the Brea-Olinda oil field area (sections *G–G′*, *H–H′*, p. 2); more commonly it is 1,200–1,600 feet in both the northern and southern parts of the area mapped (sections *D–D′*, *E–E′*, *G–G′*, pl. 2).

The present form and structural relief of the basin were established chiefly during a phase of accelerated subsidence and deposition that was initiated in the late Miocene and continued without significant interruption into the early Pleistocene. By the end of Miocene time the marine embayment had attained its greatest extent for the Cenozoic: it spread northward across parts of southern California, into the foothills of the San Gabriel Mountains, and eastward well beyond the present Puente Hills. (See Yerkes and others, 1965, p. 16–18.) This embayment received widespread and locally very thick deposits of both terrigenous and biogenic sediment that accumulated rapidly in water that was as much as 3,000 feet deep.

The upper Miocene has been divided informally into two largely contemporaneous facies on the basis of lithology and inferred depositional environment (Yerkes and others, 1965, p. 34). A relatively thin western facies of organic shale, diatomite, siltstone, and mudstone is restricted chiefly to the deeper parts of the basin. This facies is between 700 and 2,000 feet thick and apparently accumulated in water 1,800 to about 3,000 feet deep. The inland, eastern facies is best developed and most completely exposed in the Puente Hills, where it is more than 13,000 feet thick; it has been named the Puente Formation. The western facies is inferred to have progressively onlapped the eastern facies during the latest part of the Miocene.

PUENTE FORMATION

The Puente Formation (Eldridge and Arnold, 1907, p. 103) consists of micaceous shale, siltstone, sandstone, and pebble conglomerate and attains a maximum known thickness of more than 13,000 feet. The formation in the western Puente Hills area was divided informally into four members by Daviess and Woodford (1949). These members have since been differentiated throughout the hills south of lat 34° (Durham and Yerkes, 1959, 1964) and formally named (Schoellhamer and others, 1954). The nomenclature of the Puente and its members is reviewed by Durham and Yerkes (1964, p. 11–12). The members are, in stratigraphic order from top down,

Sycamore Canyon Member: pebbly sandstone and conglomerate; 3,600 feet thick in northwest and southeast Puente Hills.

Yorba Member: poorly bedded to fissile diatomaceous siltstone, mudstone, and interbedded sandstone; 3,000 feet thick in eastern Puente Hills.

Soquel Member: feldspathic sandstone and pebbly sandstone, interbedded siltstone; 3,000 feet thick in north-central Puente Hills.

La Vida Member: platy siltstone, interbedded sandstone, minor vitric tuff and dolomite; 4,150 feet thick in central Puente Hills; contains diabasic intrusions as much as 750 feet thick near Whittier fault zone.

Considerable variation in thickness of these units is due to numerous internal unconformities and intertonguing and gradational contacts.

The distribution of the members reflects and emphasizes asymmetric elongate structural highs that form the Puente Hills. The La Vida Member forms the core of a half dome elongated along and just north of the Whittier fault zone. Outcrops of the Soquel and Yorba Members outline this half dome in concentric bands.

The Sycamore Canyon Member occupies the extreme flank positions. Only the Sycamore Canyon Member of the Puente is exposed south of the Whittier fault zone near its northwest end.

LA VIDA MEMBER

The La Vida Member is exposed in the structurally high, central part of the hills just north of the Whittier fault zone; other exposures are in a fault wedge north and east of Whittier. The La Vida is expressed as broad rounded slopes, generally bare of vegetation except for sparse grass. Natural exposures are commonly poor owing to thick clayey colluvium and soil cover, which carries chips of white resistant siltstone. The La Vida consists chiefly of siltstone and sandy siltstone interbedded with sandstone, dolomite, and tuff.

Siltstone of the La Vida Member in the Puente Hills oil field area is pale yellow brown to pale gray white, laminated to thin bedded (beds as much as 4 in. thick) platy, and slightly to very sandy. Sandy beds are commonly well graded. Cement is sparse to locally abundant and commonly is calcareous. The siltstone contains locally abundant leached Foraminifera and fish scales.

Quartz-feldspar biotite-poor sandstone makes up about 10 percent of the member. It is pale yellow brown, commonly fine to medium grained but locally coarse grained, and moderately to poorly sorted. It occurs as thin to medium beds and partings (½–12 in. thick) in siltstone sequences, and locally in beds as thick as 10 feet. The proportion of sandstone increases up section in most areas.

The section east of Fullerton Road contains four pale-yellow-gray aphanitic dolomite beds as thick as 3 feet; because they are resistant to weathering, they are starkly exposed on the bare slopes. Present in the lower part of the same section are at least two beds of pale-yellow-gray extensively altered basaltic(?) crystal tuff as thick as 12 feet. X-ray diffraction analysis of samples of the two tuff beds collected along Fullerton Road were made by B. M. Madsen, of the U.S. Geological Survey. Two samples from the lower bed have the following average composition: >70 percent clay (montmorillonite?), >15 feldspar, <8 cristobalite/tridymite, <5 quartz, <5 glass, <2 mica. A sample from the upper bed consists of >75 percent clay, <5 feldspar, <10 glass including opal(?), and <5 quartz.

The lowest approximately 500 feet of strata adjoining the Whittier fault zone are so tightly and intensely crenulated and sheared that individual beds cannot be traced (fig. 3); the axial surfaces of the folds and the shears are commonly subparallel to the Whittier fault.

FIGURE 3.—View eastward of contorted siltstone of the La Vida Member, Puente Formation, in cut of Shell Oil Co. Puente D–18, west end of Brea Canyon area, Brea-Olinda oil field. The dark band is rust-colored siltstone with dolomite(?) cement; cut is in zone of intense deformation immediately north of Whittier fault. Note hammer at lower left center.

The maximum exposed thickness of the La Vida in the Puente Hills oil field area is about 2,000 feet, excluding the intensely folded band near the fault; the maximum thickness as estimated from structure section *H–H′* (pl. 2) is about 4,150 feet.

The base of the La Vida Member is not exposed in the map area. It may be conformable on the underlying Topanga Formation in the central part of the hills, but at the southeast margin of the hills, an angular discordance of about 30° is present at the base (Durham and Yerkes, 1964, p. 13). The upper part of the member in the map area is conformable and gradational with the overlying Soquel Member except locally, as in the north-central La Habra quadrangle. The La Vida Member is also transgressed by younger units in the subsurface of the Coyote Hills (section *A–A′*, pl. 1).

SOQUEL MEMBER

Because of its position on the broad gentle flanks of the half dome that underlies the hills, the Soquel Member is the most widely exposed member in the Puente Formation. It is best exposed in the north-central and east-central parts of the hills. The member also forms the flanks of some tight folds in a fault wedge near Whittier. Because it consists largely of rather poorly cemented sandstone, areas underlain by this unit are fairly well drained and easily eroded and thus afford relatively steep slopes that commonly support a moderate to dense cover of brush. In the north-central La Habra quadrangle just west of Fullerton Road, where the member is best exposed and thickest, it consists of an upper 700-foot unit of sandstone and siltstone and local lenses of pebble conglomerate, a sandstone unit 550 feet thick, an interbedded sandstone-siltstone unit about 190 feet thick, and a lower sandstone unit about 760 feet thick. (See fig. 4.)

Sandstone in the Fullerton Road section is pale yellow gray to pale yellow brown and consists of subangular quartz, feldspar, biotite, and rock fragments; it is medium to coarse grained, poorly sorted, pebbly, commonly poorly to very well graded, poorly to moderately cemented, and has a rust-colored clayey matrix. Beds are of moderate thickness (1–6 ft) and are commonly bounded by siltstone partings or are interbedded with siltstone beds as thick as 3 feet. The sandstone locally contains stringers as much as 12 inches thick of angular to subrounded pebbles. Hard dolomitic ellipsoidal concretions as much as 30 inches long are common near the base of the member. Local intraformational breccias as thick as 15 feet contain numerous angular blocks and slabs of well-cemeted sandstone and pholad-bored dolomite(?) and limy siltstone.

Siltstone is light to dark gray or pale yellow brown, is laminated to platy and thin bedded (as much as 2 in. thick), and is present as partings in sandstone sequences and as beds as much as 3 feet thick. Foraminifera occur in the siltstone, but are rare.

FIGURE 4.—Graded and pebbly sandstone of the Soquel Member, Puente Formation, in cuts of Rowland Heights Water District tank site, North Fullerton Road. Note siltstone clasts; beds face right.

Conglomerate lenses at the top and about 250 feet below the top contain angular to subrounded clasts of granitic and other crystalline rock as much as 16 inches long, but averaging about 2 inches long, and angular blocks of sandstone and siltstone.

In the area west of Hacienda Boulevard, in the northwest corner of the La Habra quadrangle, the Soquel consists chiefly of coarse-grained quartz-feldspar-biotite sandstone that contains a bed about 30 feet thick of massive unsorted conglomerate of angular to rounded clasts of crystalline rock as much as 16 inches long. An intraformational breccia of blocks and slabs of dolomite and siltstone is present near the middle of the member. The lower part consists of interbedded sandstone and poorly exposed sandy siltstone and platy siltstone. This section of Soquel totals about 185 feet in thickness.

North of Whittier the Soquel consists chiefly of coarse unsorted breccia that consists of angular blocks of plutonic rock as long as 6 feet in coarse-grained unsorted feldspathic sandstone. Interbedded with the breccia is pebbly sandstone and conglomerate, as well as minor amounts of sandstone. The sandstone contains quartz, feldspar, and biotite, is fine to medium grained, well to moderately sorted, laminated to platy or thin bedded, and occurs in sequences as thick as 6 feet.

The Soquel Member is not exposed south of the Whittier fault zone; the maximum thickness, based on well data, is about 2,000 feet in the East Coyote oil field (section *G–G′*, pl. 2). This thickness increases to about 2,800 feet in the Richfield oil field 4 miles to the southeast

(Durham and Yerkes, 1964, section *C–D*, pl. 3). The Soquel thins both eastward and westward from the Richfield oil field area. North of the Whittier fault zone, the maximum thickness is about 2,200 feet in exposures just west of Fullerton Road near the north-central part of the La Habra quadrangle. The member also thickens eastward to more than 3,000 feet in the northeast part of the Yorba Linda quadrangle, just east of the La Habra quadrangle (Durham and Yerkes, 1964, section *E–E′*, pl. 4). The Soquel thus thins northward, eastward, and westward from the central Puente Hills.

In the central Puente Hills, both the lower and upper contacts of the Soquel are commonly gradational within stratigraphic thicknesses as great as 50 feet. West of Fullerton Road in the north-central La Habra quadrangle and in some other areas, the member is locally uncomformable on the La Vida (section *F–F′*, pl. 2). In the northern Puente Hills the Soquel locally transgresses the La Vida and older sedimentary units and rests on volcanic and basement rocks.

YORBA MEMBER

The Yorba Member is exposed peripherally to the Soquel; it underlies marginal areas of the Puente and San Jose Hills, except where it is downfolded in the large Arena Blanca syncline in the eastern Puente Hills. (See Durham and Yerkes, 1964.) In its weathering characteristics the Yorba is similar to the La Vida, forming broad, gently rounded slopes mantled by a thick clayey colluvium and soil that supports chiefly sparse grass. Siltstone sequences within the member readily creep downslope. The best exposures in the map area are those west of Fullerton Road in the northeast quarter of the La Habra quadrangle.

The Yorba is about 85 percent micaceous siltstone and sandy siltstone that commonly is "punky"; interbedded are sandstone and minor dolomite beds. In many places along the Whittier fault zone, the siltstones are intensely contorted (fig. 5).

Silstone in the Fullerton Road section is pale white, pale greenish yellow, or very light gray, micaceous, slightly to quite sandy, laminated to platy, and occurs in beds ½–2 inches thick. Locally the siltstone contains abundant Foraminifera. Sandstone occurs as partings and interbeds as thick as 10–12 inches (commonly these interbeds are about ½–2 inches thick), is fairly well sorted and graded, and contains biotite and clayey cement. Siltstone sequences east of Hacienda Boulevard locally contain beds 3 inches to 1 foot thick of laminated aphanitic gray to yellow-gray dolomite; thin beds of soft white marl are locally present in the area a mile west of Hacienda Boulevard.

The Yorba is thickest in the north-central La Habra quadrangle, where about 1,200 feet is exposed, and an additional 400 feet is present in the subsurface (sections *D–D′*, *E–E′*, pl. 2). In the area north of the Whittier fault, the Yorba thins to a few hundred feet in the fault wedge north of Whittier; eastward it thickens to at least 2,000 feet in the east-central part of the hills (Durham and Yerkes, 1964), section *F–F′*, pl. 4). The Yorba is not exposed south of the Whittier fault, but thicknesses of about 3,000 feet have been penetrated at the Santa Fe Springs oil field (section *A–A′*, pl. 1) and 3,400 feet at the Brea-Olinda oil field (section *H–H′*, pl. 2).

FIGURE 5.—Very thin bedded intensely contorted siltstone and silty sandstone of the Yorba Member, Puente Formation, in upthrown block of Whittier fault zone, near fault in Whittier oil field. Note hammer on light-colored sandstone bed at lower right center.

In the map area the Yorba is gradational downward into the Soquel. In the northern Puente Hills the Yorba extends laterally beyond the Soquel and rests on the La Vida Member; east of the Chino basin (east of the Puente Hills) it rests on granitoid basement rocks (Durham and Yerkes, 1964, section *A–A′*, pl. 3). In the map area the upper contact is a sharp boundary overlain by conglomerate in the Sycamore Canyon Member.

SYCAMORE CANYON MEMBER

The uppermost member of the Puente Formation, the Sycamore Canyon Member, is preserved chiefly along the margins of the hills and locally in slices along the Whittier fault zone. The type area of the Sycamore Canyon is in Sycamore Canyon just northwest of the area shown on plate 1, where about 3,500 feet of strata are present in a complete section (Daviess and Woodford, 1949). In the type area the Sycamore Canyon consists of about 60 percent fine- to coarse-grained sandstone, about 30 percent pebble conglomerate in four lenses as much as 400 feet thick, and about 10 percent interbedded micaceous sandy siltstone. The best exposures in the map area are east of Hacienda Boulevard in the north-central La Habra quadrangle and south of the Whittier fault zone just east of Whittier. Sycamore Canyon conglomerate commonly weathers rusty brown and forms exceedingly steep resistant slopes that have very little soil cover and support brushy or grassy vegetation only on ridgetops.

The section east of Hacienda Boulevard is about half as thick as the type section and consists of about 70 percent sandy siltstone, about 20 percent pebble conglomerate in three lenses, and 10 percent sandstone. This section can be divided into six units as follows: an upper sandy siltstone-sandstone unit 410 feet thick, an upper conglomerate 25 feet thick, a middle siltstone-sandstone unit 868 feet thick, a middle conglomerate 55 feet thick, a lower siltstone-sandstone 300 feet thick, and a basal conglomerate about 275 feet thick.

The siltstone is pale yellow gray, sandy and micaceous, thin bedded (beds are ½–6 in. thick), and intensely jointed and hackly. It contains locally abundant leached Foraminifera and fine- to medium- grained biotitic sandstone in numerous irregular pods, streaks, and 1–2-inch-thick beds at 6–18 inch intervals. Conglomerate lenses are pale yellow brown, massive, and consist of densely packed very poorly sorted subangular to well-rounded clasts, chiefly of crystalline rocks, as long as 10 inches but averaging 1–2 inches, in a sparse matrix of friable rust-colored coarse-grained clayey feldspathic sand. A few subangular clasts of well-cemented intraformational sediments are present in the conglomerate.

The pebbles in the basal Sycamore Canyon conglomerate just west of Hacienda Boulevard have been studied and described by Woodford, Moran, and Shelton (1946, loc. 14; p. 542–543). Clasts in a typical bed 5 feet thick range from 1½ to 26 inches across; most are in the 1½–12 inch range. Their shape is subangular to subrounded, and the matrix is clean quartz-feldspar micaceous sand. The pebbles counted consist of 32 percent gneiss and quartzite fragments, 20 percent siliceous porphyries, 6 percent aplites, and 2 percent volcanic rocks. The most common constituents are biotite granite, quartz monzonite, and gneisses of the same compositions, suggesting a source in the San Gabriel Mountains to the north. The conglomerates in the upper part of the Sycamore Canyon northeast of the Rowland fault contain abundant boulders of andesite and other volcanic rocks and lesser amounts of boulders of tourmaline-actinolite granite—a suite also indicative of a source in the San Gabriel Mountains (Daviess and Woodford, 1949).

The partial section of Sycamore Canyon Member exposed south of the Whittier fault zone just east of Whittier consists of about 670 feet of thick-bedded, coarse-grained to pebbly sandstone that contains two zones of hard limy concretions as long as 15 inches. The base of this sequence is faulted.

Conglomerate in the Whittier section is light brown to moderate yellow brown, very poorly sorted, and bedded. It contains subangular to well-rounded clasts of light-colored crystalline rocks as long as 8 inches, but averaging 1–2 inches, and angular chips of intraformational sandstone in layers about 1 inch thick. The matrix is very poorly sorted coarse-grained sandstone containing abundant clayey material.

North of the Whittier fault zone, the Sycamore Canyon attains a thickness of about 3,500 feet in unfaulted sections at the northwestern and southeastern ends of the hills. The thickness of the only unfaulted section in the central part of the map area is about 1,930 feet (structure section *D–D′*, pl. 2). South of the Whittier fault zone, the faulted section near Whittier is about 1,590 feet thick, and an unfaulted section near Yorba Linda is about 1,700 feet thick (Durham and Yerkes, 1964, *F–F′*, pl. 4). As is also true of the Yorba Member, the Sycamore Canyon is thickest in the subsurface of the southern part of the area at the Santa Fe Springs oil field, where about 2,200 feet have been penetrated (section *A–A′*, pl. 1).

The basal conglomerate of the Sycamore Canyon commonly rests sharply, but apparently conformably, on siltstones of the Yorba Member except in a fault wedge north of Whittier where the Sycamore Canyon locally extends beyond the limits of the Yorba siltstone and rests on sandstone of the Soquel Member with an angular discordance of 10–15°. The upper boundary is not commonly well exposed in the map area.

DEPOSITIONAL ENVIRONMENT

Foraminiferal faunas from all members of the Puente Formation in the map area contain species that now live at bathyal depths (greater than 500 m or 1,600 ft). The local presence of well-graded fine-grained sandstone partings and interbeds in siltstone sequences of the La Vida and Yorba Members and the presence of deep-water forms within siltstone partings in coarse-grained well-graded sandstone sequences in the Soquel and locally in the Sycamore Canyon Members suggest deposition of the sandy intervals at bathyal depths, perhaps by turbidity currents. In addition, the Sycamore Canyon Member contains a few shallow-water forms, which were probably displaced during resedimentation processes. The presence of several intraformational breccias, especially in the Soquel Member, also suggests resedimentation, perhaps reworking of slump deposits. Conglomerates in the Sycamore Canyon Member, and locally in the Yorba and Soquel Members, contain very large boulders derived from biotite granodiorite basement rocks and boulders of Miocene volcanic rocks like those exposed in the northernmost Puente Hills. Sources for other rock types represented in the conglomerates have been identified in the nearby San Gabriel Mountains (Woodford and others, 1946). It has been inferred that the Miocene shoreline transgressed eastward from a northwest-trending position near the present margins of the Puente and San Jose Hills in early Puente time to a north-trending position near long 117°40′ in late Puente time (Woodford and others, 1946, fig. 11). The younger part of the Puente thus overlapped older parts and extended onto the basement in areas east and northeast of the Puente Hills. (See Durham and Yerkes, 1964, section *A–A′*, pl. 3.) The Puente must have been deposited in water that was at least locally deeper than 1,600 feet. Terrigenous components derived from highlands north and east of the Puente Hills were swept southwestward, probably by turbidity currents, toward deeper parts of the embayment that occupied the Puente Hills area.

AGE AND CORRELATION

All Foraminifera collected from the La Vida Member (table 1) represent the lower Mohnian Stage (early late Miocene) of Kleinpell (1938), which is the age of Foraminifera in collections from the member in the eastern Puente Hills (Durham and Yerkes, 1964, p. 17), as well as areas to the north and south (Woodford and others, 1944; Woodford and others, 1946, p. 519; Schoellhamer and others, 1954). Foraminifera collections from the Soquel, Yorba, and Sycamore Canyon Members represent the upper Mohnian Stage (late late Miocene) of Kleinpell, which agrees with the age determined from collections made in adjoining areas.

On the basis of the microfaunas, the Puente Formation is correlative with the Modelo Formation at the type area of the Mohnian Stage in the north-central Santa Monica Mountains (Natland and Rothwell, 1954, fig. 4); with the upper part of the Monterey Shale (upper part of the Altamira Shale Member, Valmonte Diatomite Member) at the Palos Verdes Hills (Woodring and others, 1946); with the upper part of the Monterey Shale in the eastern San Joaquin Hills, and with the Puente Formation of the southwestern Santa Ana Mountains (Smith, 1960; Yerkes and others, 1965, pl. 1).

DIABASIC INTRUSIVE ROCKS

Two tabular bodies of intensely altered dark-gray-green diabase intrude the La Vida Member just north of the Whittier fault zone near the east edge of the map area. The largest of these has been traced in wells 9 miles eastward along the fault zone and 2 miles north of it; in this distance and direction, the intrusive appears to cut downward across about 4,000 feet of section (Durham and Yerkes, 1964, p. 23–24). The same body has been traced northwestward about 5 miles to the north edge of the La Habra quadrangle (sections *D–D′*, *F–F′*, *G–G′*, and *H–H′*, pl. 2). The total area north of the fault known to be underlain by the intrusive is more than 30 square miles. The maximum known thickness of this large body is about 750 feet. Only its upper contact is exposed. It is overlain by about 550 feet of intensely sheared, altered, and locally baked siltstone, which locally is overlain in turn by a much thinner, less persistent intrusive. The two intrusives are probably contemporaneous and cannot be older than early Mohnian. Fragments of similar diabase are present in lower Pliocene conglomerates near the Whittier fault zone. A late Miocene age is inferred for the diabase.

Igneous rock found in the subsurface of the East Coyote oil field and previously reported as intrusive (Durham and Yerkes, 1964, p. 23) is better correlated with middle Miocene volcanic rocks that are present at this same stratigraphic position at several other localities along the Coyote Hills trend. (See sections *A–A′*, *G–G′*, pls. 1, 2.)

PLIOCENE SERIES

Subsidence and deposition continued without interruption from Miocene into and through Pliocene time in the Los Angeles basin area. The maximum rate of subsidence was attained in early Pliocene time. Because deposition did not keep pace with subsidence, water that covered the Puente Hills area probably deepened to more than 3,300 feet, and in the central part of the basin southwest of the hills the water probably attained a depth greater than 8,000 feet. During early Pliocene time great volumes of clastic material entered the basin along its north and east margins, and more than 6,000 feet of lower Pliocene deposits accumulated (Yerkes and others, 1965, fig. 12). A gradual increase in grain size and percentage of sand from base to top of the lower Pliocene sequence in the central part of the basin suggests a gradual increase of topographic relief in the source areas during the early Pliocene.

In the central-plain part of the basin, subsidence and deposition continued without interruption into late Pliocene time, but the rate of deposition gradually overtook the rate of subsidence, and the depth of water began to decrease. In marginal areas such as the southwest margin of the Puente Hills, unconformities within or at the base of the upper member of the Fernando Formation indicate tectonic activity along the Whittier fault zone and Coyote Hills trend, also shown by the presence

TABLE 1.—*Foraminifera from the Puente Formation,*

[X, present; cf., not certainly identified, but resembles listed species. See pl. 4 for location of

Species	Puente Formation																			
	Sycamore Canyon Member					Yorba Member														
	Upper Mohnian Stage																			
	m-43	m-44	m-44a	m-44b	m-45	m-46	m-47	m-48	m-49	m-50	m-51	m-52	m-53	m-54	m-55	m-56	m-56a	m-57	m-58	m-59
Bolivina bramlettei Kleinpell															X		X			
B. brevior Cushman														X	X					
B. californica Cushman																				
B. decurtata Cushman																				
B. decussata Brady															X					
B. cf. *B. floridana* Cushman																				
B. girardensis Rankin													X		X					
B. goudkoffi Rankin									X											
B. hootsi Rankin												X								
B. hughesi Cushman	X						X			X	X						X			
B. cf. *B. marginata* Cuhsman																				
B. modeloensis Cushman and Kleinpell																				
B. pisciformis Galloway and Morrey			X	X																
B. pseudobeyrichi Cushman																				
B. pseudospissa Kleinpell	X										X		X	X						
B. rankini Kleinpell										X										
B. sinuata Galloway and Wissler	X			X		X			X								X	X		
B. subadvena Cushman				X	X													X		
B. tongi Cushman										X										
B. cf. *B. vaughani* Natland													X			X			X	X
B. woodringi Kleinpell						X	X		X	X								X	X	X
Bulimina inflata Seguenza																				
B. marginata d'Orbigny										X										
B. ovula d'Orbigny		cf.				X														
B. rostrata Brady				X	X															
B. subacuminata Cushman, Stewart and Stewart			X	X	X															
B. uvigerinaformis Cushman and Kleinpell																				
Buliminella curta Cushman			X													X				
B. subfusiformis Cushman									X	X	X		X	X						
Cassidulina barbarana Cushman and Kleinpell																				
C. cushmani R. E. and K. C. Stewart											X					X				
C. translucens Cushman and Hughes																				
Chilostomella cf. *C. ovoidea* Reuss		X																		
Cibicides floridanus (Cushman)			X																	
Discorbinella valmonteensis Kleinpell							X						X							X
Elphidium spp		X													X					
Epistominella relizensis (Kleinpell)																				
E. subperuviana (Cushman)													X							
Eponides healdi R. E. and K. C. Stewart																				
E. mansfieldi Cushman														X						
E. rosaformis Cushman and Kleinpell																				
Globigerina spp								X												
Globorotalia sp														X						
Gyroidina altiformis R. E. and K. C. Stewart				X																
G. rotundimargo R. E. and K. C. Stewart		X	X			X				X								X		
Hopkinsina magnifica Bramlette			X							X									X	
Melonis pompilioides (Fichtel and Moll)				X																
Planulina ornata (d'Orbigny)																				
Plectofrondicularia californica Cushman																				
Pullenia pedroana Kleinpell						cf.														
Uvigerina hootsi Rankin									X				X				X	X		
U. senticosa Cushman					X															
U. subperegrina Cushman and Kleinpell			X	X		X				X					X					
Valvulineria araucana (d'Orbigny)	X				X															
V. vilardeboana (d'Orbigny)		X																		
Virgulina bramlettei Galloway and Morrey			X																	
V. californiensis Cushman						X														

La Habra and Whittier quadrangles

collections; table 7 for collectors, identifiers, and locality descriptions]

Puente Formation—Continued																									
Soquel Member				La Vida Member																					
Upper Mohnian Stage—Con.				Lower Mohnian Stage																					
m-61	m-61a	m-62	m-63	m-64	m-65	m-66	m-67	m-68	m-69	m-70	m-71	m-72	m-73	m-74	m-75	m-76	m-77	m-78	m-79	m-80	m-81	m-82	m-83	m-84	m-85
							X																	X	
													X												
				X					X	X	X		X	X					X		X	X	X	X	X
													X												
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													X								X				
										X	X			X	X	X					X	X	X		
										X				X		X	X	X	X	X	X		X		X
																							X		
	X		X		X	X				X						X						X	X		X
		X	X										X			X									
										X			X	X							X				
													X												
										X				X		X	X	X	X	X	X	X			X
							X	X										X					X		
	X	X								X				X					X	X			X		
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				X																	X				
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	X												X												
						X		X					X			X		X							
										X			X	X					X	X	X		X		X
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X					X										X										
			X										X			X					X		X		
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																					X				
						X										X			X	X	X		X		
				X						X	X		X	X							X		X		X
													X					X					X		X
			X										X										X		

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of Puente siltstone detritus in the upper Pliocene just south of the fault. In contrast to the uplift along the Whittier fault zone, the San Gabriel Valley just northwest of the hills began to subside relatively rapidly and became a closed basin that trapped many thousand feet of coarse-grained upper Pliocene deposits. In late Pliocene time the rising Puente Hills thus shed detritus southward and probably northwestward.

The Pliocene sequence is so uniform that basinwide subdivision and correlation on a lithologic basis has not been feasible. However, the sequence has been divided into foraminiferal zones that are used for local correlation (Wissler, 1943, pl. 5; 1958; correlation chart), and molluscan assemblages provide a twofold chronologic division (Woodring, 1938, p. 22).

The complicated history of the nomenclature of the Los Angeles basin Pliocene has recently been reviewed by Durham and Yerkes (1964, p. 24–25), who revived the original name, Fernando Formation (Eldridge and Arnold, 1907), and designated lower and upper members for the formation in the eastern Los Angeles basin area.

FERNANDO FORMATION

The Fernando Formation includes about 6,000 feet of Pliocene siltstone, sandstone, pebbly sandstone, and conglomerate exposed on the northwest- and south-facing slopes of the Puente Hills. In this part of the basin the Fernando has been divided into lower and upper Members on the basis of an extensive erosional unconformity and lithologic variations (Daviess and Woodford, 1949; Woodford and others, 1954; Yerkes and others, 1965).

LOWER MEMBER

The most complete section of the lower Fernando in the Puente hills is that exposed just northwest of the map area, where about 2,400 feet of siltstone, sandstone, and conglomerate are present (Daviess and Woodford, 1949). In the map area a partial, poorly exposed section is present just east of Hacienda Boulevard in the northwest quarter of the La Habra quadrangle; a nearly complete section is exposed just east of Whittier, south of the Whittier fault zone. This section is unique in that it has been correlated with producing zones at the Santa Fe Springs oil field by means of subsurface structure mapping (T. H. McCulloh, written commun., Mar. 1970). The pebbly sandstone and siltstone boundary exposed at Penn Park (at NW. cor. sec. 27, T. 2 S., R. 11 W.) is equivalent to the top of the "Meyer zone," and the siltstone above is equivalent to the "Meyer shale" of Santa Fe Springs.

In the vicinity of Hacienda Boulevard, the lower member of the Fernando forms subdued, rounded slopes, is mantled by a thick clayey colluvium and soil, supports a dense cover of grass, and is very poorly exposed. It consists of about 1,000 feet of sandy micaceous siltstone and very fine to medium-grained micaceous friable sandstone, which overlies a basal pebble-cobble conglomerate as much as 85 feet thick. The siltstone-sandstone sequence is pale yellow brown to light olive gray, mostly massive and contains scattered zones of limy concretions 8–12 inches long and lenses of coarse-grained nearly uncemented yellow-gray sand up to 6 inches thick.

The section of the lower member east of Whittier consists of about 65 percent sandstone and 35 percent pebble conglomerate (fig. 6). Sequences of sandstone are as thick as 195 feet and those of conglomerate as thick as 110 feet. (See fig. 6.) These rocks underlie fairly steep dissected hills and support a cover of grass and sparse brush.

Sandstone in the Whittier section is pale yellow gray to gray orange, mostly massive, except for thin intervals of well-bedded platy sandstone, which is silty, fine- to medium-grained, poorly sorted, but commonly graded, micaceous with common to abundant biotite, hackly and generally intensely jointed, and which has an abundant rust-colored clayey matrix. It contains locally common Foraminifera.

Conglomerate in the lower member of the Fernando near Whittier is gray orange to light brown and commonly massive and unsorted. It consists of more than 50 percent subrounded to well-rounded pebbles of light-colored crystalline rocks as much as 5 inches long and averaging 1 inch. The matrix is pale-gray coarse-grained

FIGURE 6.—Sandstone, pebbly sandstone, and pebbly conglomerate of the lower member of the Fernando Formation resting (at hammer) on jointed silty sandstone. Conglomerate locally contains abundant clasts of white (Miocene) siltstone. View eastward of cut near east end of Hadley Street, Whittier.

to pebbly friable sand containing biotite and rust-colored clayey material. Local intraformational breccias up to 4 feet thick within the conglomerates consist of chips and slabs of siltstone as long as 10 inches. The basal conglomerate of the formation is 122 feet thick and contains chips and slabs of siltstone from the Puente Formation as much as 4 inches long, a few beds of uncemented sand as much as 4 inches thick, and a few fragments of diabase, probably derived from instrusions near the Whittier fault. Crystalline rocks in the conglomerates resemble older rocks now exposed in the San Gabriel Mountains and in areas within and east of the Santa Ana Mountains.

The lower member is about 2,500 feet thick northwest of the map area; it is about 2,600 feet thick in exposures east of the map area and south of the Whittier fault zone near Olinda (Durham and Yerkes, 1964, pl. 3). In the map area the best-exposed section is that just east of Whittier and south of the Whittier fault zone; there about 2,700 feet are exposed. The maximum known thickness in the Puente Hills area is about 4,750 feet, measured in the subsurface near La Habra (section *E–E′*, pl. 2). The member probably thickens to more than 6,000 feet south of the Coyote Hills and west of Santa Fe Springs, but has not been completely penetrated in those areas (Yerkes and others, 1965, pl. 4).

The base of the lower member is best exposed in the hills just east of Whittier, where the basal conglomerate forms a sharp and prominent slightly irregular, but apparently conformable, contact with sandstone of the Sycamore Canyon Member of the Puente Formation. The upper contact south of the Whittier fault zone and in nearby oil fields is an erosional unconformity with an angular discordance of 5°–10°, below which foraminiferal zones recognized elsewhere in the basin are missing (Wissler, 1943, p. 213).

Depositional Environment

Foraminiferal faunas from widely separated marginal areas of the Los Angeles basin indicate deposition of the lower member in water that deepened from about 3,000 feet at the end of the Miocene to more than 4,000 feet by the end of early Pliocene time (Natland and Rothwell, 1954, fig. 6). Recent studies (Ingle, 1967, p. 260–265) of the lower member in the Repetto Hills, about 8 miles northwest of Whittier, suggest that the sequence there was deposited in water as deep as 2,500 meters (8,200 ft), as indicated by the presence of bathyal forms throughout, and that it contains sediment that was displaced downslope, perhaps by sliding, as indicated by a large proportion of displaced shallower water bathyal forms. Rapid deposition at the base of a fairly steep submarine slope is inferred on the basis of the sedimentary structures and faunas.

Molluscan faunas suggest a division into three bathymetric facies: a widely distributed deep-water facies (more than 2,000 ft deep), an intermediate-depth facies present around the margins of the central basin, and a shallow-water facies near the north and west margins of the basin (Woodring, 1938, p. 12–16). In parts of the area, these facies are mixed; this suggests proximity to land and probably transport of the shallow-water forms into deeper water. Forms collected from the lower member in the map area indicate depths greater than 3,300 feet.

The principal entry into the depositional basin for detritus was probably near the west end of the Puente Hills. From here it was swept southward and westward into deeper, subsiding parts of the basin. (See Conrey, 1958; Yerkes and others, 1965, fig. 12.) The occurrence of coarse-grained graded sandstone and conglomerate in the otherwise fine-grained lower member suggests that the coarser material may have been carried into deeper parts of the depositional basin by turbidity currents.

Age and Correlation

Foraminifera from the lower member are given in table 2; the lower Pliocene guides *Plectofrondicularia californica* and *Bolivina pisciformis* are represented in collections from two localities, and the bathyal species *Bulimina rostrata*, *Nonion affine*, *Gyroidina rotundimargo*, and *Uvigerina pygmaea* are well represented.

On the basis of megafaunal collections (table 3) and stratigraphic position, the lower member may be correlated with the lower member of the Fernando Formation in the Santa Ana Mountains to the southeast, with the upper part of the Capistrano Formation of the San Joaquin Hills and the lower part of the Fernando Formation of the Newport Bay area, and with strata commonly called Repetto Formation or Repetto Siltstone in other marginal parts of the basin. (See Yerkes and others, 1965, pls. 1, 2.)

UPPER MEMBER

The thickest preserved section of the upper member of the Fernando Formation in the Puente Hills area is exposed at the Arroyo Salinas south of the Whittier fault and northwest of La Habra. This section is faulted at the base (section *C–C′*, pl. 2), but it can be matched with exposures in the Bacon Creek area east of Whittier, where the base is preserved and the top eroded. The composite thickness is at least 3,400 feet. Section *C–C′* (pl. 2) indicates that the upper member totals about 5,000 feet in the subsurface in this area. The member is much thinner at the northwest margin of the hills, where a rich molluscan fauna has been collected (the Handorf Dairy locality of Stark, 1949). The upper member forms

TABLE 2.—*Foraminifera from the Fernando*

[×, present; cf., not certainly identified, but resembles listed species. See pl. 4 for

Species	Fernando																
	m-1	m-2	m-3	m-4	m-5	m-6	m-7	m-8	m-9	m-10	m-11	m-12	m-13	m-14	m-15	m-16	m-17
Ammonia beccarii (Linne)	×																
Anomalina pliocenica Natland																	
Bolivina argentea Cushman														×			
B. interjuncta Cushman																	
B. pisciformis Galloway and Morrey																	
B. sinuata Galloway and Wissler																	
B. spissa Cushman														×			×
B. subadvena Cushman									×								
Bulimina denudata Cushman and Parker									×	×							
B. inflata Seguenza																	
B. cf. *B. ovata* d'Orbigny		×															
B. rostrata Brady																	
B. subacuminata Cushman, Stewart and Stewart														×			
B. subcalva Cushman and K. C. Stewart																	
Buccella frigida (Cushman)							×				×						
Buliminella elegantissima (d'Orbigny)									×	×			×				
Cassidulina californica Cushman and Hughes		×			×	×											
C. cushmani R. E. and K. C. Stewart			×														×
C. limbata Cushman and Hughes		×				×	×	×	×	×	×						
C. spiralis Natland																	
C. tortuosa Cushman and Hughes						×											
C. translucens Cushman and Hughes																	
Cassidulinoides cornuta (Cushman)																	
Cibicides mckannai Galloway and Wissler						×											
C. spiralis Natland																	
C. spp							×			×							
Elphidium spp	×									×							
Epistominella pacifica (R. E. and K. C. Stewart)			×	×	×	×		×	×	×	×	×	×				
E. subperuviana (Cushman)														×			×
Eponides tenera (Brady)																	
E. umbonatus (Reuss)																	×
Frondicularia advena Cushman						×			×								
Gaudryina arenaria Galloway and Wissler					×	×	×					×					
Glandulina laevigata d'Orbigny															×	×	×
Globigerina spp									×							×	
Globobulimina pacifica Cushman							×		×								
Gyroidina rotundimargo R. E. and K. C. Stewart																	
Lagena spp		×															
Marginulinopsis capistranoensis White																	
Melonis pompilioides (Fichtell and Moll)			×														
M. scaphum (Fichtell and Moll)																	
Nodosaria spp																	
Nonion affine (Reuss)		×					×	×			×						
Nonionella miocenica stella Cushman								×	×	×	×						
Planulina ornata d'Obigny																	
Plectofrondicularia californica Cushman																	
Pullenia bulloides (d'Orbigny)																	
P. quinqueloba (Reuss)		×									×	×					
Stilostomella spp			×														
Textularia sp																	
Triloculina trigonula (Lamarck)																	
Uvigerina hootsi Rankin				cf.	cf.									×			
U. juncea Galloway and Wissler						×		×			×						
U. peregrina Cushman						×					×	×	×		×		×
U. pygmaea d'Orbigny																	
U. senticosa Cushman			×													cf.	
Valvulineria araucana (d'Orbigny)			×	×										×		×	×

fairly steep deeply dissected slopes that are ribbed by numerous well-cemented conglomerate beds. The slopes commonly support a cover of moderately dense brush.

The upper member can be divided into three parts: a lower sandstone and conglomerate unit about 650 feet thick, including a basal conglomerate about 20 feet thick (fig. 7), a middle sandstone unit about 1,935 feet thick, and an upper sandstone and pebbly sandstone unit about 825 feet thick.

The base of the upper member is well exposed in the area east of Whittier, where the well-cemented basal conglomerate overlies sandstone of the lower member. An erosional unconformity is indicated by the irregular contact surface and the presence of locally derived Puente siltstone detritus in the conglomerate. A slight angular discordance is also noticeable at this outcrop (fig. 7). Wissler (1943, p. 213–214) reported that approximately 1,000–1,500 feet of strata present elsewhere in the basin (his Middle Pico and Lower Pico) is missing at this contact in this general area. In the west-central Yorba Linda quadrangle (next east of the La Habra quadrangle), the base of the upper member of the Fernando lies on the lower member with a prominent discordance (Durham and Yerkes, 1964, pl. 1).

Conglomerate of the basal conglomerate unit is pale yellow brown, massive and unsorted, and consists chiefly of well-rounded light-colored crystalline rocks as much as 6 inches long, but averaging about 2 inches, chips and slabs of white siltstone derived from the Puente Formation, and rounded fragments of intraformational sandstone. The bottom 2 feet is well cemented, hard and resistant, and locally better sorted than the rest of the

Formation, La Habra and Whittier quadrangles

location of collections; table 7 for collectors, identifiers, and locality descriptions]

Formation																									
m-18	m-19	m-20	m-21	m-22	m-23	m-24	m-25	m-26	m-27	m-28	m-29	m-30	m-31	m-32	m-33	m-34	m-35	m-36	m-37	m-38	m-38 A	m-39	m-40	m-41	m-42
													×												
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		×	×	×									×				×			×?		×			
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unit. The matrix is coarse-grained very poorly sorted clayey biotite sandstone.

The lower pebbly sandstone and conglomerate unit is about 57 percent sandstone, 27 percent pebbly sandstone, and 16 percent pebble conglomerate and minor breccia. The sandstone is light olive gray to pale yellow brown, silty, fine to coarse grained, locally thin bedded but commonly structureless, poorly sorted and quite friable, and locally well graded. It has local partings and thin beds

FIGURE 7.—Basal thick-bedded pebbly sandstone and conglomerate of the upper member of the Fernando Formation resting (at hammer) on sandy siltstone of the lower member. Conglomerate contains abundant detritus of white (Miocene) siltstone; note angular discordance at contact. Artificial cut at site of Standard Oil Co. well Murphy-Whittier 94, Whittier oil field.

TABLE 3.—*Mollusks from the Fernando, San Pedro, and Coyote*

[X indicates that species is present as named; cf., a similar form but material inadequate for identification; aff., a close affinity but details recognizably different; ?, incorrect sense. See pl. 4 for location of collections and

Species	Coyote Hills Formation	San Pedro Formation														Upper member of Fernando Formation					
	F-2	F-3	F-4	F-5	F-6	F-7	F-7A	F-8	F-9	F-10	F-11	F-12	F-13	F-14	F-15	F-16	F-17	F-18	F-19	F-19A	F-19B	F-20
Gastropods:																						
Acanthina spirata (Blainville)									X													
Acteon traski Stearns											cf.											
Aletes																		sp.				
Antiplanes perversa (Gabb)																						
Astraea gradata Grant and Gale																						
Balcis rutila (Carpenter)									X													
Barearofusus arnoldi (Cossmann)											X			X								
B. barbarensis (Trask)																	?					
Bittium rugatum Carpenter								X		X							sp.					
Boreotrophon lasius Dall										cf.												
Bursa californica (Hinds)									X													
Calicantharus fortis (Carpenter)																						
C. humerosus (Gabb)																	X		sp.			
Callistoma dolarium (Holten)										X												
C. gemmulatum (Carpenter)										X		X					?					
C. ligatum (Gould)											cf.											
Calyptraea filosa (Gabb)																	cf.					
Cancellaria tritonidea (Gabb)									X													
Conus californicus Hinds									X		X											
Crassispira montereyensis (Stearns)									cf.													
C. zizyphus (Berry)																	cf.					
Crepidula onyx Sowerby										cf.												
C. princeps Conrad		sp.			X			X			X	X					sp.					X
Crucibulum spinosum (Sowerby)									X													
Cryptonatica clausa (Broderip and Sowerby).									X													
Cylichna attonsa Carpenter										X												
Elaeocyma hemphilli (Stearns)									X								sp.					
Epitonium indianorum (Carpenter)									X	X												
E. tinctum (Carpenter)																						
Erato vitellina Hinds									cf.													
Fusitriton oregonensis (Redfield)																					?sp.	
Glyphostoma conradiana (Gabb)										X												
"*Gyrineum*" *elsmerense* English																	X					
Halistylus pupoideus (Carpenter)										X												
Lacuna unifasciata Carpenter									X													
Littorina scutulata Gould									X													
Mangelia variegata Carpenter									X													
Megasurcula carpenteriana (Gabb)												X										
Mitrella carinata (Hinds)									X								sp.					
M. carinata gausapata (Gould)									X													
M. tuberosa (Carpenter)									X													
Nassarius californianus (Conrad)																			cf.			
N. cerritensis (Arnold)									cf.													
N. fossatus (Gould)											cf.											
N. insculptus (Carpenter)																						
N. mendicus (Gould)									X													
N. mendicus cooperi (Forbes)									X													
N. moranianus (Martin)																				?		
N. perpinguis (Hinds)					sp.				X	X	X		X				cf.		cf.			
N. tegulus (Reeve)									X													
Neptunea tabulata (Baird)								X	X	X												
N. tabulata colmaenis (Martin)									X													
Neverita recluziana (Deshayes)									X	X							X					sp.
Ocenebra foveolata (Hinds)																						
O. fusconotata (Dall)											X											
O. squamulifera Gabb										X												
Oenopota pyramidalis (Ström)																						
Olivella biplicata (Sowerby)						X			X	X												
O. pedroana (Conrad)									X	X												
Ophiodermella graciosana mercedenis (Martin)									X													
Polinices draconis Dall											X											
P. lewisii (Gould)									X	X	X											
Psuedomelatoma pencillata (Carpenter)									cf.													
Retusa harpa (Dall)									X													
Terebra albocincta pedroana Dall									X													
T. elata Hinds																						
Trochita trochiformis (Born)										X												
Turbonilla (3 sp.)									sp.													
Turitella Cooperi Carpenter												X		X			X					
T. jewetti Carpenter																						
Volvulella cylindrica Carpenter									X													
Scaphopods:																						
Dentalium neohexagonum Sharp and Pilsbry.									X	X												
D. pretiosum Nuttall and Sowerby									X	X												

Hills Formations, La Habra and Whittier quadrangles

identication of species doubtful; sp., species unidentified; ?sp., identification of genus doubtful; generic name in quotation marks indicates its use in a broad or perhaps table 7 for collectors, identifiers, and location description]

Upper member of Fernando Formation—Continued																													La Habra Formation
F-21	F-22	F-23	F-24	F-25	F-26	F-28	F-29	F-30	F-30A	F-31	F-32	F-33	F-34	F-35	F-36	F-37	F-38	F-39	F-40	F-41	F-42	F-43	F-44	F-45	F-46	F-47	F-48	F-49	F-50
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					sp.		sp.						sp.											sp.					
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sp.	×					×													×										
																											cf.		

TABLE 3.—*Mollusks from the Fernando, San Pedro, and Coyote*

[× indicates that species is present as named; cf., a similar form but material inadequate for identification; aff., a close affinity but details recognizably different; ?, incorrect sense. See pl. 4 for location of collections and table 7

Species	Coyote Hills Formation	San Pedro Formation															Upper member of Fernando Formation					
	F-2	F-3	F-4	F-5	F-6	F-7	F-7A	F-8	F-9	F-10	F-11	F-12	F-13	F-14	F-15	F-16	F-17	F-18	F-19	F-19A	F-19B	F-20
Pelecypods:																						
Acila castrensis (Hinds)												×										
Aequipecten circularis (Sowerby)				×																		
Anadara camuloensis (Osmont)																	cf.					
A. multicostata (Sowerby)																						
A. trilineata (Conrad)																	?					
Cardium					×																	
Chione californiensis (Broderip)									×													
Chlamys beringianus (Middendorff)									×													
C. hastata (Sowerby)								×										×		cf.		
C. hindsii (Carpenter)								×														
C. islandica (Müller)													×									
C. islandica jordani (Arnold)																						
C. rubida (Hinds)																						
Conchocele disjuncta Gabb																			×			
Crassatella																						
Crenella Columbiana Dall								cf.														
Cryptomya californica Conrad	sp.								×													
Cyathodonta undulata Conrad										×	×	×								?sp.		
Cyclocardia occidentalis (Conrad)								aff.					aff.									
C. ventricosa (Gould)																						×
Donax gouldii Dall									×													
Epilucina californica (Conrad)										×												
Florimetis biangulata (Carpenter)									×													
Gariedentula (Gabb)									×		×											
Glycimeris subobsoleta (Carpenter)									×				×									
Hinnites giganteus (Gray)																				×		
Humilaria perlaminosa (Conrad)													×	×								
Katherinella subdiaphana (Carpenter)								×			×		×				×					
Leptopecten latiaurita (Conrad)									×													
L. latiaurita delosi (Arnold)									×													
Lucina																						
Lucinoma acutilineata (Conrad)																						
L. annulata (Reeve)						×				×	×						×					
Lyropecten ceitosensis (Gabb)																						
Macoma calcarea (Gmelin)										cf.												
M. inconspicua (Broderip and Sowerby)	sp.																					
M. indentata Carpenter									×	×												
M. secta (Conrad)									×	×	×											
Megapitaria squalida (Sowerby)																	×					
Miltha xanthusi (Dall)																	cf.					
Miodontiscus prolongatus (Carpenter)										×												
Mytilus californianus Conrad						cf.				cf.												
M. edulis Linné						×						×										
Nemocardium centifilosum (Carpenter)																						
Nuculana taphria (Dall)										×							?					
Ostrea lurida Carpenter									×													
O. vespertina Conrad																		×		×		
O. vespertina sequeris Arnold																						
Pandora filosa (Carpenter)						×																
P. grandis Dall								×					×									
P. punctata Conrad									×													
Punope abrupt (Conrad)						×			×	×		×			×	cf.	×					
Parvilucina tenuisculpta (Carpenter)									×													
Patinopecten caurnus (Gould)							×	×					×									
P. dilleri (Dall)																						
P. healyi Arnold																		?sp.				
Pecten auburyi Arnold																	×					
P. bellus (Conard)								×		×	×	×						×				
P. hemphilli Dall			×		×																	cf.
P. stearnsii			×																	×		
Pecten																						
Periplama planiscula Sowerby									×													
Pododesmus macroschisma (Deshayes)												×	×							sp.		
Protothaca tenerrima (Carpenter)									×													
Psephidia lordi (Baird)										×												
Saxidomus nuttalli (Conrad)								×				×										
Semele incongrua Carpenter										×												
S. pulchra (Sowerby)										×												
Siliqua lucida (Conrad)											×											
Spisula catilliformis Conrad									×													
S. hemphilli (Dall)									×													
Solen sicarius Gould					sp.	×						×							sp.	sp.		
Tagelus californianus (Conrad)									cf.													
Tellina bodegensis Hinds											×											
Thracia trapezoides Conrad						×				×												
Tivela stultorum (Mawe)									×													
Trachycardium quadragenarium (Conrad)						×			×	×					×		sp.					
Transenella tantilla (Gould)										×												
Tresus nuttallii (Conrad)									×													
Volsella recta flobellata (Gould)									×													
Echinoids:																						
Dendraster diegoensis venturaensis Kew												cf.			cf.							
D. excentricus Eschscholfz			×						×	×												
Cerripods:																						
Balanus concavus Bronn									×													
Proboscideans:																						
Elephas imperator																						

Hills Formations, La Habra and Whittier quadrangles—Continued

identification of species doubtful; sp., species unidentified; ?sp., identification of genus doubtful; generic name in quotation marks indicates its use in a broad or perhaps
for collectors, identifiers, and location description]

Upper member of Fernando Formation—Continued																													La Habra Formation
F-21	F-22	F-23	F-24	F-25	F-26	F-28	F-29	F-30	F-30A	F-31	F-32	F-33	F-34	F-35	F-36	F-37	F-38	F-39	F-40	F-41	F-42	F-43	F-44	F-45	F-46	F-47	F-48	F-49	F-50
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of olive-gray siltstone and abundant rust-colored clayey matrix. It occurs in sequences as much as 95 feet thick. The pebbly sandstone is pale yellow brown to dark red brown, thick bedded to massive, and very poorly sorted and friable. It is about 50 percent well-rounded pebbles and cobbles of light-colored crystalline rocks that average 1–2 inches in length in a matrix of very poorly sorted coarse-grained rust-colored biotite sand. The conglomerate is pale yellow brown and consists of as much as 80 percent well-rounded clasts of light-colored crystalline rocks as long as 18 inches, but averaging about 2 inches. The matrix is very poorly sorted coarse friable biotite sand with rust-colored clayey cement. A 30-foot-thick bed of breccia near the top of this sequence contains abundant angular slabs and blocks of intraformational sandstone as long as 18 inches and large well-rounded clasts of crystalline rocks.

Sandstone in the middle unit is yellow gray and massive, silty to medium grained, poorly sorted, micaceous, and friable. It contains a few scattered pebbles as much as 2 inches long and, locally, chips and slabs of white siltstone derived from the Puente Formation. Abundant casts and molds of small mollusks occur in thin marly beds, and zones of limy concretions up to 12 inches long are common in the middle unit. The sandstone occurs in sequences as thick as 1,000 feet.

The upper unit is about 53 percent pebbly sandstone and 47 percent sandstone. The sandstone is grayish orange to yellowish gray, thick bedded or massive, cross-bedded locally on a small scale, friable, fine to medium grained, and poorly to moderately sorted. It contains biotite, a few 1–12-inch-thick lenses of well-rounded pebbles up to half an inch long, and numerous casts of small mollusks. The sandstone occurs in sequences up to 335 feet thick. The pebbly sandstone is pale to moderate yellow brown, massive, and contains about 25 percent well-rounded, flattish pebbles of light-colored crystalline rocks as much as 5 inches long, but averaging 1 inch or less, scattered and in thin lenses as much as 14 inches thick. The matrix is coarse-grained very poorly sorted friable feldspathic biotite sandstone having rust-colored clayey cement. The pebbly sandstone is in sequences as much as 235 feet.

Depositional Environment

Foraminfera from the upper member indicate a neritic or shelf environment. The local abundance of Mollusks in the upper member (table 3) also suggests deposition in water less than 600 feet deep (Vedder, 1960); in areas to the southwest, the water probably shoaled from depths of 3,000 or 4,000 to about 900 feet during late Pliocene time.

Age and Correlation

Foraminifera from the upper member, given in table 2, are not diagnostic as to age. The upper member in the Puente Hills area contains mollusks of late Pliocene age as based on the Pacific coast standard megafaunal sequence. These collections are of definite late Pliocene age at both northwest and southwest Puente Hills localities. (See Vedder, 1960, p. B327; Woodford and others, 1954, p. 73.) On this basis the member may be correlated with the unnamed sandstone of the Newport Bay area and the Niguel Formation of the San Joaquin Hills (see Vedder and others, 1957), with strata commonly called Pico in other marginal areas of the central basin (Soper and Grant, 1932, p. 1050–1067; Natland and Rothwell, 1954, p. 38; Yerkes and others, 1965, pl. 1), with the upper (marine) part of the Pico Formation in its type area in the Ventura basin, and with the San Diego Formation of the San Diego area. (See Durham, 1954, fig. 2.)

PLEISTOCENE SERIES

The Los Angeles depositional basin was still very large at the end of Pliocene time, but many marginal areas such as the Puente Hills were exposed. (See Yerkes and others, 1965, p. A19.) During the early Pleistocene, rapid deposition exceeded subsidence in depressed parts of the basin area, and the shoreline gradually retreated southwestward from the San Gabriel Valley. At the end of early Pleistocene time, the shoreline was approximately coincident with the southwest margin of the Puente Hills (Yerkes and others, 1965, p. 19 and fig. 14).

The lower Pleistocene section consists of marine silt, sand, and gravel; it is exposed only in the Newport Bay area and such structurally elevated marginal areas of the central basin as the uplifts along the Newport-Inglewood zone, Palos Verdes Hills, and Coyote Hills. The sequence is as much as 600 feet thick in the Palos Verdes Hills, 325 feet in exposures along the Newport-Inglewood zone, and about 100 feet at Newport Bay. Subsurface thicknesses probably exceed 2,000 feet in the central part of the basin.

Mollusks are common and locally abundant. The exceptionally abundant fauna in the Palos Verdes Hills sequence has been assigned an early Pleistocene age on the basis of its modern aspect relative to the Coast Ranges Pliocene; it also contains more apparently extinct forms than the unconformably overlying strata assigned to the late Pleistocene. (See Woodring and others, 1946, p. 96–98.) The name San Pedro Formation has been adopted for the sequence outside the Palos Verdes Hills area (Yerkes and others, 1965, pl. 1) following the practice and definition of Poland, Piper, and others (1956, p. 60–68).

SAN PEDRO FORMATION

The San Pedro Formation is exposed only locally, south of the Whittier fault zone in a thin band just north of La Habra and in the central parts of the East and West Coyote oil fields south of La Habra. The thickest section of the San Pedro is exposed in the West Coyote oil field, but the base is exposed only at the outcrops north of La Habra.

In the exposures north of La Habra, the San Pedro consists of 90 percent sand and 10 percent pebbly sand. The sand is light yellow gray to grayish white and consists of grains of quartz, feldspar, and biotite. The upper part is massive and nearly uncemented and contains scattered well-rounded pebbles up to 2 inches long and, in the top 20 feet, rare mollusks. Sand in the lower 135 feet is of the same composition, but it is darker in color, finer grained, better sorted, and better cemented and contains thin beds of dark biotitic mudstone. The underlying basal conglomerate is light gray, massive, hard, resistant, and well cemented. It consists of about 40 percent subangular to well-rounded pebbles of light-colored crystalline rocks as much as 6 inches long and averaging one-half inch long and, in addition, abundant chips and slabs of Puente siltstone. The matrix is very coarse grained arkosic sand.

The formation in the West Coyote oil field consists of an upper light-colored sand about 170 feet thick and a lower dark-colored silty sandstone about 155 feet thick. The upper sand is light gray white to pale yellow brown and consists of angular grains of quartz, feldspar, and biotite. It is massive, friable to loose, very coarse grained to pebbly, very poorly sorted, and has a rust-colored clayey matrix and locally abundant mollusks. The upper 20 feet is somewhat better sorted and more friable than the lower part. Local sandy conglomerate beds up to 15 feet thick contain abundant well-rounded flat ellipsoidal pebbles of light-colored crystalline rock as much as 2 inches long, oriented parallel to bedding. The lower sandstone is dark yellow gray to olive gray, silty and fine grained, massive, locally well graded or cross laminated, and contains loadcasts and deformed siltstone clasts. It is fairly well sorted and quite dense. The upper one-third is less silty and more friable. The unit contains abundant finely comminuated biotite and scattered mollusks. The base is not exposed; however, the unit is reported on the basis of well data to be conformable with underlying Pliocene strata, and no lithologic break between the two has been recognized (W. H. Holman, written commun., July 16, 1959).

The part of the formation exposed in the East Coyote field is only about 45 feet thick and consists of light-yellow-gray massive medium- to coarse-grained pebbly sandstone that contains a single bed of well-preserved mollusks. The base is not exposed.

The maximum exposed thickness of the San Pedro Formation is 325 feet at West Coyote. On the basis of well data, the total thickness in this area is 1,500 feet. The maximum known thickness is about 1,750 feet in the subsurface of the southwest part of the Whittier quadrangle (section *C–C′*, pl. 2). Greater thicknesses are probable in the central part of the basin to the southwest.

The San Pedro appears to be conformable with the underlying upper member of the Fernando in the area north of La Habra. The upper contact is an angular unconformity at the base of the overlying nonmarine La Habra Formation.

The molluscan fauna from the San Pedro at the Palos Verdes Hills has been grouped into several depth-facies associations that in general indicate shoaling of the water from moderate to shallow during early Pleistocene time. (See Woodring and others, 1946, p. 89–92.) The molluscan fauna from the San Pedro at West Coyote (table 3) is inferred to have lived in the 120–240-foot-depth range in water somewhat cooler than that now present at this latitude (Hoskins, 1954). Valentine (1961, p. 414–415) considered the San Pedro fauna from West Coyote to be older than that from the upper part of the formation in the Palos Verdes Hills section and probably older than that from the lower part of the formation; he also considered the West Coyote fauna to resemble those faunas from the lower Pleistocene part of the Pico and Saugus Formations in the Ventura basin.

In inland parts of the Los Angeles basin such as the Puente Hills area, where marine deposition ceased before late Pleistocene time, upper Pleistocene and Holocene deposits are not easily separated except qualitatively on the basis of degree of consolidation, weathering, and deformation.

During late Pleistocene and Holocene time, floods of coarse clastic material from rising highland areas to the north and east were deposited in the central part of the basin, resulting in continuing retreat of the shoreline even farther southward and westward. Interfingering lagoonal and marine and nonmarine deposits that attain a thickness of about 2,500 feet probably are conformable on marine lower Pleistocene strata and are overlain by as much as 200 feet of Holocene alluvium.

By the beginning of late Pleistocene time, the sea had virtually withdrawn from the area mapped, and a sequence of brackish- or fresh-water marl, mudstone, and pebbly sandstone (the Coyote Hills Formation) was deposited over the southern half of the area. These and underlying strata were then unconformably overlapped in latest Pleistocene time by an extensive and locally thick flood-plain deposit, the La Habra Formation. Locally thick upper Pleistocene stream-terrace and alluvial-fan deposits accumulated; they subsequently were dissected, deeply weathered, and locally faulted along the Whittier fault zone.

COYOTE HILLS FORMATION (NEW NAME)

The Coyote Hills Formation is here named for a sequence of nonmarine mudstone and pebbly sandstone exposed in the Coyote Hills in the southwestern part of the La Habra quadrangle. The formation appears to extend northward in the subsurface to the central part of the quadrangle, eastward into the southwestern Yorba Linda quadrangle (where it was termed "unnamed strata of Pleistocene age" by Durham and Yerkes (1964, p. 28)), and westward in the subsurface an undetermined distance into the south part of the Whittier quadrangle. It extends southward in the subsurface and thickens toward the central part of the Los Angeles basin. The type locality of the formation is the south flank of the East Coyote oil field structure, SW¼ sec. 23, T. 3 S., R. 10 W., in the southeast quarter of the La Habra quadrangle.

At its type locality, the Coyote Hills Formation is 715 feet thick and consists of an upper part, about 495 feet thick, that is 60 percent mudstone and 40 percent sandstone and pebbly sandstone and a lower part, 220 feet thick, of pebbly sandstone(fig. 8). The formation rests unconformably and discordantly on the San Pedro Formation. The contact is sharp and irregular, and the angular discordance between the two formations is about 5°. The upper contact is a prominent regional unconformity at the base of the upper Pleistocene La Habra Formation. A maximum thickness of 1,210 feet

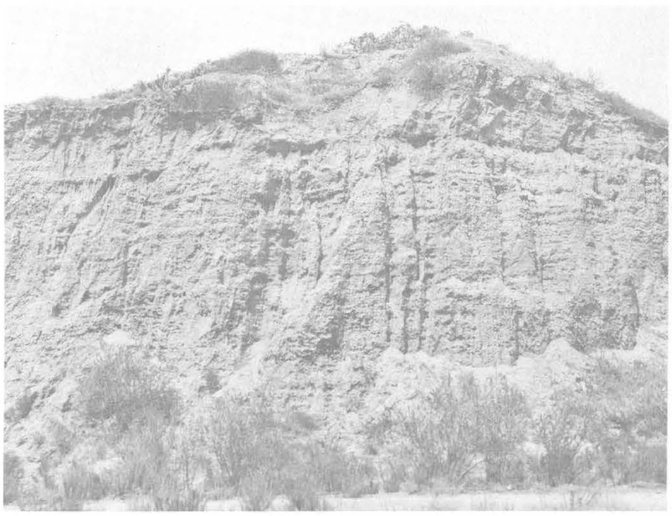

FIGURE 8.—Basal thick-bedded pebbly sandstone of the Coyote Hills Formation, West Coyote oil field. This unit rests with slight unconformity on silty sandstone of the San Pedro Formation. Exposure about 25 feet high.

is present at the west end of the East Coyote field (section *G–G′*, pl. 2).

Pebbly sandstone that makes up the lower part is moderate yellow brown, massive, and grades into sandy pebble conglomerate. It is locally interbedded with numerous well-defined beds or lenses 1 inch thick of coarse-grained fairly well sorted friable biotitic arkose. Pebbles in the conglomerate consist of well-rounded light-colored crystalline rocks as much as 4 inches long, but mostly less than 2 inches, in a matrix of coarse-grained earthy iron-stained arkosic sand.

Mudstone of the upper part of the Coyote Hills Formation is pale olive gray to brownish gray, massive, earthy, and occurs with thin sand partings in sets as thick as 100 feet. It contains abundant coarse grains of quartz, zones of calcium carbonate, and sparse brackish- or fresh-water mollusks, ostracodes, and plant remains. Sandstone in the upper part is light yellow gray to pinkish gray, in beds from 6 inches to 30 feet thick, and medium to coarse grained or pebbly. One 60-foot-thick sequence near the center has lenses of well-rounded pebbles of red volcanic and light-colored crystalline rocks as much as 2 inches long.

At the West Coyote oil field (see pl. 4) the formation is about 285 feet thick. The upper two-thirds is pebbly sandstone similar to the basal part of the formation at East Coyote. The lower third in the West Coyote area consists chiefly of mudstone interbedded with sandstone and pebble conglomerate and thin beds of chalky marl that locally contain abundant molds and casts of the pelecypods *Macoma balthica* and *Cryptomya californica*, as well as *Planorbis*(?), ostracodes, and plant fragments.

The presence of the brackish- or fresh-water fauna in mudstone suggests deposition of organic silt and sandy mud in an intertidal environment. The succeeding beds near the top are nonmarine fluvial sand and gravel. The Coyote Hills Formation is interpreted to record the last marine regression from this part of the basin. Present-day counterparts of the environment of the Coyote Hills Formation are the tidal marches along the present coastline, which in historic time extended as much as 4 miles inland and received alternating thin layers of marine sand, organic muck, and fluvial deposits.

Eckis (1934, p. 49) and Dudley (1943, p. 350–351) assigned an early Pleistocene age to a thick sequence of strata that includes the present Coyote Hills Formation as well as the overlying La Habra Formation. Wissler (1943, p. 212) noted that the La Habra unconformably overlaps fossiliferous marine strata of early Pleistocene, as well as Pliocene age, and assigned it a late Pleistocene age; this assignment has been substantiated by detailed mapping. (See Durham and Yerkes, 1964, p. 29.) The

Coyote Hills Formation is provisionally assigned an early late Pleistocene age because it is unconformable on the marine lower Pleistocene San Pedro Formation and is unconformably overlain by the nonmarine upper Pleistocene La Habra Formation. The Coyote Hills is probably equivalent to the unnamed upper Pleistocene nonmarine deposits of Poland, Piper, and others (1956, p. 55–60) but may range in age from early to late Pleistocene.

LA HABRA FORMATION

The La Habra Formation of late Pleistocene age underlies the south half of the map area and is well exposed along the south margin of the Puente Hills and in the Coyote Hills. It thickens southward into the central-plain part of the basin. The name, which was coined in an unpublished report by H. M. Bergen of Fullerton, Calif., was first published by Eckis (1934, p. 38, 49, pl. B) for water-bearing strata in his Pliocene and lower Pleistocene Fernando Group, although the unit was not differentiated on his geologic map. Wissler (1943, p. 212) recognized that the La Habra overlapped marine Pliocene and lower Pleistocene strata and so assigned it a late Pleistocene age. Durham and Yerkes (1959) provided a formal definition and age assignment and also recognized that the unit is intensely deformed in the area just south of the Whittier fault zone.

A detailed section of the La Habra Formation in its type area in the west-central Yorba Linda quadrangle consists of about 211 feet of reddish-brown to gray earthy sand, pebbly sandstone, mudstone, and a basal conglomerate crowded with debris derived from the Puente Formation (Durham and Yerkes, 1964, p. 28–29). The maximum exposed thickness is north of La Habra, where it is about 1,000 feet thick and consists of mudstone, fluvial sandstone, and conglomerate. It has about the same thickness in the subsurface south of the Coyote Hills (sections *F–F′*, *G–G′*, *H–H′*, pl. 2).

Mudstone forms the upper two-thirds of the unit. It is nonresistant, friable, poorly exposed, and is mantled with a thick black clayey soil. The mudstone is olive gray to moderate red-brown, sandy to pebbly, and commonly shot through with streaks and pipes of calcium carbonate. Local marly streaks in the mudstone contain fresh-water snails, ostracodes, and plant fragments. Sandstone in the La Habra Formation is pale yellow gray to moderate red brown, massive or very crudely stratified, unsorted, very coarse grained to pebbly, poorly cemented, and has an earthy, clayey matrix. Locally it contains small pebbles of crystalline rocks in thin lenses. The basal pebbly sandstone-conglomerate is about 40 feet thick, pale yellow gray to pale yellow brown, massive or very crudely stratified, and unsorted. It contains angular to subrounded clasts of crystalline rocks as much as 5 inches long, but averaging 1 inch, and abundant chips and slabs of platy white siltstone derived from the Puente Formation. The basal part fills irregular channels cut into underlying strata, and the formation rests on underlying rocks with an angular discordance of about 15°.

The La Habra Formation unconformably overlies marine strata of late Pliocene and early Pleistocene age, as well as the late Pleistocene Coyote Hills Formation (fig. 9). Tusk fragments of *Elephas imperator*(?) were found at the base of the La Habra in a trench along Imperial Highway just west of the West Coyote oil field (1,100 ft east of the SW. cor. sec. 7, T. 3 S., R. 10 W.). The La Habra probably represents a flood-plain deposit and is correlative, at least in part, with the San Dimas Formation of Eckis (1934, p. 57) and with marine and nonmarine terrace deposits of late Pleistocene age in the Palos Verde Hills. (See Yerkes and others, 1965, pl. 1, col. 8.)

PLEISTOCENE AND HOLOCENE(?) SERIES

During late Pleistocene time, alluvial fan and terrace deposits accumulated in the Puente Hills area and between the Puente Hills and the central part of the Los Angeles basin. These deposits date at least from the last pre-Holocene high-sea stand, as they were dissected during a later Pleistocene low-sea stand. Later (Holocene) rise of sea level has caused aggradation of the central part of the basin, consequent burial of the late Pleistocene alluvial deposits there (Poland and others, 1956, p. 16), and deposition of young alluvium in stream courses and on the flood-plain of the San Gabriel River.

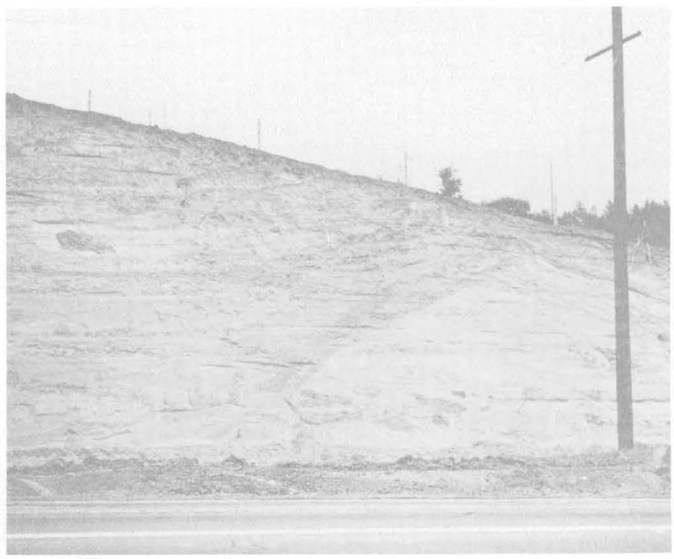

FIGURE 9.—View eastward of gently north-dipping reddish-brown silty sandstone of the La Habra Formation (at left) resting unconformably on south-dipping sandstone of the Coyote Hills Formation, west end of East Coyote oil field.

OLD ALLUVIUM

The La Habra Valley area between Santa Fe Springs and Yorba Linda (see fig. 11) is underlain by older alluvial fans and several levels of stream-terrace deposits. These rocks consist of semiconsolidated poorly sorted earthy and clayey gravel, sand, and silt (fig. 10). The deposits are extensively dissected; in parts of the area, such as north of East Coyote, dissection has nearly destroyed the original physiographic surface. The deposits commonly have a thick soil developed on them and characteristically weather reddish brown.

Exposed thickness of the old alluvium is as much as 30 feet where modern streams or excavations have trenched the deposits.

The old alluvium is considered to be as old as late Pleistocene for several reasons: A thick soil has been developed on it; it is everywhere extensively dissected; it is locally faulted; and it is buried by alluvium of the present cycle in stream courses and in the central part of the basin to the south.

HOLOCENE SERIES

Holocene (Recent) deposits include all those accumulated during the present cycle of alluviation; in the mapped area they consist of young alluvium in stream courses and on the flood plain of the San Gabriel River. In the southwest corner of the area, young alluvium forms the surface of the central basin.

YOUNG ALLUVIUM

The young alluvium consists of unweathered, unconsolidated, poorly sorted, but locally crudely stratified, gravel, sand, and silt. In the area south of the Coyote Hills, the deposits consist chiefly of silt and fine sand and are as much as 100 feet thick (Poland and others, 1956, p. 43). A buried tongue of fresh-water-bearing gravel (the Gaspur zone) trends southwestward along the course of the San Gabriel River through the westernmost part of the map area (fig. 11; Poland and others, 1956, pl. 7). Gravel in the Gaspur is as much as 4 inches in diameter. The deposit is 2–4 miles wide and 30–60

FIGURE 10.—Old alluvium along north margin of the La Habra Valley, in Brea Canyon area of the Brea-Olinda oil field. Upper third of exposure is reddish-brown clayey soil; light-colored central part consists of white (Puente) siltstone detritus in friable calcareous clayey sand; lower part consists of light-gray-brown silt and pebbly sand.

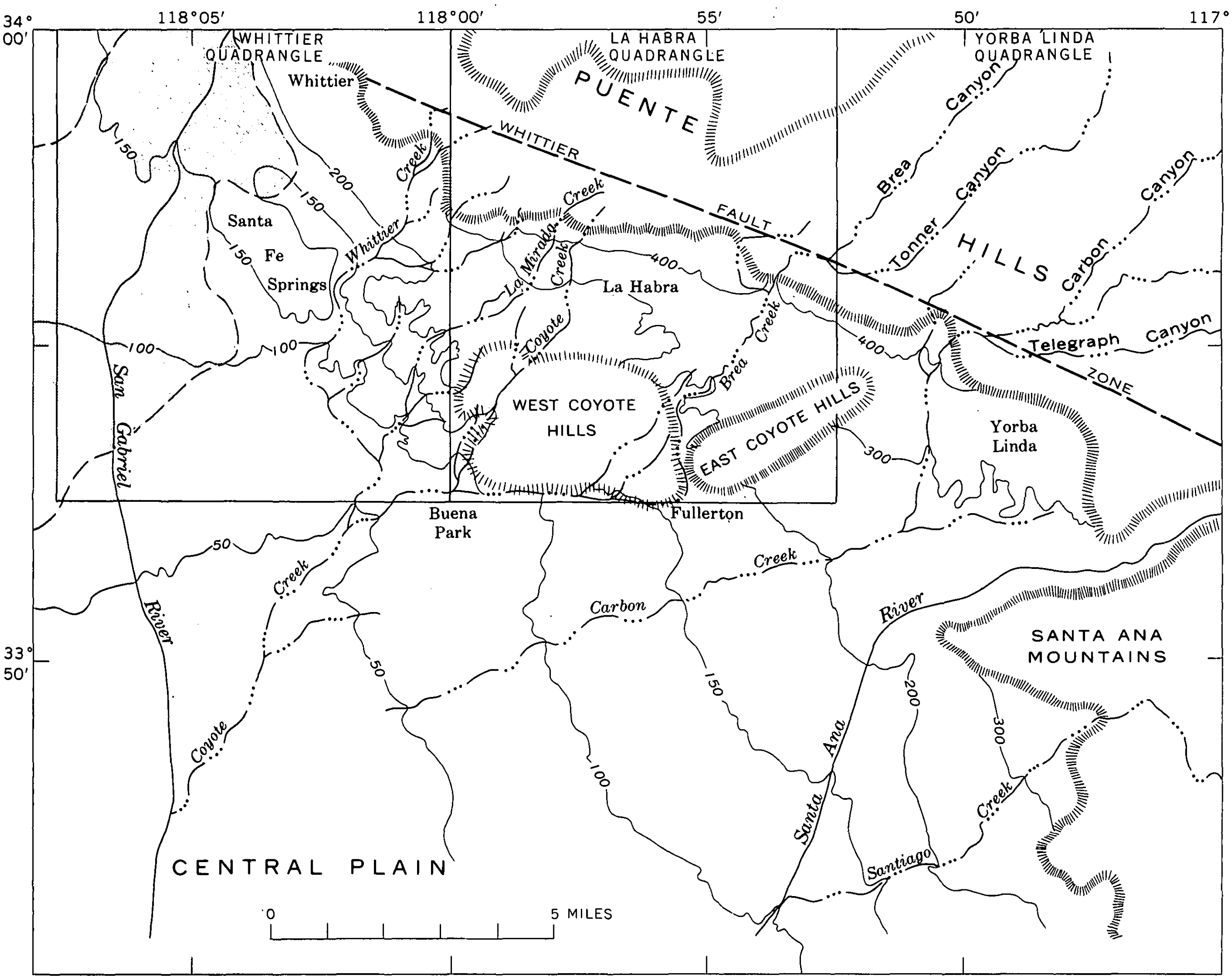

FIGURE 11.—Southwestern Puente Hills area showing drainage pattern, area underlain by Gaspur gravel (shaded) as mapped by California Department of Water Resources (1961, pl. 10A), and selected topographic contours to illustrate configuration of the alluvial fans of the San Gabriel and Santa Ana Rivers. Base from U.S. Army Corps of Engineers 15-minute (1:62,500) Anaheim and Downey topographic quadrangles, editions of 1942–1943.

feet thick. Its base is now about 50 feet above sea level in the map area, but it is well below sea level south of the map area. Poland, Piper, and others (1956, p. 45) concluded that the coarseness and textural uniformity of the Gaspur required a streamflow greater than that of the present San Gabriel River to transport the relatively coarse detritus. The width of the deposit suggests that the depositing stream migrated laterally.

LANDSLIDES AND LANDSLIDE DEPOSITS

Slope failures are fairly common in the siltstone units that crop out in the Puente Hills and are especially numerous on slopes underlain by the Yorba and Sycamore Canyon Members of the Puente Formation. Most of the mapped landslides are combinations of rotational slump in the upslope part and debris flow in the lower part. Some of the smaller slides, including many too small to map, involve chiefly colluvium or soil. The boundaries of most mapped slides coincide with faults, bedding surfaces, or joints. Very few of them can be separated into parts of different ages, but some may have a history of alternating quiescence and activity. The scarps of all the landslides were quite degraded when viewed in 1960, and the deposit boundaries as mapped may include some areas of scarp. Although the scarps are degraded, the deposits are commonly undissected or only slightly dissected, indicating their youth relative to adjoining slopes.

STRUCTURE

The Puente and San Jose Hills form the structurally elevated east half of the northeastern structural block of the Los Angeles basin (Yerkes and others, 1965, figs. 2, 3). The block is wedge-shaped in plan, is underlain at relatively shallow depths by granitic-metamorphic basement rocks, and is intermediate in structural elevation between the central plain of the basin to the south and the San Gabriel Mountains to the north. The Puente-San Jose Hills area is bounded on the south by the Whittier fault zone, on the west by the structural depression of the San Gabriel Valley, on the north by the San Gabriel Mountains, and on the east by the Chino fault and Chino basin. (See Yerkes and others, 1965, fig. 3.) South of the Whittier fault zone, the Coyote Hills–Santa Fe Springs trend of structural highs and the adjoining Anaheim nose (Yerkes and others, 1965, fig. 3) separates the synclinal La Habra Valley on the north from the deep syncline of the central basin on the south.

The Whittier fault zone trends west-northwestward across the northeastern part of the map area (figs. 11, 12). Immediately north of the fault zone, two elongate basement "half domes" underlie the structural highs of the Puente Hills at depths of about 3,000 feet subsea: one near the east boundary of the map area (the Puente Hills oil field area) and one near the La Habra–Whittier quadrangle boundary (Whittier oil field area). The basement surface slopes west, north, and east from these highs to depths of 6,000–8,000 feet subsea along the map area boundaries (fig. 2). The basement surface is downthrown between 10,000 and 12,000 feet along the Whittier fault zone; south of the fault zone, the basement surface beneath the La Habra Valley plunges northwestward from about 18,000 feet subsea at the east, closed end of the syncline, to about 22,000 feet near the San Gabriel River. The Coyote Hills–Santa Fe Springs trend consists of several separate anticlinal structures in the Pliocene section; in general, the basement surface crests at about 16,000 feet subsea along an east-west anticlinal trend beneath the Coyote Hills and plunges northwestward to about 20,000 feet beneath the San Fe Springs oil field. From the Coyote Hills the basement surface slopes southwestward toward the central part of the Los Angeles basin syncline and is about 30,000 feet subsea beneath the southwest corner of the map area. Southward from the Coyote Hills the slope of the basement surface is interrupted by the west end of another northwest-trending anticlinal feature, the Anaheim nose, which merges with the north flank of the central cyncline of the basin in a shelflike area near the south center of the map area (Yerkes and others, 1965, fig. 2).

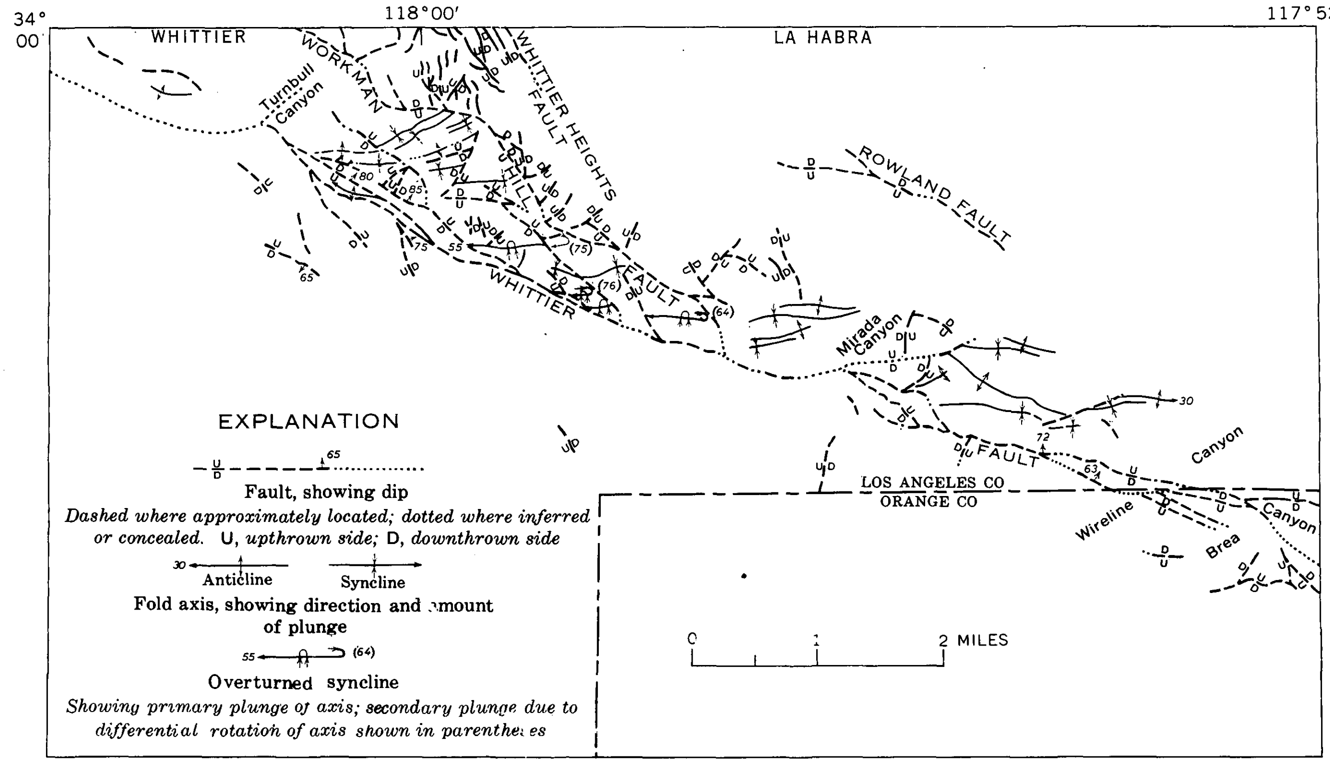

FIGURE 12.—Map of structural features of the northern part of the mapped area showing faults and distribution and attitude of folds in the upthrown block of the Whittier fault zone.

WHITTIER FAULT ZONE

The Whittier fault zone is one of the most prominent structural features of the Los Angeles basin. It has a vertical separation of 6,000–12,000 feet at the basement surface, which compares with such mountain-front boundaries as the Santa Monica and Cucamonga faults (Yerkes and others, 1965, figs. 2, 3).

The trace of the Whittier fault zone extends at least from the Santa Ana River at the southeast margin of the Puente Hills (Yerkes and others, 1965, fig. 5) to Turnbull Canyon near Whittier at the northwest, a distance of 20 miles. Southeast of the Santa Ana River, it merges with the Elsinore fault. In the subsurface northwest of Whittier, it has not been traced with any degree of confidence beyond the San Gabriel River, although it may form the very steep south flank of the buried Elysian Hills anticline west of San Gabriel Valley (Yerkes and others, 1965, figs. 2, 3). The fault zone juxtaposes Miocene and Pliocene strata subparallel to their strike along most of its length. The vertical stratigraphic separation of upper Miocene strata across the zone increases northwestward from about 2,000 feet near the Santa Ana River to a maximum of about 14,000 feet in the Brea-Olinda oil field area. Farther to the northwest, it decreases to about 3,000 feet in the Whittier Narrows of the San Gabriel River.

In the map area the zone trends N. 65°–70° W. and dips 65°–75° NE. The trace consists of three main subparallel en echelon segments, 2–4 miles long, that, in general, are stepped to the left from segment to segment (see fig. 12) in a manner characteristic of right-lateral strike-slip faults. At the intersection of each pair of such segments, a relatively large drainage area crosses the zone: Turnbull Canyon north of Whitter, La Mirada Creek near the center of the map, and Brea Canyon at the east edge. Each of the segments contains several faults and slices. The "Whittier" fault is taken as the Miocene-Pliocene contact in each segment; in the map area this is commonly the southernmost through-going trace.

Several southwest-trending drainage courses are deflected 4,000–5,000 feet in a right-lateral sense where they intersect the zone in the east part of the map area (fig. 13); drainage courses to the northwest and the southeast of this area are not so prominently deflected.

The deflected stream courses may be attributable at least in part to differential erosion as suggested by English (1926, p. 65), especially as similar-size courses elsewhere along the zone are not prominently deflected. However, right-lateral movement is the most obvious means of forming the band of right-handed en echelon folds. (See Badgley, 1965, p. 59, 81.) Furthermore, mapped beds in one large overturned fold (fig. 14) are truncated by the fault in a manner seeming to require right-lateral slip. Right slip of 4,000–5,000 feet, the amount of stream deflection, may be combined with maximum apparent vertical separation of 14,000 feet to obtain a cumulative right-oblique net slip of about 15,000 feet. Woodford, Schoellhamer, Vedder, and Yerkes (1954, p. 75) postulated right slip of 15,000 feet on the fault, on the basis of a possible correlation of offset cross faults near the Santa Ana River (the Horseshoe Bend and Scully Hill faults; see Durham and Yerkes, 1964, pl. 1). A unique solution for movement on the Whittier fault zone is probably not obtainable; however, right-oblique net slip of about 15,000 feet and variable rake of slip from about 60° in the central part of the trace to about 10° at the distal ends appears to satisfy the stratigraphic relations along the fault zone in the Puente Hills.

The upthrown block of the Whittier fault zone has been thrust relatively southward to cause at least 2,000 feet of crustal shortening normal to the trend of the zone. In upper Miocene strata of the downthrown block this overthrusting conceals an anticline, in which oil accumulates in some of the fields.

The Whittier fault zone existed as a deep-seated zone of weakness when the diabase bodies were intruded along it, probably late in Miocene time; activity along the zone clearly dates back to early Pliocene time, when it formed a scarp from which Puente detritus was shed into the lower Fernando sea, a process that also contributed much detritus to the basal parts of the upper member of the Fernando, San Pedro, Coyote Hills, and La Habra Formations. However, much of the movement is late Pleistocene or younger, as indicated by tilted, locally overturned, and faulted La Habra beds and faulted old alluvium in the Brea-Olinda oil field area. Young alluvial deposits are not known to be disturbed by faulting along the zone.

WORKMAN HILL FAULT

The most prominent secondary fault in the map area is the Workman Hill fault, which diverges northwestward from the Whittier fault just northwest of La Habra (fig. 12). At the surface this fault forms the north boundary of an uplifted wedge of folded strata that underlies the Whittier oil field area; in the subsurface it forms the northeast flank of a basement high that underlies the Whittier-La Habra oil field area. The Workman Hill fault dips about 50° NE. in the map area. Maximum stratigraphic separation parallel to the dip of the fault is about 7,000 feet (structure section *C–C′*, pl. 2) and about 6,500 feet where the fault intersects the north edge of the map. The fault cannot be traced on the surface as far as the north margin of the hills, which is

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FIGURE 13.—View eastward of Whittier fault zone and Brea Canyon area of Brea-Olinda oil field. The Brea Canyon area extends from lower left (behind viewer) along Whittier fault zone to Brea Canyon at right center. Brea Canyon extends from upper left to right center and is deflected to the right along the fault zone. Puente Hills at left constitute the upthrown block of the Whittier fault zone and are underlain by the Puente Formation; foothills at right are underlain by the upper member of the Fernando Formation and younger strata. Santa Ana Mountains at upper right are beyond the Santa Ana River.

about a mile north of the map area, but may be present in the subsurface beneath the valley just beyond the hills to the north, where vertical stratigraphic separation apparently has decreased to about 500 feet. (See Daviess and Woodford, 1949, structure section *W′–X*.) Stratigraphic separation is also very small where the fault merges with the Whittier fault (section *D–D′*, pl. 2).

The apparent vertical stratigraphic separation across the Whittier zone at the La Habra-Whittier quadrangle boundary is about 5,000 feet, upthrown on the north. Vertical stratigraphic separation across the Workman Hill fault in the same area is about the same amount, but is downthrown on the north (section *C–C′*, pl. 2). The Workman Hill fault also truncates the en echelon folds, and its movement therefore postdates the folding, which resulted from movement on the Whittier fault. The Workman Hill fault probably predates the latest movement of the Whittier.

WHITTIER HEIGHTS FAULT

Only the southernmost part of the Whittier Heights fault, in the northwest corner of the LaHabra quadrange, is within the map area (fig. 12). The fault trends subparallel to the Workman Hill fault and in the Turnbull oil field area is a steeply northeast-dipping normal fault having about 500 feet of stratigraphic separation. The fault dies out near the north margin of the hills, about 2 miles north of the map area (Daviess and Woodford, 1949). An associated fault, the Handorf fault, which diverges northward from the Whittier Heights fault about one-fourth mile north of the map area, is marked by an eroded scarp about 450 feet high, but does not cut old stream-terrace deposits. (See Daviess and Woodford, 1949.)

ROWLAND FAULT

The Rowland fault, in the north-central La Habra quadrangle, is a steeply dipping fault that trends subparallel to the Whittier zone. Maximum vertical stratigraphic separation is about 500 feet. A westerly trending fault that intersects the Rowland has similar, but compensating, displacement (section *D–D′*, pl. 2). Both faults die out at the margins of the hills and are not known to cut alluvial deposits.

NORWALK FAULT

The "Whittier" earthquake of 1929 (magnitude 4.7) was attributed by Richter (1958, p. 43) to the Norwalk fault, shown to extend westward across the south part of the La Habra and Whittier quadrangles (Richter, 1958, p. 39). The epicenter was first located, on the basis of apparent intensity and aftershocks (Wood and Richter, 1931), about 2 miles southeast of the Santa Fe Springs oil field (NW ¼ sec. 16, T. 3 S., R. 11 W.). This location was later shifted about 3½ miles west-southwestward (NE ¼ sec. 23, T. 3 S., R. 12 W.) on the basis of revised travel times (Richter, 1958, p. 39, 43). Richter also emphasized (1958, p. 43) that "There is good reason to suppose that the Norwalk fault is capable of producing an earthquake of the magnitude of the Long Beach earthquake (6¼)."

The linearity of the south margin of the Coyote Hills in the southwest corner of the La Habra quadrangle suggests that it may be an eroded fault scarp. Although this feature coincides with the Norwolk fault of Richter, it may be due instead to erosion by drainage from the Coyote Hills being constricted between the hills and the growing alluvial fan of the Santa Ana River. There is no other surface evidence for a fault of this trend east or west of the "scarp."

It is in just this area south of the West Coyote oil field that subsurface evidence (both water well and oil well) for such a fault is weakest (see structure section *E–E′*, pl. 2). To the west, in the south part of the Whittier quadrangle, subsurface structure indicates the presence of a buried, north-dipping reverse fault that trends generally east-southeastward between the two epicentral locations cited above and perhaps is coincident with the Norwalk fault of Richter; apparent stratigraphic separation on this fault is as great as 2,000 feet (structure sections *B–B′*, *C–C′*, *D–D′*, pl. 2). However, on the basis of presently available evidence, this fault is inferred to bend and merge with a prominent north-northeast-trending cross-fault that cuts the central part of the West Coyote oil field structure, rather than to maintain an east-southeasterly trend such as required to have formed the "scarp" at the south margin of the hills.

Thus, although the epicenters of the "Whittier" earthquake can be associated spatially with a buried fault, the only possible surface expression of faulting in this area (the West Coyote "scarp") that can be associated with the Norwalk fault of Richter cannot be correlated with any recognized subsurface feature.

HISTORIC RUPTURES

About October 1, 1968, surface rupture occurred along a north-trending zone about 1,000 feet long located near the bottom of a small north-trending canyon at the north margin of the West Coyote oil field (near the W¼ cor. sec. 17, T. 3 S., R. 10 W.; pl. 1). The rupture was first observed on October 9 and was mapped on October 18; it was reexamined on November 21, 1968, when no evidence of renewed movement was found. The ruptures did not follow any previously mapped fault, but may represent a northward extension of such a fault. The zone, which was 5–38 feet wide, consisted of a series of an echelon cracks up to 15 feet long; the zone trended northward, whereas individual cracks trended N. 20–25° W. and dipped about 55° E. Dip slip was 1–3 inches, displacement was up on the east, and left-lateral slip of up to 2 inches was locally present. The zone occupied the stream bottom in large part; however, where the zone crossed an east-sloping spur ridge, displacement of the down-slope block was relatively up. Two seismic events that might be related to the faulting were recorded by the Seismological Laboratory, California Institute of Technology (J. M. Nordquist, personal commun., Oct. 1968):

1. September 23, 1968, 1715 G.C.T. at 33°56′ N. and 117° 33′ W., magnitude 2.6(?). (These coordinates plot about 23 miles east of the fault.)
2. October 3, 1968, 1745 G.C.T. at 34°04′ N. and 117°47′ W., magnitude 2.2.

(These coordinates plot about 15 miles northeast of the fault.)

FOLDS

A band three-fourths mile wide of east-trending anticlines and synclines extends for at least 8 miles adjacent to the Whittier fault zone in the upthrown block (fig. 12). The axes of the folds make an angle of 20°–30° with the fault trace and partly overlap one another en echelon. Individual fold axes are about 1 mile long. Folds in the western part of the La Habra quadrangle are confined to the wedge-shaped area between the Whittier and Workman Hill faults. Most of the folds in this wedge are inclined so that their axial surfaces are subparallel to the Whittier fault and their north limbs overturned (fig. 14). The axes of several of these folds are differentially rotated such that the folded beds are canoe shaped in longitudinal section (fig. 15).

En echelon folds commonly result from shearing along a strike-slip fault (Badgley, 1965, p. 58–59, 81), but such folds initially have almost vertical axial surfaces and gentle plunges. The inclination of the fold axes, due to rotation or shear in a plane normal to their trend, may be related to the vertical (reverse) component of movement on the Whittier fault.

Evidence is insufficient to establish the regional plunge of the en echelon folds, although several synclines in the fold wedge plunge westward. The differential rotation, or reversal of plunge, of the axes in the hinges of several of these synclines is probably due to drag on subsidiary faults that intersect the rotated hinges.

A northeast-trending anticline in La Vida Member beds of the fold wedge immediately south of the Workman Hill fault in the northwest corner of the La Habra quadrangle (NE¼ sec. 24, T. 2 S., R. 11 W.) has been drilled by an exploratory well that penetrated middle Miocene volcanic rocks at about 300 feet above sea level (well 166, section *C–C′*, pl. 2). At least two wells (170 and 396) in Turnbull Canyon, about 1½ miles to the west, penetrate middle Miocene volcanic or sedimentary rocks below depths of 5,283 feet subsea, indicating that the gross structure of the fold wedge has a westerly plunge of about 30°.

The Santa Fe Springs, Leffingwell, West Coyote, and East Coyote oil fields overlie separate culminations along an arcuate northwest- to northeast-trending structural culmination in the basement surface. The Santa Fe Springs and Leffingwell structures have almost no surface expression; the axes of the West and East Coyote structures are doubly plunging and approximately parallel the trend of the basement feature, although they are not alined with it.

The Coyote Hills structure dates from at least late Miocene time, when folding and faulting, concentrated in the West Coyote area, caused prominent local unconformities and southeastward thinning in the upper Miocene section (section *A–A′*, pl. 1). At Santa Fe Springs

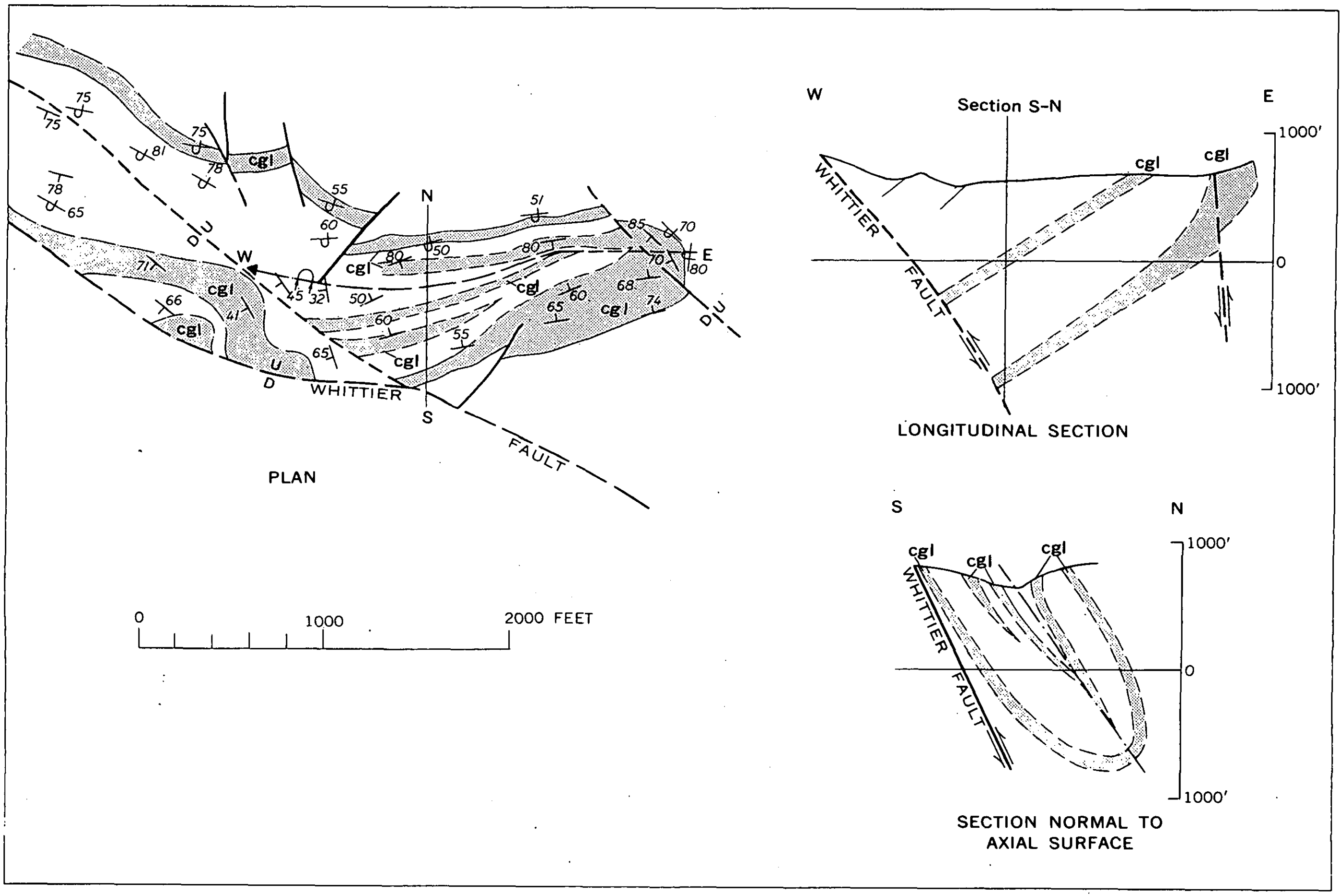

FIGURE 14.—Overturned syncline along the Whittier fault, N½ sec. 25, T. 2 S., R. 11 W. Pebbly sandstone and conglomerate beds labeled cgl.

FIGURE 15.—View (east) of rotated axis of overturned syncline (producing canoe-shaped longitudinal section), West area (site 1–B) of Sansinena oil field. Yorba siltstone in axial area is flanked by (older) Soquel sandstone; axis here plunges about 70° E., but overall plunge of fold is 30°–55° W.

local structural relief at the base of the Pleistocene is less than 500 feet, whereas that at the base of the upper and lower Pliocene is more than 1,200 feet. Equivalent values at West Coyote are 1,000–1,200 feet for each of three horizons. Deformation was probably most pronounced in the mid-Pleistocene, but has continued into and through the late Pleistocene: the La Habra Formation, old alluvium, and the topographic surface are arched and breached by erosion at East and West Coyote. Similarly, the La Habra Valley syncline appears to be actively subsiding; the base of the Pleistocene is more than 1,000 feet below sea level along much of the axis of the valley.

PHYSIOGRAPHY

The physiographic features of the Puente Hills area are the result of a complex history dominated by relative uplift along the Whittier fault zone and the Coyote Hills trend.

The crests of the Puente and the San Jose Hills are believed to be remnants of a greatly dissected upland that once extended well beyond the present limits of the hills (English, 1926, p. 64–69; Woodford and others, 1954, p. 79–80; Durham and Yerkes, 1964, p. 35). The upland surface truncated complexly folded and faulted rocks over large areas. In the Puente Hills area it was crossed by several south-flowing streams that headed in the San Gabriel Mountains to the northeast. Following uplift along the Whittier fault, the surface was dissected by some of the streams that maintained themselves in antecedent valleys having upward-convex longitudinal profiles (Durham and Yerkes, 1964, fig. 16). After a late Pleistocene regional lowering of baselevel (Poland and others, 1956, p. 30), the through-flowing streams were beheaded by diversion upstream north of the hills. Recent erosional history in the hills is characterized by pronounced entrenchment of narrow channels by ephemeral streams that cross the broad alluvium-filled valleys.

The Whittier fault zone is expressed by a band of ridges and valleys that are alined more or less en echelon along the zone. The alinement is caused in part by the right-hand deflection of many of the stream courses that intersect the zone, as well as by elongate ridges of resistant Fernando conglomerates, alternating with relatively unresistant siltstones, that trend subparallel to the zone immediately south of the fault. The deflection of the stream courses has been attributed to differential erosion (English, 1926, p. 65), but is here attributed, at least in part, to strike-slip movement along the zone.

The area south of the Whittier fault zone is dominated by the Coyote Hills uplift and the structural depression of the La Habra Valley, which trends subparallel to the hills and to the fault zone. By late Pleistocene time, erosion had formed an extensive surface of low relief across this area. The erosion surface was warped during relative uplift along the Coyote Hills trend to the present general form of the hills. Crests near 580 feet at both East and West Coyote are about 300 feet above the La Habra Valley to the north and nearly 400 feet above the margin of the central plain to the south. Within the hills the erosion surface is now greatly dissected. The hills are drained by such antecedent streams as Coyote and Brea Creeks (fig. 11); Coyote Creek may well have been deflected and captured by Brea Creek during warping in the Brea area. The south flanks of the Coyote Hills are dissected by relatively long ephemeral streams; the south edge of the hills is probably in part a faultline scarp.

The Santa Fe Springs structure has only slight topographic expression (fig. 16), yet the subsurface fold has considerable structural relief in even the younger units (sections *A–A′*, *B–B′*, pls. 1, 2). English 1926, pp. 67, 68) recognized this anomaly, as well as the youth of the structure, and suggested that the ancient San Gabriel River eroded the west end of the rising dome, the course of the river at that time (the early part of the uplift) having been about 1 mile east of its present position. English's interpretation is supported by the presence of an undeformed buried gravel, the Gaspur aquifer, interpreted as a basal Holocene deposit of the San Gabriel River (fig. 11). The east boundary of the

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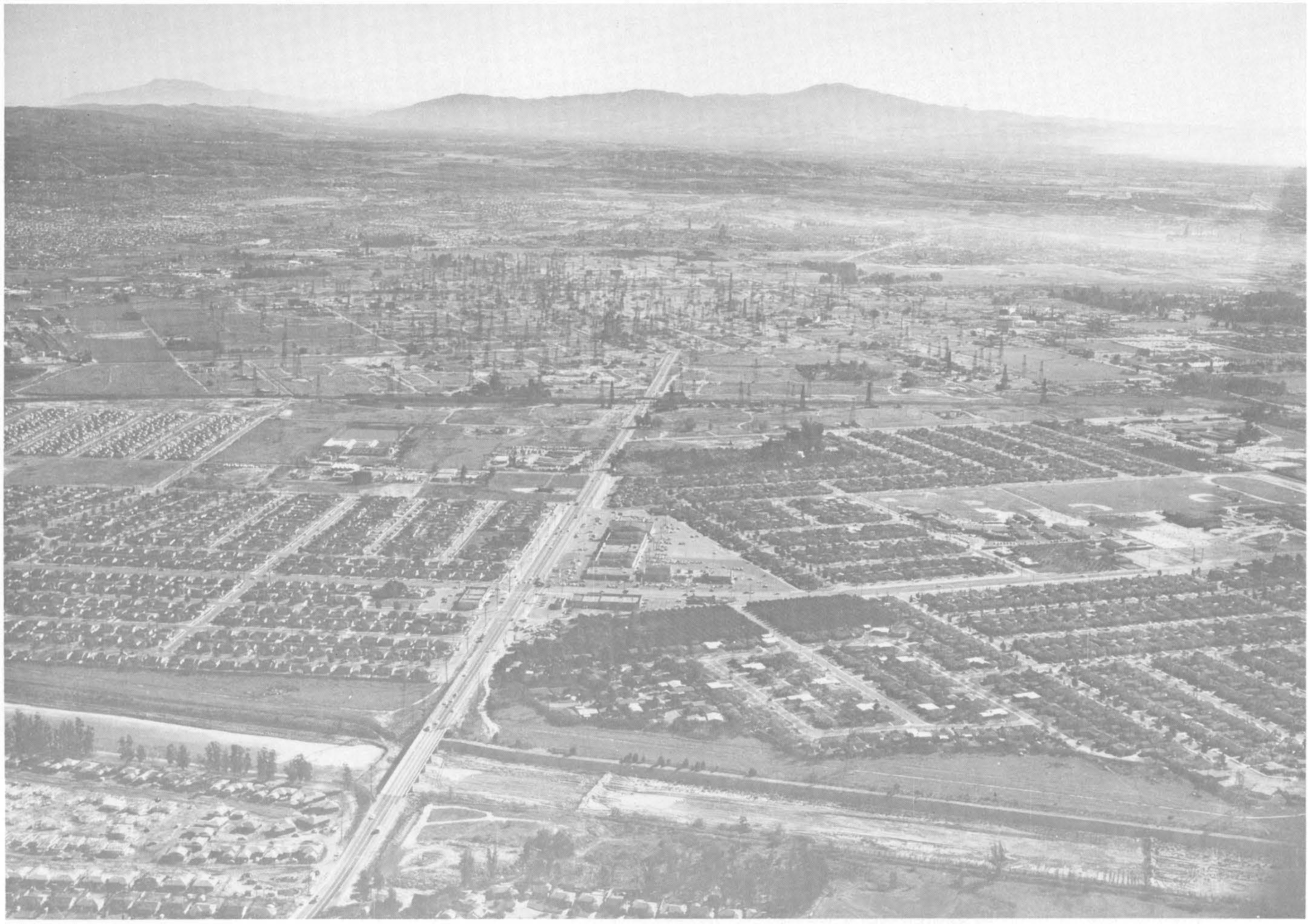

FIGURE 16.—View eastward of Santa Fe Springs oil field illustrating lack of surface expression of underlying anticlinal structure (compare with fig. 18). San Gabriel River in foreground, Santa Ana Mountains in background; December 1957.

Gaspur indicates that the San Gabriel River channel at the beginning of Holocene time occupied the west quarter of the Santa Fe Springs oil field area.

The lack of surface expression for the main part of the structural dome at Santa Fe Springs cannot be similarly explained. At least 200 feet of folded upper Pleistocene, pre-Gaspur strata are present on the flanks of the dome, but are missing at the crest (California Dept. Water Resources, 1961, structure section *N–N′*, pl. 6F). As these strata survived erosion during Gaspur (earliest Holocene) time, they—and any hills formed during folding—must have been eroded later in post-Gaspur time.

English (1926, p. 68) also offered an explanation for the seemingly anomalous deflection of Brea and Coyote Creeks sharply westward along the south margin of the Coyote Hills (fig. 11). The westward encroachment of the Santa Ana River alluvial fan from southeast of the map area along a line through the sites of Fullerton and Buena Park deflected the Coyote Hills drainage westward along the junction between the hills and the fan. Similarly, encroachment of the San Gabriel River fan southeastward from the Santa Fe Springs area probably deflected the Whittier Creek drainage southeastward toward the junction between the two fans, just west of Buena Park. The deposits of the two fans merge imperceptibly on the surface of the central plain, but at most places their topographic form is well preserved.

PETROLEUM GEOLOGY

Petroleum is the chief mineral resource of the Puente Hills area. At the end of 1967, oil fields within the mapped area had produced 1,183 million barrels, of which about 85 percent was from the Puente Hills area. This constituted 21 percent of the total production from the Los Angeles basin as of that date (table 4). Fields in the map area occur chiefly along two structural

TABLE 4.—*Production and reserves of oil fields in the La Habra and Whittier quadrangles*

	Year discovered	Year of greatest production	Production statistics (bbl)				Maximum productive area (acres) [3]	Cumulative production per maximum area (bbl/per acre)
			1967 production [1]	Cumulative production, Jan. 1, 1968 [1]	Estimated reserves, Jan. 1, 1968 [2]	Estimated ultimate recovery		
Brea-Olinda:								
Brea Canyon area [4]	1899	1953	[4] 1,445,400	[4] 266,918,000	[5] 12,992,000	279,910,000	[5] 745	358,279
Buena Park, West	1944	1945	(abandoned 1950)	50,700		50,700	10	5,070
Coyote, East: [6]			[6] 677,400	[6] 26,964,300	[5] 7,724,000	34,418,300	[5] 1,175	22,718
Hualde dome	1917	1922	144,200	9,344,700				
Stern area	1934	1952	533,200	17,349,600				
Coyote, West:			2,634,500	215,540,600	18,307,000	233,847,600	1,125	191,592
East area	1909	1918	1,004,300	84,608,300				
West area	1916	1934	1,630,200	130,932,300				
La Mirada	1945	1946	(abandoned 1951)	25,300		25,300	20	1,265
Leffingwell	1946	1954	17,700	730,700		>730,700	125	5,846
Newgate	1956	1963	12,700	148,400		>148,400	10	14,840
Puente Hills	1880	(?)	16,300	3,775,800		>3,775,800	160	23,599
Rideout Heights	1901	1935	23,200	1,945,900		>1,945,900	90	21,621
Sansinena:			1,148,000	40,041,400	9,679,000	49,720,400	640	62,565
Central area	1955	1956	24,000	534,800			35	
East area	1953	1955	252,000	11,710,800			260	
West area [7]	1898	1953	838,500	25,868,500			345	
Other areas	1940	1943	33,500	1,927,300				
Santa Fe Springs [8]	1919	1923	1,623,200	593,157,600	21,629,000	614,781,600	1,480	400,782
Turnbull	1941	1943	(abandoned 1965)	765,700		765,700	75	10,209
Whittier: [9]								
Main area	1898	1930	1,443,700	32,680,500	16,484,000	49,164,500	865	37,781
La Habra area	1941	1945	(abandoned~ 1954)	75,000		75,000	80	938
Total			13,502,000	1,182,549,900	86,810,000	1,269,359,900	6,590	179,446
Los Angeles basin			138,687,300	5,706,614,100	2,057,379,000	7,763,993,100	59,732	95,537

[1] Data from Conservation Committee of California Oil Producers (1968).
[2] Data from Oil and Gas Journal (1968).
[3] Data from California Division of Oil and Gas (1967), table 1.
[4] Excludes Olinda and Tonner areas, all east of present map area.
[5] Prorated on areal basis.
[6] Excludes Anaheim area, largely east of present map area.
[7] Includes Curtis, New England, 6-A, and 12-G areas.
[8] Excludes Newgate, listed separately.
[9] Excludes Rideout Heights, listed separately.

trends: the Whittier fault zone in the northeast part and the Coyote Hills–Santa Fe Springs trend in the southern part.

Production statistics and oil field nomenclature are from the Annual Review of California Oil and Gas Production for 1967 (Conservation Committee of California Oil Producers, 1968). Nomenclature of producing zones and pools (fig. 17) is from Wissler (1958). Semiannual and cumulative production figures for fields, as well as boundaries and detailed descriptions of many fields and pools, are published in Summary of Operations–California Oil Fields (California Division of Oil and Gas). Short generalized summaries of basic data and map sheets on most oil fields in southern California have been published recently as California Oil and Gas Fields, Maps and Data Sheets (California Division of Oil and Gas, 1961). A brief (nongeologic) history of early development and production of the Coyote Hills, Olinda, Puente Hills, and Whittier oil fields was presented by Prutzman (1913) and McLaughlin and Waring (1914, p. 358–363).

The first commercial oil in Los Angeles basin was discovered in about 1880 in the Puente Hills oil field, immediately north of the Whittier fault in the east-central La Habra quadrangle. As it was for most of the fields along the fault zone, oil was discovered on the basis of tar and oil seeps, a guide used earlier in Ventura County. Development of the field was by projection along the line of successful wells, an empirical technique for finding oil in use around the turn of the century, and still in good repute a decade later (Prutzman, 1913, p. 274). However, beginning around 1900, geologic principles were applied with the recognition of the significance of anticlines which led to discovery of the West Coyote field in 1908 (Hoots and Bear, 1954, p. 5). Santa Fe Springs, which has very slight surface expression and no oil seeps, and is not alined with other fields, was discovered in 1919 on the basis of petroleum gas that leaked into local water wells (Case, 1923, p. 6). By about 1930 all structural features in the basin that had surface expression had been tested, and exploratory drilling was virtually at a standstill. In 1941 projection of geologic data led to discovery of the small Turnbull oil field in northwest La Habra quadrangle. In the early 1950's significant amounts of oil were discovered in the Brea Canyon area of the Brea-Olinda oil field and in the East and Central areas of the Sansinena oil field by projecting structural and stratigraphic trends based largely on subsurface data. The latest discoveries in the map area were deep oil-bearing zones at Santa Fe Springs in 1956 and at Whittier in 1963.

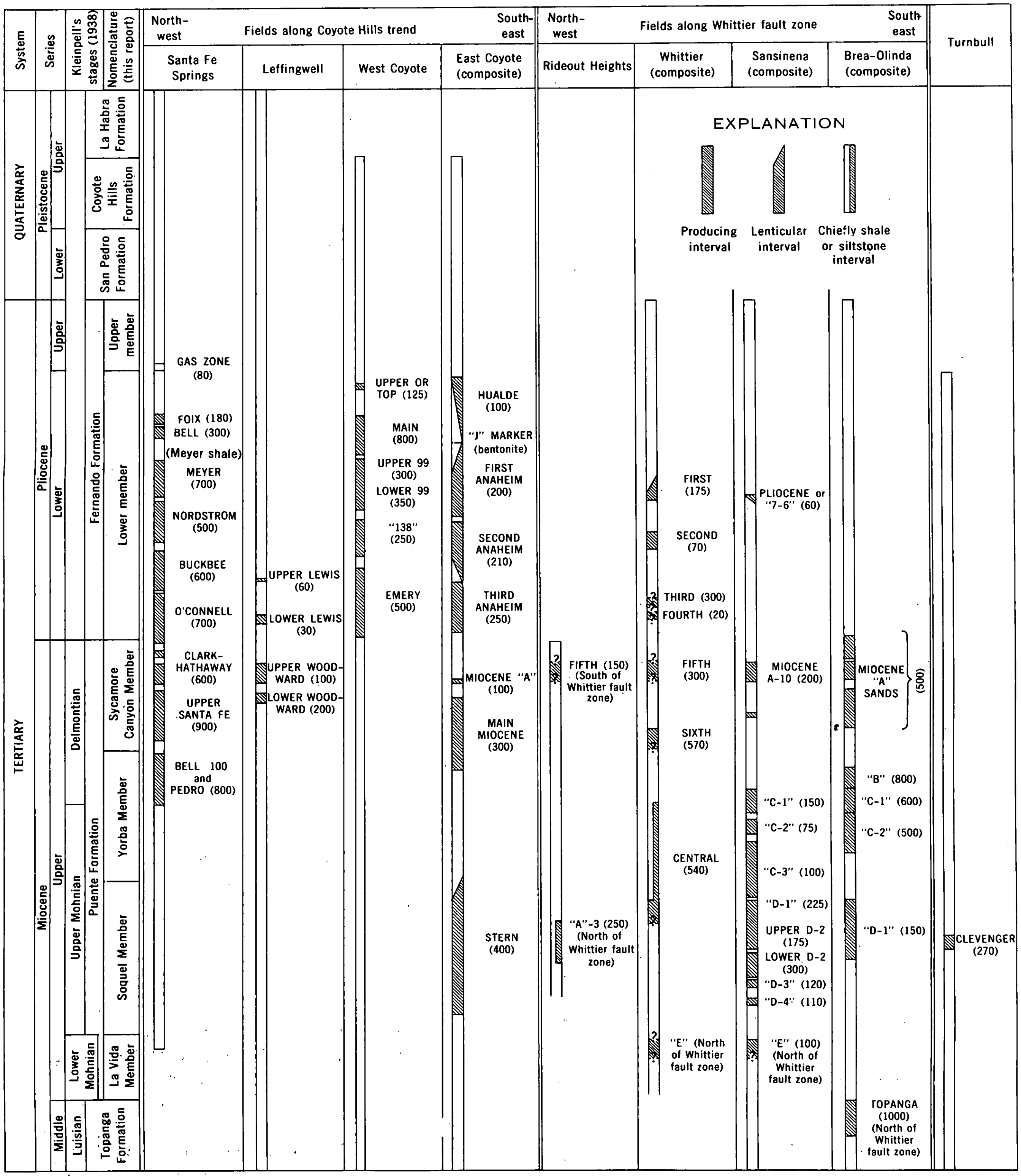

FIGURE 17.—Correlation chart of oil-producing zones and stratigraphic units in oil fields of the La Habra and Whittier quadrangles. Stratigraphic penetration of field is indicated by length of column; figures in parentheses give average thickness of zones in feet. Modified from Wissler (1958). (See also pl. 4.)

FIELDS ALONG OR NORTH OF THE WHITTIER FAULT ZONE

PUENTE HILLS OIL FIELD

The first commercial oil discovery in the Los Angeles basin was in about 1880 in the Puente Hills field in the north-central part of the La Habra quadrangle. The field was discovered on the basis of small tar seeps along the axis of an east-trending anticline in secs. 34 and 35, T. 2 S., R. 10 W., in the upthrown block of the Whittier fault (pl. 4). The field has an area of approximately 160 acres. Tightly folded siltstone of the La Vida Member of the Puente Formation is exposed at the surface. Until 1902, oil was produced from crushed siltstone and sandstone of the La Vida between 700 and 1,600 feet in depth. Later wells produced from sandstones in the Topanga Formation at depths as great as about 5,000 feet, but averaging about 2,000 feet (section *G–G′*, pl. 2). Several wells drilled in this area penetrated rocks of the basement complex (section *F–F′*; *G–G′*, *H–H′*, pl. 2). Although the cumulative production at the end of 1967 was more than 3¾ million barrels, the area produced only about 16,000 barrels in 1967 and is now considered subcommercial (Scribner, 1958, p. 108).

BREA-OLINDA OIL FIELD

The Brea-Olinda field extends eastward from the east-central part of the La Habra quadrangle and includes four early discovered, once-separate areas: Brea Canyon, Stearns, Tonner, and Olinda. (See Norris, 1930.) Development since the 1930's has resulted in a continuous field about 6 miles long and one-half mile wide. The basic structural feature of the field is a steeply southwest-dipping homocline that is truncated by the Whittier fault zone. Oil is trapped in updip pinchouts of the sandstones and in fault traps. (See Gaede and others, 1967; Scribner, 1958.) The field now totals 2,285 proved acres, of which 790 are in the map area. Its cumulative production averaged about 358,280 barrels per acre at the end of 1967.

The Brea Canyon area of the field (pl. 4) occupied about 265 acres in the mouth of Brea Canyon in the N½ secs. 1 and 2, T. 3 S., R. 10 W., and extended southeastward into the S½ sec. 6, T. 3 S., R. 9 W. (Norris, 1930, pl. 1). This area was first drilled in 1899 on the evidence of oil-bearing sandstone beds exposed in the steeply south-tilted and faulted Fernando Formation south of the main trace of the Whittier fault zone. Oil was originally produced from a zone less than 500 feet deep in Fernando strata. Wells in this area now average 3,000–5,000 feet in depth and produce from sandstones in the lower part of the Fernando and upper part of the Puente Formation. Sandstones in the Soquel Member have been the deepest drilling target south of the fault zones, but the member has not been completely penetrated (section *H–H′*, pl. 2).

The so-called Stearns Lease comprises about 900 acres in parts of secs. 1 and 12, T. 3 S., R. 10 W., and secs. 6 and 7, T. 3 S., R. 9 W., just east of the Brea Canyon area. Drilling on this property began in 1905 and continued until about 1915. Between 1915 and 1927 the upper zone (lower member of the Fernando) was semidepleted and production was stopped for 1 year. In April of 1928 injection of imported natural gas was begun in the upper zone to expel the oil. In about 1 year 590 million cubic feet of gas was injected into the zone over an area of 150 acres through three wells, increasing the gas pressure in adjoining wells. In August 1929 injection of oil imported from the Santa Fe Springs field was begun through three wells, and by March 1930, when the injection was stopped, a total of 584,300 barrels of crude oil and 600 million cubic feet of gas had been injected, resulting in a considerable increase in pressures. Results of these injection procedures are not known. An account dated 1932 indicates that there was no evidence of migration of injected oil and gas beyond the lease area and that the higher gravity Santa Fe Springs oil was expected to diffuse with the heavy local oil, making it lighter and more easily produced (Norris, 1930; Hodges and Johnson, 1932). The post-1932 production history of the Stearns Lease area cannot be determined from published data.

SANSINENA OIL FIELD

Sansinena, also a composite oil field, joins the west end of the Brea-Canyon area and consists of the Central, East, and West areas, plus a group of separate pools. Eldridge (Eldridge and Arnold, 1907, p. 115–117) described the geology of the old La Habra discovery area in the south-central part of the West area (SE. cor. sec. 30, T. 2 S., R. 10 W.).

The discovery well of the West area was in the old La Habra field, which was located on the basis of tar seeps along the main trace of the Whittier fault zone and was drilled in 1898 to a depth of 1,295 feet. Five additional wells were drilled in the same area by 1912 to depths as great as 3,000 feet, but production was affected by entry of water, and all were abandoned by the mid-twenties (English, 1926, p. 88). By 1945 a total of only 25,000 barrels of oil had been produced from the field. In 1945 the Miocene "D" zones were discovered, and development of these commercial zones was begun. The latest discovery was made in 1957, and oil is now produced from several upper Miocene zones from depths of about 2,900–3,600 feet. The principal structural feature of the West area is an intensely faulted asymmetrical anticline adjacent to the main Whittier fault (Woodward, 1958, p. 113, 116).

The East area of Sansinena was discovered in 1953 on the basis of subsurface data obtained from a nearby exploratory well; two drilling islands produce oil from five upper Miocene zones at depths ranging from 3,600 to 6,400 feet. The oil is trapped in an updip pinchout of sandstone on the south flank of a faulted anticline below the main fault of the Whittier zone. (See Woodward 1958, p. 115–116.)

The cumulative production of the entire 625 acres of the Sansinena field was about 62,565 barrels per acre at the end of 1967.

WHITTIER OIL FIELD

The Whittier field is described briefly in previously mentioned summaries by Eldridge and Arnold (1907, p. 110–114), English (1926, p. 77–78), and Norris (1930, p. 8–9). Two detailed descriptions of the field form the basis of the present description: one by Holman (1943, p. 288–290) published before the discovery of deeper production in 1953 and one by Gaede (1964, p. 59–65).

The Whittier field consists of about 740 acres in secs. 22, 23, and 26, T. 2 S., R. 11 W., southeast of the city of Whittier (pl. 4). The La Habra area, southeast of the Whittier field in the S½ sec. 25, T. 2 S., R. 11 W., was active as a subcommercial producer from its discovery in 1941 to about 1957, at which time the first and second zones were depleted and converted to use as temporary storage for imported natural gas.

The discovery well of the Whittier oil field was drilled in 1896 near the center of the present field on the evidence of oil seeps. It was drilled to 984 feet, and about 10 barrels of oil per day was pumped from 865 to 984 feet in the third zone (fig. 17). Development of the field was rapid, and by 1904 there were about 100 wells producing oil from the second, third, fourth, and sixth zones. By 1916 the first uppermost zone had been discovered, and an annual production of about 1 million barrels from 135 wells was attained. After a peak year of more than one million barrels in 1919, production declined steadily to 640,000 barrels in 1924, even though the number of producing wells was increased to a maximum of 163. In 1938 the same number of wells produced only about 303,000 barrels, and by 1941 production had declined to about 129,000 barrels from only 47 active wells. These five early-developed zones were not protected from water intrusion either during drilling or after abandonment; as a result, water infiltration has been a permanent production problem.

The field was developed before the introduction of micropaleontological or electrical logging techniques, and recognition and correlation of the several oil-producing zones was solely on the basis of water-bearing intervals; correlations were empirical and uncertain.

The Whittier field was reactivated in 1942, but after the war emergency, production again declined steadily until 1953, when the Central zone was discovered at depths of 4,370–5,050 feet. Seventy-three new wells were drilled during the next 8 years and by the end of 1960 annual production from the field from 151 wells was 541,000 barrels. In 1961, 157 new wells were drilled as part of an intensive field development program, and in March 1963, 10 years after discovery of the Central zone, the "184 anticline" was discovered in the central area of the field. The discovery well, Murphy-Whittier 184, about 1,200 feet northwest of the center of sec. 26 T. 2 S., R. 11 W., was drilled to a depth of 8,006 feet; initial production was 100 barrels of oil per day. Production from the "184 anticline" is reported to be from between depths of 5,000–7,000 feet. Development of the fifth, sixth, and 184 zones (upper Miocene) accounts for most of the increased production of the field after 1963. Production from the central area increased from 849,000 barrels in 1962 to 2,112,000 barrels in 1966, more than twice the entire field production for 1962 (Conservation Committee of California Oil Producers, 1962–66). Cumulative production of the Whittier field at the end of 1967 was 32,680,500 barrels, an average of 37,780 barrels per acre.

Figure 17 presents the stratigraphic correlation and average thickness of the producing zones at Whittier. The main structural feature is basically a south-dipping homocline (section *C–C′*, pl. 2), oriented such that the upper six zones crop out within the producing area. The first (uppermost) zone is exposed near the center of the field, and the lower zones crop out in succession northwestward from the center. (See Gaede, 1964, pl. 3.) Closure of the fold is caused by the Whittier fault zone to the northeast and a small-displacement fault to the southeast. Limits of the field to the southwest are controlled by edgewaters. Subcommercial amounts of oil have been produced from contorted beds of the Puente Formation on the north side of the fault that locally dip northward away from the fault zone. These beds are chiefly severely crushed siltstone and apparently lack indigenous oil.

RIDEOUT (RIDEAU) HEIGHTS OIL FIELD

The Rideout Heights field consists of 45–50 acres in secs. 16 and 17, T. 2 S., R. 11 W., within the city limits of Whittier (pl. 4). The area is commonly considered as part of the Whittier oil field, but is treated separately here because it is not contiguous and was discovered separately. Though activity dates from 1901, when two unsuccessful wells were drilled, the first commercial oil well was completed in 1919. The flowing well produced 200–250 barrels of oil per day from a depth of 3,120–3,292 feet. Development of the field was slow because of low yields and competition from the adjacent Whittier field; however, in 1923 a sixth producing well was completed flowing 500–800 barrels per day, and activity was renewed. During 1924–1926, 12 dry holes and six producing wells were drilled. The maximum annual production was in 1926, when 161,500 barrels was produced from 14 wells. Only 18 wells had been completed by 1940; the most recent activity (to 1966) was in 1956, when five new wells were completed.

The Whittier fault zone divides the area into a steeply south-dipping homocline of Fernando Formation beds on the south side and steeply north- to northwest-dipping beds of the Puente Formation on the north. Vertical separation across the fault reportedly exceeds 5,000 feet (Ingram, 1962, p. 95; see section *B–B′*, pl. 2). The south-block producing zone is about 2,500 feet deep, is about 400 feet thick, and is correlated with the fifth zone of the Whittier oil field (fig. 17).

A total of 62 wells have been drilled in the area, of which 26 were completed as oil wells. In 1967 total production was 23,200 barrels of oil from nine wells, and cumulative production of the field averaged about 21,620 barrels per acre.

TURNBULL OIL FIELD (ABANDONED)

The Turnbull field consists of about 75 acres in the east-central part of sec. 13, T. 2 S., R. 11 W., in the northwest corner of the La Habra quadrangle. The field was discovered in 1941, and during the period 1941–1945 nine wells were drilled and five completed at depths of about 3,700 feet.

The main structural feature of the field is a small gently northeast-plunging anticline that is truncated on the southwest end by the Whittier Heights fault. (See fig. 12; section *C–C′*, pl. 2.) The field is notable in that beds correlated with the Eocene to lower Miocene Sespe Formation were penetrated by a well drilled through the Workman Hill fault. The oil occurs in a zone of sandstone about 115 feet thick in a 700-foot sequence of poorly consolidated pebbly sandstone correlated with the Soquel Member of the Puente Formation. Peak production of 122,380 barrels was obtained from six wells in 1943, after which production declined steadily. In 1962 four wells produced 7,775 barrels, and in 1965 the field was converted to a temporary storage field for imported natural gas.

FIELDS ALONG THE COYOTE HILLS TREND

The arcuate Coyote Hills trend, which extends from the southeast corner to the west center of the map area, contains some of the largest oil fields in the Los Angeles basin: the Santa Fe Springs and West and East Coyote fields, as well as the smaller Leffingwell, Newgate, and abandoned West Buena Park and La Mirada fields.

Oil fields along the Coyote Hills trend account for about half of the annual production from the map area and about 73 percent of the cumulative production (table 4). The Santa Fe Springs field has produced the third largest amount of oil in the Los Angeles area, and the highest daily and monthly production rates of the field (about 238,000 barrels per day in 1923), from only two of nine zones now known, still stand as records for the basin.

SANTA FE SPRINGS OIL FIELD

The Santa Fe Springs oil field was such a prolific producer and its oil so profligately produced that an extensive literature has accumulated. The following references are selected from a much larger list and form the basis of the description in this report. The best early history is that of Case (1923), who wrote a complete review of the record production year. The discoveries and periods of development of the deeper zones commonly were followed by historical reviews and descriptions of the activity: Hendrickson and Weaver's (1929) report after discovery of the Nordstrom, Buckbee, O'Connell, and Clarke zones; Winter's (1943) summary of the discovery and production history for a symposium on California fields; and Ybarra's (1957) and Elmore's (1958) reports after discovery of the Santa Fe zone and Pedro pool. Eldridge (Eldridge and Arnold, 1907, p. 109) predicted the discovery of oil in the crest of the Coyote Hills anticline and also noted the presence of a large gas well 3 or 4 miles south of Whittier, the Santa Fe Springs area. English (1926, pl. 11) included several photographs of historic interest, including one of craters made by gas blowouts during the early stages of development.

The Santa Fe Springs field is in the center of the Whittier quadrangle chiefly in secs. 5 and 6, T. 3 S., R. 11 W. (pl. 4). The field roughly coincides with a very slight topographic dome that is elongate northwestward (fig. 16). In 1967 the productive area of the field had declined from a maximum of about 2,000 to 975 acres. The field was named for Santa Fe Hot Springs, the center of, and probably the cause for, a preexisting town lot subdivision of a part of section 6.

The first two attempts at drilling in 1907 were unsuccessful. Significant amounts of gas were noted in the holes, the deepest of which was 1,445 feet, but no additional wells were drilled for 8 years. Early in 1917, after 2 years of "arduous struggle" (Case, 1923, p. 6), the first producing well was completed, flowing about 3,000 barrels of oil per day from about 4,568 feet. Water contamination was a problem, however, and after recompletion the production rate dropped to about 150 barrels per day. The relatively great depth and low production rate did not then divert much activity from oil fields that were being developed in other parts of the basin. The fourth exploratory well, begun nearly 2 years later 1⅓ miles northwest of the discovery well, was brought in as a "gusher" in November 1921. The well produced more than 2,500 barrels per day from a depth of 3,763 feet and set off a drilling boom.

Within 4 months 41 wells were being drilled, and a second "gusher" was drilled in April 1922. Meanwhile, the town lot lease holders had obtained equipment and began to drill numerous wells in the area near the center of the dome. Some of these wells were as close as 50 feet to their neighbors, and Case (1923, p. 7) estimated, rather conservatively, that $5,500,000 was wasted in excess drilling costs because of unnecessary crowding in the town lot area. During the 18-month period November 1921 to June 1923, 447 notices of intent to drill in the area of the field were filed with the State agency; it was noted that there were already 60 wells in one 40-acre tract.

In January 1922 the first of several serious gas blowouts occurred from a depth of 2,067 feet, demolishing the rig, forming a "vast" crater, and blowing out the upper segment of 12½-inch casing that had been cemented at 2,000 feet. This experience led only to efforts to commercially develop the gas deposit instead of installation of blowout-prevention equipment.

In January 1923 a second blowout occurred in a well 2,016 feed deep being drilled by the same operator. The gas accidentally was ignited, and the well burned out of control for several days. The following month a third blowout occurred, again in a well of the same operator, at a depth of about 2,203 feet; the gas ignited, and the rig was destroyed. This gas zone was subsequently developed to some extent by a production and distributing agency that drilled several wells in 1922 to depths of about 2,100 feet and piped the gas directly into Los Angeles without treatment or boosting. Production in these wells was as high as 10 million cubic feet per day (Case, 1923, p. 11).

The upper three zones, the Foix, Bell, and Meyer, were discovered and developed during the 1921 to mid-1923 period. By the end of May 1923 the daily production of the field was 235,755 barrels from 112 wells, of which 109 were flowing; 247 more wells were being drilled, and there were 38 different operators active in a field area of 1,995 acres. Case (1923, p. 19) estimated that 117 million cubic feet of gas was wasted every day by flaring to the atmosphere, which unnecessarily depleted the reservoir energy and certainly helped to account for the rapid decline of the field.

By the end of 1923 daily production from 500 wells had declined to about 125,000 barrels, and at the end of 1926 production from about 280 wells had further declined to about 69,000 barrels (Ybarra, 1957, pl. 6). In July 1928 the Buckbee zone discovery well, which flowed about 2,000 barrels of oil per day from a depth of 5,856 feet, started a second drilling boom. The Nordstrom zone, which is between the Meyer and Buckbee zones, was discovered by accident in September 1928 in a well that produced 5,500 barrels of oil per day plus 9 million cubic feet of gas. By December 222 new wells were being drilled below the Meyer zone, and a few of the older wells were being deepened. In February 1929 the O'Connell zone (fig. 17) was discovered at a depth of 6,360 feet in a townlot well and, when completed, flowed 1,300 barrels of oil and 2,000 barrels of water per day. Wells producing from the Buckbee zone were then deepened to the O'Connell zone. The Clark zone, about 1,000 feet below the O'Connell, was was also discovered during this period of development. During this period the daily production rate increased from about 58,000 barrels from 320 wells at the end of 1927 to about 212,000 barrels from 415 producing wells as the end of 1929 and then declined to about 110,000 barrels per day from 460 wells in only 1 year. By the end of 1938 production had further declined to about 46,000 barrels of oil per day from 580 wells.

The production of large amounts of oil in 1923 and 1928 greatly overloaded Pacific coast storage and transportation facilities to the extent that for several months in 1928 crude oil and gas from Santa Fe Springs were injected back into a depleted reservoir at the nearby Brea-Olinda field. (See Norris, 1930; Hodges and Johnson, 1932.)

The Bell 100 zone was discovered in March 1938, but was abandoned 3 years later after producing 71,091 barrels from a depth of 9,070–9,880 feet. Production rates continued to fall, and at the end of 1954 only about 21,000 barrels per day were produced from 575 wells.

The Santa Fe zone discovery well, completed in February 1956, flowed 1,187 barrels of oil plus 1,240 million cubic feet of gas per day from depths of 8,050–8,396 feet and 8,524–8,790 feet including the Bell 100 zone at 8,935–9,010 feet. The daily rate of production declined from 14,420 barrels from 580 wells at the end of 1956 to about 4,544 barrels per day from 425 wells in 1967.

Figure 17 shows the sequence, thickness, and correlation of the nine stratigraphically distinct oil-bearing zones in the upper Miocene to lower Pliocene section at Santa Fe Springs; these zones aggregate about 4,550 feet in thickness. The post-Pliocene sequence (apparently entirely Pleistocene in age) averages about 1,000 feet in thickness, the upper member of the Fernando Formation about 1,200 feet, and the lower member about 5,200 feet. About 4,900 feet of the Puente Formation has been penetrated (section *A–A′*, pl. 1).

The main structural feature of the Santa Fe Springs field is an elongated dome that trends about N. 70° W. and is cut by cross-faults that are apparently pre-Pleistocene in age (section *A–A′*, pl. 1). Although the Santa Fe Springs structure may not be genetically related to the Coyote Hills structure, because the latter is characterized by prominent relative uplift in late Miocene time as well as later, influence of the Coyote Hills deformation was reflected at Santa Fe Springs by southeastward thinning of the upper Miocene (section *A–A′*, pl. 1). The plunge of the anticlinal axis is about 6° or 7°, and the flanks of the fold dip about 10°–12°, except along the southwest flank near the projection of the "Norwalk" fault, where dips of 20°–25° are evident.

The Santa Fe Springs field is somewhat unique in that wells were completed simultaneously in a number of different oil-producing zones, thus increasing the production of the field. The cumulative production at the end of 1967 was 593,157,600 barrels of oil, or about 400,800 barrels per acre, one of the largest averages in California.

NEWGATE OIL "FIELD"

The Newgate oil "field" is less than one-half mile southeast of the Santa Fe Springs field, near the SE¼ cor. sec. 4, T. 2 S., R. 11 E. The 10-acre area contains one producing well. The discovery well at Newgate was completed in January 1957 immediately following discovery of deeper zones at Santa Fe Springs and produced 125 barrels of oil per day from the interval 8,160–9,032 feet in upper Miocene beds of the Sycamore Canyon Member of the Puente Formation. Cumulative production at the end of 1967 was 148,400 barrels.

WEST COYOTE OIL FIELD

The West Coyote oil field is in the southwest quarter of the La Habra quadrangle (pl. 4). Although the field is over a prominent topographic dome (fig. 18) that has about 300 feet of relief, historical descriptions commonly attribute the early exploratory drilling in 1908 to oil and gas shows in water wells (Reese, 1943; Mefferd and Cordova, 1962). The first producing well was completed in April 1909. This discovery was the fourth in the map area and was the first based on geologic principles. The success at West Coyote led directly to drilling in the following fields:

- East Coyote, drilling begun in 1908, commercial oil discovered in 1917 (Dudley, 1943, p. 349);
- Richfield, just east of present map area, drilling begun in 1915, oil discovered in 1919 (Musser, 1926);
- Dominguez, in the Dominguez Hills along the Newport-Inglewood zone, drilling begun in 1916, oil discovered in 1924 (Graves, 1954);
- Inglewood, at Baldwin Hills along the Newport-Inglewood zone, drilling begun in 1916, oil discovered in 1924 (Driver, 1943, p. 306);
- Long Beach, at Signal Hill, also along Newport-Inglewood zone, drilling begun in 1916, oil discovered in 1921 (Stolz, 1943, p. 320).

Competitive drilling, excessive well density, and profligate production have not been problems at West Coyote because the field has been controlled by one operator (English 1926, p. 83; Reese, 1943, p. 347).

The discovery well was completed in the main zone, at the depth of 3,300 feet in the upper part of the lower member of the Fernando Formation (fig. 17). After 9 years of development, 69 wells were producing 31,640 barrels per day from the main zone, which is 250–700 feet thick. The upper 99 zone is 4,100 feet in depth, about 300 feet thick, and was discovered in 1916 during an early stage of development in the east block. The lower 99 zone, at 4,400 feet, is about 450 feet thick and is productive over only a small part of the crest. An unconformity separates the lower 99 from the underlying 138 zone, discovered in 1930, which is 400–700 feet thick, about 4,850 feet deep, and restricted in extent. The Emery zone, near the base of the lower Fernando, the lowest producing interval, is 700–1,250 feet thick and about 5,425 feet deep. It was discovered in 1930 and produces over the entire structure. Development drilling to outline the extent of the several zones resulted in additional zone or pool completions in 1939, 1944, 1962, and 1966.

The main structural feature is a faulted anticline elongate east-west and asymmetrical in that the south limb dips more steeply than the north owing to drag on a reverse fault (the Norwalk?) (Mefferd and Cordova, 1962, pl. 2; section *E–E′*, pl. 2). Displacement on the northnortheast-trending steep reverse fault that separates the field into downthrown east and upthrown west blocks is about 600 feet at the crest of the fold.

During World War II the field was operated at an increased rate, and while the number of wells increased

FIGURE 18.—View eastward of West Coyote oil field illustrating intense dissection of both the topographic structure and the post-La Habra (late Pleistocene) erosion surface; central part of hills in foreground underlain by San Pedro Formation. East La Habra Valley in background. December 1957.

from 67 at the end of 1940 to 182 at the end of 1945, annual production per well decreased from 39,600 barrels to 29,200 barrels. Daily production of the field has declined from a peak of 34,560 barrels from 69 wells in 1918 to about 7,700 barrels from 262 wells in 1966. Cumulative production of the field at the end of 1967 was 215,540,600 barrels from a maximum area of about 1,125 acres, an average of about 191,592 barrels per acre.

EAST COYOTE OIL FIELD

The East Coyote field was discovered in 1911 in the southeast quarter of the La Habra quadrangle (pl. 4), about 1½ miles northeast of the West Coyote anticline, in an alluviated area on the trend of the West Coyote field. The discovery well produced 600 barrels per day from the first zone in the middle part of the lower member of the Fernando Formation from a depth of 2,830–3,340 feet (fig. 17). Subsequent drilling outlined the Anaheim dome, a buried east-trending anticline. An en echelon anticline, the Hualde dome, was discovered in 1914, and a smaller dome to the east was discovered in 1927. Oil was discovered later in areas between the two principal domes. The east-trending Hualde anticline underlies an elongate topographic high (fig. 19) that trends northeast, has relief of about 250 feet, and is about 2¼ miles long by 1 mile wide; this anticline has an exceptionally steep south flank owing to faulting along a north-dipping reverse fault.

A composite stratigraphic section of the field includes about 500 feet of upper Pleistocene nonmarine beds, about 350 feet of lower Pleistocene marine strata, 1,500 feet of upper Pliocene rocks, 2,600 feet of lower Plio-

FIGURE 19.—View eastward of East Coyote oil field illustrating dissection of topographic structure as well as the post-La Habra (late Pleistocene) erosion surface that truncates the structure.

cene rocks, and more than 3,500 feet of upper Miocene rocks (section *A–A′*, pl. 1). The oil zones are not uniformly distributed throughout these rocks. The highest zone is the Hualde zone, at a depth between 2,000 and 3,000 feet; it is about 100 feet thick and is productive only in the southeastern part of the Hualde dome. The Anaheim zone is near the base of the Pliocene; it is about 1,400 feet thick and ranges in depth from 2,800 feet at the east to 4,600 feet at the west. The first Anaheim zone, about 200 feet thick, has been the most prolific Pliocene producer and is productive to some extent throughout the field. The second Anaheim zone is about 300 feet thick and is productive chiefly in the Hualde dome area. The third Anaheim zone, the most productive zone in the Hualde dome area, is about 700 feet thick at the Hualde dome, and thins to about 100 feet in the Anaheim dome area. The Miocene "A" zone, latest Miocene in age, is about 100 feet thick and is productive chiefly in the eastern part of the Hualde dome. Westward, this interval (the Sycamore Canyon Member) is truncated below an unconformity at the base of the lower member of the Fernando Formation (section *A–A′*, pl. 1). The Stern zone, of late Miocene age, is about 1,200 feet thick, but is developed only in the west end of the Hualde dome area.

Daily field production declined steadily from a peak in 1917, when less than 100 wells produced about 10,400 barrels, to a low production in 1934, when about 60 wells produced about 1,600 barrels. English (1926, p. 84–85) stated that the decline was fairly rapid and attributed it in part to water flooding due to defective completion practices; he noted that top, intermediate, and bottom waters were present. In 1934, discovery of the Miocene "A" and Stern zones initiated an increase in production that was as high as 7,500 barrels per day from 230 wells in 1952, declining to about 3,286 barrels per day in

1967 from 271 wells. Total production of the field for 1967 was 1,182,800 barrels, and cumulative production at the end of 1967 was 91,708,300 barrels from a maximum of 1,175 acres, an average of 78,049 barrels per acre.

LEFFINGWELL OIL FIELD

Leffingwell oil field is a small elongate field that has no surface relief; it is located in the center of the map area (pl. 4). The discovery well was completed in January 1946 and produced 162 barrels per day from a depth of 6,880–6,913 feet in the upper Lewis zone of the lower member of the Fernando Formation (fig. 17). This well was abandoned 4 months later, after production had declined to 13 barrels per day of oil and 16 barrels per day of water. In September 1946 the same well was deepened and flowed 145 barrels per day from a depth of 7,600–7,660 feet in the lower Lewis zone near the base of the lower member of the Fernando Formation. After 2 years, production from this zone had declined to 2 barrels per day, and the well was shut down and sold. In March 1953 a second well was completed and produced 196 barrels per day from the upper Miocene lower Woodward zone, at a depth of 8,486–8,657 feet. By 1967, 13 producing wells had been completed, which produced a total of about 17,700 barrels of oil in that year. At the end of 1967 cumulative production for the field was about 730,700 barrels from 125 acres, and average of 5,846 barrels per acre.

The main structural feature of the field is a gently east-plunging anticlinal nose that is closed at the west by a north-trending fault of pre-Pliocene age (Gaede, 1958). The field is notable in that drilling here and at La Mirada has demonstrated the presence of middle Miocene volcanic rock on the flanks of the Coyote Hills trend, whereas they have apparently been removed from the crest in this area (section *A–A′*, and *E–E′*, pls. 1, 2).

LA MIRADA OIL FIELD (ABANDONED)

The La Mirada field is in the southeast quarter of the Whittier quadrangle on the south flank of the Coyote Hills structural trend. The discovery well was completed in February 1946 and produced 268 barrels per day from a depth of about 11,900 feet in the Librown zone in the uppermost part of the Soquel Member of the Puente Formation. The zone is about 500 feet thick, about 20 acres in area, and produced about 25,250 barrels of oil before being abandoned in 1954. Peak production of 53 barrels per day was in 1946.

The oil is trapped beneath the base of the Fernando Formation, which overlies the Puente and older strata with angular discordance (section *D–D′*, pl. 2).

WEST BUENA PARK OIL FIELD (ABANDONED)

The West Buena Park field, near the south center of the map area, has no surface relief and was a one-well field. It was discovered in September 1944, and produced 135 barrels of oil per day from the 130-foot-thick Heath zone, at a depth of about 11,000 feet. The oil accumulated in a stratigraphic trap beneath an erosional unconformity at the base of the Fernando Formation on the northwest extremity of the Anaheim nose. Peak production was 45 barrels per day in 1945. The field was abandoned in 1950 after producing 51,000 barrels from about 10 acres.

SUMMARY AND OUTLOOK

Of the total amount of oil produced in the map area through 1966, 73 percent has come from the lower member of the Fernando Formation, 23 percent from Yorba Member of the Puente Formation, less than 2 percent each from the Sycamore Canyon and Soquel Members of the Puente, and less than one-half percent from the Topanga Formation (table 5). In the onshore Los Angeles basin as a whole, more than 57 percent of the cumulative production through 1961 was from rocks of early Pliocene age, and more than 41 percent from rocks of late Miocene age. The proportion of oil from upper Miocene rocks has increased since that time because of recent deep discoveries in the central and west Los Angeles area. The high proportion of oil from early Pliocene strata in the map area is due chiefly to the very thick section of lower Pliocene reservoir rocks at Santa Fe Springs (fig. 17).

The Yorba Member is not commonly productive in the northeastern part of the basin, but in the downthrown block of the Whittier fault zone and locally along the Coyote Hills trend, the Yorba Member contains oil in unusually thick coarse-grained lenses of

TABLE 5.—*Cumulative production of oil fields in the La Habra and Whittier quadrangles through 1967 by geologic unit*

[Data from Conservation Committee of California Oil Producers (1968)]

Formation	Member	Cumulative production (1000 bbl)	Percentage of total	Fields in which unit produces
Fernando	Lower	860,688.1	72.8	West Buena Park, East and West Coyote, Leffingwell, West Sansinena, Santa Fe Springs, Whittier.
Puente	Sycamore Canyon.	22,463.0	1.9	East Coyote, Leffingwell, Rideout Heights, East and West Sansinena, Santa Fe Springs, Whittier.
Do	Yorba	274,338.1	23.2	Brea-Olinda, East and West Sansinena, Santa Fe Springs.
Do	Soquel	21,284.9	1.8	Brea-Olinda, East Coyote, La Mirada, Turnbull.
Topanga		3,775.8	.3	Puente Hills.
Total		1,182,549.9	100.0	

sandstones ("B" and "C" sands at Brea Canyon, Central zone at Whittier) that are concentrated along the fault zone (Scribner, 1958; Woodward, 1958).

Oil is produced from the Soquel Member of the Puente Formation in the following fields: Richfield (east of the present map), East Coyote, Brea Canyon, and Sansinena. Along the Whittier fault the Soquel is deeply buried, intensely faulted, and has relatively low permeabilities. So far as is known, the Soquel has not been completely penetrated at the Santa Fe Springs or Whittier fields.

Although the Topanga Formation is clearly identified as the reservoir from which oil is produced in the old Puente Hills field (Scribner, 1958), the gravity of the oil, 25° API (American Petroleum Institute), suggests that it migrated upward from upper Miocene or younger strata in the downthrown block of the Whittier fault. (See section *G–G′*, pl. 2.) The Topanga has been rather thoroughly tested in many parts of the eastern Puente Hills, and although some shows of oil have been reported, no commercial accumulations have been found (Durham and Yerkes, 1964, p. 42). Throughout the Puente Hills the Topanga Formation consists of well-cemented low-porosity indurated siltstone, sandstone, and pebbly sandstone; in the map area, it is underlain by volcanic or basement rock and, locally, by nonmarine strata of the Sespe Formation. Hence it does not contact any older potential source rocks.

Recently discovered oil pools or "oil-producing zones" in the map area have been entirely in long-established oil fields, especially in sandstone lenses in the Puente Formation in the downthrown block of the Whittier fault zone. Oil has also been produced recently from equivalent sandstones at Santa Fe Springs and West Coyote, but these sandstones have not been important producers in those fields.

The inferred buried structure west of Whittier (section *B–B′*, pl. 2) is based on incomplete, scanty data from relatively few wells. This area, and that southwest of the Santa Fe Springs oil field, must be considered as marginally potential until they have been more completely explored.

Total annual production from fields in the map area declined by nearly 2 million barrels between 1961 and 1966 despite significant new production at Whittier and institution of water-flooding at West Coyote and Whittier. Water production exceeds oil production in all the fields but Sansinena; at Santa Fe Springs and West Coyote, water exceeds oil production by more than 10 to 1, and at East Coyote and Whittier by more than 2 to 1.

The possibility for any future increase in production from the map area appears to depend chiefly on new discoveries in areas west of Whittier and southwest of Santa Fe Springs, on deeper pool developments at Whittier and Santa Fe Springs, and on the success of secondary recovery programs.

EXPLORATORY WELLS

All exploratory wells and selected producing wells drilled in the La Habra and Whittier quadrangles prior to June 30, 1968, are given in table 6, and where records are adequate, the inferred geologic sequence penetrated is given.

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*

[All wells abandoned dry holes unless otherwise stated under "Remarks." Parentheses under "Location" indicate projected section in unsurveyed areas. Symbols for geologic units: Qal=young alluvium, Qao=old alluvium, Qlh=La Habra Formation, Qch=Coyote Hills Formation, Qsp=San Pedro Formation, Qu=undivided Quaternary deposits, Tfu=upper member of Fernando Formation, Tfl=lower member of Fernando Formation, Td=diabasic intrusive rocks, Tp=Puente Formation undivided, Tpsc=Sycamore Canyon Member of Puente Formation, Tpy=Yorba Member of Puente Formation, Tps=Soquel Member of Puente Formation, Tpl=La Vida Member of Puente Formation, Tt=Topanga Formation, Tv=extrusive and pyroclastic igneous rocks, Tvs=Vaqueros and Sespe Formations undifferentiated, Kjs=unnamed greenschist]

Map No. (pl. 4)	Operator	Well	Location			Year begun	Altitude (ft)	Total depth (ft)	Geologic information		Remarks (depths in ft)
			Sec.	T. (S.)	R. (W.)				Interval (ft)	Unit	
1	Abraham, Michael	Bloomfield Community 1.	30	3	11	1956	67	13,675	0–1,085 1,085–3,100 3,100–9,040 9,040–13,675	Qu Qsp Tfu Tfl	See section *C–C′*, pl. 2.
2	Aeco Corp	Rideout Heights Community 1.	(17)	2	11	1955	415	8,574	0–1,550 1,550–3,150 3,150 3,150–8,574	Tpsc Tpy Whittier fault Tp	Produces from 1,614 to 1,862; bottoms 1,575 ft S. at 7,756 subsea; see section *B–B′*, pl. 2.
3	Albercalif Petroleums, Ltd	Accarius 1	(32)	2	11	1952	175	5,200	0–1,110 1,110–2,100 2,100–5,200	Qu Tf Tfl	
4	American Oilfields Co	McComber 1	26	3	11	(?)	100	5,295	No data		
5	Anchor Petroleum Co	Hudson 1	(19)	2	10	1927	720	4,824	0–767 767–2,368 2,368–4,824	Tfl Tpsc Tp	Data from Daviess and Woodford (1949).
6	Anglin Development Co	Fallis 1	(29)	2	11	1934	155	1,210	No data		
7	Arden Oil Co., Inc	Rowland 1	(15)	2	10	1930	422	3,330	No data		
8	Arc-Bee Oil Syndicate No. 1	1	(7)	3	11	pre-1925	112	4,845	No data		

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location Sec.	T. (S.)	R. (W.)	Year begun	Altitude (ft)	Total depth (ft)	Geologic information Interval (ft)	Unit	Remarks (depths in ft)
9	Are-Bee Oil Syndicate No. 2	21	(7)	3	11	pre-1925	111	3,768	No data		
10	do	22	(36)	2	12	1922	136	3,475	No data		
11	Artesia Oil Co	Benson 1	25	3	12	1922	67	5,236	Bottoms in Tfu		
12	Associated Piping & Engineering Co.	Simmons 1	(1)	3	11	1945	257	5,469	0–1,070	Qu	See section *D–D'*, pl. 2.
									1,070–2,630	Tfu	
									2,630–5,469	Tfl.	
13	Atlantic Oil Co	Butterworth 1	(5)	3	11	1953	166	5,100	No data		
14	do	Meyer 1	(8)	3	11	(?)	154	8,056	No data		
15	do	Meyer 1–A	(8)	3	11	1952	153	8,282	0–1,000±	Qu	
									1,000±–2,260	Tfu	
									2,260–7,940	Tfl	
									7,940–8,282	Tpsc	
16	Atlantic Richfield Oil Corp	Broderick 1	(17)	2	11	1926	320	6,475	No data		Shows reported: 2,593–2,638.
17	do	Edwards 1	15	3	10	1953	309	9,591	0–150±	Qao	Redrilled 5,913 to 6,410 and produced small amount of oil; see section *G–G'*, pl. 2.
									150±–470	Qlh	
									470–985	Qch	
									985–1,195	Qsp	
									1,195–2,785	Tfu	
									2,785–6,062	Tfl	
									6,062–6,230	Tpy	
									6,230–8,432	Tps	
									8,432–9,240	Tpl	
									9,240–9,380	Tv	
									9,380–9,546	Tt(?)	
									9,546–9,591	Tvs	
18	do	Flood Control 1	(14)	2	12	1946	167	9,255	0–1,578	Qu	
									1,578–2,285	Tfu	
									2,285–8,075	Tfl	
									8,075–9,255	Tpsc	
19	do	Mayberry 1	(5)	3	11	1929	165	8,745	No data		
20	Atlas Productions, Inc	Community 1–1	(17)	2	11	1946	273	3,450	0–480 (fault)	Qao, Tpsc	
									480–3,450	Tfl	
21	do	Grey 1	(17)	2	11	1944	324	4,974	(Same as well 228)		Redrilled to 3,412.
22	Axis Petroleum Co	W. R. Rowland 1	(21)	2	10	1942	690	2,468	40–800	Tfl	Data from Daviess and Woodford (1949).
									800–1,380	Tpsc	
									1,380–2,424	Tpy	
									2,424–2,468	Tps	
23	Bandini Petroleum Co	Norswing 1	(7)	3	11	pre-1925	125	5,208	No data		
24	Barnsdall Oil Co	Emery Trust 1 Redrill.	25	3	11	1949	192	11,469	0–150(?)	Qao	Directed hole; bottoms 750 ft N. 36° W. at about 11,300 subsea; see section *E–E'*, pl. 2.
									150(?)–420(?)	Qlh	
									420(?)–725(?)	Qch	
									725–2,408	Qsp	
									2,408–7,925	Tfu	
									7,925–11,270	Tfl	
									11,270–11,469	Tt(?)	
25	Barry Oil Co	Rowland 1	(14)	2	10	1942	440	2,423	0–150(?)	Qal, Tpy	Produced small amount of oil from 1,160 to 1,170.
									150(?)–2,423	Tps	
26	Bastanchury, Gaston	1	30	3	10	1926	200	5,580	No data		
27	Behr, C. B., Oil Syndicate	1	(1)	3	12	1923	121	4,039	No data		
28	Bell Petroleum Co	Bell 100	(6)	3	11	1937	150	11,314	0–900(?)	Qu	Producing well; see section *A–A'*, pl. 1.
									900(?)–1,940	Tfu	
									1,940–7,115	Tfl	
									7,115–9,270	Tpsc	
									9,270–11,314	Tpy	
29	do	Bell 107	(6)	3	11	1949	152	13,541	0–900(?)	Qu	Produces from 7,310 to 7,904; deepest test of Santa Fe Springs oil field; see section *A–A'*, pl. 1.
									900(?)–1,962	Tfu	
									1,962–7,113	Tfl	
									7,113–9,280	Tpsc	
									9,280–11,750	Tpy	
									11,750–12,400	Tps	
									12,400–13,541	Tpl(?)	
30	do	Bell 112	(31)	2	11	1957	157	7,997	No data		
31	Bell View Oil Syndicate	Pellissier 1	(17)	2	11	1942	388	1,655	No data		Shows at 1,146 to 1,150.
32	Bender Oil Operations	Mayo 1	(30)	2	10	1953	924	6,785	0–1,420	Tpsc	
									1,420–2,470	Tpy	
									2,470–3,442	Tps	
									3,442–5,345	Tpl	
									5,345–6,785	Tt	
33	Bernard Oil Co	1	(36)	2	12	1923	137	2,000	No data		
34	Bernstein, M. T	Millard 1	25	3	12	1934	68	6,020	Bottoms in Tfu		
35	B. G. T. Oil Co	Marbles 1	(5)	3	11	(?)	158	(?)	No data		
36	do	Marbles 1–A	(5)	3	11	(?)	158	(?)	No data		
37	do	Marbles 1–B	(5)	3	11	(?)	158	(?)	No data		
38	Bidart Oil Co	Rowland 1	(15)	2	10	1932	420	3,220	No data		
39	Bishop, Bradford	Flood Control District 1.	14	2	12	1961	165	7,936	0–2,830	Qu, Tfu	Directed hole below 1,300; see well 18 for similar section.
									2,830–7,936	Tfl	
40	Blanton, Gendron, and Cook.	56	(1)	3	12	pre-1925	124	4,825	No data		
41	Brady 8 Well Syndicate	1	(8)	3	11	pre-1925	151	5,340	No data		
42	Brady 8 Well Syndicate No. 2	1	(8)	3	11	pre-1925	145	4,020	No data		
43	Brea Cañon Oil Co	47	1	3	10	1929	590	7,344	0–750	Tfu	
									750–5,504	Tfl	
									5,504–7,344	Tpsc	
44	Buena Vista Co	1	(27)	2	10	(?)	815	(?)	No data		
45	Burbank Oil Co	Crittenden 1	(26)	2	12	1923	142	4,988	Bottoms in Tfu		
46	Butler, C. R	1	(14)	2	10	1935	430	4,133	0–250	Qal, Tpy	See section F–F', pl. 2.
									250–2,205	Tps	
									2,205–4,098	Tpl	
									4,098–4,133	Tv	
47	California Petroleum Products Syndicate.	2	(15)	3	12	1923	89	2,170	No data		
48	do	2–A	(15)	3	12	1923	89	4,774	No data		
49	California Western Oil Co	Koolhaas 1	29	3	11	1954	63	3,102	0–1,190	Qu	
									1,190–3,050	Qsp	
									3,050–3,102	Tfu	
50	Calumet Gold Mines Co	Jones-Central 1	24	2	11	1946	930	1,276	No data		

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location			Year begun	Altitude (ft)	Total depth (ft)	Geologic information		Remarks (depths in ft)
			Sec.	T. (S.)	R. (W.)				Interval (ft)	Unit	
51	Cathcart, G. E.	Toler 1	7	3	10	1922	272	5,276	No data		
52	C.C. Oil Refining Co.	1	(12)	3	12	(?)	113	5,226	No data		
53	Central Oil Co.	Los Nietos 1	(31)	2	11	1921	157	4,926	No data		
54	Chanslor-Western Oil and Development Co.	East Whittier Community 1-1.	(34)	2	11	1943	275	5,571	0–925	Qu	See section *C–C′*, pl. 2.
									925–2,330	Tfu	
									2,330–5,571	Tfl	
55	do	East Whittier Community 4-1.	(2)	3	11	1944	241	6,133	0–850±	Qu	
									850±–2,445	Tfu	
									2,445–6,133	Tfl	
56	Chase, L. B., Oil Co.	1	(11)	3	12	1923	116	4,514	Bottoms in Tfu		
57	Clarke, E. A.	1	(17)	2	11	(?)	360	(?)	No data		
58	Cohearn Oil Co.	Hanlon 1	(5)	3	11	(?)	160	(?)	No data		
59	Commercial Refining Co.	Schumacher 1	(1)	3	12	(?)	119	5,276	No data		
60	Commonwealth Oil Co.	Hellman 1	16	2	11	1903	900	1,170	No data		
61	Continental Oil Co.	Buehler 1	14	2	11	1945	1,255	4,154	0–1,980 (fault)	Tpsc	
									1,980–2,120	Gouge and Td	
									2,120–2,870	Tpl	
									2,870–3,507	Tt	
									3,507–4,113	Tv	
									4,113–4,154	Tt	
62	do	Felix 1	(31)	2	11	1960	168	11,109	0–1,190	Qu	See section *B–B′*, pl. 2; directed hole; bottoms 920 S. and 400 E. at 10,920 subsea.
									1,190–3,300	Tfu	
									3,300–6,160 (fault)	Tfl	
									6,160–10,100	Tfl	
									10,100–11,109	Tpsc	
63	do	McNally 1	10	3	11	1928	145	5,913	No data		
64	do	Turnbull Community 6.	(13)	2	11	1945	920	3,892	0–617	Tpsc	
									617–2,200	Tpy	
									2,200–2,885	Tps	
									2,885–3,478	Tpl	
									3,478–3,545	Td	
									3,545–3,728	Tpl	
									3,728–3,892	"Gouge"	
65	Cooperative Petroleum Syndicate.	1	(7)	3	11	pre-1925	113	5,251	No data		
66	do	3	35	2	12	1923	145	5,485	Bottoms in Tfu		
67	Cornerstone Oil Co.	1	34	2	10	(?)	550	4,545	No data		
68	Coyote Hills Oil Co.	1	14	3	11	1910	200	3,030	No data		
69	do	2	14	3	11	(?)	175	4,725	No data		
70	Cox, M. A.	Arroues 1	15	3	10	1934	334	5,455	0–2,400	Qu, Tfu	Bottoms near base of Tfl.
									2,400–5,455	Tfl	
70–A	Crestmont Oil Co.	M.G.M. Unit 1	(36)	2	12	1968	138	7,200	No data		
71	Daly Oil Syndicate	(Unnamed)	(4)	3	11	pre-1925	158	5,005	No data		
72	Delta Projects, Ltd	Baker 1	(6)	3	11	1964	136	4,850	No data		
73	Derby Oil and Gas Co.	Butch 1	24	3	11	1952	260	3,828	No data		Produced small amount of oil.
74	Dietzel, J. W.	W. Y. Rowland 1	(14)	2	10	1930	425	4,908	0–150	Qal, Tpy	Geology from Daviess and Woodford (1949); produced small amount of oil from 2,450.
									150–2,180	Tps	
									2,180–3,825	Tpl	
									3,825–3,900	Td	
									3,900–4,045	Tpl	
									4,045–4,260	Tv	
									4,260–4,908	Tt(?)	
75	Dolke-Thomas Oil Syndicate.	Sheppard 1	27	3	10	1921	300	4,480	No data		
76	Dollar Oil Co.	Bellflower 11	23	3	12	1928	80	5,008	Bottoms in	Tfu	
77	Douglas Oil Co. of California.	East Coyote 1	24	3	10	1936	380	6,054	0–750±	Qu, Qsp	Produces from 3,516 to 3,885; see section *A–A′*, pl. 1.
									750±–1,900(?)	Tfu	
									1,900±–4,510	Tfl	
									4,510–5,245	Tpsc	
									5,245–6,054	Tpy	
78	Drillers Incorporated	1	22	2	11	1936	420	1,640	No data		
79	Dunlap-Apex and Associates.	Dunlap-Apex 1	7	3	10	1955	252	8,836	0–600±	Qlh	See section *E–E′*, pl. 2.
									600±–750±	Qch(?)	
									750±–1,145	Qsp	
									1,415–3,655	Tfu	
									3,655–8,325	Tfl	
									8,325–8,836	Tpsc	
80	East Santa Fe Oil Co.	Jalk 6	(6)	3	11	(?)	134	(?)	No data		
81	East Whittier Oil Co.	1	24	2	11	1900	1,010	1,540	No data		
82	do	2	24	2	11	1901	980	2,200	No data		
82–A	El Moro Oil Co.	1	14	2	11	1900(?)	1,220	1,395	No data		
83	do	2	14	2	11	1901	1,180	1,200	No data		
84	Empire Drilling Co.	Gaffey 1	14	2	12	1928	166	5,500	Bottoms in Tfu		
85	Epsilon Oil and Gas Co.	22–22	22	2	11	1965	510	3,682	No data		
86	Equitable Oil Syndicate	1	17	3	11	(?)	99	1,430	No data		
87	do	1–A	17	3	11	(?)	99	2,106	No data		
88	Erin Oil Co.	Freedman-North La Habra 1.	5	3	10	1954	410	8,750	0–582	Qao, Qlh	See section *E–E′*, pl. 2; redrilled 8,000± to 8,765.
									582–1,238	Qsp	
									1,238–3,700	Tfu	
									3,700–8,620	Tfl	
									8,620–8,750	Tpsc	
89	Farrington, H. J.	1	22	2	11	1946	860	1,874	0–1,874	Tpl	
90	Finch, G. B., Oil Co.	Hilo-Cinnabar 1	(1)	3	11	1944	294	8,759	0–905	Qu	
									905–2,560	Tfu	
									2,560–7,930±	Tfl	
									7,930±–8,759	Tpsc	
91	First National Petroleum Syndicate.	1	(35)	2	12	1923	134	5,005	Bottoms in Tfu		
92	Fisher-Gregg Oil Syndicate	1	(1)	3	12	1923	120	5,001	No data		
93	Flanders and Brown	Jesuran 2	(17)	2	11	1924	317	4,712	No data		
94	Foster, F.B., & Co.	52	(1)	3	12	pre-1925	126	4,780	No data		
95	do	61	(1)	3	12	pre-1925	124	4,802	No data		

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location Sec.	Location T. (S.)	Location R. (W.)	Year begun	Altitude (ft)	Total depth (ft)	Geologic information Interval (ft)	Geologic information Unit	Remarks (depths in ft)
96	Fowler Drilling Co.	Saunders 1	(13)	2	11	1944	481	4,030	0–2,210 2,210–3,344 3,344–3,631 3,631–4,030	Qu, Tfl Tpsc Tpy Tps	
97	Frick, W. J.	Badger 1	22	2	11	(?)	697	(?)	No data		
98	Fullerton Oil Co.	Burmudez 1	(31)	2	11	pre-1925	155	4,236	No data		
99	do	Gumgrove 1	(5)	3	11	(?)	158	(?)	No data		
100	do	La Habra 5	25	2	11	1948	770	2,325	No data		
101	General Exploration Co. of California.	Emery 1	24	3	11	1955	220	11,753	0–584 584–5,140 5,140–10,880 10,880–11,753	Qu, Qsp Tfu Tfl Tpu	May bottom in Tv.
102	do	Emery 2	19	3	10	1955	285	10,692	0–260(?) 260(?)–570 570–4,308 2,818(?) (fault) 4,308–9,745 9,745–10,684 10,684–10,692	Qch Qsp Tfu Tfl Tpu Tv	Shows 10,265 to 10,565; see section *E–E'*, pl. 2.
103	do	Emery-McNally 1	24	3	11	1957	160	9,662	0–628 628–3,865 3,865–9,662	Qu, Qsp Tfu Tfl	Bottoms near base Tfl.
104	Getty Oil Co.	1	(35)	2	12	1922	140	4,462	Bottoms in Tfu		
105	do	Benton 1	(4)	3	11	pre-1925	166	5,269	No data		
106	do	Brea Community 2-1.	11	3	10	1948	350	8,476	0–150± 150±–1,325 1,325–3,545 3,545–6,752 6,752–8,476	Qao Qlh Tfu Tfl Tpsc	See section *H–H'*, pl. 2; directionally redrilled as well 2-1A from 2,000 to 8,519; bottoms 1,423 ft S. and 1,282 ft W. at 8,030 subsea.
107	do	Hualde 7	23	3	10	1945	421	7,962	0–525± 525±–1,600 1,600–4,635 4,635–5,275 5,275–6,415 6,415–7,962	Qch, Qsp Tfu Tfl Tpsc Tpy Tps	Produces from 3,355 to 4.300; see sections *A–A'*, *H–H'*, pls. 1, 2.
108	do	Hualde 21	23	3	10	(?)	415	5,325	0–500 500–1,560 1,560–4,550 4,550–5,175 5,175–5,325	Qch, Qsp Tfu Tfl Tpy Tpy	Produces from 4,000 to 4,550; see section *A–A'*, pl. 2.
109	do	McNally 1	23	3	11	1921	227	4,270	No data		
110	do	McNally 1-36	22	3	11	1953	87	12,229	0–700(?) 700(?)–1,546 1,546–2,240± (fault). 2,240±–6,835 6,835–11,347 11,347–11,600 11,600–12,229	Qu Qsp Tfu Tfu Tfl Tpy Tps	Abandoned; produced from 11,878 to 11,958; see section *D–D'*, pl. 2.
111	do	McNally 1-K-2	23	3	11	1954	192	6,594	0–680 680–3,105 3,105–6,594	Qu, Qsp Tfu Tfl	Directed hole; bottoms 104 ft N. and 817 ft. E. at 6,219 subsea.
112	do	McNally 2	10	3	11	1924	215	6,018	No data		
113	do	Kellam 1	(27)	2	12	1929	144	5,001	Bottoms in Tfu		
114	do	Marland 1	(26)	2	12	1927	148	5,010	Bottoms in Tfu		
115	do	Stern Realty 12	22	3	10	1942	309	9,506	0–200± 200±–475± 475±–910 910–1,950 1,950–4,815 4,815–6,015 6,015–7,820 7,820–8,365 8,365–8,846 8,846–9,506	Qlh Qch Qsp Tfu Tfl Tpy Tps Tpl Tt Tvs	Produces from 5,360 to 6,435; deepest test of East Coyote oil field; see section *A–A'*, pl. 2.
116	Gilbert Petroleum Corp.	Doty 1	(7)	3	11	pre-1925	124	5,320	No data		
117	Gilbert Petroleum Interests Inc.	1	(7)	3	11	pre-1925	129	4,861	No data		
118	Globe Petroleum Co.	Del Eau 1	(1)	3	12	(?)	122	3,976	No data		
119	Grunwell Oil Corp.	1	(5)	3	11	pre-1925	161	4,731	No data		
120	Gulf Oil Corp.	Buena Park Core Hole 1.	27	3	11	1935	63	1,000	No data		
121	do	Newgate Unit A-1	(9)	3	11	1956	160	9,556	0–820 820–3,287 3,287–8,365 8,365–9,556	Qu Tfu Tfl Tpsc	Produces from 8,156 to 9,045; directed hole; bottoms 304 ft N. and 888 ft W. at 9,276 subsea; see sections *A–A'*, *C–C'*, pls. 1, 2
122	do	Newgate Unit B-1	(9)	3	11	1957	125	9,499	0–893 893–2,872 2,872–8,555 8,555–9,499	Qu Tfu Tfl Tpsc	Directed hole; bottoms 1,105 ft W. at 9,127 subsea; see section *C–C'*, pl. 2; redrilled 5,500 to 8,976; bottoms 1,691 ft N. 62° W. at 8,370 subsea.
123	do	Orchardale Unit A-1.	10	3	11	1951	214	10,089	0–150± 150±–960 960–3,150 3,150–8,162 8,162–9,530 9,530–10,089	Qao Qu Tfu Tfl Tpsc Tpy	See section *A–A'*, pl. 1.
124	Hale, J. M.	1	24	3	10	pre-1934	350	3,655	No data		
125	Hamilton & Sherman	Union Stewart Fee 54-10.	10	3	10	1954	351	8,027	0–130± 130±–1,035 1,035–1,190 1,190–1,625 1,625–3,685 3,685–6,685 6,685–7,718 7,718–8,027	Qao Qlh Qch Qsp Tfu Tfl Tpsc Tpy	See section *G–G'*, pl. 2.

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location Sec.	Location T. (S.)	Location R. (W.)	Year begun	Altitude (ft)	Total depth (ft)	Geologic information Interval (ft)	Geologic information Unit	Remarks (depths in ft)
126	Hansen, Melvin	Dragna 1	(24)	2	10	1940	584	3,227	0–300± 300±–3,227	Tps Tpl	See section *H–H′*, pl. 2.
127	do	Hansen 2	(24)	2	10	1943	640	1,104	No data		
128	Hanson, L. A	Associated Telephone 1.	(32)	2	11	1953	153	4,825	Bottoms in Tfl		
129	Hart and Hayes	1	(30)	2	10	1902	990	1,700	No data		
130	Hartman, S. L	Campos 1	(31)	2	11	1922	155	5,278	No data		
131	Hathaway Co	Finck 1	12	3	11	1954	247	10,267	0–950 950–2,750 2,750–7,885 7,885–8,744 8,744–10,267	Qu Tfu Tfl Tpsc Tpy	See section *D–D′*, pl. 2.
132	do	La Mirada 1	10	3	11	1948	197	5,830	0–896 896–3,205 3,205–5,830	Qu Tfu Tfl	
133	do	Rossi 1	(22)	2	12	1944	165	7,832	0–1,416 1,416–2,850 2,850–7,832	Qu Tfu Tfl	See section *A–A′*, pl. 1.
134	do	Strain 1	24	3	10	1947	360	5,766	0–1, 450 1,450–2,160 2,160–4,562 4,562–5,080 5,080–5,766	Qu, Qsp Tfu Tfl Tpsc Tpy	
135	do	Woodward 4	11	3	11	1955	235	8,744	0–810± 810±–2,804 2,804–7,845 7,845–8,744	Qu Tfu Tfl Tpsc	
136	do	Woodward Community K-1.	11	3	11	1945	237	12,184	0–825 825–2,860 2,860–7,855 7,855–8,824 8,824–10,190 10,190–10,950 10,950–11,222 (fault). 11,222–11,450 11,450–11,965 11,965–12,184	Qu Tfu Tfl Tpsc Tpy Tps Tpl Tv Tt Tvs	Produces from 7,599 to 7,658; deepest test of Leffingwell area; see section *D–D′*, pl. 2.
137	Holden Petroleum Corp	1	(5)	3	11	(?)	168	(?)	No data		
138	Hollandia Oil Association	1	30	3	11	1953	62	1,155	Bottoms in non-marine(?) Qu.		
139	Honolulu Oil Corp	Montebello core hole 1.	(14)	2	12	1936	197	4,302	Bottoms in Tfu		
140	Hudson, J. W	1	19	2	10	pre-1910	630	(?)	No data		
141	Humble Oil and Refining Co.	Whittier Opr. Unit One-1.	(20)	2	11	1963	241	7,754	0–445 445–575 575–2,210 2,210–6,745 6,745–7,754	Qu Qsp? Tfu Tfl Tpsc	Directed hole; bottoms 1,735 ft N. 72°32′ E. at 7,153 subsea; see section *B–B′*, pl. 2.
142	Illinois Oil Co	Unnamed	36	2	11	1901	560	2,300	No data		
143	Industrial Oil Syndicate 2	22	(7)	3	11	pre-1925	124	5,365	No data		
144	Industrial Oil Syndicate 4	42	(7)	3	11	1923	124	4,387	No data		
145	Jackson, R. W	Florey Community 1.	19	2	11	1929	162	1,449	Bottoms in Qu		
146	Julian, C. C	8	(1)	3	12	(?)	122	4,977	No data		
147	Kirkpatrick Syndicate 2	Wilshire-Gill 1	(6)	3	11	pre-1925	130	4,610	No data		
148	do	Wilshire-Gill 2	(6)	3	11	(?)	130	(?)	No data		
149	Kirkpatrick Syndicate 3	Huling 1	(7)	3	11	pre-1925	116	4,508	No data		
150	Klokke Investment Co	1	24	3	10	pre-1934	270	3,242	No data		
151	Klondyke Oil Co	Whittier 1	(9)	3	11	1923	105	1,020	No data		
152	Laddie Boy	1	(1)	3	12	1923	123	4,572	No data		Well 2 drilled to unknown depth from same location.
153	LaHabra Midway Oil Co	2	5	3	10	pre-1910	460	(?)	No data		
154	do	Scott 1	5	3	10	1921	362	5,445	No data		
155	La Habra Oil Co	Golden Gate 1	(30)	2	10	1904	910	>2,000	No data		
156	do	New England 1	(30)	2	10	1900	800	400	No data		
157	do	New England 2	(30)	2	10	1901	1,000	1,000	No data		
158	do	New England 3	(30)	2	10	(?)	975	2,250	No data		
159	Lang Wall	5	16	2	11	1926	385	1,895	No data		
160	Lawrence Santa Fe Oil Co	Owen 1	(7)	3	11	pre-1925	112	3,200	No data		
161	Lehigh, J. V	1	(30)	2	10	1920	975	2,067	No data		
162	do	2	(30)	2	10	(?)	1,000	(?)	No data		
163	do	3	(30)	2	10	(?)	1,020	(?)	No data		
164	Livingston Drilling & Development Co.	Dewey 1	(1)	3	11	1947	293	8,521	0–852 852–2,475 2,475–7,830 7,830–8,521	Qu Tfu Tfl Tpsc	See section *D–D′*, pl. 2.
165	Lomi Oil Corp	John Rowland 1	(14)	2	10	1943	458	3,246	No data		
166	Los Angeles Brewing Co	Jones Community 1	24	2	11	1945	935	2,745	0–660 660–1,590 1,590–2,100 2,100–2,745	Tpl Tv Gouge Tt	See section *C–C′*, pl. 2.
167	Los Nietos Valley Oil Co	Woodward 1	(29)	2	11	1942	158	3,586	No data		
168	Luneta Oil Co	1-A	(9)	3	11	(?)	150	(?)	No data		
169	do	Mayberry 1	(9)	3	11	pre-1925	155	3.423	No data		Redrilled to 5,060 ft. as well 2-A from same location.
170	Lytle, Robert S	Central 1	15	2	11	1942	700	5,912	0–5,283 5,283–5,912	Tpl Tt	
171	do	Core Hole A	15	2	11	1942	680	678	0–678	Tpl	
172	do	Core Hole B	15	2	11	1942	754	1,586	0–1,586	Tpl	
173	Marine Oil Co	Strong 1	24	3	12	1926	81	5,872	Bottoms in Tfu		
174	McKeon, J., and Associates	Carmenita 1	21	3	11	1938	76	9,157	0–2,700± 2,700±–7,190 7,190–9,157	Qu Tfu Tfl	

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TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location: Sec.	Location: T. (S.)	Location: R. (W.)	Year begun	Altitude (ft)	Total depth (ft)	Geologic information: Interval (ft)	Geologic information: Unit	Remarks (depths in ft)
175	McVicar, H. H.	Rowland Estate 1	(20)	2	10	1950	510	3,523	0–125(?)	Tfl	See section *D–D′*, pl. 2.
									125(?)–1,600	Tpsc	
									1,600–2,778	Tpy	
									2,778–3,523	Tps	
176	Midfield Oil Co.	Walker-Strong 1	(19)	2	11	1933	177	5,027	0–1,800(?)	Qu	
									1,800(?)–3,575	Tfu	
									3,575–5,027	Tfl	
177	Mobil Oil Corp.	H. B. Allen 1	(12)	3	12	1943	104	10,363	0–1,885	Qu	
									1,885–4,215	Tfu	
									4,215–4,860 (fault)	Tfl	
									4,860–5,897	Tfu	
									5,897–10,363	Tfl	
178	do	Clarke 1	(17)	2	11	1920	390	2,063	No data		
179	do	Community 14–1 Redrill.	(7)	3	11	1944	110	7,520	0–1,175	Qu	Directed hole; bottoms about 1,000 ft W. at about 7,295 subsea; see section B–B′, pl. 2.
									1,175–4,250 (fault)	Tfu	
									4,250–5,055	Tfu	
									5,055–7,520	Tfl	
180	do	Heath 1	34	3	11	1944	62	11,422	0–360±	Qao	Abandoned; produced from 11,000 to 11,130; see section E–E′, pl. 2.
									360±–820±	Qlh	
									820±–1,150	Qch	
									1,150–3,090	Qsp	
									3,090–8,309	Tfu	
									8,309–11,120	Tfl	
									11,120–11,422	Tv	
181	do	La Mirada Community 46–1.	16	3	11	1946	92	12,629	0–1,480	Qu, Qsp	Shows from 11,260 to 11,415; see section *C–C′*, pl. 2.
									1,480–5,290	Tfu	
									5,290–7,326± (fault).	Tfl	
									7,326±–11,020	Tfl	
									11,020–11,765	Tpsc	
									11,765–12,030	Tpy	
									12,030–12,275	Tps	
									12,275–12,557	Tt	
									12,557–12,629	Tv	
182	do	Librown 1	21	3	11	1945	70	12,600	0–800(?)	Nonmarine Qu	Abandoned; produced from 12,037 to 12,517; see section D–D′, pl. 2.
									800(?)–2,295	Qsp	
									2,295–6,750	Tfu	
									6,750–11,682	Tfl	
									11,682–11,885	Tpy	
									11,885–12,443	Tps	
									12,443–12,462	Tpl(?)	
									12,462–12,600	Tv	
183	do	McNally 1	22	3	11	1950	104	11,606	0–650	Nonmarine Qu	See section *D–D′*, pl. 2.
									650–1,130	Qsp	
									1,130–3,770	Tfu	
									3,770–6,850± (fault).	Tfl	
									6,850–±11,080	Tfl	
									11,080–11,185	Tpy	
									11,185–11,390	Tps	
									11,390–11,525	Tpl(?)	
									11,525–11,606	Tv	
184	do	Santa Fe 243	(5)	3	11	1955	158	10,640	0–900	Qu	
									900–1,975	Tfu	Produces from 8,051 to 8,287; see section *A–A′*, pl. 1.
									1,975–7,230	Tfl	
									7,230–9,300	Tpsc	
									9,300–10,640	Tpy	
185	Mohawk Oil Co.	McClintock 1	(31)	2	11	(?)	157	5,173	No data		
186	Montejo and Johnson	Clark 1	(17)	2	11	1924	275	3,739	No data		
187	Monterey Oil Co.	Monterey Fee 2	25	2	11	1956	765	7,289	0–1,075	Tfu	Redrilled from 1,900 to 5,325 and completed as producing well.
									1,075–2,664 (fault)	Tfl	
									2,664–3,608	Tpy	
									3,608–7,289	Tps	
188	Morning Star	(?)	27	2	10	(?)	600	(?)	No data		
189	Morton and Sons	William Rowland Estate 3–1.	(16)	2	10	1945	470	8,677	0–300	Qal and Tfl	See section *D–D′*, pl. 2.
									300–1,900	Tpsc	
									1,900–2,770	Tpy	
									2,770–3,935	Tps	
									3,935–5,511	Tpl	
									5,511–5,718	Td	
									5,718–6,267	Tpl	
									6,267–7,570	Tt	
									7,570–8,600	Tv	
									8,600–8,667	KJg(?)	
190	do	William Rowland Estate 3–2.	(16)	2	10	1946	415	7,522	0–950	Qal, Tfl	See section *D–D′*, pl. 2.
									950–2,300	Tpsc	
									2,300–2,910	Tpy	
									2,910–4,275	Tps	
									4,275–5,725	Tpl	
									5,725–5,955	Td	
									5,955–6,405	Tpl	
									6,405–7,522	Tt	
191	Nepple, Edward	Nepple-Thompson 1.	(31)	2	11	1957	145	11,092	0–950±	Qu	Produces from 9,360 to 9,500; see sections *A–A′*, *B–B′*, pl. 1, 2.
									950±–2,205	Tfu	
									2,205–7,765	Tfl	
									7,765–9,837	Tpsc	
									9,837–11,092	Tpy	
192	Nevada-Ventura Oil Syndicate.	1	16	3	11	1921	115	3,608	No data		
193	do	2–A	16	3	11	1922	115	5,449	No data		
194	Oakes and Combs, et al	Whittier 1	22	2	11	1954	580	5,207	0–3,250	Tpsc	
									3,250–5,207	Tpy	
195	Oak Ridge Oil Co.	Rossi 1	(22)	2	12	1923	167	5,060	No data		
196	Occidental Petroleum Corp.	Durbun, Ltd	6	3	10	1967	350	8,501	No data		See well 391 for equivalent section.

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location Sec.	Location T. (S.)	Location R. (W.)	Year begun	Altitude (ft)	Total depth (ft)	Geologic information Interval (ft)	Geologic information Unit	Remarks (depths in ft)
197	O'Donnell, J. E	Seward-Rideout 4	(17)	2	11	(?)	360	(?)	No data		
198	do	Seward-Rideout 7	(17)	2	11	(?)	420	(?)	No data		
199	Pacific Lighting Gas Supply Co.	Turnbull Community 2.	(13)	2	11	1941	548	3,792	0–1,910 1,910–3,100 3,100–3,250 3,250–3,460 3,460–3,690 (fault) 3,690–3,792	Tfl Tpsc Tpy(?) Tps(?) "Gouge" and Td. Tvs	See section *C–C'*, pl. 2; redrilled as producing well; bottoms 446 ft N. 49° E. at 3,229 subsea.
200	do	Turnbull Community 3.	(13)	2	11	1942	577	5,608	0–2,200 2,200–3,322 3,322–3,486 3,486–4,313 4,313–5,250 5,250 (fault)–5,485 5,485–5,608	Tfl Tpsc Tpy(?) Tps(?) Tpl "Gouge" and Td. Tvs	See section *C–C'*, pl. 2; redrilled as producing well; bottoms 790 ft S. 43° W. at 3,086 subsea.
201	Pacific States Petroleum Co.	1	(6)	3	11	(?)	123	4,017	No data		
202	Padre Oil Co	Tuffree 1–19	19	3	9	1951	327	7,050	0–580 580–1,300 1,300–4,215 4,215–4,585 4,585–6,760 6,760–7,050	Qu, Qch Tfu Tfl Tpsc Tpy Tps	See section *A–A'*, pl. 1.
203	Pasadena Oil Co	Fay-Granger 1	24	2	11	1911	726	(?)	No data		
204	Pasadena-Puente Oil Co	1	24	2	11	1921	550	2,700	No data		
205	Patterson Oil Co	1	15	3	10	(?)	323	>3,200	No data		
206	Petroleum Center Land Co.	Hawley 1–A	19	3	11	1922	77	4,625	Bottoms in Tfu		
207	Petroleum Midway Co., Inc.	Bell 1	(31)	2	11	(?)	165	4,231	No data		
208	Petroleum Products Syndicate.	1	14	3	11	1923	180	5,283	No data		
209	Petroleum Securities Co	Rideout 1	(17)	2	11	1927	335	4,968	No data		
210	Pike Drilling Co	Pike-Bolsa British-American Stern 1.	14	3	11	1945	198	5,598	0–2,560 2,560–5,598	Qu, Tfu Tfl	
211	Pomoco, Inc	Daisy 2	19	3	9	1957	325	3,982	0–400 400–780 780–1,400 1,400–3,982	Qao, Qlh Qch Tfu Tfl	See section *A–A'*, pl. 1.
212	Pray, Max	La Habra Community 1.	4	3	10	1953	486	7,700	0–868 868–1,265 1,265–3,645 3,645–7,635 7,635–7,700	Qlh Qsp Tfu Tfl Tpsc	See section *F–F'*, pl. 2.
213	Puente Hills Oil Co	1	(16)	2	10	1922	467	(?)	No data		
214	Raymond Oil Co	1	25	2	11	1901	790	2,269	No data		
215	Reed Gold Mines Co	Rowland 1	22	2	10	1956	525	2,591	0–120± 120±–2,132 2,132–2,591	Tpy Tps Tpl	See section *F–F'*, pl. 2.
216	Reid and Campbell	1	(1)	3	12	(?)	114	(?)	No data		
217	Rheem, R. S	Placentia Fruit Co. 1	25	3	10	1955	243	8,404	0–1,704 1,704–2,236 2,236–2,814 2,814–3,655 3,655–6,220 6,220–7,220 7,220–7,870 7,870–8,404	Qu, Qlh Qch Qsp Tfu Tfl Tpsc Tpy Tps	See section *H–H'*, pl. 2.
218	Ridge Hill Oil Co	Meyer 1	(8)	3	11	1954	148	6,383	0–1,092 1,092–2,380 2,380–6,383	Qu Tfu Tfl	
219	Ring Oil Co	Patterson 1	(6)	3	11	(?)	136	(?)	No data		
220	do	Petterson 6	(6)	3	11	(?)	138	(?)	No data		
221	Rio Grande Oil Co	Osborne 1	(34)	2	12	1928	134	5,149	Bottoms in Tfu		
222	Roth, J. H	1	(35)	2	12	(?)	133	(?)	No data		
223	Rothschild Oil Co	Chapman 1	26	3	10	1950	238	2,725	0–1,783 1,783–2,725	Qu, Qsp Tfu	
224	do	East Santa Fe Springs Community 1.	(10)	3	11	1946	203	5,788	0–944 944–3,230 3,230–5,788	Qu Tfu Tfl	See section *A–A'*, pl. 1.
225	do	Fouquet 1	(11)	3	11	1953	223	8,800	0–970 970–3,200 3,200–7,995 7,995–8,800	Qu Tfu Tfl Tpsc	
226	do	Lopicollo 1	12	3	11	1953	246	8,550	0–985 985–2,740 2,740–7,966 7,966–8,550	Qu Tfu Tfl Tpsc	See section *D–D'*, pl. 2.
227	do	Nuckols 1	(30)	2	10	1952	670	5,526	0–2,575 (fault) 2,575–3,000 3,000–4,930 4,930–5,526	Tfl Tpy Tps Tpl	Abandoned; produced from 4,210 to 5,022; see section *D–D'*, pl. 2.
228	do	Pellisier 5	(17)	2	11	1948	322	3,286	0–1,333 1,333–1,837 (fault) 1,837–3,286	Qu, Tpsc Tpy Tfl(?)	
229	do	Woodward 1	(11)	3	11	1953	232	8,700	0–875± 875±–3,175 3,175–7,880 7,880–8,700	Qu Tfu Tfl Tpsc	Abandoned producer from 8,200 to 8,300.
230	Rucker & Croul	Grazide 2	(22)	2	10	1930	565	2,188	0–1,888 1,888–2,188	Tps Tpl	See section *F–F'*, pl. 2.
231	Rucker, Smith, & Croul	1	(27)	2	10	1929	575	3,644	0–1,275 1,275–3,078 3,078–3,644	Qal, Tps Tpl Td	See section F–F', pl. 2.
232	Russell Oil Co	3	(1)	3	12	(?)	123	(?)	No data		
233	do	6	(1)	3	12	(?)	125	(?)	No data:		
234	Ryan and Morrow	1	(3)	3	11	1949	170	6,986	0–3,265 3,265–6,986	Qu, Tfu Tfl	

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location			Year begun	Altitude (ft)	Total depth (ft)	Geologic information		Remarks (depths in ft)
			Sec.	T. (S.)	R. (W.)				Interval (ft)	Unit	
235	Saint Anthony Oil Corp.	Barley 2	(32)	2	11	(?)	155	(?)	No data		
236	do	Mary Barley Community 1.	(32)	2	11	(?)	152	(?)	No data		
237	do	Smith-Mizener 1	4	3	11	1954	144	5,760	0–1,000±	Qu	
									1,000±2,765	Tfu	
									2,765–5,760	Tfl	
238	Santa Fe-Ball Oil Corp.	1	(12)	3	12	1923	109	4,725	No data		
239	Santa Fe Chief Oil Syndicate.	1	(35)	2	12	1923	142	2,809	Bottoms in Tfu		
240	Santa Fe Dome Oil Co.	Meyer 1	(8)	3	11	1923	146	4,500	No data		
241	Santa Fe Dome Oil Co. 2	1	(8)	3	11	1923	147	4,500	No data		
242	Santa Fe Springs Oil Syndicate 2.	3	(7)	3	11	pre-1925	130	5,069	No data		
243	Santa Fe Springs Oil Syndicate 3.	1	(7)	3	11	(?)	131	(?)	No data		
244	Scientific Oil Co.	1	21	3	11	1920	98	4,214	No data		
245	Seacoast Oil Co.	Wardman 1	3	3	10	1945	560	5,824	0–120±	Qao	See section *G–G′*, pl. 2.
									120±–2,850	Tfu	
									2,850–5,550	Tfl	
									5,550–5,824	Tpsc	
246	Security Land and Water Co.	Security 1	9	3	10	1940	300	5,185	No data		
247	Security Oil Syndicate	1	(7)	3	11	pre-1925	121	4,945	No data		
248	Sentinel Oil Co.	1	36	2	11	pre-1910	430	500±	No data		
249	Severns Drilling Co.	Armstrong 1	14	3	10	1950	314	4,300	0–963	Qu, Qsp	Begun in 1923 by Fisher Oil Co.
									963–2,406	Tfu	
									2,406–4,300	Tfl	
250	Shamrock Oil Co.	1	(8)	3	11	(?)	127	985	No data		
251	Shell Oil Co.	Bastanchury 1	28	3	10	1929	258	6,024	0–1,250(?)	Qu, Qlh	Core description only; see section *F–F′*, pl. 2.
									1,250(?)–2,250	Qch	
									2,250–2,800(?)	Qsp	
									2,800–3,450(?)	Tfu	
									3,450–6,024	Tfl	
252	do	Hart 1	14	2	11	1919	1,124	4,032	No data		
253	do	Menchego 6	(36)	2	10	1952	781	6,854	0–783	Qao, Td	See section *H–H′* pl. 2; directed hole; bottoms 1,670 ft N. 18° E. at 5,621 subsea.
									783–1,550 (fault)	Tpl	
									1,550–5,760 (fault)	Tpu	
									5,760–5,960	Td	
									5,960–6,130	Tt	
									6,130–6,854	KJs	
254	do	Menchego 6-Redrill	(36)	2	10			9,007	0–2,920	Same as original hole.	Produces from 1,720 to 1,992; directed hole; botttoms 1,617 ft N. and 269 ft E. at 7,968 subsea; see section *H–H′*, pl. 2.
									2,920–6,830 (fault)	Tp	
									6,830–7,712	Brecciated Tpy	
									7,712–8,500	Tpy	
									8,500–9,007	Tps	
255	do	Pansini 1	(23)	2	12	1945	186	9,310	0–734	Nonmarine Qu	Drilled to 5,516 by C. G. Willis.
									734–1,582	Qsp	
									1,582–2,440	Tfu	
									2,440–8,200±	Tfl	
									8,200±–9,310	Tpsc	
256	do	Pico 17-Redrill	2	3	10	1958	526	9,854	0–750±	Tfu	Directed hole; bottoms 1,483 ft N. and 12 ft E. at 8,998 subsea; section *H–H′*, pl. 2.
									750±–1,550	Fault gouge	
									1,550–2,500	Tfl	
									2,500–5,780	Tpsc	
									5,780–9,435	Tpy	
									9,435–9,854	Tps	
257	do	Puente A–1	(35)	2	10	pre-1926	1,100	4,526	0–820	Tpl	Produces from 2,523 to 2,998.
									820–2,000	Tt(?)	
									2,000–4,480	Tt	
									4,480–4,526	KJs	
258	do	Puente A–3	(35)	2	10	1949	1,090	5,010	0–885	Tpl	Producing well; see section *G–G′*, pl. 2.
									885–2,110	Tt(?)	
									2,110–4,457	Tt	
									4,457–5,010	KJs	
259	do	Puente A–6	(35)	2	10	1951	1,030	4,618	0–1,055	Tpl	Produces from 1,758 to 3,295; see section *G–G′*, pl. 2.
									1,055–1,285 (shear)	Td	
									1,285–2,270	Tt(?)	
									2,270–4,448	Tt	
									4,448–4,618	KJs	
260	do	Puente B–8	(35)	2	10	1950	750	8,098	0–150± (fault)	Tpl	Producing well; directed hole; bottoms 3,200 ft N. 5° E. at 6,148 subsea.
									150±–1,500± (fault).	Tpy	
									1,500±–3,400±	Tfl	
									3,400±–4,660±	Tpsc	
									4,660±–6,100	Tpy	
									6,100–7,870 (fault)	Tps	
									7,870–8,098	KJs	
261	do	Puente B–9	(34)	2	10	1950	650	7,205	0–60±	Qao	Producing well; directed hole, bottoms 428 ft N. and 241 ft E. at 7,147 subsea; see section *G–G′*, pl. 2.
									60±–1,960	Tfu	
									1,960–5,250	Tfl	
									5,250–7,205	Tp	
262	do	Puente D–2	(34)	2	10	1954	725	4,475	0–1,270± (fault)	Tpl	Produces from 3,460 to 4,080; directed hole, bottoms 945 ft N. and 300 ft E. at 3,590 subsea; see section *F–F′*, pl. 2.
									1,270±–1,835	Tfl	
									1,835–2,685	Tpsc	
									2,685–3,534	Tpy	
									3,534–4,270 (fault)	Tps	
									4,270–4,475	KJs	
263	do	Puente D–10	(34)	2	10	1955	986	5,954	0–950 (fault)	Tpl	Producing well; directed hole, bottoms 1,560 ft N. 20° E. at 4,373 subsea.
									950–2,370	Tf	
									2,370–4,870	Tpsc, Tpy	
									2,370–4,870	Tps	
									4,870–5,765 (fault)	Tps	
									5,765–5,954	KJs	

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location Sec.	Location T. (S.)	Location R. (W.)	Year begun	Altitude (ft)	Total depth (ft)	Geologic information Interval (ft)	Geologic information Unit	Remarks (depths in ft)
264	do	Puente Core Hole 2.	(27)	2	10	1951	735	3,316	0–2,663 2,663–3,255 3,255–3,316	Tpl Td Tpl(?)	
265	do	Slayden 1	(5)	3	11	pre-1925	158	4,995	No data		
266	do	Slusher 29	(6)	3	11	1956	129	10,157	0–950(?) 950(?)–2,165 2,165–7,630 7,630–9,650 9,650–10,157	Qu Tfu Tfl Tpsc Tpy	Producing well; directed hole, bottoms about 260 ft N. 9° E. at about 10,013 subsea; see section *B–B'*, pl. 2.
267	do	Stubbs 1	(11)	3	11	1925	219	5,937	No data		
268	do	Thompson 5	(31)	2	11	1923	153	3,960	No data		
269	Shively, N. O	1	23	2	10	1934	466	3,190	0–1,700 1,700–3,190	Qal, Tps Tpl	See section *G–G'*, pl. 2.
270	Sierra Petroleum Co	Lester-Cole 1	(2)	3	11	(?)	207	(?)	No data		
271	Signal Oil and Gas Co	Stern 1	11	3	11	1953	240	8,958	0–908 908–2,995 2,995–8,050 8,050–8,958	Qu Tfu Tfl Tpsc	Abandoned producer; bottoms near base of Tpsc.
272	do	Stern Realty 1	12	3	11	(?)	240	8,760	0–1,000± 1,000±–3,150± 3,150±–7,925 7,925–8,760	Qu Tfu Tfl Tpsc	Abandoned producer; bottoms near base of Tpsc.
273	Signal Petroleum Corp	Rowland 1	(14)	2	10	(?)	428	(?)	No data		
274	South Slope Oil Co	Childs 3	16	2	11	1926	520	3,907	No data		
275	Southwest Petroleum Syndicate.	Harris 1	(35)	2	12	1923	140	960	Bottoms in Qu		
276	Stall, C. C., Oil Association	1	(35)	2	12	1923	131	4,906	Bottoms in Tfu		
277	Standard Oil Co. of California.	(?)	12	3	11	pre-1925	295	>3,500	No data		
278	do	Anchor 2	22	2	11	1897	615	1,125	No data		
284	do	Carmenita Community 1.	(4)	3	11	1936	172	11,367	0–925(?) 925(?)–2,635 2,635–5,455(fault) 5,455–8,145 8,145–10,090 10,090–11,367 10,300±fault	Qu Tfu Tfl Tfl Tpsc Tpy 	See section *A–A'*, pl. 1.
285	do	Central Fee 49–A	15	2	11	1906	1,120	3,000	No data		Abandoned producer(?).
286	do	Central Fee 56	23	2	11	(?)	1,090	(?)	No data		
287	do	Central Fee 114	23	2	11	1948	900	7,664	0–1,250±(fault) 1,250±–4,550 4,550–7,664	Tpsc Tpy Tps	
288	do	Chapman 1	26	3	10	1913	345	3,735	0–2,600 2,600–3,735	Qu, Tfu Tfl	
289	do	Coyote 2–2	22	3	10	1914	380	3,290	No data		
290	do	Coyote 2–9	22	3	10	(?)	240	4,254	No data		
291	do	Coyote 2–16	22	3	10	(?)	305	6,925	0–325 325–670 670–1,825 1,825–4,775 4,775–4,975 4,975–6,030 6,030–6,925	Qch Qsp Tfu Tfl Tpsc Tpy Tps	Produces from 6,030 to 6,600; see section *A–A'*, pl. 1.
292	do	Coyote 2–19	22	3	10	1957	336	8,340	0–460 460–776 776–2,200 2,200–3,150±(fault) 3,150±–3,623 3,623–6,460 6,460–7,410 7,410–8,340	Qch Qsp Tfu Tfl Tfu Tfl Tpy Tps	Produces from 6,610 to 8,100; see section *G–G'*, pl. 2.
293	do	Culp Community 1	19	2	11	1924	167	5,766	0–2,375 2,375–4,430 4,430–5,766	Qu Tfu Tfl	
294	do	Donnelly 1	(31)	2	11	1921	165	4,409	No data		
295	do	Donnelly 2	(31)	2	11	1922	159	5,532	No data		
296	do	Emery 35	24	3	11	1919	375	4,681	No data		
297	do	Emery 87	13	3	11	1948	196	11,020	0–150(?) 150(?)–2,100 2,100–6,195 6,195–8,595 8,595–9,055 9,055–9,185 9,185–9,258 9,258–9,795 9,795–10,075 10,075–11,020	Qal, Qsp Tfu Tfl Tp Tv Tt Tv Tt Tv Tvs	Produces from 3,323 to 4,130; see section *A–A'*, pl. 2.
298	do	Emery 92	13	3	11	1952	450	12,048	0–570 570–2,085 2,085–6,290 6,290–8,210 8,210–9,255 9,255–10,800 9,610± fault 10,800–12,048	Qsp Tfu Tfl Tpu Tv Tt Tvs	Produces from 6,010 to 6,180; deepest test of West Coyote oil field; see section *A–A'*, pl. 1.
299	do	Emery 101	13	3	11	1958	202	4,222	No data		Redrilled from 4,222 to (?) as Emery 102.
300	do	German Community 1.	11	3	11	1947	193	10,304	0–804 804–2,900 2,900–7,815 7,815–8,656 8,656–10,015 10,015–10,190 10,190–10,304	Qu Tfu Tfl Tpsc Tpy Tps Tv	See sections *A–A'*, *D–D'*, pls 1, 2.

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location Sec.	Location T. (S.)	Location R. (W.)	Year begun	Altitude (ft)	Total depth (ft)	Geologic information Interval (ft)	Geologic information Unit	Remarks (depths in ft)
301	do	Gerrard Community 1.	11	3	11	1946	255	7,043	0–970	Qu	
									970–3,050	Tfu	
									3,050–7,043	Tfl	
302	do	Hadley Ranch 1	23	2	12	1925	162	5,900	Bottoms in Tfu		
303	do	Houghton Community 1-1.	(36)	2	12	1947	136	14,444	0–1,040	Qu	See section *A–A′*, pl. 1.
									1,040–2,985	Tfu	
									2,985–7,530	Tfl	
									7,530–7,860 (fault)	Tpu	
									7,860–8,090	Tfl	
									8,090–10,355	Tpsc	
									10,355–13,386	Tpy	
									13,386–14,444	Tps	
304	do	Leffingwell 1	11	3	11	1910(?)	198	5,913	No data		
305	do	McNally 2	24	3	11	1914	162	3,858	No data		
306	do	McNally 2-1	15	3	11	1922	135	5,702	No data		
307	do	McNally 4	24	3	11	1915	150	4,330	No data		
308	do	Murphy-Coyote 1	18	3	10	1907(?)	220	3,300	0–600	Qsp	Abandoned producer(?).
									600–2,045±	Tfu	
									2,045±–3,300	Tfl	
309	do	Murphy-Coyote 13	13	3	11	1914	220	(?)	No data		
310	do	Murphy-Coyote 126.	18	3	10		540	6,085	0–500(?)	Qch, Qsp	Produces from 5,360 to 6,085; see section *A–A′*, pl. 1.
									500(?)–2,320	Tfu	
									2,320–6,085	Tfl	
311	do	Murphy-Coyote 129.	18	3	10	1941	513	9,295	0–140±	Qch	Produces from 5,350 to 6,150; see section *A–A′*, pl. 1.
									140±–474	Qsp	
									474–2,100	Tfu	
									2,100–6,100	Tfl	
									5,725 fault		
									6,100–6,755	Tpsc	
									6,755–8,340	Tp	
									8,340–9,140	Tt	
									9,140–9,192	Tv	
									9,192–9,295	Tt	
312	Standard Oil Co	Murphy-Coyote 164	20	3	10	(?)	466	6,051	0–2,605	Qch, Qsp, Tfu.	Produces from 4,400 to 4,650; see section *A–A′*, pl. 1.
									2,605–6,015	Tfl (fault at 5,350).	
313	do	Murphy-Coyote 166	17	3	10	(?)	501	6,035	0–2,475	Qch, Qsp, Tfu.	Produces from 5,630 to 6,035; see section *A–A′*, pl. 2.
									2,475–6,035	Tfl (fault at 5,240).	
314	do	Murphy-Coyote 275	18	3	10	(?)	564	6,110	0–2,425	Qch, Qsp, Tfu.	Produces from 3,500 to 3,930; see section *A–A′*, pl. 1.
									2,425–6,110	Tfl (fault at 5,160).	
315	do	Murphy-Coyote 284	20	3	10	(?)	359	8,704	0–2,510	Qch, Qsp, Tfu.	Produces from 5,080 to 5,140; see section *A–A′*, pl. 1.
									2,510–6,745	Tfl (fault at 6,300).	
316	do	Murphy-Whittier 56	26	2	11	pre-1925	476	4,430	No data		
317	do	Murphy-Whittier 59	26	2	11	pre-1925	475	3,793	Bottoms in Tfl		
318	do	Murphy-Whittier 62	26	2	11	1943	675	8,033	0–3,662	Tfl	Produces from 1,308 to 2,708; see section *C–C′*, pl. 2.
									3,662–5,870	Tpsc	
									5,870–7,825	Tpy	
									7,825–8,033	Tps	
319	do	Murphy-Whittier 71	26	2	11	1954	560	3,150	No data		
319a	do	Murphy-Whittier 101	26	2	11	1961	426	10,950	0–6,030	Tfl	Directed hole; bottoms approx. 700 ft. N. 48° W.
									6,030–7,796	Tpsc	
									7,796–9,260	Tpy	
									9,260–10,370	Tps	
									10,370–10,950	Tpl	
320	do	Newsom Community 1.	(36)	2	12	1946	138	10,319	0–1,280	Qu	
									1,280–3,275	Tfu	
									3,275–5,775 (fault)	Tfl	
									5,775–7,825	Tfl	
									7,825–10,125	Tpsc	
									10,125–10,319	Tpy	
321	do	Otto Community 1	(35)	2	11	1963	136	8,777	0–4,975	Qu, Tfu	Directed hole; bottoms approx. 1600 ft. N 73° W.
									4,975–8,777	Tfl	
322	do	Pacific Community 1.	26	3	11	1954	68	11,651	0–350	Qao	Directed hole; bottoms 1,088 ft N. and 2,228 ft E. at 11,238 subsea; see section E–E′, pl. 1.
									350–790	Qlh	
									790–1,100	Qch	
									1,100–2,880	Qsp	
									2,880–8,090	Tfu	
									8,090–11,160	Tfl	
									11,160–11,240	Tv	
									11,240–11,375	Tt(?)	
									11,375–11,651	Tvs	
323	do	Patten 1	(17)	2	11	1924	410	6,053	No data		
324	do	Ravera Community 1.	21	3	11	1956	75	13,145	0–635	Nonmarine Qu	See section C–C′, pl. 2.
									635–2,435	Qsp	
									2,435–7,114	Tfu	
									7,114–11,970	Tfl	
									11,970–12,385	Tpsc	
									12,385–12,804	Tpy	
									12,804–12,940	Tps	
									12,940–13,145	Tv	
325	Standard Oil Co. of California.	Rowland Estate 1	(21)	2	10	1949	667	4,340	0–240	Tpsc	See section *E–E′*, pl. 2.
									240–1,927	Tpy	
									1,927–3,720	Tps	
									3,720–4,340	Tpl	
326	do	Sanchez 1-A	(32)	2	11	1922	157	4,789	No data		
327	do	Santa Fe Community 1.	10	3	11	1919	222	4,918	No data		

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location			Year begun	Altitude (ft)	Total depth (ft)	Geologic information		Remarks (depths in ft)
			Sec.	T. (S.)	R. (W.)				Interval (ft)	Unit	
328	do	Stern Community 2-1.	7	3	10	1946	308	11,725	0-1,060 1,060-3,165 3,165-8,085 8,085-9,195 9,195-10,345 10,345-10,940 10,940-11,155 11,155-11,725	Qu, Qsp Tfu Tfl Tpsc Tpy Tps Tv Tt	See section *E-E'*, pl. 2.
329	do	Sunny Hills 1	21	3	10	1953	310	7,897	0-495 495-1,045 1,045-2,545 2,545-6,414 6,414-7,765 7,765-7,897	Och Qsp Tfu Tfl Tpy Tps	See sections *A-A'*, pl. 1.
330	do	Toler 1	12	3	11	about 1910	273	4,611	No data		
331	do	Watson 1	(1)	3	12	pre-1925	126	5,374	No data		
332	do	Watson 2	(1)	3	12	pre-1925	128	4,772	No data		
333	do	Williams 1	9	3	10	1911	307	3,885	No data		
334	do	W. L. Houghton 1	(36)	2	12	1923	136	5,613	No data		
335	do	W. L. Houghton 1	(36)	2	12	1923	135	4,670	No data		
336	do	W. L. Houghton 2	(36)	2	12	1923	132	4,672	No data		
337	do	W. L. Houghton 3	(36)	2	12	1924	136	4,665	No data		
338	do	Wolfskill 2	(31)	2	11	1923	155	4,780	No data		
339	do	Woodhead 1	(7)	3	11	1947	118	3,998	No data		
340	do	Yriarte 1	14	3	10	1913	336	4,300	0-2,450± 2,450±-4,300	Qu, Tfu Tfl	
341	Stanton and Bingham	1	(25)	2	10	1921	603	4,238	Bottoms in Tpl		
342	State Co	W. Y. Rowland 1	(14)	2	10	1941	437	2,767	0-2,040 2,040-2,767	Qal, Tps Tpl	
343	Steele, H	Kenwood 1	(16)	2	10	1943	470	4,272	0-1,918 1,918-2,776 2,776-3,928 3,928-4,272	Qu, Tpsc Tpy Tps Tpl	
344	Sterling and Trousdale	McNally 1	23	3	11	1953	183	9,146	0-700± 700±-3,187 3,187-9,146	Qu, Qsp Tfu Tfl	
345	Strain, Thomas	1	24	3	10	(?)	325	4,202	No data		
346	Sunhill Petroleum Co	Edwards 1	16	3	10	1952	305	6,605	No data	See well 201	
347	Sunray-Midcontinent Oil Co.	F. H. Bixby Ranch Co. 1.	20	2	10	1961	550	3,476	0-355 355-1,761 1,761-2,997 2,997-3476	Qu, Tfl Tpsc Tpy Tps	
348	Superior Oil Co	1	22	3	12	1922	83	4,420	Bottoms in Tfu		
349	Syndicate Petroleum Co		11	3	10	1910	370	4,200	No data		Precise location unknown.
350	Taylor, W. H	Taylor-Calif. Royalties 1.	(17)	2	11	(?)	272	(?)	No data		
351	Temple, W. P. Oil Co	1	(30)	2	10	(?)	876	2,030	No data		Abandoned producer.
352	do	2	(30)	2	10	1922	970	(?)	No data		Abandoned producer.
353	do	Prouty 1	(30)	2	10	pre-1925	960	4,789	No data		
354	Texaco, Inc	Clanton 1	28	3	11	1961	69	12,561	0-2,830 2,830-7,624 7,624-12,224 12,224-12,561	Qu, Qsp Tfu Tfl Tp	
355	do	Denny 1	16	2	11	1924	485	3,807	No data		
356	do	McNally A-1	22	3	11	1941	106	9,000	0-1,250 1,250-6,100± (fault?). 6,100±-6,875 6,875-9,000	Qu, Qsp Tfu Tfu Tfl	
357	do	McNally A-2	15	3	11	1942	112	9,658	0-1,455 1,455-3,530 3,530-9,658	Qu, Qsp Tfu Tfl	
358	do	McNally A-3	22	3	11	1943	122	9,535	0-1,432 1,432-3,575 3,575-9,535	Qu, Qsp Tfu Tfl	Possible fault at 8,000±.
359	do	McNally Ranch 1	23	3	11	1951	135	10,280	0-1,020 1,020-3,405 3,405-8,225 (fault?) 8,225-10,280	Qu, Qsp Tfu Tfl Tfl	
360	do	McNally Ranch B-10-1.	(10)	3	11	1952	215	10,000	0-930 930-3,200 3,200-8,006 8,006-9,232 9,232-10,000	Qu Tfu Tfl Tpsc Tpy	Produced small amount oil from 8,820 to 8,935.
361	do	Neal 1	28	3	11	1923	68	5,495	Bottoms in Tfu		
362	do	Pico 1	(13)	2	12	1933	171	2,334	Bottoms in Tfu		
363	do	Shimizu 1	(15)	2	12	1953	187	9,206	0-1,575 1,575-2,440 2,440-7,892 7,892-9,206	Qu, Qsp Tfu Tfl Tpsc	
364	Top Notch Syndicate 1	1	(8)	3	11	1923	155	4,850	No data		
365	Triangle Oil Co	1	(7)	3	11	(?)	115	(?)	No data		
366	Triangle Oil Syndicate 2	1	(7)	3	11	pre-1925	116	3,450	No data		Drilled No. 2 (located 350 ft E.) to 1,122 in 1923.
367	Tricolor Oil Co	1	(26)	2	12	1923	144	800	Bottoms in Qu		
368	Tri-field Producing Syndicate.	Tri-field 1	(7)	3	11	1922	108	2,660	No data		
369	Tristate Oil Co	1	8	3	10	1910(?)	315	5,500	No data		
370	Troy Petroleum Co	1	27	2	10	1945	585	2,925	0-1,540 1,540-2,925	Qal, Tps Tpl	See section *F-F'*, pl. 2.
371	Tureco Oil Co	Cole 1	(29)	2	11	1930	162	5,586	Bottoms in Tfl		
372	Union Oil Co. of California	Bastanchury 2	16	3	10	1910	370	660	No data		
373	do	Bastanchury 3	16	3	10	1911(?)	330	5,128	No data		
374	do	Bastanchury 4	21	3	10	1913	340	>4,076	No data		Abandoned producer.
375	do	Bastanchury 6	28	3	10	1916	225	5,233	No data		

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location: Sec.	Location: T. (S.)	Location: R. (W.)	Year begun	Altitude (ft)	Total depth (ft)	Geologic information: Interval (ft)	Geologic information: Unit	Remarks (depths in ft)
376	do	Carmenita Community 1.	(5)	3	11	1952	167	8,445	0–970 970–2,394 2,394–8,038 8,038–8,445	Qu Tfu Tfl Tpsc	See section *A–A'*, pl. 1.
377	do	Carmenita Community 2.	(8)	3	11	1953	167	5,400	No data		
378	do	Downey Community 1.	(2)	3	12	1922	118	4,968	Bottoms in Tfu		Reported to have produced small amount of oil.
379	do	Flood Control 1	36	2	12	1921	145	5,245	No data		Reported to have produced small amount of oil.
380	do	Fullerton Fee 1	25	2	11	1947	750	4,865	0–595 595–2,115 (fault) 2,115–2,900 2,900–4,865	Tfu Tfl Tpy Tps	Producing well.
381	do	Fullerton Heights 1	22	3	10	1934	300	6,040	0–250 250–500 500–4,600(?) 4,600–6,040	Qch Qsp Tfu Tfl	See section *G–G'*, pl. 2.
382	do	Hill 40	10	3	10	1928	340	5,635	0–3,310 3,310–5,635	Qu, Tfu Tfl	Core description only.
383	do	Hole 3	23	3	10	(?)	381	4,500	0–460 460–1,575 1,575–4,430 4,430–4,500	Qsp Tfu Tfl Tpsc	Produces from 3,050 to 3,600; see section *A–A'*, p. 1.
384	do	Hole 25	23	3	10	(?)	315	4,875	0–570 570–1,650 1,650–4,600 4,600–4,875	Qch, Qsp Tfu Tfl Tpsc	Produces from 3,150 to 3,360; see section *A–A'*, pl. 1.
385	do	Hole 56–14	14	3	10	1957	345	8,601	0–220± 220±–450± 450±–845 845–2,012 2,012–5,087 5,087–6,995 6,995–8,485 8,485–8,601	Qlh Qch Qsp Tfu Tfl Tpsc Tpy Tps	See section *H'–H'*, pl. 2.
386	do	McNally 1	22	3	11	1926	110	5,608	No data		
387	do	Meyer 1	(9)	3	11	pre-1921	172	>4,600	No data		
388	do	Meyer 2	(9)	3	11	pre-1921	176	(?)	No data		
389	do	Meyer 5	(4)	3	11	1921	174	4,977	No data		
390	do	Meyer 11	(5)	3	11	(?)	163	(?)	No data		
391	do	Milhaus 1	6	3	10	1956	348	9,866	0–586 586–993 993–2,765 2,765–8,870 8,870–9,866	Qu Qsp Tfu Tfl Tpsc	Directed hole; bottoms 2,142 ft N. and 348 ft W. at 8,724 subsea.
392	do	Mineral Springs 1	25	2	11	1911	750	3,230	No data		
393	do	Mineral Springs 3	25	2	11	1948	815	4,415	No data		Produced small amount oil from above 2,606.
394	do	Orchardale Community 1.	10	3	11	1930	218	6,375	No data		
395	do	Probe Hole 1	29	2	10	1962	740	(?)	No data		
396	do	Puente Farms 1	15	2	11	1954	1,060	6,977	0–6,292 6,292–6,632(fault?) 6,632–6,977	Tpl Tv Tpl	Hole directed southward below 1,770; bottom location not known.
397	do	Sanchez 1	(32)	2	11	1921	162	4,150	No data		
398	do	San Juan 1	17	3	10	1909	280	4,695	No data		
399	do	Sansinena 1–B–15	30	2	10	1945	875	4,336	0–200(?) 200(?)–1,692 1,692–2,300(fault) 2,300–2,775 2,775–4,336	Tpy Tps Tpl Tpy Tps	Producing well; see section D–D', pl. 2.
400	do	Sansinena 8–B–2	(33)	2	10	1953	870	5,211	0–640± 640±–1,400± 1,400±–4,710 4,710–5,211	Tpl Td Tpl and Tt KJs	Directed hole; bottoms 1,320 ft N. 10° E. at 4,059 subsea; redrilled as producing well.
401	do	Sansinena 9–B–2	(33)	2	10	1952	538	8,003	0–175(?) 175(?)–500(?) 500(?)–2,800± 2,800±–4,035± 4,035±–6,000± (fault). 6,000±–6,785± 6,785±–8,003	Qlh Qsp Tfu Tfl Tpu Tpu Tps	Producing well; directed hole; bottoms 4,200 ft N. at 5,875 subsea; see section *F–F'*, pl. 2.
402	do	Sansinena 10–A–3	(32)	2	10	1954	578	9,586	0–2,270 2,270–7,427 7,427–8,400± 8,400±–9,345 (fault). 9,345–9,586	Tfu Tfl Tpsc Tpy Tps	See section *E–E'*, pl. 2.
403	do	Sansinena 12 Redrill.	(31)	2	10	1940	535	5,698	0–1,300± 1,300±–3,775 (fault). 3,775–4,555 4,555–5,236 5,236–5,698	Tfu Tfl "Gouge" Tpy Tps	Directed hole; bottoms 1,987 ft N. and 435 ft E. at 4,680 subsea.
404	do	Sansinena 14	(32)	2	10	1944	575	4,700	No data		
405	do	Sansinena 16	(33)	2	10	1945	775	4,267	0–1,075 1,075–2,412 2,412–4,012 4,012–4,267	Tpl Fault zone Tpsc Tpy	See section *E–E'*, pl. 2.
406	do	Sansinena 16 Redrill.	(33)	2	10	1945	775	5,984	0–2,500 same as original hole. 2,500–3,295 3,295–3,970 (fault) 3,970–4,445 (fault) 4,445–4,645 4,645–5,340 5,340–5,984	 Tpsc Tpy Tfl Tpsc Tpy Tps	Directed hole; bottoms 1,161 ft N. and 33 ft W. at 4,991 subsea; see section *E–E'*, pl. 2.

TABLE 6.—*Exploratory and selected producing wells drilled in the La Habra and Whittier quadrangles before June 30, 1968*—Con.

Map No. (pl. 4)	Operator	Well	Location Sec.	Location T. (S.)	Location R. (W.)	Year begun	Altitude (ft)	Total depth (ft)	Geologic information Interval (ft)	Geologic information Unit	Remarks (depths in ft)
407	do	Stern 1	12	3	11	1954	220	8,977	0–1,105 1,105–3,230 3,230–8,463 8,463–8,977	Qu, Qsp Tfu Tfl Tpsc	
408	do	Sunny Hills 2–1	21	3	10	1951	286	8,008	0–1,050 1,050–2,200 2,200–5,850 5,850–6,170 6,170–8,008	Qu, Qsp Tfu Tfl Tpy Tps	Abandoned producer from 5,325 to 5,500.
409	do	Sunny Hills 1(?)	9	3	10	(?)	274	4,608	No data		
410	do	Sunny Hills 2	22	3	10	1944	315	6,522	0–100± 100±–300± 300±–600± 600±–1,085 1,085–2,300 2,300–5,175 5,175–6,000 6,000–6,522	Qao Qlh Qch Qsp Tfu Tfl Tpy Tps	Produces from 6,048 to 6,359; see section *A–A′*, pl. 1.
411	do	Sunny Hills 3	21	3	10	1945	296	6,982	0–110± 110±–300± 300±–625± 625±–1,160 1,160–2,460 2,460–5,940 5,940–6,982	Qao Qlh Qch Qsp Tfu Tfl Tpy	Abandoned; produced from 6,370 to 6,474; see section *A–A′*, pl. 1.
412	do	Sunny Hills 5	21	3	10	1950	311	6,571	0–110± 110±–300± 300±–660 660–1,140 1,140–2,380 2,380–5,364 5,364–6,300 6,300–6,571	Qao Qlh Qch Qsp Tfu Tfl Tpy Tps	Producing well; see section *A–A′*, pl. 1.
413	do	Toussau 5	22	3	10	(?)	290	7,537	0–120± 120±–350± 350±–590 590–925 925–2,200 2,200–5,240 5,240–6,135 6,315–7,537	Qao Qlh Qch Qsp Tfu Tfl Tpy Tps	Produces from 5,300 to 6,425; see sections *A–A′*, *G–G′*, pls. 1, 2.
414	do	Toussau 9	22	3	10	(?)	321	6,400	0–150± 150±–450± 450±–700± 700±1,080 1,080–2,260 2,260–5,600 5,600–6,400	Qao Qlh Qch Qsp Tfu Tfl Tps	Produces from 5,450 to 6,400; see section *G–G′*, pl. 2.
415	do	Union Apex Norwalk-Bellflower 2.	23	3	12	1968	84	16,008	0–3,405 3,405–10,730 10,730–16,008	Qu Tfu Tfl	Directed hole; bottoms 6,194 ft. N. 57½° E. at 14,228 subsea. See section *B–B′*, pl. 2.
416	do	Whittier City 2–1	22	2	11	1957	585	5,200	0–5,200	Tps, Tpl	Directed hole; bottoms 484 ft S. and 1,700 ft W. at 4,202 subsea; three directed redrills.
417	do	Whittier Crude 1	22	2	11	1951	586	6,069	No data		
418	do	Whittier Crude 2	22	2	11	1951	525	5,431	No data		
410	U.S. Oil and Royalties Corp.	Well 2	(12)	3	12	(?)	114	(?)	No data		
420	do	Well 2B	(12)	3	12	(?)	113	(?)	No data		
421	do	Well 3	(12)	3	12	1923	113	2,750	No data		
422	Utility Petroleum Co	Strain 1	24	3	10	1954	340	4,506	0–1,625 1,625–2,125 2,125–4,506	Qu, Qsp Tfu Tfl	
423	Valley View Oil Co	Home Lease 1	22	2	11	1937	535	1,046	No data		
424	Wardman, A	Boeseke 4	(1)	3	12	(?)	127	(?)	No data		
425	Webb Oil Co	Lawrence 1	(19)	2	10	1954	490	4,637	No data		
425a	Westates Exploration Co	S. E. Santa Fe Springs 1.	16	3	11	1969	106	11,589	0–5,594 5,594–9,105 9,105–11,365 11,365–11,589	Qu, Tfu Tfl Tp Tt	Directed hole; bottoms 4,541 ft N. 79½° E. at 10,470 subsea. See section *C–C′*, pl. 2.
426	Westates Petroleum Co	Bowen 1	24	3	10	1937	270	4,057	0–250 250–560 560–750 750–1,850 1,850–4,057	Qao, Qlh Qch Qsp Tfu Tfl	See section *A–A′*, pl. 1.
427	Whittier Consolidated Oil Co.	1, Sec. 16	16	2	11	1901	620	1,300	No data		
428	do	2, Sec. 16	16	2	11	1901	520	1,000	No data		
429	do	1, Sec. 24	24	2	11	1901	517	900	No data		
430	do	2, Sec. 24	24	2	11	1901	510	940	No data		
431	Whittier Crude Oil Co	11	22	2	11	pre-1911	600	1,970	No data		
432	Whittier-Des Moines Oil Co	1	7	3	10	pre-1911	245	3,634	No data		
433	Whittier-Grand Oil Co	1	25	2	11	pre-1910	790	900	No data		
434	Whittier Oil and Development Co.	1	24	2	11	1903	680	2,200	No data		
435	Willard, E. T	Lawrence Estate 1	(29)	2	10	1949	950	3,006	0–405 405–2,005 2,005–3,006	Tpsc Tpy Tps	See section *D–D′*, pl. 2.
436	Willis, C. G	Butler Community 1.	(15)	2	12	1947	182	6,239	Bottoms in Tfl		
437	Willmore and Hazzard	3	(5)	3	11	1922	157	1,036	No data		
438	Wilshire Oil Co., Inc	1	(6)	3	11	(?)	130	(?)	No data		
439	do	1	(8)	3	11	1920	160	5,089	No data		
440	do	5	(7)	3	11	pre-1925	132	4,766	No data		
441	Woodmar Partnership	Union Fee 1	14	2	11	1952	800	687	0–687	Tpsc	
442	World Petroleum Co	Blythe 1	22	3	12	(?)	82	5,008	No data		

FOSSIL LOCALITIES

Table 7 presents collector, identifier, and location for the fossil faunas listed in tables 1, 2, and 3. Many of the collections have been reported by general age range (Daviess and Woodford, 1949) but not by fauna, or have been reported by fauna but not plotted relative to a geologic map (Kundert, 1952, p. 14–15); others, such as those made during this investigation, have not been reported previously. The collections from the San Pedro Formation, made chiefly by C. W. Hoskins in the West Coyote area, are especially significant because no other such extensive collections of San Pedro age fossils are known from areas so far inland from the present shoreline.

TABLE 7.—*Collectors, identifiers, and locations of fossil collections from the La Habra and Whittier quadrangles*

[Foraminifera listed in tables 1, and 2 mollusks, table 3. Map numbers prefixed by CJK indicate reference to Kundert (1952, p. 15.) Parentheses under "Location" indicate projected section in unsurveyed areas]

Map reference No. (pl. 4)	Collected by—	Identified by—	Location
Foraminifera collections			
m-1	R. F. Yerkes	P. B. Smith	Sec. (31), T. 2 S., R. 10W.: artificial cut 1,350 ft N. and 1,575 ft E. of SW. cor., La Habra quad.
m-2 (CJK-F33)	C. J. Kundert	M. L. Natland	Sec. (31), T. 2 S., R. 10W.: artificial cut 2,070 ft S. and 750 ft E. of NW. cor., La Habra quad.
m-3 (CJK-F34)	do	do	Sec. (31), T. 2 S., R. 10W.: artificial cut 1,150 ft S. and 3,550 ft E. of NW. cor., La Habra quad.
m-4 (CJK-F35)	do	do	Sec. (31), T. 2 S., R. 10W.: artificial cut 1,115 ft S. and 4.200 ft E of NW. cor., La Habra quad.
m-5 (CJK-F39)	do	do	Sec. (32), artificial cut 3,250 ft N. and 925 ft E. of SW. cor., La Habra quad.
m-6	H. F. Simmons.	P. B. Smith	Sec. (32), T. 2 S., R. 10W.: 1,000 ft N. and 850 ft E. of SW. cor., La Habra quad.
m-7	do	do	Sec. (32), T. 2 S., R. 10W.: 1,860 ft N. and 325 ft E. of SW. cor., La Habra quad.
m-8	do	do	Sec. (32), T. 2 S., R. 10W.: artificial cut 4,200 ft N. and 780 ft W. of SE. cor., La Habra quad.
m-9	do	do	Sec. (32), T. 2 S., R. 10W.: artificial cut 3,600 ft N. and 2,200 ft E. of SW. cor., La Habra quad.
m-10	do	do	Sec. (33), T. 2 S., R. 10 W.: 3,680 ft N. and 800 ft E. of SW. cor., La Habra quad.
m-11	do	do	Sec. (33), T. 2 S., R. 10 W.: 3,620 ft N. and 1,850 ft E. of SW. cor., La Habra quad.
m-12 (CJK-F40)	C. J. Kundert	M. L. Natland	Sec. (33) T. 2 S., R. 10 W.: artificial cut 1,000 ft S. and 900 ft E. of NW. cor., La Habra quad.
m-13 (CJK-F27)	do	do	Sec. 25, T. 2 S., R. 11 W.: 1,475 ft N. and 2,100 ft E. of SW. cor., La Habra quad.
m-14 (CJK-F14)	do	do	Sec. 26, T. 2 S., R. 11 W.: 885 ft S. and and 213 ft E. of NW. cor., Whittier quad.
m-15 (CJK-F15)	do	do	Sec. 26, T. 2 S., R. 11 W.: artificial cut 1,860 ft N. and 2,810 ft E. of SW. cor., Whittier quad.
m-16 (CJK-F16)	do	do	Sec. 26, T. 2 S., R. 11 W.: artificial cut 2,300 ft N. and 2,925 ft E. of SW. cor., Whittier quad.
m-17 (CJK-F17)	do	do	Sec. 26, T. 2 S., R. 11 W.: 1,050 ft S. and 2,025 ft W. of NE. cor., La Habra quad.
m-18 (CJK-F18)	do	do	Sec. 26, T. 2 S., R. 11 W. artificial cut 1,400 ft S. and 1,520 ft W. of NE. cor., La Habra quad.
m-19 (CJK-F19)	do	do	Sec. 26, T. 2 S., R. 11 W.: 675 ft S. and 860 ft W. of NE. cor., La Habra quad.
m-20 (CJK-F20)	do	do	Sec. 26, T. 2 S., R. 11 W.: 525 ft S. and 1,090 ft W. of NE. cor., La Habra quad.
m-21 (CJK-F21)	do	do	Sec. 26, T. 2 S., R. 11 W.: 1,775 ft S. and 1,400 ft W. of NE. cor., La Habra quad.
m-22 (CJK-F22)	do	do	Sec. 26, T. 2 S., R. 11 W.: artificial cut 1,800 ft S. and 1,015 ft W. of NE. cor., La Habra quad.
m-23 (CJK-F23)	do	do	Sec. 26, T. 2 S., R. 11 W.: artificial cut, 2,185 ft S. and 1,550 ft W. of NE. cor., La Habra quad.
m-24 (CJK-F24)	do	do	Sec. 26, T. 2 S., R. 11 W.: artificial cut 2,650 ft S. and 125 ft W. of NE. cor., La Habra quad.
m-25 (CJK-F8)	do	do	Sec. 35, T. 2 S., R. 11 W.: artificial cut 450 ft S. and 3,110 ft E. of NW. cor., Whittier quad.
m-26 (CJK-F28)	do	do	Sec. 35, T. 2 S., R. 11 W.: artificial cut 625 ft. S. and 2,145 ft E. of NW. cor., Whittier quad.
m-27 (CJK-F29)	do	do	Sec. 36, T. 2 S., R. 11 W.: 800 ft. S. and 525 ft E. of NW. cor., La Habra quad.
m-28 (CJK-F30)	do	do	Sec. 36, T. 2 S., R. 11W.: 0 ft S. and 1,000 ft. W. of NE. Cor., La Habra quad.
m-29 (CJK-F31)	do	do	Sec. 36, T. 2 S., R. 11 W.: 2,600 ft S. and 2,300 ft E. of NW. cor., La Habra quad.
m-30 (CJK-F32)	do	do	Sec. 36, T. 2 S., R. 11 W.: 1,950 ft S. and 300 ft W. of NE. cor., La Habra quad.
m-31	R. F. Yerkes	P. B. Smith	Sec. 1, T. 3 S., R. 10 W.: artificial cut 810 ft S. and 800 ft E. of NW. cor., La Habra quad.
m-32	G. J. Bellemin	do	Sec. (17) T. 2 S., R. 10 W.: 2,380 ft N. and 2,280 ft E. of SW. cor., La Habra quad.
m-33	do	do	Sec. (17), T. 2 S., R. 10 W.: 2,075 ft N. and 2,430 ft W. of SE cor., La Habra quad.
m-34	do	do	Sec. (19), T. 2 S., R. 10 W.: 1,125 ft S. and 2,280 ft E. of NW. cor., La Habra quad.
m-35 (CJK-F5)	C. J. Kundert	M. L. Natland	Sec. 23, T. 2 S., R. 11 W.: 200 ft N. and 800 ft E. of SW. cor., Whittier quad.
m-36 (CJK-F6)	do	do	Sec. 23, T. 2 S., R. 11 W.: artificial cut 60 ft N. and 175 ft E. of SW. cor., Whittier quad.
m-37 (CJK-F7)	do	do	Sec. 26, T. 2 S., R. 11 W.: artificial cut 460 ft S. and 865 ft E. of NW. cor., Whittier quad.
m-38 (CJK F9)	C. J. Kundert	M. L. Natland	Sec. 23, T. 2 S., R. 11 W.: 475 ft N. and 900 ft E. of SW. cor., Whittier quad.
m-38A	W. H. Holman	J. W. Ruth	Sec. 23, T. 2 S., R 11 W.: artificial cut 1,140 ft N. and 1,440 ft E. of SW. cor., Whittier quad.
m-39 (CJK-F10)	C. J. Kundert	M. L. Natland	Sec. 23, T. 2 S., R. 11 W.: 200 ft N. and 1,650 ft E. of SW. cor., Whittier quad.
m-40 (CJK-F11)	do	do	Sec. 26, T. 2 S., R. 11 W.: artificial cut 125 ft S. and 1,570 ft E. of NW. cor., Whittier quad.
m-41 (CKJ-F13)	do	do	Sec. 26, T. 2 S., R. 11 W.: 225 ft S. and 2,675 ft E. of NW. cor., Whittier quad.
m-42	R. F. Yerkes	P. B. Smith	Sec. 1, T. 2 S., R. 10 W.: artificial cut 1,660 ft S. and 1,850 ft E. of NW. cor., La Habra quad.
m-43	S. N. Daviess	do	Sec. 13, T. 2 S., R. 11 W.: 575 ft N. and 60 ft E. of SW. cor., La Habra quad.
m-44 (CJK F36)	C. J. Kundert	M. L. Natland	Sec. 22, T. 2 S., R. 11 W.: 1,340 ft S. and 425 ft E. of NW. cor., Whittier quad.
m-44a	W. H. Holman	J. W. Ruth	Sec. 23, T. 2 S., R. 11 W.: artificial cut 1,400 ft N. and 2,325 ft E. of SW. cor., Whittier quad.
m-44b	do	do	Sec. 23, T. 2 S., R. 11 W.: artifiical cut 1,530 ft N. and 2,435 ft E. of SW. cor., Whittier quad.
m-45 (CJK F12)	C. J. Kundert	M. L. Natland	Sec. 23, T. 2 S., R. 11 W.: 400 ft N. and 2,150 ft W. of SE. cor., La Habra quad.
m-46	G. J. Bellemin	P. B. Smith	Sec. (22), T. 2 S., R. 10 W.: 250 ft N. and 475 ft E. of SW. cor., La Habra quad.
m-47	do	do	Sec. (29), T. 2 S., R. 10 W.: 1,400 ft S. and 100 ft W. of NE. cor., La Habra quad.

TABLE 7.—*Collectors, identifiers, and locations of fossil collections from the La Habra and Whittier quadrangles*—Continued

Map reference No. (pl. 4)	Collected by—	Identified by—	Location
Foraminifera collections—Continued			
m-48	S. N. Daviess	do	Sec. (30), T. 2 S., R. 10 W.: 1,715 ft S. and 250 ft E. of NW. cor., La Habra quad.
m-49	D. van Sickle	P. J. Smith	Sec. (33) T. 2 S., R. 10 W.: 4,125 ft N. and 1,925 ft E. of SW. cor., La Habra quad.
m-50	H. F. Simmons.	do	Sec. (33) T. 2 S., R. 10 W.: 4,200 ft N. and 2,100 ft E. of SW. cor., La Habra quad.
m-51	do	do	Sec. (33) T. 2 S., R. 10 W.: artificial cut 4,280 ft N. and 1,700 ft E. of SW. cor., La Habra quad.
m-52	R. F. Yerkes	do	Sec. (35) T. 2 S., R. 10 W.: artificial cut 115 ft N. and 1,900 ft W. of SE. cor., La Habra quad.
m-53	S. N. Daviess	do	Sec. 23, T. 2 S., R. 11 W.: artificial cut 1,970 ft S. and 735 ft E. of NW. cor., Whittier quad.
m-54	do	do	Sec. 23, T. 2 S., R. 11 W.: 2,140 ft N. and 600 ft E. of SW. cor., Whittier quad.
m-55	do	do	Sec. 23, T. 2 S., R. 11 W.: 1,800 ft N. and 1,275 ft W. of SE. cor., La Habra quad.
m-56	do	do	Sec. 23, T. 2 S., R. 11 W.: 850 ft N. and 2,540 ft E. of SW. cor., Whittier quad.
m-56a	W. H. Holman.	J. W. Ruth	Sec. 23, T. 2 S., R. 11 W.: artificial cut 1,650 ft N. and 2,325 ft E. of SW. cor., Whittier quad.
m-57 (CJK-F25)	C. J. Kundert.	M. L. Natland.	Sec. 25, T. 2 S., R. 11 W.: 680 ft S. and 1,900 ft W. of NE. cor., La Habra quad.
m-58 (CJK-F26)	do	do	Sec. 25, T. 2 S., R. 11 W.: 2,325 ft S. and 975 ft W. of NE. cor., La Habra quad.
m-59	S. N. Daviess.	P. B. Smith	Sec. 25, T. 2 S., R. 11 W.: 1,000 ft S. and 1,000 ft W. of NE. cor., La Habra quad.
m-60	R. F. Yerkes	do	Sec. 1, T. 3 S., R. 10 W.: artificial cut 1,800 ft S. and 2,450 ft E. of NW. cor., La Habra quad.
m-61	G. J. Bollemin.	do	Sec. 27, T. 2 S., R. 10 W.: 2,350 ft N. and 2,200 ft E. of SW. cor., La Habra quad.
m-62 (CJK-F37)	C. J. Kundert	M. L. Natland.	Sec. (29), T. 2 S., R. 10 W.: artificial cut 400 ft N. and 860 ft E. of SW. cor., La Habra quad.
m-63	S. N. Daviess	P. B. Smith	Sec. 25, T. 2 S., R. 11 W.: 2,500 ft S. and 650 ft W. of NE. cor., La Habra quad.
m-64	do	do	Sec. (30), T. 2 S., R. 10 W.: 4,450 ft S. and 435 ft W. of NE. cor., La Habra quad.
m-65 (CJK-F38)	C. J. Kundert	M. L. Natland.	Sec. (30), T. 2 S., R. 10 W.: 1,200 ft N. and 3,550 ft E. of SW. cor., La Habra quad.
m-66	R. F. Yerkes	P. B. Smith	Sec. (34), T. 2 S., R. 10 W.: artificial cut 2,280 ft N., and 960 ft W. of SE. cor., La Habra quad.
m-67	do	do	Sec. (35), T. 2 S., R. 10 W.: artificial cut 3,535 ft N. and 1,080 ft W. of SE. cor., La Habra quad.
m-68	do	do	Sec. (35), T. 2 S., R. 10 W.: artificial cut 2,840 ft N. and 1,100 ft E. of SW. cor., La Habra quad.
m-69	S. N. Daviess	do	Sec. 14, T. 2 S., R. 11 W.: 330 ft N. and 2,000 ft E. of SW. cor. Whittier quad.
m-70	do	do	Sec. 14, T. 2 S., R. 11 W.: 160 ft N. and 1,985 ft E. of SW. cor., Whittier quad.
m-71	do	do	Sec. 14, T. 2 S., R. 11 W.: 460 ft N. and 1,680 ft W. of SE. cor., La Habra quad.
m-72 (CJK-F3)	C. J. Kundert	M. L. Natland.	Sec. 22, T. 2 S., R. 11 W.: 625 ft S. and 1,875 ft E. of NW. cor., Whittier quad.
m-73	S. N. Daviess	P. B. Smith	Sec. 22, T. 2 S., R. 11 W.: artificial cut 460 ft S. and 2,140 ft W. of NE. cor., Whittier quad.
m-74	do	do	Sec. 23, T. 2 S., R. 11 W.: 850 ft S. and 425 ft E. of NW. cor., Whittier quad.
m-75	do	do	Sec. 23, T. 2 S., R. 11 W.: 80 ft S. and 1,375 ft E. of NW. cor., Whittier quad.
m-76	do	do	Sec. 23, T. 2 S., R. 11 W.: 1,660 ft S. and 1,800 ft E. of NW. cor., Whittier quad.
m-77	do	do	Sec. 23, T. 2 S., R. 11 W.: 785 ft S. and 1,740 ft E. of NW. cor., Whittier quad.
m-78	do	do	Sec. 23, T. 2 S., R. 11 W.: art. cut 1,910 ft S. and 1,725 ft W. of NE. cor., La Habra quad.
m-79	do	do	Sec. 23, T. 2 S., R. 11 W.: 1,460 ft S and 150 ft W. of NE. cor., La Habra quad.
m-80	do	do	Sec. 23, T. 2 S., R. 11 W.: 1,575 ft S. and 610 ft W. of NE. cor., La Habra quad.
m-81	do	do	Sec. 23, T. 2 S., R. 11 W.: 960 ft S. and 1,000 ft W. of NE. cor., La Habra quad.
m-82	do	do	Sec. 23, T. 2 S., R. 11 W.: 350 ft S. and 50 ft W. of NE. cor., La Habra quad.
m-83	do	do	Sec. 24, T. 2 S., R. 11 W.: 1,725 ft N. and 2,350 ft E. of SW. cor., La Harba quad.
m-84	do	do	Sec. 24, T. 2 S., R. 11 W.: 1,525 ft S. and 925 ft E. of NW. cor., La Habra quad.
m-85	do	do	Sec. 24, T. 2 S., R. 11 W.: artificial cut 400 ft S. and 340 ft E. of NW. cor., La Habra quad.
Mollusk collections			
F-2	R. F. Yerkes	W. H. Holman	Sec. 17, T. 3 S., R. 10 W.: artificial cut 175 ft N. and 800 ft W. of SE. cor., La Habra quad.
F-3	do	do	Sec. 23, T. 3 S., R. 10 W.: artificial cut 2,500 ft N. and 820 ft W. of SE. cor., La Habra quad.
F-4	do	W. H. Holman, J. G. Vedder.	Sec. 23, T. 3 S., R. 10 W.: artificial cut 2,450 ft S. and 2,330 ft E. of NW. cor., La Habra quad.
F-5	do	do	Sec. 19, T. 3 S., R. 10 W.: artificial cut 1,440 ft S. and 2,240 ft E. of NW. cor., La Habra quad.
F-6	do	do	Sec. 20, T. 3 S., R. 10 W.: artificial cut 60 ft S. and 1,100 ft E. of NW. cor., La Habra quad.
F-7	C. W. Hoskins	C. W. Hoskins	Sec. 24, T. 3 S., R. 11 W.: 350 ft S. and 380 ft W. of NE. cor., La Habra quad.
F-7A	R. F. Yerkes	W. H. Holman, J. G. Vedder.	Sec. 24, T. 3 S., R. 11 W.: artificial cut 550 ft S. and 315 ft W. of NE. cor., La Habra quad.
F-8	C. W. Hoskins	C. W. Hoskins	Sec. 24, T. 3 S., R. 11 W.: 125 ft S. and 225 ft W. of NE. cor., La Habra quad.
F-9	do	do	Sec. 17, T. 3 S., R. 10 W.: artificial cut 1,340 ft S., and 60 ft E. of NW. cor., La Habra quad.
F-10	do	do	Sec. 18, T. 3 S., R. 10 W.: 1,800 ft N. and 375 ft W. of SE. cor., La Habra quad.
F-11	do	do	Sec. 17, T. 3 S., R. 10 W.: 55 ft N. and 2,430 ft W. of SE. cor., La Habra quad.
F-12	do	do	Sec. 18, T. 3 S., R. 10 W.: 1,400 ft N. and 1,360 ft W. of SE. cor., La Habra quad.
F-13	do	do	Sec. 18, T. 3 S., R. 10 W.: 1,210 ft N. and 980 ft E. of SW. cor., La Habra quad.
F-14	do	do	Sec. 18, T. 3 S., R. 10 W.: 1,560 ft N. and 2,040 ft W. of SE. cor., La Habra quad.
F-15	do	do	Sec. 18, T. 3 S., R. 10 W.: 1,825 ft N. and 1,490 ft W. of SE. cor., La Habra quad.
F-16	R. F. Yerkes.	W. H. Holman, J. G. Vedder.	Sec. (32), T. 2 S., R. 10 W.: artificial cut 1735 ft N. and 600 ft W. of SE. cor., La Habra quad.
F-17	F. R. Goodban.	H. E. Stark, J. G. Vedder.	Sec. 2, T. 3 S., R. 10 W.: stream cut, 1,900 ft N. and 840 ft W. of SE. cor., La Habra quad.
F-18	R. F. Yerkes.	J. G. Vedder.	Sec. 25, T. 3 S., R. 11 W.: artificial cut 2,500 ft S. and 1,350 ft W. of SE. cor., La Habra quad.
F-19	do	W. O. Addicott.	Sec. 26, T. 2 S., R. 11 W.: artificial cut 2,550 ft S. and 500 ft E. of NW. cor., Whittier quad.
F-19A	W. H. Holman.	W. H. Holman.	Sec. 27, T. 2 S., R. 11 W.: 1,600 ft S. S. and 1,580 ft E. of NW. cor., Whittier quad.
F-19B	R. F. Yerkes.	W. O. Addicott.	Sec. 27, T. 2 S., R. 11 W.: 1,200 ft S. and 2,575 ft E. of NW. cor., Whittier quad.
F-20	do	do	Sec. 26, T. 2 S., R. 11 W.: artificial cut 200 ft N. and 2,325 ft W. of SE. cor., Whittier quad.
F-21	do	J. G. Vedder	Sec. (32) T. 2 S., R. 10 W.: artificial cut 1,100 ft N. and 1,935 ft E. of SW. cor., La Habra quad.

Table 7.—*Collectors, identifiers, and locations of fossil collections from the La Habra and Whittier quadrangles*—Continued

Map reference No. (pl. 4)	Collected by—	Identified by—	Location
Mollusk collections—Continued			
F-22	do	W. O. Addicott, J. G. Vedder.	Sec. (31) T. 2 S., R. 10 W.: artificial cut 1,285 ft N. and 2,100 ft E. of SW. cor., La Habra, quad.
F-24	do	J. G. Vedder	Sec. (32) T. 2 S., R. 10 W.: artificial cut 1,625 ft N. and 1,140 ft E. of SW. cor., La Habra quad.
F-25	do	do	Sec. (32) T. 2 S., R. 10 W.: artificial cut 1,290 ft N. and 2,600 ft E. of SW. cor., La Habra quad.
F-26	do	W. O. Addicott.	Sec. (31), T. 2 S., R. 10 W.: artificial cut, 1,400 ft S. and 700 ft E. of NW. cor., La Habra quad.
F-28 (CJK-Alb)	C. J. Kundert.	C. J. Kundert.	Sec. 35, T. 2 S., R. 11 W.: 500 ft S. and 2,050 ft W. of NE. cor., La Habra quad.
F-29 (CJK-A2c)	do	do	Sec. 35, T. 2 S., R. 11 W.: 1,450 ft S. and 2,425 ft W. of NE. cor., Whittier quad.
F-30 (CJK-A2)	do	do	Sec. 26, T. 2 S., R. 11 W.: artificial cut 600 ft S. and 2,340 ft E. of NW. cor., Whittier quad.
F-30A	W. H. Holman.	W. H. Holman.	Sec. 26, T. 2 S., R. 11 W.: 810 ft S. and 2,080 ft E. of NW. cor., Whittier quad.
F-31 (CJK-A3)	C. J. Kundert.	C. J. Kundert.	Sec. 26, T. 2 S., R. 11 W.: artificial cut 2,350 ft N. and 1,465 ft W. of SE. cor., La Habra quad.
F-32 (CJK-A4)	do	do	Sec. 26, T. 2 S., R. 11 W.: 2,335 ft S. and 285 ft W. of NE. cor., La Habra quad.
F-33 (CJK-A5)	do	do	Sec. 26, T. 2 S., R. 11 W.: 2,550 ft N. and 650 ft W. of SE. cor., La Habra quad.
F-34 (CJK-A6)	do	do	Sec. 26, T. 2 S., R. 11 W.: 1,700 ft S. and 1,260 ft E. of NW. cor., La Habra quad.
F-35 (CJK-A7)	do	do	Sec. 25, T. 2 S., R. 11 W.: 2,340 ft N. and 1,520 ft W. of SE. cor., La Habra quad.
F-36 (CJK-A8)	do	do	Sec. 25, T. 2 S., R. 11 W.: 2,350 ft S. and 1,760 ft W. of NE. cor., La Habra quad.
F-37 (CJK-A9)	do	do	Sec. 25, T. 2 S., R. 11 W.: 1,975 ft N. and 1,700 ft E. of SW. cor., La Habra quad.
F-38 (CJK-A10)	do	do	Sec. 25, T. 2 S., R. 11 W.: 1,700 ft N. and 2,400 ft E. of SW. cor., La Habra quad.
F-39 (CJK-A11)	do	do	Sec. 25, T. 2 S., R. 11 W.: 1,000 ft N. and 2,200 ft W. of SE. cor., La Habra quad.
F-40 (CJK-A12)	do	do	Sec. 16, T. 2 S., R. 11 W.: 750 ft S. and 2,335 ft W. of NE. cor., La Habra quad.
F-41 (CJK-A13)	do	do	Sec. (31) T. 2 S., R. 10 W.: 2,050 ft N. and 1,020 ft E. of SW. cor., La Habra quad.
F-42 (CJK-A14)	do	do	Sec. (32), T. 2 S., R. 10 W.: 500 ft and 550 ft E. of NW. cor., La Habra quad.
F-43 (CJK-A15)	do	do	Sec. (32) T. 2 S., R. 10 W.: artificial cut 2,600 ft S. and 2,000 ft W. of NE. cor., La Habra quad.
F-44 (CJK-A16)	do	do	Sec. (32), T. 2 S., R. 10 W.: 1,000 ft N. and 1,540 ft E. of SW. cor., La Habra quad.
F-45 (CJK-A17)	H. F. Simmons.	H. E. Stark	Sec. (32), T. 2 S., R. 10 W.: artificial cut 1,490 ft N. and 1,990 ft W. of SE. cor., La Habra quad.
F-46 (CJK-A18)	C. J. Kundert.	C. J. Kundert.	Sec. (32), T. 2 S., R. 10 W.: 885 ft N. and 1,420 ft E. of SW. cor., La Habra quad.
F-47 (CJK-A19)	H. F. Simmons.	H. E. Stark	Sec. (32), T. 2 S., R. 10 W.: artificial cut 2,420 ft N. and 1,350 ft W. of SE. cor., La Habra quad.
F-48 (CJK-A20)	do	do	Sec. (32), T. 2 S., R. 10 W.: artificial cut 2,930 ft N. and 2,980 ft W. of SE. cor., La Habra quad.
F-49 (CJK-A21)	C. J. Kundert.	C. J. Kundert.	Sec. (33), T. 2 S., R. 10 W.: 1,800 ft S. and 1,490 ft E. of NW. cor., La Habra quad.
F-50	J. E. Schoellhamer, R. F. Yerkes.	Theodore Downs.	Sec. (7), T. 3 S., R. 10 W.: 1,175 ft E. of SW. cor., La Habra quad.

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