Stratigraphy and Sedimentology of the Eocene Tejon Formation, Western Tehachapi and San Emigdio Mountains, California

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STRATIGRAPHY AND SEDIMENTOLOGY OF THE EOCENE TEJON FORMATION, WESTERN TEHACHAPI AND SAN EMIGDIO MOUNTAINS, CALIFORNIA

Aerial view of south end of San Joaquin Valley, western Mojave Desert, and Transverse Ranges.

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By TOR H. NILSEN

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STRATIGRAPHY AND SEDIMENTOLOGY OF THE EOCENE TEJON FORMATION, WESTERN TEHACHAPI AND SAN EMIGDIO MOUNTAINS, CALIFORNIA

By Tor H. Nilsen

ABSTRACT

The Tejon Formation is exposed in its type area in the San Emigdio and western Tehachapi Mountains at the south end of the Great Valley of California, northwest of the Garlock fault and northeast of the San Andreas fault. It consists of breccia, conglomerate, sandstone, siltstone, and shale containing a marine megafauna and microfauna diagnostic of early, middle, and late(?) Eocene age. The formation records a major eastward transgression across the outcrop area during early and middle Eocene time, followed by a major westward regression during later middle Eocene time.

The Tejon Formation consists, in ascending and conformable order, of: (1) a basal nearshore breccia, conglomerate, and sandstone, (2) finer grained sandstone and shale deposited farther offshore, (3) an upper sandstone containing some interbedded conglomerate and shale that was deposited in shallow-marine environments adjacent to a regressing shoreline, and (4) an uppermost laterally restricted shallow-marine siltstone. Paleocurrent data indicate that the dominant transport of sediment was in an offshore or westward direction.

The Tejon Formation rests unconformably on a pre-Tertiary crystalline basement complex. In the central and eastern parts of the outcrop area, this basement consists of upper Mesozoic partly gneissose granodiorite, quartz monzonite, and quartz diorite that is locally migmatitic; these rocks are similar in lithology and age (77-86 m.y.) to plutonic rocks of the eastern Sierra Nevada. In the western part of the outcrop area, the Tejon rests on mafic and ultramafic rocks that include metadiabase, gabbro, pyroxenite, and hornblende-quartz diorite-gabbro for which K-Ar dates from hornblende indicate ages ranging from 130 to 220 m.y. The eastern and central areas, underlain by continental crust, formed a narrow Eocene continental shelf that deepened westward to a continental slope and deep-marine basin underlain by the mafic and ultramafic rocks.

The Tejon Formation generally consists, except for the persistence of the nearshore basal conglomerate, of shallow-marine facies to the east and deeper marine facies to the west. In its eastern exposures, the marine Tejon Formation is overlain conformably by the nonmarine Tecuya Formation of Eocene(?) to Miocene age and also grades laterally eastward into nonmarine red beds inseparable from and, therefore, also assigned to the Tecuya Formation. To the west, the Tejon is overlain by the marine San Emigdio Formation of late Eocene and Oligocene age; it contains a basal shallow-marine sandstone that interfingers to the east with red beds of the lower part of the Tecuya Formation.

The basal unit of the Tejon Formation is the Uvas Conglomerate Member, a discontinuous basal breccia, conglomerate, and sandstone that rests unconformably on a highly irregular erosional surface on the basement complex. Though locally absent, this member may be as thick as 400 feet (122 m) where deposited on topographic lows. Characteristic sedimentary features include medium- to large-scale cross strata, local channeling or cut- and-fill structures, ripple marks, well-sorted flat-stratified sandstone probably deposited on beaches, largely vertically oriented cylindrical trace fossils, boulder beds, and residual in-place breccia. It contains a locally abundant megafauna indicative of deposition at inner neritic depths, commonly on a rocky substrate in warm, aerated, locally brackish waters. It is early Eocene in its westernmost exposures and middle Eocene in its easternmost exposures.

The Uvas Conglomerate Member is overlain by the Liveoak Shale Member, which is locally as thick as 2,000 feet (610 m). It is generally sandier in its lower and upper parts, contains a locally abundant microfauna, and grades from a deep-marine argillaceous shale eastward to a shallow-marine silty and sandy shale. It wedges out at the east end of the outcrop area into underlying and overlying shallow-marine transgressive and regressive sandstone units. The Liveoak is early and middle Eocene in its westernmost exposures and middle Eocene in its central and easternmost exposures.

Conformably overlying the Liveoak is a regressive upper sandstone unit, the Metralla Sandstone Member, locally as thick as 2,000 feet (610 m). It is locally conglomeratic and contains an abundant shallow-marine megafauna in its eastern exposures, where it contains medium- and large-scale cross strata, ripple marks, abundant trace fossils of various types, conspicuous calcareous concretions, and, locally, flat-stratified, well-sorted sandstone suggestive of deposition on or adjacent to a beach. It grades laterally westward into finer grained and thinner bedded sandstone characterized by an absence of megafauna, abundant synsedimentary slumps, and flyschlike interbedded sandstone and shale. At the west end of the outcrop area these flyschlike beds pinch out into argillaceous shale of the Liveoak Shale Member. The Metralla is of middle Eocene age.

The Metralla Sandstone Member is locally overlain by the fourth and uppermost member of the Tejon Formation, the Reed Canyon Siltstone Member. This thin and discontinuous member is present mainly in the east-central part of the outcrop area; its maximum thickness is about 200 feet (61 m). It consists primarily of bioturbated silty shale with scattered microfauna but locally contains a shallow-marine megafauna and thin layers of coal and other carbonaceous debris. It was probably deposited in a variety of shallow-marine and brackish-water environments, including lagoons behind offshore bars or islands. The Reed Canyon is of middle and late(?) Eocene age.

The Tejon Formation thickens steadily westward from zero near Tunis Creek to more than 4,000 feet (1,220 m) near Pleito Creek in the central San Emigdio Mountains. Westward from there, it thins to approximately 1,000 feet (305 m) near Santiago Creek; however, the upper Oligocene and Miocene Temblor Formation in this area truncates the Eocene sequence with angular unconformity, and so the original thickness of the Tejon Formation here might have been greater.

The westward facies change in the Liveoak Shale and Metralla Sandstone Members to deeper-marine, probable slope deposits corresponds to the change in basement type from granitic (continental) in the east to gabbroic and ultramafic (oceanic) in the west. The older pre-Tertiary ocean-continental boundary may have persisted into the Eocene as a major submarine slope that formed the boundary between the shelf-type sandstone of the Tejon to the east and the flyschlike sandstone and hemipelagic shale deposits to the west. Thus, the Tejon Formation records an advancing and retreating shoreline across a narrow continental shelf, bordered on the east by upland source areas and alluvial plains and on the west by an irregular continental borderland in which deep-sea fans were deposited in local basins. Similar Eocene sequences along the west edge of North America have been reported along the west edges of the northern and central Sierra Nevada, the Peninsular Ranges, and northern Baja California, Mexico.

Stratigraphic and paleontologic data indicate that the Tejon Formation has been offset about 190 miles (305 km) right laterally by the San Andreas fault from once-contiguous strata west of the fault in the northern Gabilan Range. This once-contiguous unit, the San Juan Bautista Formation of Kerr and Schenck (1925), is early to late Eocene and younger, rests on similar mafic and ultramafic rocks, and consists of a dominantly deep-marine shale sequence virtually identical to that of the Liveoak Shale Member at the west end of the San Emigdio Range.

Much oil has been recovered from the shallow-marine facies of the Tejon Formation from wells drilled directly north of the outcrop area. The porous, well-sorted sandstone of the Metralla Sandstone Member is a good reservoir, and the Liveoak Shale Member provides a good source for hydrocarbons. The westward facies changes suggest that exploration for oil in the western part of the outcrop area will be less successful.

INTRODUCTION

The Eocene Tejon Formation crops out along the north edge of the western Tehachapi and San Emigdio Mountains at the south end of the San Joaquin Valley, California (pl. 1; figs. 1, 2). It is the oldest Tertiary unit in the area and rests unconformably on a pre-Tertiary basement complex. It is overlain conformably in the east by nonmarine strata and in the west by marine strata, and consists of marine sandstone and shale and some conglomerate and siltstone. The sequence of strata in the Tejon is critical to an understanding of the early Tertiary paleogeography and tectonic history of California and the history of movement along major strike-slip faults because only this area provides exposures in an upended cross section of the Eocene rocks that lie buried beneath younger sediment of the Great Valley northward for 450 miles (720 km).

Rocks contemporaneous with the Tejon Formation that crop out locally in the Sierra Nevada foothills consist of nonmarine auriferous fluvial conglomerate and sandstone deposited by streams that flowed westward toward the Pacific margin of the North American continent (Lindgren, 1911; Hackel, 1966; Bateman and Wahrhaftig, 1966). Coeval Eocene rocks in the Coast Ranges to the northwest consist primarily of deep-marine sandstone and shale inferred to have been deposited in the deep basins of an irregular continental borderland (Clarke, 1973; Nilsen and Clarke, 1975). Thus, outcrops of the Tejon Formation record the transition from nonmarine fluvial deposition in the east to deep-marine turbidite and hemipelagic sedimentation in the west. The model of Eocene depositional environments, facies changes, and paleogeography derived from study of the Tejon Formation can be extrapolated northward for Eocene rocks of similar character that underlie the Great Valley and have been penetrated by numerous oil wells.

The first geologist to examine rocks now assigned to the Tejon Formation was W. P. Blake of the Pacific Railroad Survey, who found some fossils in a boulder from Grapevine Creek (Blake, 1857, p. 46); the fossils were sent to T. A. Conrad, a paleontologist in Philadelphia, who determined that they were of Eocene age (Conrad, 1855), the first Eocene fossils identified in California. Some years later, W. M. Gabb, a paleontologist with the California Geological Survey, and J. D. Whitney, then head of the Survey, made a new collection of fossils from Liveoak Canyon, located a short distance to the east (pl. 1). Gabb applied the name Tejon Group to these beds and considered them to be of Late Cretaceous age (Whitney, 1865; Gabb, 1869). An argument that ensued for many years between Gabb and Conrad as to the age of these rocks was finally resolved when new evidence for the Eocene age of the fossils became firmly established.

Unfortunately in some ways, the name "Tejon" was subsequently extended throughout much of California and the Pacific Coast region for rocks of Eocene age, and the term "Tejon Formation" is still used for widely scattered and in some places stratigraphically unrelated Eocene rocks. I use the term in this paper in its restricted and original sense, namely for marine rocks coextensive with the Tejon Formation in the Grapevine Creek area. As such it crops out only in the San Emigdio and western Tehachapi Mountains; use of the term "Tejon Formation" to describe Eocene rocks in other areas should be abandoned.

The term "Tejon" has also been used as an informal provincial megainvertebrate stage name in California (Clark and Vokes, 1936; Weaver and others, 1944; Addicott, 1972). This provincial stage is presently thought to correspond generally to the benthic foraminiferal Narizian Stage and thus to the middle Eocene (Schmidt, 1975; Poore, 1976). However, as shall be pointed out in this report, the Tejon Formation, on the basis of paleontologic data, is known to span four provincial megainvertebrate stages thought to range in age from early through middle Eocene, and thus is only in small part equivalent in age to the "Tejon Stage."

PREVIOUS WORK

Many studies of the Tejon Formation have been undertaken since the Gabb-Conrad controversy, but most focused either on a single aspect of the unit or on a small part of the total outcrop area. Early work by Anderson (1912), Dickerson (1915, 1916), Gester (1917), Pack (1920), Stock (1920, 1932), Clark (1921, 1926), Wagner and Schilling (1923), Anderson and Hanna (1925), Hoots (1930), Clark and Vokes (1936), and Henny (1938) was summarized adequately by DeLise (1967) and Nilsen and others (1973).

Marks (1941a, 1943) subdivided the Tejon Formation into members, based on a study of it in the Liveoak Canyon and Grapevine Creek areas. Thesis mapping and paleontologic studies by Harris (1950, 1954) in the Pastoria Creek area, Van Amringe (1957) in the Brush Mountain area, Hammond (1958) in the Santiago Creek area, and McGill (1951) and DeLise (1967) in the San Emigdio Canyon area added substantial knowledge regarding the local stratigraphic and lithologic characteristics of the Tejon Formation. Additional paleontologic data were provided by Durham and others (1954), Stirton (1960), Tedford (1961), and Kleinpell and Weaver (1963).

Geologic maps of the area were prepared by Dibblee and Kelly (1948), Dibblee (1961), Crowell (1964), Jennings and Strand (1969), Dibblee and Nilsen (1973), and Dibblee (1973a). The geology of the pre-Tertiary basement rocks was summarized by Ross (1970, 1972) and Ross and others (1973). The subsurface geology of the Tejon Formation and immediately overlying units has been discussed by Tipton (1971), Tipton and others (1973, 1974), and Weber (1973). The general stratigraphy and

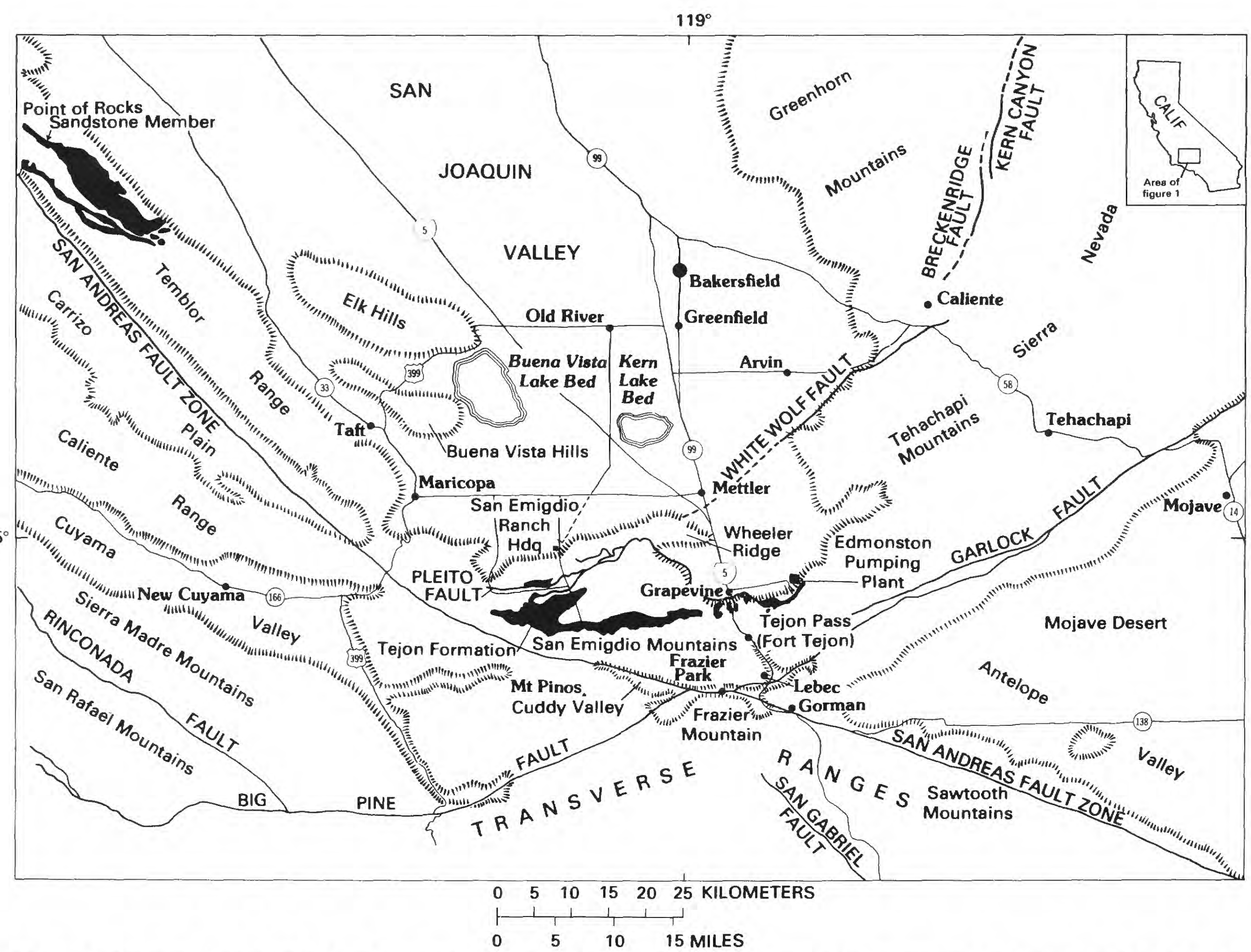

FIGURE 1.—Index map of south end of San Joaquin Valley and adjacent areas, showing major faults, geographic features, and distribution of outcrops of the Tejon Formation and closest outcrop of correlative rocks (Point of Rocks Sandstone Member of Kreyenhagen Formation east of San Andreas fault).

stratigraphic nomenclature of the region were summarized by Nilsen and others (1973). Possible offsets along the San Andreas fault of strata equivalent to the Tejon Formation were discussed by Clarke and Nilsen (1973), Nilsen and Link (1975), and Nilsen and Clarke (1975).

This paper supplants and incorporates my own previously published abstracts (Nilsen, 1972, 1973a,b) and informal field trip guides (Nilsen, 1973c,d). In addition to the published literature, various oil companies have made extensive studies of the Tejon Formation in the search for oil. Some of these unpublished data are incorporated in this paper and are acknowledged as such.

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LAND OWNERSHIP AND HISTORY OF AREA

The western Tehachapi and San Emigdio Mountains area has been a pivotal region during much of the history of California during the past 200 years. Although the mountains form a natural barrier that has served to separate northern and southern California and isolate the southern San Joaquin Valley, commercial and agricultural interests from major urban centers to the south and north have vied for control and use of these lands (Boyd, 1972). The richness of the mountains and adja-

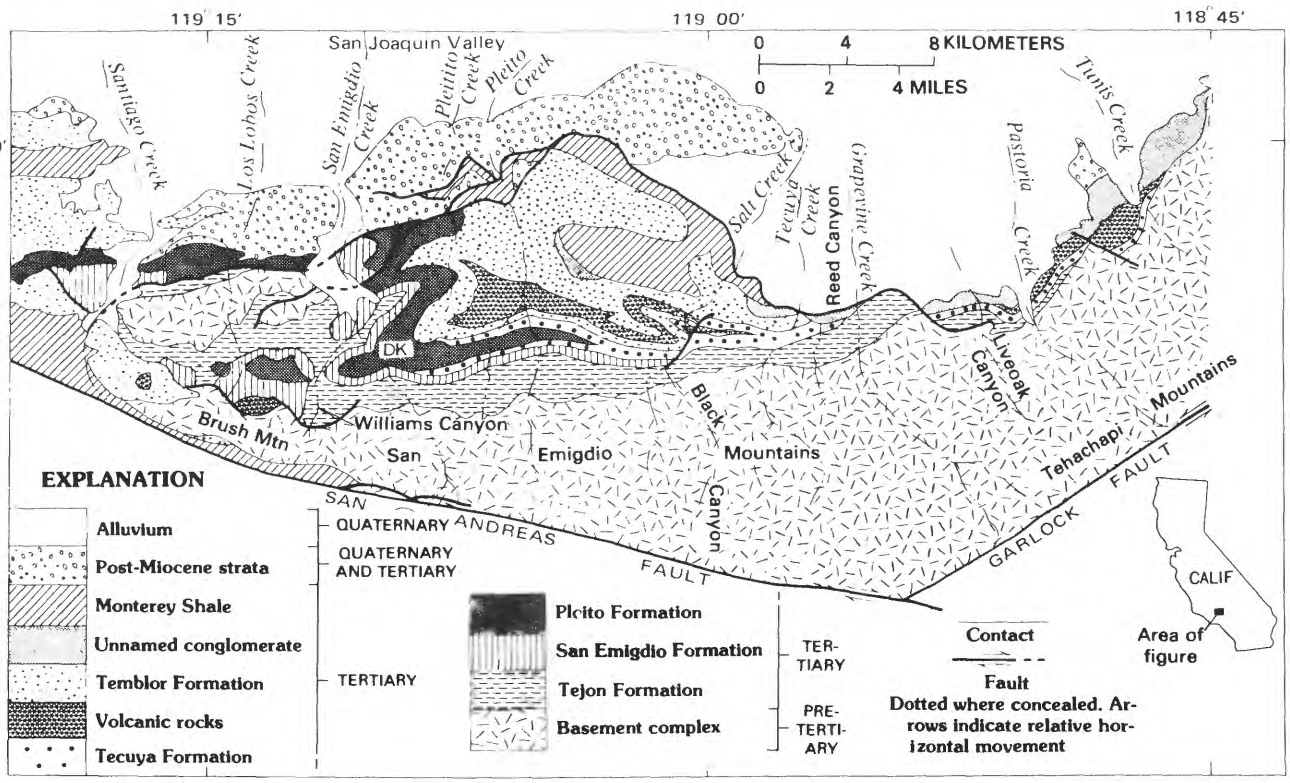


FIGURE 2.—Simplified geologic map of western Tehachapi and San Emigdio Mountains, from Nilsen and others (1973, fig.1). Modified from Geologic Map of California (Smith, 1964; Jennings and Strand, 1969). DK, Devils Kitchen area, location of Devils Kitchen syncline.

cent areas of Kern County has led, at various times, to the development of major industries involving gold mining, cattle ranching, citrus, rice, and grain agriculture, sheep raising, and petroleum.

The first visit to the region by a white man and the first crossing of Tejon Pass through Grapevine Creek was made in 1772, by Captain Don Pedro Fages, who traveled from San Diego northward into the San Joaquin Valley and thence westward to San Luis Obispo, stopping enroute at a large Indian village on the shore of Buena Vista Lake (fig. 1). Father Francisco Garces traveled northward through Tejon Pass in 1776, trying to discover a shorter route from Monterey to Yuma; he made many detailed notations of the geography and Indian languages, customs, and settlements. Many later expeditions by Spanish missionaries and soldiers to the area eventually led to the naming of Tejon (badger) Pass and Canada de las Uvas (Grapevine) Canyon; these expeditions were generally for the purposes of recapturing Indians who had fled the coastal missions, Christianizing Indians outside the reach of the missions, exploring for new mission sites, capturing army deserters, and putting down Indian uprisings. Although the mission authorities had plans at one time for developing a chain of inland missions in the San Joaquin Valley, including one in either the Tejon Pass or San Emigdio Canyon area, none were ever established, and financial difficulties led to the decline of the mission system after the 1820's.

The first American explorations in this area were by Jedediah Smith (1826-27), Ewing Young and Kit Carson (1830-32), and then a host of trappers, including Joseph Walker, Jim Bridger, and trappers of the Hudson's Bay Company (Bailey, 1972). John C. Fremont traversed the area in 1844 to 1846, with E. M. Kern, Joseph Walker, Kit Carson, and Alex Godey in his parties.

After California became a State, Lieutenant Edward F. Beale, who was appointed Commissioner of Indian Affairs for California and Nevada in 1853, devised plans for military reservations in the area rather than Indian reservations in order to control California's Indian population (Magruder, 1950). Beale recommended in the early 1850's that Fort Tejon be established at its present site in Tejon Pass (fig. 1) to protect both Indians in the southern San Joaquin Valley from gold miners and government property at the San Sebastian Indian Reservation, located 17 miles (27 km) to the north. Another objective of the location was to control the flow of stolen cattle and horses through Grapevine Creek from the San Joaquin Valley to markets in the southwest. The fort was established on August 10, 1854 as the regimental headquarters for the First U.S. Dragoons and quickly became the military, social, and political center of the large area between the San Joaquin Valley and Los Angeles. More than 20 adobe buildings were constructed, making it one of the largest settlements in southern California, and in 1858 a Butterfield overland mail station was established there on the main route from St. Louis to San Francisco. The fort represented law and order in southern California, and the Dragoons were assigned to guard miners, chase bandits and rustlers, and protect Indians and Indian lands; their activities took them as far east as the Colorado River and occasionally to Salt Lake City, north into the San Joaquin Valley and Owens Valley, and south to Los Angeles.

The most interesting bit of history at the fort was the establishment in the 1850's of the U.S. Army Camel Corps under the direction of then Secretary of War Jefferson Davis. Both Davis and Beale felt that camels would be far more suitable for transporting troops and provisions throughout the arid Southwest. A total of 28 camels were imported and brought overland to Fort Tejon from San Antonio, Texas in the fall of 1857 by Lieutenant Beale. The camel experiment was completely successful, for Beale found that the camels could traverse ground covered by sharp volcanic rock without injury to their feet, that they could climb with heavy packs over mountains where unloaded mules found it difficult to go, and they could plunge into rivers and swim across them with ease. In fact, the camels carried water for the mules, and Beale concluded that he wouldn't trade one of the dromedaries for four of his best mules. The major problem with the camels was the reluctance of the Army's muleskinners to care for them. With the change in administration and coming of the Civil War, the camels were removed to Los Angeles and sold to private owners. The government retains only bones of one animal, killed by its mate and now preserved in a case in the Smithsonian Institution.

The January 9, 1857, Tejon earthquake, probably the strongest during California's recorded history, severely damaged the fort, knocking down adobe walls and causing considerable damage to most buildings. A report by the Inspector General stated that "one person has been killed by the fall of an adobe wall and a cow has been swallowed up."

The inscription "Peter LeBeck, killed by a X (that is, grizzly) bear, October 17, 1837" was carved on an oak tree in a corner of the parade ground of Fort Tejon. Little is known of the origin of the man. The inscription was first noted in 1853. In 1890, the remains of LeBeck were recovered near the base of the tree, and 25 years later, a French 5-franc coin dated 1837 was found at the site, adding some credence to the speculation that LeBeck was a French agent sent to California first to prepare a future home for Napoleon Bonaparte and then later to spy out the land for a possible French colony (Cullimore, 1941; Magruder, 1950).

With the coming of the Civil War, federal troops at the fort were transferred to Wilmington to control Confederate sympathizers in the Los Angeles area, and until 1864 the fort was occupied by state militia of the California Volunteers. Despite petitions by Beale, the fort was finally abandoned in 1864. It is now a State park and has been substantially restored.

The entire outcrop area of the Tejon Formation in the western Tehachapi and San Emigdio Mountains lies within two large ranches, the Tejon Ranch to the east and San Emigdio Ranch to the west. The Tejon Ranch covers an area centered in the Tehachapi Mountains of about 300,000 acres (120,000 ha), extending eastward for about 30 miles (50 km) from about one mile (1½ km) west of Grapevine Pass. Tejon Ranch comprises an area three-eighths the size of the State of Rhode Island, although it was originally four separate land grants made by the Mexican government in the 1840's. During this period, Mexico was attempting to consolidate its control over Alta California and the southwest by granting large parcels of land to Mexican citizens to encourage settlement. The four land grants covering Tejon Ranch included Ranchos Castaic of 22,178 acres (8,775 ha) and El Tejon of 97,612 acres (39,504 ha) in 1843 and Ranchos La Liebre of 48,799 acres (19,749 ha) and Los Alamos y Agua Caliente of 26,626 acres (10,775 ha) in 1846; the original owners lived in either Los Angeles or Santa Barbara. When Lieutenant Beale was Surveyor General of California and Nevada in the 1850's, he began to purchase each of the original grants, incorporating them into Rancho El Tejon. La Liebre was purchased in 1855 by Beale's wife for $1500, or 3 cents per acre (7½ cents/ha); Los Alamos y Agua Caliente, after several changes in ownership, was purchased by Beale in 1865 for $2,986, about 11 cents an acre (28 cents/ha). The El Tejon grant was also purchased by Beale in 1865 for $21,000, or 21 cents an acre (53 cents/ha). About the same time, Rancho Castaic, including cattle and sheep, was purchased by Beale for $6,500, or 34 cents an acre (72 cents/ha). Beale also purchased Rancho San Emigdio to the west in 1869, but sold it two years later for $10,000. The Tejon Reservation, which Beale had helped establish in the early 1850's when he was Commissioner of Indian Affairs, was removed from Rancho Tejon in 1864 to the Tule River Reservation.

The ranch continued to grow and prosper in the late 1800's with farming, sheep raising, and cattle raising being the principal sources of income. In 1879 Beale's famous drive of 17,000 sheep to Green River, Wyoming, took place with only 8,500 sheep surviving the trip. Beale, who was appointed Minister to Austria-Hungary in 1876 by President Grant, died in 1893, and his son took over the ranch. In 1912 Chandler and Sherman purchased the ranch, which became incorporated as the Tejon Ranch Company in 1936; the Chandler family from Los Angeles currently owns the ranch (Bonsal, 1912; Magruder, 1950).

San Emigdio Ranch was named after the Spanish patron saint for earthquakes. San Emigdio Canyon was originally the site of one of the largest Indian villages in the southern San Joaquin Valley. Fages visited the area in 1773 and commented on the good character and physical strength of the Indians there. The canyon was originally the main route of transport for Indians and Spaniards between Santa Barbara and the San Joaquin Valley because of the number of annoying grizzly bears at Tejon Pass. In 1824 Mexican troops from Santa Barbara battled Indian runaways from Santa Barbara in San Emigdio Canyon, claiming a big victory, although few Indians or horses were captured. Although San Emigdio Canyon was carefully discussed as a possible mission site, and padres baptized numerous Valley Indians and recommended that missions be established at both the Tejon and San Emigdio sites, neither the Spanish nor Mexican governments would appropriate funds for either a presidio or mission, especially because the Valley Indians objected strongly to being forced into missions.

The ranch was originally a land grant to Jose Antonio Dominguez in 1842, who built a ranch house about a mile (1.6 km) south of the present ranch headquarters. He died in 1853, leaving many heirs and much confusion about the ownership of the ranch, compounded when John C. Fremont claimed title to the entire ranch at the same time. The Board of Land Commissioners in 1855 awarded half the ranch to Fremont and half to the heirs of Dominguez, and this decision was upheld by the U.S. District Court in 1858. However, Fremont never lived at the ranch, and in 1860 deeded his half to his daughter, who sold it to Beale in 1869; Fremont's famous scout Alex Godey lived on the ranch for many years as overseer. The Dominguez heirs subsequently sold their half, and a variety of owners held it for several years. Finally, in the 1870's, the ranch passed into the hands of J. B. Haggin, one of the founders of the Kern County Land Company. He later deeded the ranch to the Kern County Land Company, which retained ownership until a few years ago, when the company was absorbed by Tenneco, Inc. (Berg, 1971).

The mountainous parts of the region have retained their character as large undeveloped ranches, although the 20th century has brought extensive and continuing oil exploration and increased agriculture throughout most of the area (Kreiser and Hunt, 1961). Large amounts of oil have been recovered from the Tejon Hills, Tejon-Grapevine, Tejon North, Wind Gap, Northeast, Wheeler Ridge, Los Lobos, Metson, Pleito, White Wolf, and other oil fields (pl. 1), and much of this production has come from the Tejon Formation. Tejon Pass is now the site of Interstate Highway 5, a major connecting route between northern and southern California (fig. 1). Farther east, water from northern to southern California is transferred via the California Aqueduct through the A. O. Edmonston Pumping Plant of the California State Water Project, where 31,000 gallons (117 m^3) of water per second are lifted 2,000 feet (610 m) from the floor of the San Joaquin Valley to near the top of the Tehachapi Mountains, and thence southward (Nilsen, 1973d; fig. 1; pl.

REGIONAL GEOLOGY

GEOGRAPHY AND ACCESS TO THE AREA

The east-west trending western Tehachapi and San Emigdio Mountains rise steeply from the floor of the Great Valley, about 800-1,500 feet (245-460 m) in elevation, to high mountain peaks over 7,000 feet (2,145 m) in elevation. Tertiary rocks crop out on the north flank of the range, which is cut by a series of north-flowing stream channels that provide generally excellent exposures that were suitable sites for measuring detailed columnar sections. Consequently, much of the geologic work in the area was concentrated along the canyon walls adjacent to these creeks, some of which head or originate in the fault-controlled valleys to the south.

Good exposures of the Tejon Formation are present, from east to west, along the following creeks and canyons: Tunis Creek, Pastoria Creek, Liveoak Canyon, Grapevine Creek (Tejon Pass), Tecuya Creek, Black (or Black Bob) Canyon, Salt Creek, Pleito Creek, San Emigdio Creek, Williams (or Doc Williams) Canyon, Los Lobos Creek, and Santiago Creek (fig. 2; pl. 1). Smaller canyons that provide good exposures include Metralla and Reed Canyons, both located less than two miles (3.2 km) west of Pleito Creek; Pleitito Canyon, located about two miles (3.2 km) west of Pleito Creek; and two creeks at the western end of the outcrop area located less than one mile (1.6 km) east of Santiago Creek, informally called East and West Twin Creeks by Hammond (1958).

Access into the area varies from good to very difficult. The only paved road across the area is Interstate Highway 5 (State Highway 99) through Grapevine Canyon, although paved roads skirt the mountain front from Grapevine eastward to the Edmonston Pumping Plant and from Mettler westward to Maricopa (State Highway 166). Unpaved private roads and jeep trails extend from the paved roads southward into the mountains along Pastoria Creek; along the mountain fronts one-half mile (0.8 km) east of Liveoak Canyon to Grapevine Peak and on the west side of Grapevine Pass to the top of the unnamed peak; part way along Tecuya Creek; along Black Bob Canyon; part way along Salt, Pleito, San Emigdio, and Williams Canyons; along upper Los Lobos and Santiago Creeks; and eastward along the mountain front to the west side of Brush Mountain. Permission for access to these routes is necessary from the Tejon Ranch Co. and from the San Emigdio Ranch.

The only habitation within the mountains, aside from that along Interstate Highway 5 along Grapevine Creek, is at the San Emigdio Ranch Headquarters at the mouth of San Emigdio Canyon. Limited services are available at Maricopa, Mettler, Grapevine, adjacent to Old Fort Tejon, and Lebec.

TECTONIC SETTING

The western Tehachapi and San Emigdio Mountains form an east-west trending range of mountains located north of both the northeast-trending left-lateral Garlock fault and the northwest-trending right-lateral San Andreas fault (figs. 1, 2; pl. 1). Grapevine Creek forms the geographic boundary between the Tehachapi and San Emigdio Mountains. East of Pastoria Creek, the east-west structural trends of the western Tehachapi Mountains bend northeast into the main mass of the Tehachapi Mountains; 25 miles (40 km) farther northeast, the Tehachapi Mountains bend to the north-south or northwest structural trend of the Sierra Nevada and Greenhorn Mountains. Westward, the east-west structural trends of the San Emigdio Mountains bend northwestward and merge with the Temblor Range about 10 miles (16 km) west of Santiago Creek. Thus, the area of study, which constitutes part of California's southern Coast Ranges structural province, is uniquely dominated by east-west structural trends like that of the Transverse Ranges structural province to the south, in contrast to the rest of the Coast Ranges province, where structural trends are principally northwestward (fig. 3).

The San Andreas, Garlock, and Big Pine faults intersect within the southern edge of the area and effectively separate five major structural and physiographic provinces (fig. 1): the Coast Ranges to the west and northwest, the Great Valley to the north, the Sierra Nevada to the northeast, the Mojave Desert to the east and southeast, and the Transverse Ranges to the south (Hill and Dibblee, 1953). The San Andreas fault, which is the dominant structural feature of western California, bends away from its usual northwest orientation in this area to an approximately east-west orientation (fig. 1).

Late Tertiary uplift in the areas north and south of the bend in the San Andreas fault resulted in exposure of pre-Tertiary basement rocks adjacent to the fault in the San Emigdio Mountains and Frazier Mountain areas. The uplift is associated with extensive thrust faulting on both sides of the San Andreas fault—to the north along the Pleito, Pastoria, and associated thrust faults in the San Emigdio and western Tehachapi Mountains area, and to the south along the north and south Frazier Mountain thrust faults in the Frazier Mountain area (Jennings and Strand, 1969).

The south-dipping Pleito fault is approximately 30 miles (48 km) long. It comprises numerous associated smaller thrust faults, and records the thrusting of basement rocks and Tertiary sedimentary cover northward toward the San Joaquin Valley. Geomorphic evidence indicates that the Pleito fault is currently active (Cotton and others, 1977). The White Wolf fault, oriented parallel to and located about 20 miles (32 km) north of the Garlock fault, has both left-lateral and northward-thrusting components of movement. It is also an active fault, having last moved during the Kern County earthquake of 1952 (Oakeshott, 1955; Dibblee, 1955). It may extend southwestward in subsurface under Wheeler Ridge and the San Emigdio foothills, and discontinuously northeastward into the Breckenridge-Kern Canyon fault system, which separates the southern Sierra Nevada into two north-trending blocks (Dibblee, 1955).

The overall tectonic setting indicates that north-south compression is taking place in areas adjacent to the bend in the San Andreas fault, resulting primarily from the relative northward movement of the block west of the San Andreas fault (Hill and Dibblee, 1953). This

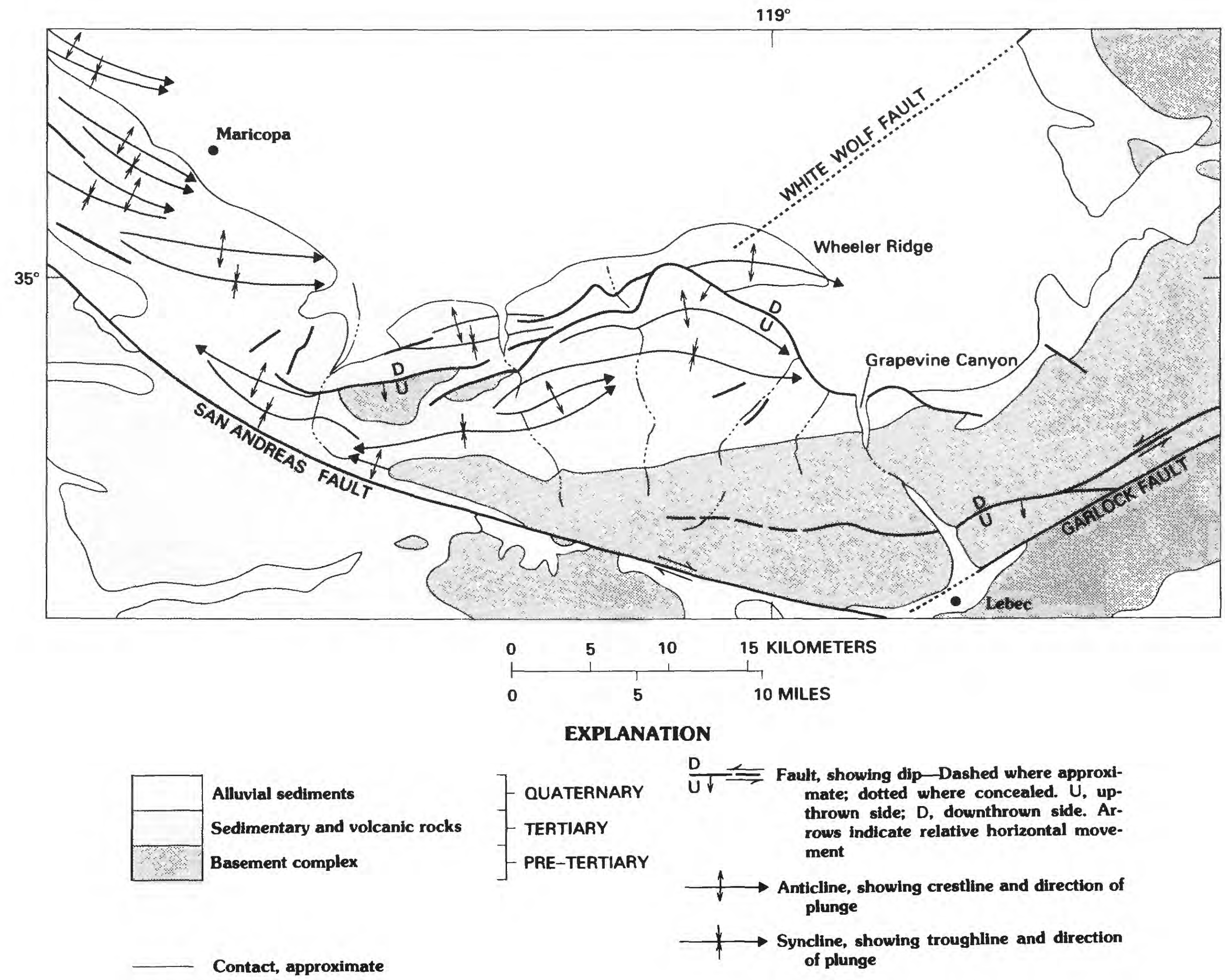


FIGURE 3.—Map showing tectonic setting of western Tehachapi and San Emigdio Mountains (from Dibblee, 1961).

compression has resulted in uplift of the western Tehachapi and San Emigdio Mountains area with east-west orientation and exposure of the Tejon Formation and associated lower and middle Tertiary stratigraphic units essentially as an east-west trending homocline dipping northward off the pre-Tertiary basement complex. Some folds along primarily east-west-trending axes are present in the San Emigdio Mountains area; the Devils Kitchen syncline in the San Emigdio Canyon area and the Wheeler Ridge area anticline are major folds (Dibblee, 1961). Faulting includes the main south-dipping Pleito thrust and subsidiary faults, which are particularly abundant near San Emigdio Canyon; the thrusting has locally yielded numerous fault slices that contain and expose lower and middle Tertiary stratigraphic units. Smaller northeast- and northwest-trending high-angle tear faults with both right-lateral and left-lateral senses of movement are common.

Because of the steep slopes, seismicity, and active uplift of the area, landslide deposits are numerous, particularly on north-facing slopes of the upper plate of the Pleito thrust, as seen in the Grapevine and Pleito Hills areas (figs. 4, 5; pl. 1). The entire area is very active tectonically; the January 9, 1857 earthquake centered near Fort Tejon in Grapevine Creek is probably the strongest earthquake recorded in California during historical time. This tectonic activity has resulted in uplift, exposing the lower and middle Tertiary sequence that is buried to the north beneath the Great Valley.

BASEMENT COMPLEX

In the central and eastern parts of the outcrop area, the Tejon Formation rests unconformably on felsic Sierra Nevada-type plutonic and gneissic basement rocks that form the central core of the San Emigdio and western Tehachapi Mountains (fig. 2; pl. 1). These basement rocks are of Mesozoic age and cogenetic with the Sierra Nevada batholiths; although not mapped in detail north of the San Andreas and Garlock faults, they are known to consist mostly of granodiorite to quartz monzonite (the Lebec Quartz Monzonite of Crowell, 1952, p. 8-10) on the south that are thrust northward over gneissic rocks (Crowell, 1952; Ross, 1972, p. 50-52). The thrust relations are particularly clear along the Pastoria fault near Tejon Pass (pl. 1). The gneissic terrane consists predominantly of massive to foliated granodiorite and quartz diorite, but also includes quartz monzonite, diorite, hornblende diorite, gneiss, various types of banded schist, quartzite, and marble, all of which are cut by pegmatitic dikes

FIGURE 4.—View southeast of east side of Grapevine Creek showing large landslide deposits downslope from Grapevine Peak (4,814 ft (1,468 m) in elevation).

(Pack, 1920; Harris, 1954; Dibblee, 1961; Crowell, 1964). The granodioritic rocks locally include some alaskite in the Brush Mountain area (Ross, 1972) and are locally migmatitic (pl. 1). Evernden and Kistler (1970), from two samples of these felsic plutonic rocks in Grapevine Creek north of the San Andreas and Garlock faults, reported potassium-argon ages of 86 m.y. on biotite and 77 m.y. on hornblende; these ages are similar to those derived from most of the eastern Sierra Nevada from rocks of the Cathedral Range intrusive epoch of Late Cretaceous age.

In the western part of the San Emigdio Mountains, the Tejon Formation rests on unusual gabbroic and related rocks. These gabbroic rocks crop out between San Emigdio and Santiago Creeks and include fine-grained igneous rocks with relict diabasic texture, gabbro, pyroxenite, and hornblende quartz diorite-gabbro (Hammond, 1958; Ross, 1970, 1972). These rocks have been interpreted by Ross (1970) as Mesozoic ophiolitic ocean crust that previously had been thrust beneath the granodioritic continental crust represented by Sierran rocks to the east. He inferred that these mafic rocks represent a remnant of a pile of volcanic and diabasic rocks intruded by a gabbro-pyroxenite sequence, which in turn was intruded by a quartz diorite-quartz gabbro mass. Reitz (1983) interpreted the rocks to be part of a Jurassic magmatic arc. Ross and others (1973) obtained, from hornblendes, potassium-argon radiometric ages of 134 ± 4 and 165 ± 4 m.y. from hornblende quartz gabbros and about 207 ± 10 m.y. from a hornblende-andesine-quartz pegmatite. A uranium-lead radiometric age of 160 m.y. has been obtained from the hornblende-quartz gabbro (D. Kimbrough, written commun., 1982). Gravity data suggest that the mafic rocks are not rooted but are probably enclosed within a thrust slice (W. F. Hanna, oral commun., 1973).

The contact between the contrasting felsic and mafic basement rock types is covered by Tertiary sedimentary rocks (pl. 1). However, because both types of basement are overlain by the Tejon Formation, the period of subduction postulated by Ross must have been completed before the deposition of the Tejon Formation.

TERTIARY STRATIGRAPHIC SEQUENCE

The lower and middle Tertiary sequence thickens westward from a few hundred feet (75 m) in the easternmost exposures in the Tehachapi Mountains to many thousands of feet (3,000 m) in the western San Emigdio Mountains, and some of the units extend northwestward into the Temblor Range. The formations and their inferred ages are summarized in figure 6 and described in detail by Nilsen and others (1973).

Rocks of Eocene age include the Tejon Formation, the San Emigdio Formation, and possibly the lowest part of the Tecuya Formation. The sequence is overlain unconformably by predominantly nonmarine upper Cenozoic sedimentary rocks that have been described and mapped by Hoots (1930) and Dibblee (1961) and are shown on plate 1.

The lower Tertiary of California has been divided into provincial stages on the basis of megainvertebrate and benthic foraminiferal fossils (fig. 6). Ages of the Tejon Formation and its members and adjacent formations in this paper are based on the time-rock correlations of Kleinpell (1938), Weaver and others (1944), and Mallory

FIGURE 5.—View southwest of west side of Grapevine Creek showing large landslide deposits. Interstate Highway 5 at left edge of photo.

(1959), with subsequent changes based on Schmidt (1970, 1975), Brabb and others (1971), Steineck and Gibson (1971), Gibson and Steineck (1972), Poore (1976, 1980), and Nilsen and Clarke (1975, table 1). Thus, early Eocene is equivalent to the provincial "Capay" and Penutian Stages; middle Eocene is equivalent to the "Domengine," "Transition," "Tejon", Ulatisian, and Narizian Stages; late Eocene is equivalent to the Refugian Stage; and early Oligocene is equivalent to part of the unnamed megainvertebrate stage and part of the Zemorrian Stage (fig. 6). Studies based on planktic foraminifers, nannoplankton, and coccoliths have resulted in revision of older correlations.

Other Eocene rocks include the marine Famosa sand of Hackel (1966), similar to the Tejon in age, thickness, and lithology. It is present in subsurface beneath the eastern margin of the Great Valley to the north (Beck, 1952; American Association of Petroleum Geologists, 1957; Hackel, 1966). The Famosa is about 200-600 feet (61-183 m) thick and may represent the northward subsurface extension of the upper part of the Tejon Formation. It interfingers westward in the subsurface with the Kreyenhagen Formation, which consists of 250-650 feet (76-198 m) of Ulatisian and Narizian dark organic shale with thin interbedded sandstone beds (Clarke, 1973). To the northwest, the nearest outcropping strata that are in part coeval with the Tejon Formation comprise the upper part of the Lodo(?) Formation, the Avenal Sandstone, and the Kreyenhagen Formation in the Temblor Range (Dibblee, 1973b, 1974, fig. 6; Clarke, 1973; Nilsen and Clarke, 1975; Maher and others, 1975). The Point of Rocks Sandstone Member of the Kreyenhagen Formation is a marine sandstone interpreted to be of deep-marine origin that fingers out eastward and northward

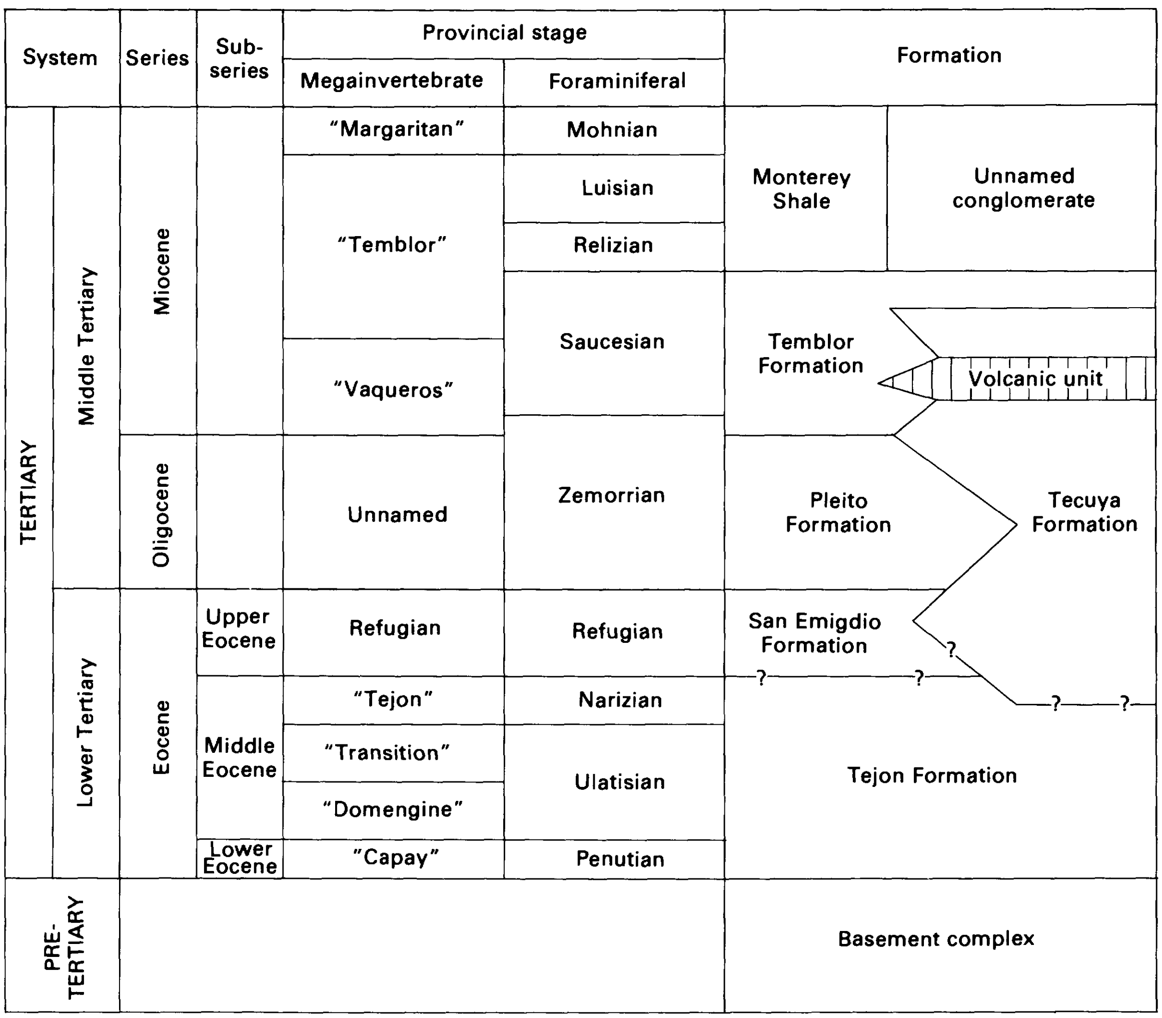


FIGURE 6.—Lower and middle Tertiary formations exposed in western Tehachapi and San Emigdio Mountains, from Nilsen and others (1973, fig. 2). Foraminiferal stages from Kleinpell (1938) and Mallory (1959); megainvertebrate stages from Weaver and others (1944) and Addicott (1972).

in subsurface into shale of the Kreyenhagen Formation (Clarke, 1973, fig. 1). In the southwestern corner of the San Joaquin Valley in the vicinity of Maricopa, Eocene strata are too deeply buried beneath younger strata to have been penetrated by wells drilled for oil, so that the subsurface stratigraphic relations between the Tejon and Kreyenhagen Formations in this area are unknown.

The Famosa sand to the northeast interfingers eastward in subsurface with the lower part of the nonmarine upper Eocene to early Miocene Walker Formation (American Association of Petroleum Geologists, 1957; Clarke, 1973). The Walker Formation crops out along the southeast margin of the San Joaquin Valley (Dibblee and Chesterman, 1953, p. 33-35; Addicott, 1970a, b; Bartow and Doukas, 1978; Bartow and McDougall, 1984). It is 1,800-1,950 ft (550-900 m) thick and consists of interstratified kaolinitic claystone, sandstone, and conglomerate; it contains a pumice tuff dated by potassium-argon methods at 21.4 m.y. about 500 feet (160 m) above its base.

Additional nonmarine strata, the Witnet Formation, possibly of Eocene age, and the Goler Formation, in part of Eocene age, are present to the southeast in isolated basins in the southern Tehachapi and El Paso Mountains, respectively (Dibblee, 1967). A lateritic paleosol and subaerial debris-flow deposits present in the El Paso Mountains are probably of Paleocene age (Cox, 1979). Possible coeval and congeneric Eocene units now located west of the San Andreas fault are discussed by Nilsen and Link (1975) and in a later section of this paper.

The Tejon Formation is overlain in the west by a conformable sequence of marine units having a total thickness of about 5,500 feet (1,680 m) and comprising, in ascending order, the San Emigdio, Pleito, and Temblor Formations (fig. 7). These formations interfinger eastward with the nonmarine Tecuya Formation, which overlies the Tejon Formation in the east and is about 2,300 feet (700 m) thick near Tecuya Canyon. The Tejon Formation is overlain conformably by the San Emigdio Formation west of Salt Creek and by the Tecuya Formation east of Salt Creek. This eastward facies change from marine to nonmarine strata records the general position of a late Eocene, Oligocene, and early Miocene shoreline that oscillated back and forth over an east-west distance of about 15 miles (24 km) (Nilsen and others, 1973). Volcanic rocks composed of basalt, andesite, and dacite are present within the Tecuya Formation and as isolated bodies in the Temblor Formation; these rocks were dated by potassium-argon methods at 21.5 ± 0.7 m.y. by Turner (1970, p. 101). In addition to the major unconformity at the base of the Tertiary sequence, several other smaller and areally restricted unconformities are present in stratigraphically higher parts of the sequence along the margins of the area; these minor unconformities record local uplift and erosion, probably adjacent to active fault zones. In the southwestern part of the area, adjacent to the San Andreas fault near Brush Mountain, the Pleito, San Emigdio, and Tejon Formations are truncated with angular unconformity by the Temblor Formation, which here rests directly on basement rocks. Between Pastoria and Tunis Creeks, the Tejon Formation pinches out eastward so that the Tecuya Formation rests unconformably on basement rock east of there. Still farther east, the Tecuya is truncated with angular unconformity by an unnamed nonmarine conglomerate of Miocene age, which rests unconformably on basement rocks (fig. 7).

Younger rock units overlying the San Emigdio and Tecuya Formations include the marine Pleito Formation, the marine Temblor Formation, the marine Monterey Shale, an unnamed early or middle Miocene nonmarine conglomerate, the Etchegoin Formation of Dibblee (1961), and a variety of Pliocene and Quaternary nonmarine deposits (pl. 1; Dibblee, 1961; Nilsen and others, 1973).

The lower and middle Tertiary sequence, with the two exceptions noted above, appears to record a local series of marine transgressions and regressions that resulted in continuous, uninterrupted deposition of marine conglomerate, sandstone, and shale in the west and nonmarine sandstone and conglomerate in the east. The lower and middle Tertiary marine formations (Tejon, San Emigdio, Pleito, and Temblor Formations) have been interpreted as individual transgressive-regressive depositional sequences: each formation contains a coarse-grained nearshore conglomerate or sandstone at the base, siltstone and shale deposited offshore in the middle part, and shallow-marine sandstone in the upper part (Nilsen and others, 1973; DeLise, 1967; Wagner and Schilling, 1923). The regressive sandstone of the upper parts is generally overlain by a finger of the nonmarine Tecuya Formation that extends westward and helps define the boundaries between the marine formations (fig. 7).

An additional transgressive-regressive cycle may be represented by the interfingering of the unnamed nonmarine conglomerate westward with the Monterey Shale (fig. 7); however, the unconformity at the base of the unnamed conglomerate suggests that the tectonic framework of sedimentation may have changed markedly between deposition of the Tecuya and Temblor Formations and these younger rocks.

The early and middle Tertiary stratigraphy of the western Tehachapi and San Emigdio Mountains appears to resemble that from classical examples and models of shelf sedimentation, such as those described by Sears and others (1941), Young (1955), Weimer (1960), Hollenshead and Pritchard (1961), Sabins (1963), and Masters (1967) for Cretaceous rocks in the San Juan Basin of New Mexico, Book Cliffs of Utah, and other parts of the Rocky Mountains. Herein we shall examine in detail the first nearly complete cycle of transgression, inundation, and regression, recorded in the Tejon Formation, on a narrow shelf that was present at the south end of the early Tertiary San Joaquin basin and is now exposed in the San Emigdio and western Tehachapi Mountains.

TEJON FORMATION

DISTRIBUTION

The outcrop area of the Tejon Formation as defined herein is shown on plate 1. The eastern outcrop limit is located between Pastoria and Tunis Creeks about 0.2 mi (0.4 km) west of the Tunis fault. Here the Tejon Formation pinches out and is overlapped by the Tecuya Formation, which directly overlies the basement complex farther east (fig. 7). The western outcrop limit of the Tejon Formation is along the east bank of Santiago Creek; farther west it lies buried beneath younger Cenozoic sedimentary rocks but has been penetrated in some wells drilled for oil. Strata west of Santiago Creek that were included by Dibblee (1961) within the Tejon Formation have been assigned a Refugian age on the basis of new paleontologic data presented herein (Dibblee and Nilsen, 1973; Dibblee, 1973a; USGS Cenozoic localities M4595, M4596, M4597, and M4598) and are more appropriately mapped as the San Emigdio(?) Formation.

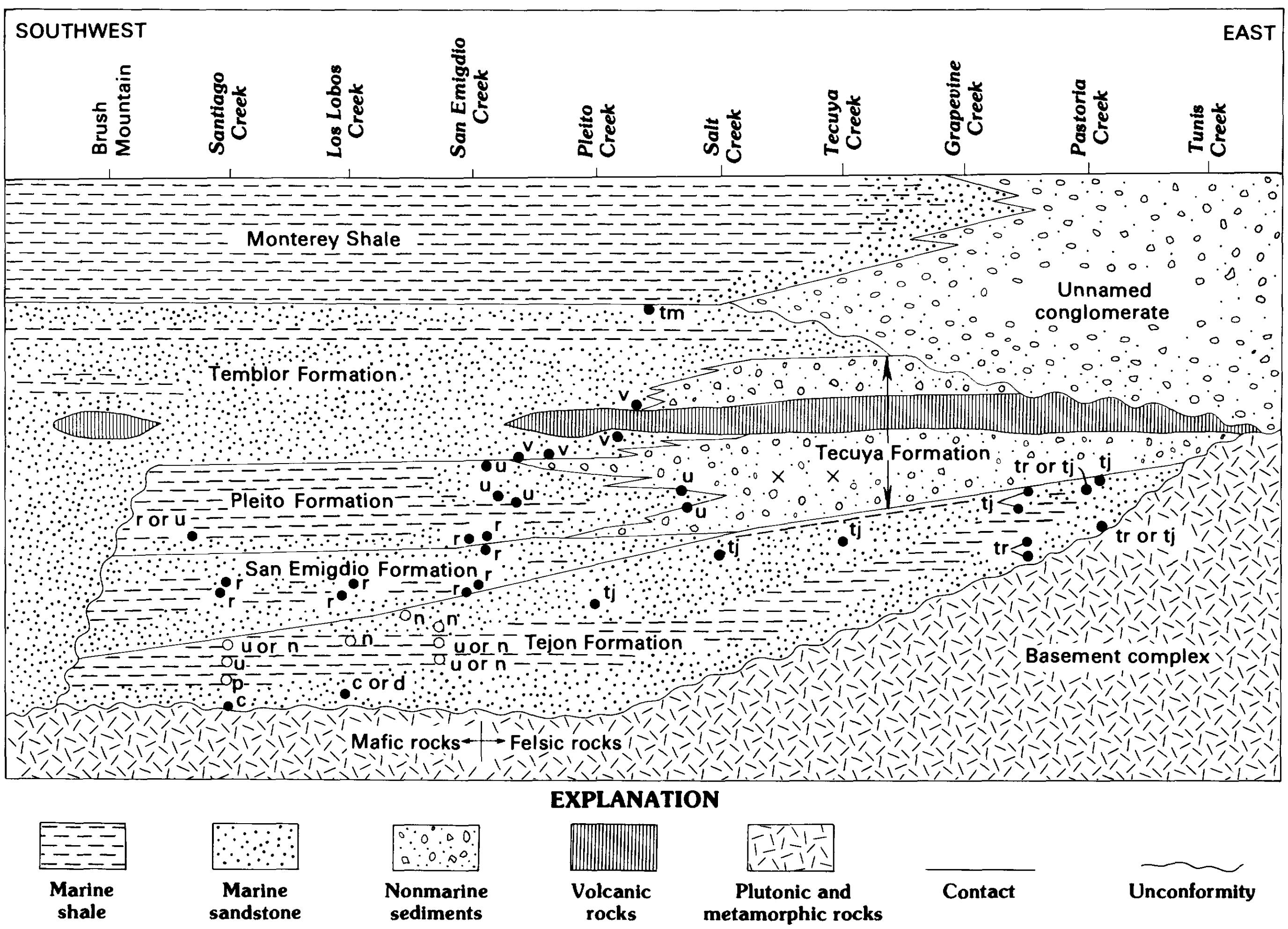


FIGURE 7.—Stratigraphic relations from southwest to east and critical age determinations from lower and middle Tertiary stratigraphic units of western Tehachapi and San Emigdio Mountains, modified from Nilsen and others (1973, fig. 3). Dots with letters indicate critical megainvertebrate collections and stage assignment: c, "Capay Stage"; d, "Domengine Stage"; tr, "Transition Stage"; tj, "Tejon Stage"; r, Refugian Stage; u, unnamed stage (Addicott, 1972); v, "Vaqueros Stage", tm, "Temblor Stage". Circles with letters indicate critical foraminiferal collections and stage assignment: p, Penutian; u, Ulatisian; n, Narizian. Locations of early Arikareean mammals in the Tecuya Formation (Stock, 1920, 1932) are indicated by ×. Not drawn to scale nor with reference to time lines.

The outcrop pattern of the Tejon Formation from its eastern limit to San Emigdio Canyon is relatively simple, permitting fairly continuous observations of the unit in a north-dipping homocline that locally dips very steeply and is overturned toward the north. Its strike is generally east-west but east of Pastoria Creek bends to the northeast. Minor tear faults near Salt Creek and some small folds near Pleito Creek interrupt the homoclines. Extensive landsliding also breaks the continuity of the homocline east and west of Grapevine Creek, where the Pleito thrust fault forms the base of the mountain front. The radial distributions of the scattered northeast- and northwest-striking outcrop blocks adjacent to the high peaks east and west of Grapevine Creek suggest that these blocks, which are as much as several square kilometers in area, may be rotated, tilted, and overturned coherent masses of bedrock that were transported downslope within less coherent landslide debris (figs. 4 and 5). Restricted outliers of the Tejon Formation are present within the basement complex south of the main homocline; the largest are located in the Liveoak Canyon area.

The outcrop pattern of the Tejon Formation from San Emigdio Creek to Santiago Creek is more complex because of numerous faults, asymmetric folds, high relief, the unconformity in the Tertiary section near Brush Mountain, the outlier of gabbroic basement complex near Los Lobos Creek, and volcanic rocks in the Brush Mountain area. The large proportion of shale in the formation in this area, which results in poor exposures and abundant landslides, combined with a scarcity of megafossils, makes the correlation and identification of units more difficult in this area than farther east.

The Devils Kitchen syncline is the largest and most prominent fold in this area and dominates the structural pattern of the area; it is flanked on the north by lesser folds that can be traced westward from near Pleito Creek to the vicinity of Brush Mountain. The Devils Kitchen syncline is asymmetric, with a more steeply dipping south limb; it is succeeded to the north by an asymmetric anticline and another asymmetric syncline that have been thrust northward along several branches and thrust faults associated with the Pleito fault system (pl. 1; fig. 3). These faults and folds separate outcrops of the Tejon into two bands, the northern, located on the north side of and in depositional contact with the outlier of gabbroic basement in the lower part of the upper plate of the Pleito thrust fault, and the southern, located south of and in depositional contact with the gabbroic outlier. Near Santiago Creek, the two bands join around the west side of the outlier. In the San Emigdio to Santiago Creek area, the Tejon outcrops are truncated on the south by a major fault that juxtaposes basement rocks against the Tejon and on the southwest by the unconformable Temblor Formation.

STRATIGRAPHY

STRATIGRAPHIC NOMENCLATURE

Marks (1941b, 1943) examined the Tejon Formation in its type area, which he defined as "the elongate strip of land on the north flank of the Tehachapi Mountains between Tecuya Creek on the west, and Pastoria Creek on the east. it extends about 5 miles [8 km] to the east and 3 miles [4.8 km] to the west of the point where U.S. Highway 99 enters the Tehachapi Mountains." Within the type area, Marks divided the Tejon into a conformable sequence of four members, in ascending order, the Uvas Conglomerate Member, Liveoak Member, Metralla Sandstone Member, and Reed Canyon Silt Member. He designated type localities for each member and provided thicknesses, ages, and lithologic descriptions. However, he did not examine or describe the Tejon Formation east or west of his designated type area.

Harris (1950, 1954), working between Pastoria and Tunis Creeks east of the type area, did not recognize the four members of Marks but did prepare a measured section of the sequence he observed. The section consists primarily of sandstone with some interbedded conglomerate; Harris believed that the Tejon Formation exposed in this area was equivalent to the upper part of Marks' (1941b, 1943) Liveoak Member. Van Amringe (1957), working in the Brush Mountain area, also did not recognize the members of Marks; instead, he mapped and described the Tejon Formation as undifferentiated conglomerate, sandstone and shale.

Hammond (1958) divided Eocene strata between San Emigdio Creek and Santiago Creek into a lower conglomerate and sandstone and an upper shale, siltstone and slabby sandstone. He decided not to use the name Tejon Formation for these strata, although acknowledging that they probably correlated with the Tejon Formation in the type area, because the term "Tejon" had been used by Clark and Vokes (1936) for the provincial megainvertebrate stage that was formerly thought to be equivalent to the late Eocene but is now considered to be middle Eocene.

Dibblee (1961), who mapped sandstone and shale of the Tejon Formation west of Grapevine Creek, did not differentiate or name these units or relate them to the four members recognized by Marks. DeLise (1967) divided the Tejon Formation in the San Emigdio Canyon area into three informal units rather than members, because he felt that abrupt lateral lithologic changes in the units did not permit them to be mapped clearly as formal stratigraphic units. He recognized a basal sandstone with interbedded conglomerate and shale, a middle mudstone and siltstone, and an upper interbedded sandstone and shale.

My own studies, combined with geologic mapping by Dibblee (1973a) and Dibblee and Nilsen (1973) and paleontologic studies by W. O. Addicott, W. V. Sliter, and R. Z. Poore, permit the redefinition or redescription of the four members of Marks (1941b, 1943) and show clearly that they can be traced throughout the map area. The four members of Marks can be traced and mapped relatively continuously from near Tunis Creek on the east to Santiago Creek on the west (fig. 7; pl. 1). Some major facies changes are present, particularly within the Metralla Sandstone Member, but these have now been clearly mapped and are evident in the field.

The provincial megainvertebrate stage "Tejon," though not defined, is a well established term and at present need not be confused with the Tejon Formation if authors clearly state in which context the term is used and quotation marks are used for the stage. Because outcrops of the Tejon Formation are relatively continuous in the western Tehachapi and San Emigdio Mountains and are separated from coeval strata for long distances by a cover of younger sedimentary rocks or major strike-slip faults, I strongly suggest that this name not be applied to Eocene strata elsewhere in California other than those cropping out in the western Tehachapi and San Emigdio Mountains.

The Uvas Conglomerate Member is the basal member of the Tejon Formation. It was named by Marks (1941b) for outcrops on the west side of Grapevine Creek, formerly called Canada de las Uvas, about 2 miles (3.2 km) south of Grapevine (pl. 1). Here it is about 110 feet (34 m) thick, well exposed, and lies with depositional contact upon the quartz diorite-granodiorite basement complex (fig. 8). The section shown by Marks (1943, figs. 232, 233) of the Uvas Conglomerate Member is herein designated the type section and is discussed below in more detail.

The Liveoak Member of Marks (1941b, 1943) was renamed the Liveoak Shale Member by Nilsen (1972). It was named by Marks (1941b) for outcrops located primarily on the east side of Liveoak Canyon, its type locality, about 3 miles (4.8 km) east of Grapevine and about ⅔ mile (1.1 km) south of the mouth of the canyon (pl. 1). According to Marks, the Liveoak at its type section is 1,970 feet (600 m) thick and rests directly on the basement complex, the other members of the Tejon Formation being absent. My work suggests that Marks erred in assigning all of the Tejon section in Liveoak Canyon to the Liveoak; the Uvas Conglomerate and Metralla Sandstone Members are also present in Liveoak Canyon. These three members have an aggregate thickness of only about 1,270 feet (387 m) in this section and the entire upper part of the sequence measured by Marks along the creek consists of landslide debris that also covers the basal contact of the Tejon Formation. I measured the upper part of the Tejon section along the ridge crest northeast of Liveoak Canyon, where the section is not covered by landslide debris. Because the Liveoak generally is poorly exposed throughout the region, a good reference section is lacking; consequently, Liveoak Canyon is retained as the type section, but the Liveoak Shale Member there is herein stratigraphically restricted on the basis of the new detailed mapping.

The Metralla Sandstone Member was named by Marks (1941b, 1943) for Metralla Canyon, about one mile (1.6 km) to the east and parallel to Reed Canyon, the type locality of the Metralla Sandstone Member. The type locality is on the east side of Reed Canyon, about 2 miles (3.2 km) southwest of Grapevine and about ¾ mile (1.2 km) south of the mouth of the canyon (pl. 1). Marks measured a thickness of about 1,300 feet (397 m) for the section of the Metralla at its type locality, where it lies conformably between the Liveoak Shale and Reed Canyon Siltstone Members. My work indicates that the thickness of the Metralla at this section was overestimated by Marks as a result of extensive landsliding. This landsliding probably involves the downslope movement of large blocks of relatively coherent bedrock, with attendant folding and faulting, as shown on plate 1. As a result the Metralla is repeated in Reed Canyon, a repetition also suggested by paleontologic data; the true thickness of the unit here is less than 1,300 feet (397 m). Another section, measured in detail along Colorful Creek (pl.1), is herein designated a reference section.

The Reed Canyon Silt Member of Marks (1941b, 1943) was renamed the Reed Canyon Siltstone Member by Nilsen (1972) and is the uppermost member of the Tejon Formation. The Reed Canyon was named for outcrops at its type locality in Reed Canyon, where it crops out above the Metralla Sandstone Member and beneath the Tecuya Formation. Marks (1943) measured a thickness for it here of about 160 feet (49 m), noting that Reed Canyon and the first adjacent canyon to the east are the only places in the type area of the Tejon where it crops out. The section measured by Marks (1943, fig. 232) at the type locality of the Reed Canyon is designated herein as the type section and is discussed below in more detail.

UVAS CONGLOMERATE MEMBER

DEFINITION

The Uvas Conglomerate Member, the lowest member of the Tejon Formation, forms a sequence of buff-weathering marine conglomerate and sandstone as thick as 400 feet (122 m). It rests unconformably on the basement complex and generally grades upward into the Liveoak Shale Member; the upper contact locally may be abrupt rather than gradational. The Uvas Conglomerate Member crops out relatively continuously from Santiago Creek eastward to about ¾ mile (1.2 km) east of Pastoria Creek. East of the Pastoria Creek area, the Tejon Formation is thin and consists primarily of sandstone and conglomerate from which the Uvas cannot be differentiated from other members (pl. 1). The Uvas locally contains abundant molluscan fossils and large foraminifers.

TYPE SECTION

The section on the west side of Grapevine Creek (fig. 9) is here designated the type section of the Uvas Conglomerate Member. It is located 1.75 miles (2.8 km) south of Grapevine and about 200 feet (61 m) upslope (S ½ sec. 29, T. 10 N., R. 19 W., San Bernardino base line and meridian, Grapevine 7½-minute quadrangle) from a Mobil Oil Company pipeline station located on an auxiliary road west of the southbound lane of Interstate Highway 5.

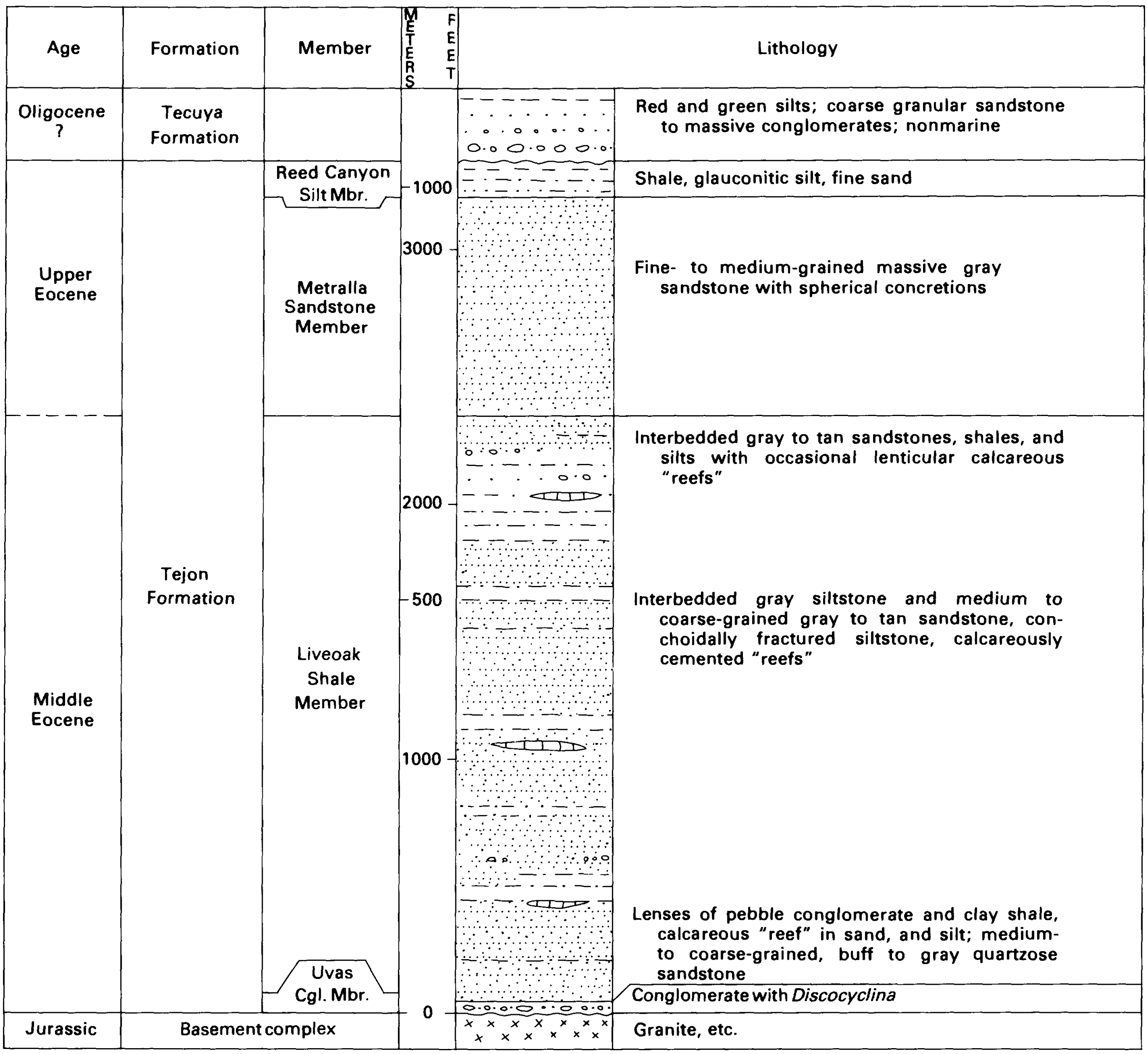


FIGURE 8.—Stratigraphic section slightly modified from Marks (1943, fig. 233) of the Tejon Formation.

	Thickness	
	Feet	*Meters*
Tejon Formation (part):		
Liveoak Shale Member (lower part):		
Fine-grained sandstone, siltstone, and shale; thin-bedded.		
Contact with Uvas Conglomerate Member conformable		
Uvas Conglomerate Member:		
12. Sandstone, medium- to coarse-grained; finer grained at top; beds, massive, 1-3 ft (0.3-1 m) thick; contains pebbles as large as 3 in. (7.6 cm) in diameter scattered throughout but most abundant at base; bioturbation local. Oyster and ribbed pelecypod shells abundant at base; variety of fossils at top, including small pelecypods, *Turritellas*, and other gastropods	20.0	6.1
11. Siltstone, shale, and fine- to coarse-grained sandstone, interbedded and poorly stratified; bioturbation local in sandstone and siltstone; pebbles as large as 6 in. (15 cm) in diameter scattered throughout unstratified siltstone matrix. Oyster shells abundant in upper part............	14	4.3
10. Cobble conglomerate and coarse-grained sandstone, interbedded. Conglomerate contains clasts of mostly quartzite and porphyritic volcanic rocks, clasts as large as 12 in. (30.5 cm) in diameter. Sandstone, flat stratified beds as thick as 1-6 ft (0.3-1.8 m); contains abundant shell material, broken and unbroken, mostly gastropods and ribbed pelecypods........................	15	4.6
9. Cobble conglomerate; contains a variety of clasts, mostly quartzite and porphyritic volcanic rocks as large as 8 in. (20 cm) in diameter; contains gastropods and mollusk shells, broken and unbroken, scattered	23	0.7
8. Sandstone, coarse-grained, finely conglomeratic; bedding thick, irregular; contains abundant gastropods, some pelecypods, and locally abundant *Spiroglyphus*-type worm tubes.......................	8	2.4
Covered interval (landslide debris).............	7	2.1
7. Calcareous sandstone, medium- to coarse-grained, interbedded with noncalcareous sandstone, fine- to medium-grained. Calcareous sandstone, massive beds 1-3 ft (0.3-0.9 m) thick; contains some broken shells. Noncalcareous sandstone, beds ¼-2 in. (0.6-5 cm) thick, laminated to flat-stratified; contains rare unbroken mollusk shells	2.5	0.8
6. Sandstone, calcareous, medium-grained, hard; contains shell debris, finely broken, and some carbonaceous material..........................	1.5	0.5
5. Sandstone, fine-grained, well-sorted, thin-bedded, flat-stratified, bioturbated; contains small amounts of carbonaceous material and broken shells.............................	12	3.7
4. Sandstone, coarse-grained, finer grained upward, conglomeratic; contains scattered boulders and small amounts of broken shell debris......	11.5	3.5
3. Sandstone, medium-to coarse-grained; contains shell material, abundant, broken, sorted, and concentrated in irregular thin layers................	10	3.1
2. Sandstone, very coarse to coarse-grained, conglomeratic; contains locally abundant gastropods and conglomerate clasts of gneissic schist, quartz diorite-granodiorite, schist, quartzite, and pegmatite as large as 3 feet (0.9 m) in diameter.............	3.5	1.1
1. Sandstone, very coarse grained, finely conglomeratic, poorly sorted; beds irregular, 1-5 ft (0.3-1.5 m) thick; unfossiliferous. Sandstone looks similar to underlying gneissic granodiorite except for crude layering and is probably a residual product from weathering of basement complex...........................	3.5	1.1
Total thickness of Uvas Conglomerate member...........................	110.8	34.8
Basement complex:		
Gneissic quartz diorite-granodiorite, coarse-grained to pegmatitic.		
Contact with overlying Uvas Conglomerate Member unconformable.		

LITHOLOGY, THICKNESS, AND STRATIGRAPHIC RELATIONS

The contact of the Uvas Conglomerate Member with the basement complex is topographically irregular, apparently reflecting a depositional surface with considerable relief. The Uvas is consequently thick over topographic lows and thin or absent over topographic highs on this surface. The Liveoak Shale Member thus rests directly on the basement complex in some areas, such as between Tecuya and Salt Creeks (pl. 1). The Uvas ranges in thickness from zero to about 400 feet (122 m), averaging perhaps about 200 feet (61 m). The gradational upper contact is not always easily located, because the Uvas grades upward through thinner bedded, finer grained sandstone with more abundant shale and siltstone interbeds into the Liveoak Shale Member. I have mapped the contact at the top of the uppermost prominent bed of coarse-grained sandstone or conglomerate, inasmuch as sandstone in the lower part of the Liveoak is generally medium grained or finer.

The Uvas is characterized by abrupt lateral and vertical changes in lithology, petrology, and grain size. The unit includes coarse boulder conglomerate composed of clasts derived from the directly underlying basement rocks, finer grained pebble and cobble conglomerate derived from more distant sources, accumulations of irregular-sized breccia fragments that appear to have been formed in place by weathering processes, and thin- to thick-bedded sandstone and shale.

Conglomerate of the Uvas contains abundant well-rounded clasts of quartzite and porphyritic volcanic rocks in addition to locally derived gneissic, granodioritic, and gabbroic materials. Sandstones are typically fairly well sorted, have moderately rounded grains and are compositionally mature; locally where they are very well sorted, have well-rounded grains, and

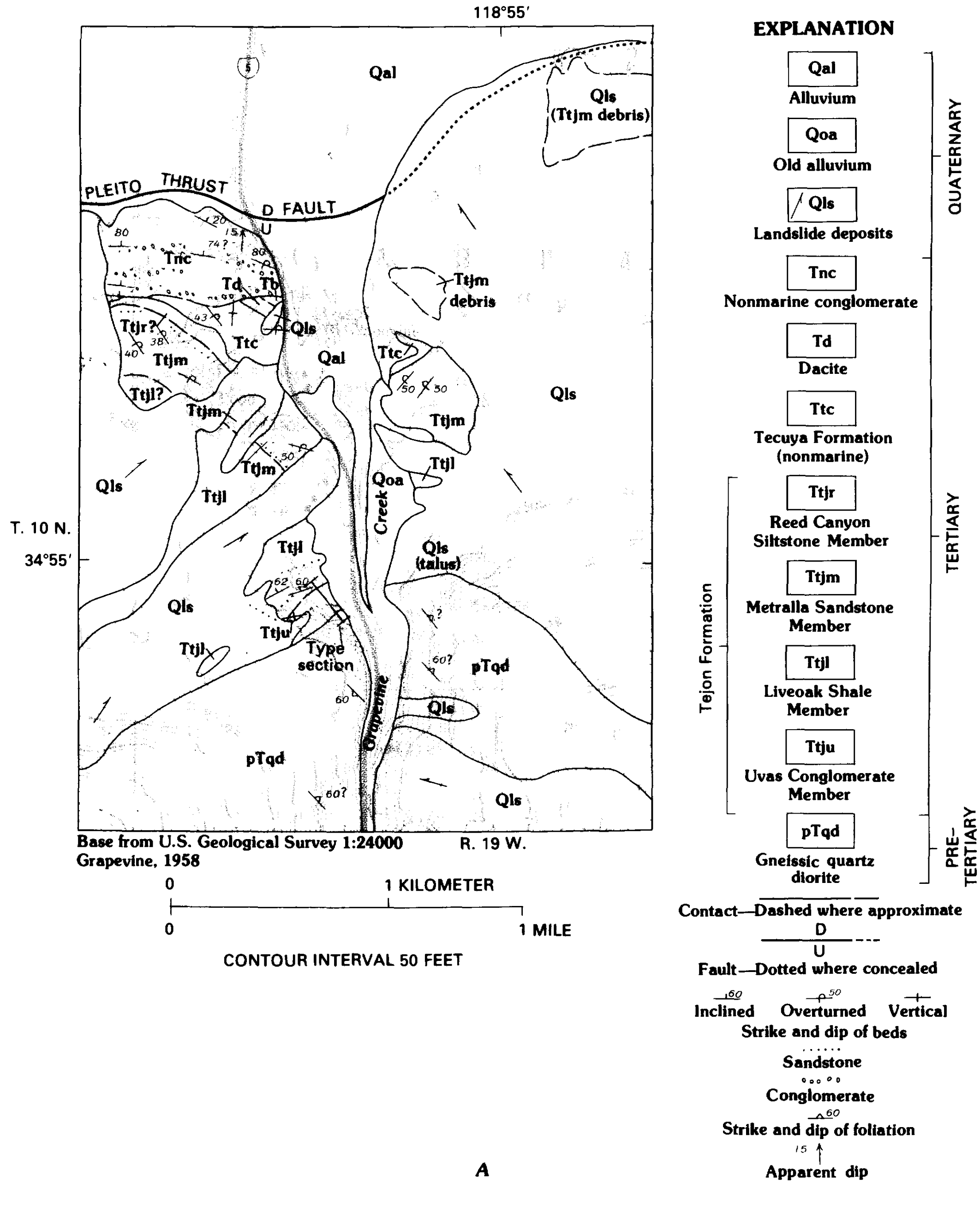


FIGURE 9.—Geologic map of Grapevine Creek area and type section of the Uvas Conglomerate Member of the Tejon Formation. *A*, Geologic map from Dibblee and Nilsen (1973).

are very rich in quartz, they were probably deposited in high-energy environments such as shoreline areas. Common sedimentary structures in the Uvas include medium- to large-scale cross-strata, flat strata, current ripple markings, massive bedding, and abundant trace fossils—in particular, long vertically oriented cylindrical burrows. The conglomerates are characterized by a variety of fabrics, including locally well-developed imbrication of pebbles, cobbles, and shells. Abrupt vertical and lateral variations in bedding thickness and maximum clast size are typical.

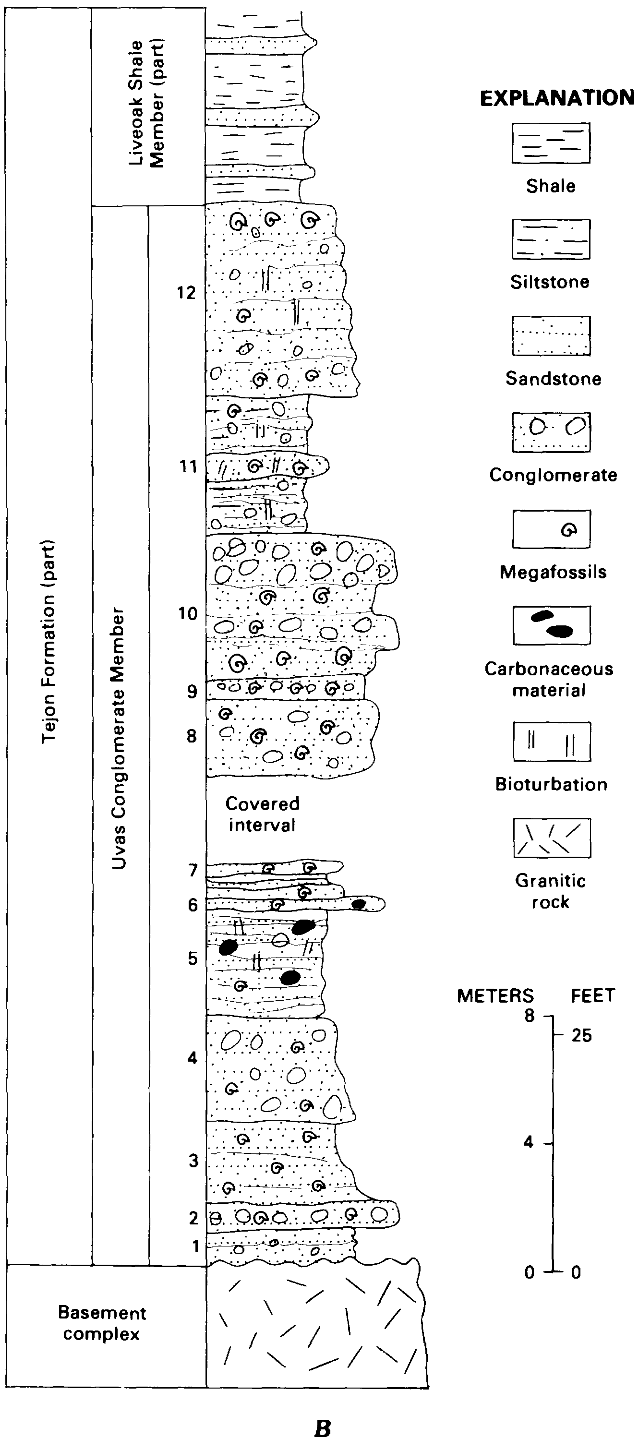


FIGURE 9.—Continued. *B*, Type section. Numbers refer to units described in type section.

The Uvas Conglomerate Member contains locally abundant megafossils that invariably indicate shallow-marine deposition, generally less than 90 ft (27 m), and commonly nearshore environments with bare rock exposed as shoals or reefs, and possibly locally intertidal conditions (W. O. Addicott, written commun., Feb. 18, 1972). The lowermost faunas are generally more epifaunal and indicative of extremely shallow, probably rocky or intertidal, environments, whereas uppermost faunas are more representative of sandy, level bottoms at inner sublittoral or deeper depth (low tide to about 300 ft, 180 m), as seen in the measured section at the Edmonston Pumping Plant (USGS localities M4631, M4632, M4633, M4634, and M4639).

East of the Edmonston Pumping Plant the Tejon Formation is very thin and its members have not been differentiated. The basal part contains unfossiliferous reddish-weathering conglomeratic strata that appear to be nonmarine in origin, so that instead of simply being overlapped by the basal beds of the nonmarine Tecuya Formation, the Tejon (including the basal undifferentiated part inferred to be equivalent to the Uvas Conglomerate Member) probably grades laterally into partly coeval nonmarine strata. In the westernmost exposures, the Uvas Conglomerate Member is correlative with the lower unit of Eocene rocks mapped by Hammond (1958).

AGE

Marks (1940, 1941a, b) assigned the Uvas Conglomerate Member to the late middle Eocene on the basis of the large foraminifers (*Actinocyclina* cf. *A. aster* Woodring, 1930, and *Discocyclina* sp. nov.), numerous small foraminifers, oyster fragments, the annelid tube *Tubulostium tejonensis* (Arnold), and abundant calcareous algae (Stanford Univ. locality 2255). Collections by the author from the middle and upper parts of the Uvas in Liveoak Canyon to the east (USGS localities M4644 and M4645) yield assemblages that include *Ectinochilus canalifera supplicatus* that are indicative of the "Transition" and "Tejon" Stages, respectively. Farther east at the Edmonston Pumping Plant, molluscan fossils from the lower part of the exposed section (USGS localities M4631, M4632, M4633, and M4634) yield assemblages diagnostic of the "Transition" or "Tejon" Stages; the fauna from localities M4632, M4633, and

M4634 include the gastropods *Macoma viticola, Tellina castacana, Ficopsis remondi,* and *Turritella uvasana sargeanti,* which are restricted to the "Tejon" Stage. East of there, molluscan fossils from the lower part of the Uvas indicate "Transition" or "Tejon" ages (USGS Locality M4630).

Molluscan fossils from the Uvas in the Los Lobos Creek area (USGS localities M4649 and M4659) indicate a "Capay" or "Domengine" age, based on the presence of *Ectinochilus macilentus.* A "Capay" age is indicated by molluscan fossils, including *Turritella merriami, Ficopsis meganosensis packardi,* and *Turritella andersoni susannae,* from the Uvas Conglomerate Member in East Twin Creek of Hammond (1958), less than one mile (1.6 km) east of Santiago Creek (USGS localities M4654 and M4656). These localities east of Santiago Creek are the same as those from which Hammond (1958, p. 30; UCLA fossil locality 3492) collected a "Capay"-age megafauna from the lower unit of Eocene rocks. Hammond (1958, p. 30) also collected "Capay"-age molluscan fossils from UCLA locality 3552 in upper Los Lobos Creek (pl. 1).

To summarize, on the basis of paleontologic interpretations, the Uvas is of early and middle Eocene age. It is oldest in the west, where "Capay"-stage mollusks were collected near Santiago Creek. It is progressively younger eastward, ranging through the "Domengine Stage" and "Transition Stage" to the "Tejon Stage" east of Grapevine Creek (fig. 5, pl. 1). Thus, the Uvas is a basal conglomerate that records a marine transgression across the outcrop area from west to east that spanned much of the Eocene Epoch.

LIVEOAK SHALE MEMBER

DEFINITION

The Liveoak Shale Member, the second and generally thickest member of the Tejon Formation, consists of shale with some interbedded fine-grained sandstone and siltstone as thick as about 2,000 feet (610 m). It gradationally conformably overlies the Uvas Conglomerate Member and conformably grades upward into the Metralla Sandstone Member. It crops out continuously from about ¾ mile (1.2 km) east of Pastoria Creek westward to Santiago Creek; east of Pastoria Creek, the Liveoak Shale Member cannot be differentiated because the Tejon Formation is thinner and consists primarily of sandstone and conglomerate that cannot be differentiated into members (pl. 1). The Liveoak Shale Member locally contains some molluscan fossils and relatively abundant foraminifers.

TYPE SECTION

The type section of Marks (1941b, 1943) is here stratigraphically restricted to exclude rocks now assigned to the Uvas Conglomerate and Metralla Sandstone Members. It is located on the east side of and about ⅔ mile (1.1 km) south of the mouth of Liveoak Canyon in the S¼ sec. 23, T. 10 N., R. 19 W., San Bernardino base line and meridian, Grapevine 7½-minute quadrangle (figs. 10 and 11). It is poorly exposed in the canyon but is reasonably well exposed on the ridge crest east of the canyon.

	Thickness Feet	Thickness Meters
Tejon Formation (part):		
Metralla Sandstone Member (lower part):		
Sandstone, fine-grained, flat-stratified; contains abundant mollusks, including oriented *Turritellas.*		
Contact with Liveoak Shale Member conformable.		
Liveoak Shale Member:		
8. Siltstone, massive; bioturbated	10	3
7. Sandstone, fine- to medium-grained, flat-stratified; mollusks abundant	8	2.4
6. Siltstone, massive; bioturbated	20	6
5. Sandstone, fine-to medium-grained, massive; mollusks abundant	6	1.8
4. Shale, with interbedded siltstone and sandstone. Shale, thin-bedded or laminated, contains foraminifers. Siltstone and fine-grained sandstone beds thin; contain rare megafossils which are more abundant at the top and bottom	391	119
3. Siltstone, massive; bioturbated	12	3.7
2. Sandstone, fine- to medium-grained, very thinly stratified; contains some scattered mollusks	8	2.4
1. Siltstone, massive; bioturbated	15	4.6
Total thickness	470	143.0
Uvas Conglomerate Member (upper part):		
Sandstone, fine- to medium-grained, massive; weathers brown. Contains abundant mollusks in place and coiled tubules of annelid worms.		
Contact with overlying Liveoak Shale Member conformable.		

LITHOLOGY, THICKNESS, AND STRATIGRAPHIC RELATIONS

The Liveoak Shale Member (called the "worm-impression siltstone" by some petroleum geologists) consists generally of a thick (0-2,000 ft [0-610 m]), monotonous sequence of laminated to massive shale and mudstone containing interlaminated siltstone. It is sandier, in both its lower and upper parts, where it grades into the adjacent sandy members of the Tejon Formation. It contains a few rare pebbly sandstone beds in the central part of the area near Pleito Creek.

The Liveoak Shale Member is characteristically so extensively bioturbated that stratification is commonly almost completely destroyed. However, west of San Emigdio Canyon, stratification generally is preserved and consists of thin, flat laminae of silt- and clay-sized sediment and local small-scale cross-laminae produced by migrating current ripples. Bioturbation consists of a great variety of burrows and borings that are generally very irregular in trace and shape. The thin interbedded sandstone beds in the upper and lower parts of the Liveoak are commonly graded and cross-stratified, and some have sole markings suggestive of deposition by turbidity currents.

In the Santiago Creek area, the foraminiferal assemblages indicate deposition at lower bathyal to abyssal depths, similar to the Kreyenhagen Formation to the northwest (R. S. Beck, written commun., June 4, 1971). In the San Emigdio Canyon area, the foraminiferal assemblages indicate deposition at bathyal depths (DeLise, 1967, p. 15). Farther east, the Liveoak eventually grades laterally into sandy shale and sandstone containing abundant shallow-marine megafossils. Because it becomes coarser grained, it cannot be

FIGURE 10.—View north into Liveoak Canyon showing exposures of the Uvas Conglomerate (uv), Liveoak Shale (lo), and Metralla Sandstone (m) Members of the Tejon Formation. Other abbreviations: bc, basement complex; tc, Tecuya Formation; ls, landslide deposit; CA, California Aqueduct.

differentiated lithologically as a shale unit east of Pastoria Creek, although megafossils identified by W. O. Addicott (written commun., Aug. 27, 1972) from the sandstone in the middle part of the Tejon Formation at the Edmonston Pumping Plant (USGS localities M4632, M4634, and M4639) indicate deposition at deeper depths than those at the base and top (pl. 1).

AGE

Marks (1941b, 1943) assigned the Liveoak Shale Member to the middle Eocene on the basis of molluscan fossils and small foraminifers collected from his type section. However, the type section is now stratigraphically restricted to exclude rocks now assigned to the Uvas Conglomerate and Metralla Sandstone Members. Molluscan fossils collected by me from within the Liveoak Shale Member in Liveoak Canyon (USGS Locality M4643; fig. 8) are diagnostic of a "Transition" age (W. O. Addicott, written commun., Feb. 18, 1972) on the basis of the joint occurrence of *Ficopsis horni* ("Transition" to "Tejon") and *Ficopsis remondi* ("Capay" to "Transition").

Foraminiferal faunules from the Liveoak Shale Member indicate a Penutian to Narizian age in the Santiago Creek area (USGS Cenozoic localities Mf2513, 2514, 2515, 2516; see also R. S. Beck, written commun., June 14, 1971 in foraminiferal list). In the San Emigdio Canyon area, DeLise (1967, p. 19) determined a Narizian age for it. In addition, because it rests conformably on the Uvas Conglomerate Member, which has been dated on the basis of megafossils as "Capay" to "Tejon," its suggested Penutian to Narizian age is consistent with the regional stratigraphic relations. The age of the Liveoak is therefore early and middle Eocene.

METRALLA SANDSTONE MEMBER

DEFINITION

The third member of the Tejon Formation, the Metralla Sandstone Member, forms a sequence of marine sandstone with lesser amounts of siltstone, conglomerate and shale as thick as 2,000 feet (610 m). It gradationally overlies the Liveoak Shale Member, and is overlain generally gradationally, but locally abruptly, by the Reed Canyon Siltstone Member, the Liveoak Shale

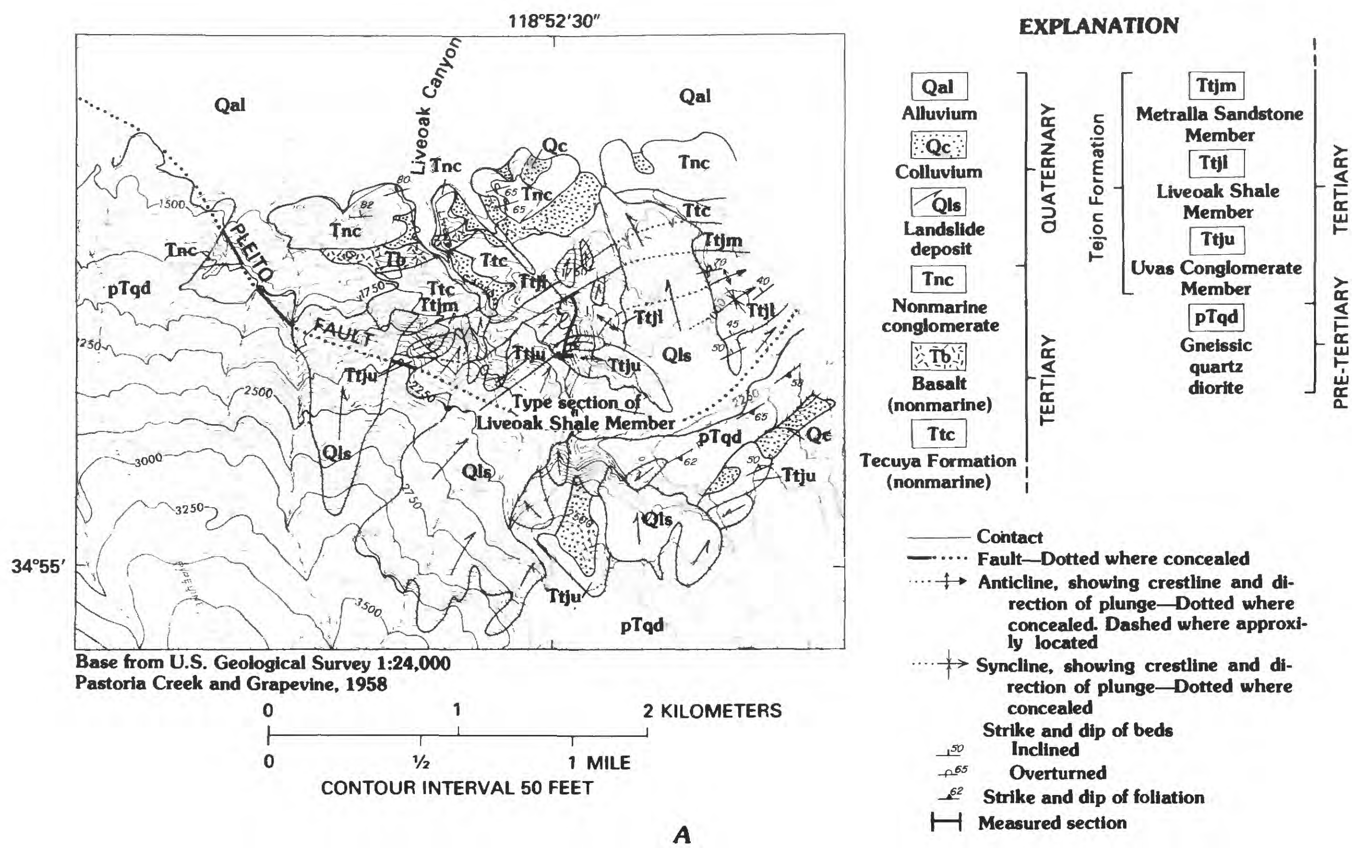


FIGURE 11.—Geologic map of Liveoak Canyon area and measured section of the Tejon Formation. *A*, Geologic map from Dibblee and Nilsen (1973).

Member (in its western exposures as a result of interfingering), the San Emigdio Formation, and the Tecuya Formation. It crops out continuously from about 1.5 miles (2.4 km) northeast of Pastoria Creek to Williams Canyon, and some isolated bodies are present as far west as Los Lobos Creek (pl. 1). Molluscan fossils are locally abundant in sandstone and conglomerate as far west as San Emigdio Canyon, and foraminifers are locally abundant in shale and siltstone. East of Grapevine Creek, mollusks are especially abundant.

TYPE LOCALITY

The section measured by Marks (1941b, 1943) at the type locality of the Metralla Sandstone Member is on the east side of Reed Canyon about 3/4 mile (1.2 km) south of the mouth of the canyon, in the W1/2 sec. 30, T. 10 N., R. 19 W., San Bernardino base line and meridian, Grapevine 7½-minute quadrangle (pl. 1; fig. 12). Unfortunately, this section is poor because of structural

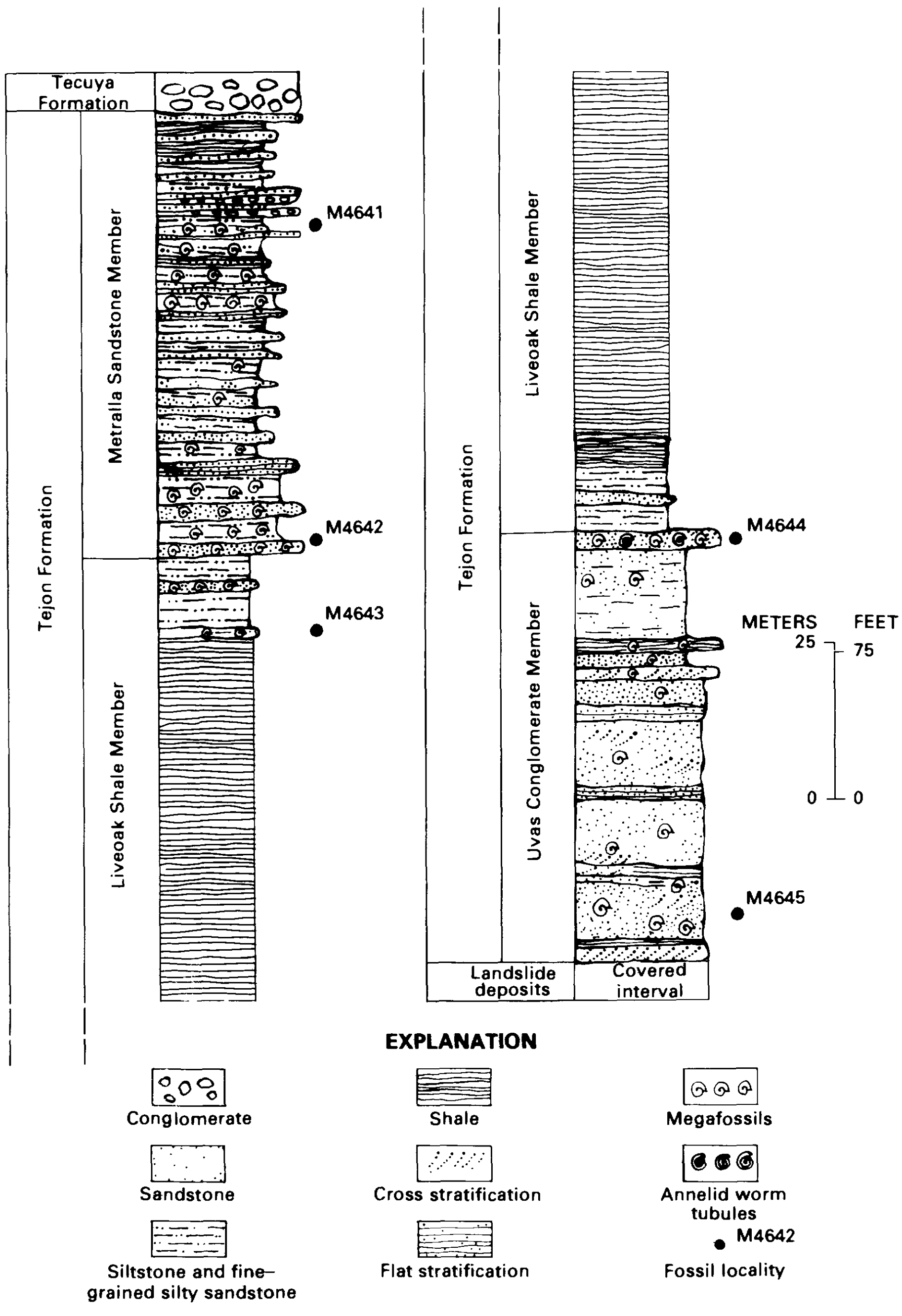


FIGURE 11.—Continued. *B*, Measured section, including type section of the Liveoak Shale Member of the Tejon Formation.

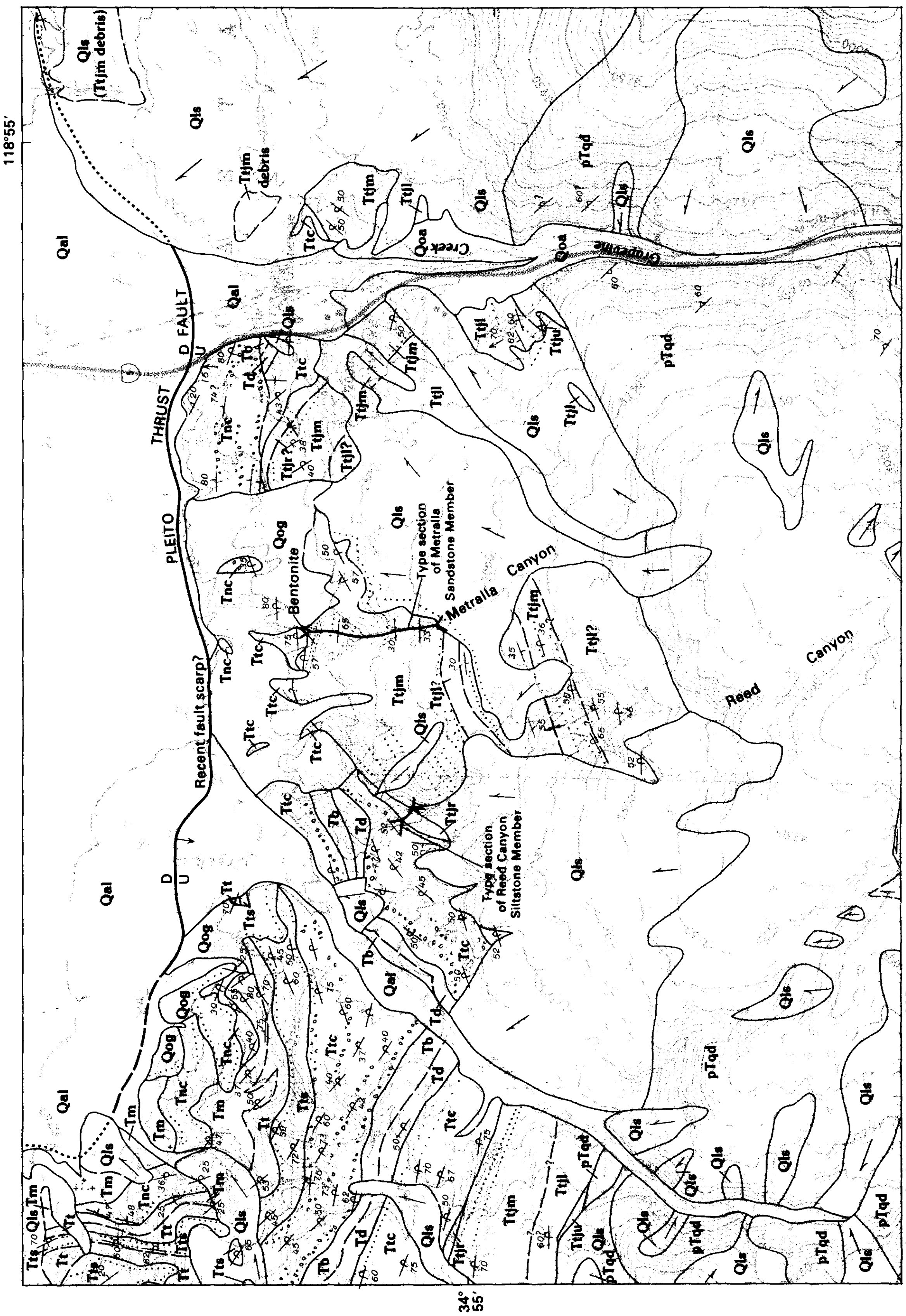
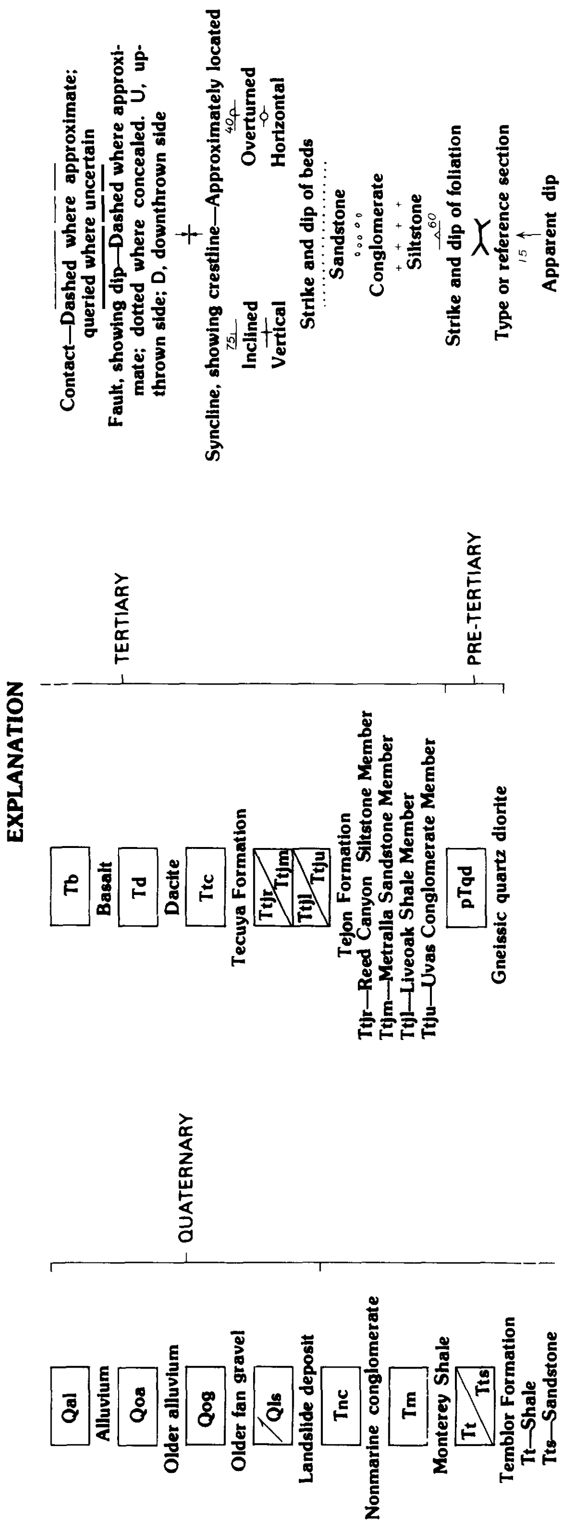
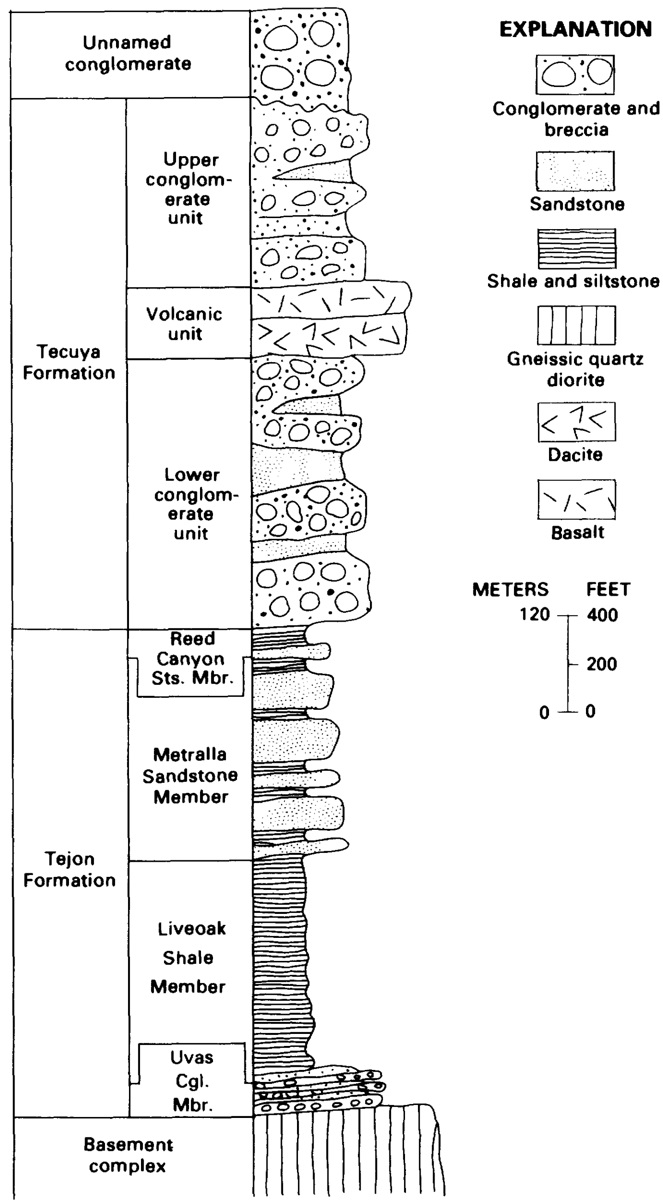


FIGURE 12.—Geologic map and composite measured section of the Tejon Formation. *A*, Geologic map from Dibblee (1973a).





B

FIGURE 12.—Continued. *B*, Composite measured section of the Tejon Formation from Grapevine and Tecuya Creeks and Metralla and Reed Canyons.

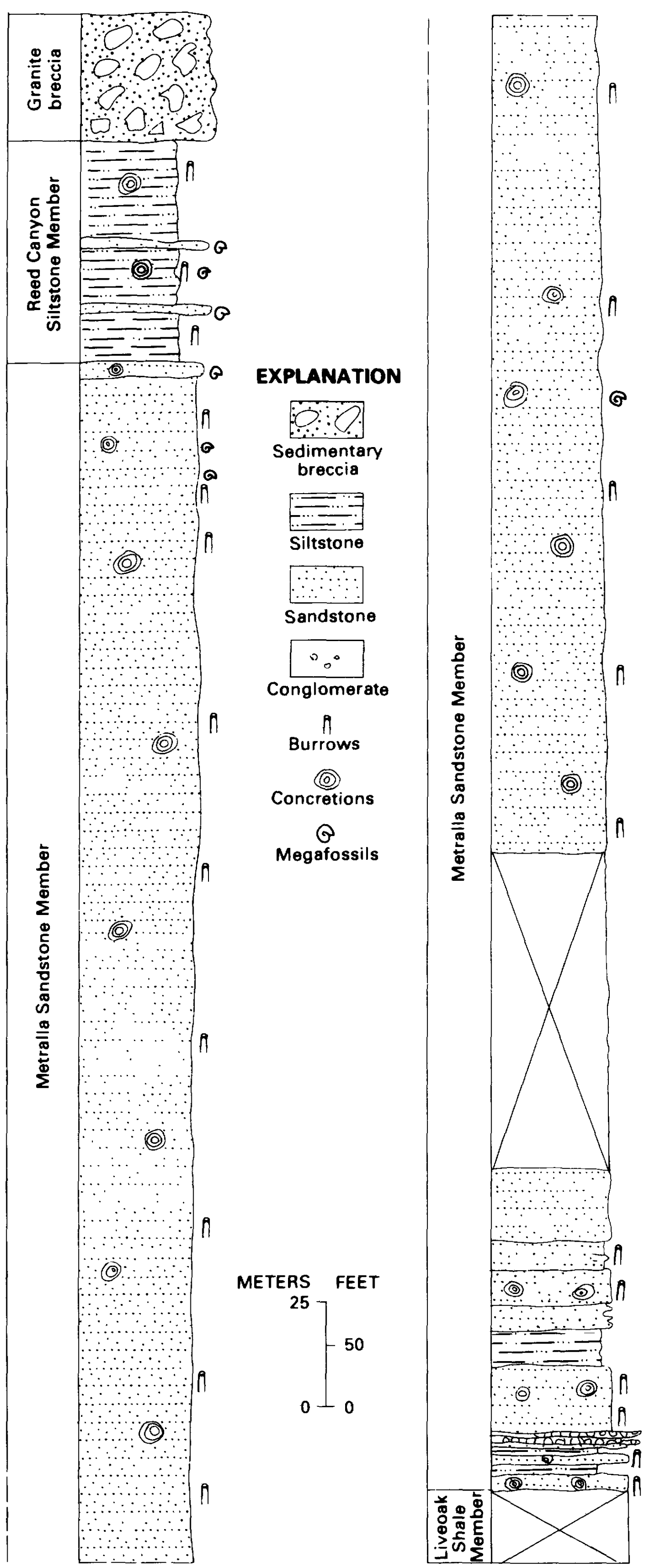


FIGURE 12.—Continued.

complications and landsliding; as a result, it was not remeasured in detail, and the following description of the section is very general.

	Thickness Feet	Thickness Meters
Tejon Formation (part):		
Reed Canyon Siltstone member (lower part):		
Siltstone with some shale interbeds.		
Contact with underlying Metralla Sandstone Member conformable.		
Metralla Sandstone Member:		
Sandstone and shale. Sandstone, silty, fine-grained, massive; beds 1–15 feet (0.3–4.6 m) thick; bioturbated extensively; lacks internal sedimentary structures; carbonaceous material locally abundant; megafossil-rich beds rare; concretions range in size from small spherules an inch (2.5 cm) in diameter to very large irregular megaconcretions 50–100 feet (15–30 m) long. Shale interbeds few, more abundant in lower part....	540	165
Total thickness...........................	540	165
Liveoak Shale Member (upper part):		
Siltstone, silty shale, and shale, interbedded.		
Contact with overlying Metralla Sandstone Member conformable.		

Another section of the Metralla Sandstone Member, however, was measured in detail. This section, located in Colorful Creek (pl. 1), is here designated a reference section. It is located in Colorful Creek, 1 mile (1.6 km) west of Tecuya Creek, along the creek bottom and on the ridge crest to the west, in SE¼ sec. 27, T. 10 N., R. 20 W., Grapevine 7½-minute quadrangle (see pl. 1).

	Thickness Feet	Thickness Meters
Tejon Formation (part):		
Reed Canyon Siltstone Member (lower part):		
Silty shale and siltstone, massive, unstratified.		
Sandstone, fine-grained, calcareous; beds thin, discontinuous, 10 percent of unit; locally fossiliferous. Shale, black, very carbonaceous; extensively burrowed; contains calcareous concretions.		
Total thickness...........................	172	52
Metralla Sandstone Member:		
Sandstone, silty, fine-grained, unstratified; very bioturbated; locally fossiliferous; contains large calcareous concretions.....	28	9
Sandstone, silty, fine-grained, poorly stratified; contains some interbeds of shale and siltstone. Highly bioturbated, largely unfossiliferous; contains large calcareous concretions	1,552	476
Covered interval..........................	242	74
Sandstone, silty, fine-grained, massive, very bioturbated, unfossiliferous; contains rare calcareous concretions.........	60	18
Siltstone and shale, thin interbeds, very bioturbated	7	5
Sandstone, silty, fine-grained, massive to thinly stratified; very bioturbated	3	1

Metralla Sandstone Member—Continued:	Thickness Feet	Thickness Meters
Sandstone, silty, fine-grained, massive, bioturbated; contains large calcareous concretions	27	8
Siltstone and shale, massive; sandstone, fine-grained, one bed 6 in. (0.2 m) thick	5	2
Sandstone, silty, fine-grained, massive, very bioturbated; contains small calcareous concretions	3	1
Siltstone and shale, laminated	2	.6
Sandstone, silty, fine-grained, massive, very bioturbated; contains calcareous concretions	9	3
Siltstone, laminated to massive, locally very bioturbated; some interbedded sandstone, silty, very fine grained, unfossiliferous	29	8
Sandstone, silty, fine-grained, very bioturbated; contains large calcareous concretions; some siltstone, thin beds; very coarse grained sandstone or fine conglomerate at base	65	22
Conglomerate, largest clasts 6 in. (0.2 m) in diameter	1	.3
Sandstone, coarse- to very coarse grained, well sorted, massive; contains calcareous concretions	8	2
Conglomerate, largest clasts 2 in. (0.1 m) in diameter	0.1	.02
Sandstone, medium-grained, well sorted, thin bedded, not bioturbated	1	.3
Covered interval	5	2
Sandstone, medium-grained, well-sorted, massive, not bioturbated	1	.3
Siltstone and sandstone. Siltstone, massive. Sandstone, silty, fine-grained, mostly flat-stratified but with some small-scale cross strata, not bioturbated	10	.3
Sandstone, medium-grained, massive to flat-stratified, not bioturbated	2	.6
Sandstone, fine- to medium-grained; grades upward to shale	1	.3
Sandstone, medium-grained, massive to flat-stratified; interbedded with shale, thin bedded	10	3
Sandstone, silty, fine-grained, massive, bioturbated	2	.6
Siltstone and shale, thinly interbedded. Sandstone, very coarse to coarse-grained, massive; beds 1–3 in. (0.1 m) thick, contains some calcareous concretions, makes up 10 percent of unit	16	5
Sandstone, silty, fine-grained, very bioturbated; contains calcareous concretions	25	8
Total thickness	2,114	656
Liveoak Shale Member (upper part):		
Covered interval with abundant shale float.		

LITHOLOGY, THICKNESS, AND STRATIGRAPHIC RELATIONS

The Metralla Sandstone Member grades upward from the Liveoak Shale Member. It contains locally abundant megafossils in its eastern exposures and abundant conglomerate east of Grapevine Creek. It increases in thickness westward from a few hundred feet (100 m) near Pastoria Creek to about 2,000 feet(610 m) near Pleito Creek; farther west, it thins abruptly by grading laterally into thinly bedded sandstone and shale (fig. 7). Near San Emigdio Canyon, the Metralla interfingers westward with siltstone and shale of the Liveoak Shale Member; here it is locally overlain by shale of the Liveoak Shale Member. Thus, the Metralla Sandstone Member consists of two very distinctive parts or facies—a shallow-marine, megafossil-rich, conglomeratic sandstone to the east, and a deeper marine, microfossil-rich, finer grained sandstone to the west.

The eastern shallow-marine part of the Metralla is characteristically a very bioturbated, silty, fine-grained sandstone; it locally contains abundant mollusks and polymict conglomerate containing primarily clasts of quartzite, porphyritic volcanic rocks, gneiss, and quartz diorite-granodiorite as long as an inch (2.5 cm). Sedimentary features include extensive bioturbation of various sorts, including vertical cylindrical burrows, medium- to large-scale cross-strata, current ripple markings, flat strata, and spherical calcareous concretions (the Metralla has been called the "cannonball sandstone" by some petroleum geologists). It is generally poorly sorted, suggesting a depositional environment with less energy than that of the Uvas Conglomerate Member.

The deeper marine part of the Metralla has some characteristic features of turbidites such as groove casts, flute casts, primary current lineations, mudstone rip-up clasts, load casts, convolute laminations, graded bedding, contorted stratification, synsedimentary slumps, and the development of Bouma (1962) sequences. Minute, deep-water pelecypods in these rocks (USGS locality 4657) indicate middle or even outer sublittoral depths. This part of the Metralla consists mostly of rhythmically alternating beds of sandstone and shale; the sandstone interfingers westward with the dominantly siltstone and shale sequence of the Liveoak Shale Member, which was deposited in even deeper water.

AGE

Marks (1941b), based on numerous megafossil and microfossil collections, particularly from Grapevine Creek and Reed Canyon, concluded that the Metralla Sandstone Member was late Eocene in age. Numerous additional megafossil collections from near Pastoria Creek (USGS locality M4640 and California Academy of Sciences locality 816), Liveoak Canyon (USGS localities M4641 and M4642), Tecuya Creek (USGS locality M4637), east of Salt Creek (USGS localities M4647 and

M4648), Pleito Creek (USGS locality M4651) and east of San Emigdio Creek (USGS locality M4657) indicate a "Tejon" (middle Eocene) age. *Turritella uvasana sargeanti, Oleaguahia horni,* and *Tellina lebecki* from Liveoak Canyon and farther east, and *Turritella uvasana sargeanti* from Pleito Creek indicate the "Tejon" age. Foraminifers from the upper part of the Tejon Formation (the Metralla Sandstone Member of this paper) in San Emigdio Canyon indicate a Narizian age (DeLise, 1967).

Foraminiferal collections from the middle shale unit of the overlying San Emigdio Formation indicate a Narizian age (DeLise, 1967). Megafossils from the San Emigdio Formation indicate a Refugian age west of San Emigdio Creek (USGS localities M4595, M4596, M4597, and M4598) on the presence of *Acila shumardi,* in Los Lobos Canyon (USGS localities M4664 and M4666), and in the San Emigdio Canyon area (USGS localities M4638, M4660, M5785, M5786, M5787, M5788, and M5789). The overwhelming amount of data from the Metralla Sandstone Member support a "Tejon" or Narizian (middle Eocene) age for it.

REED CANYON SILTSTONE MEMBER

DEFINITION

The Reed Canyon Siltstone Member, the uppermost member of the Tejon Formation, forms a sequence of marine and brackish siltstone with minor amounts of fine-grained sandstone and shale. I measured a thickness of 99 feet (30 m) at its type locality, compared to 160 feet (49 m) by Marks (1943); the Reed Canyon Siltstone Member ranges in thickness from zero to about 200 feet (61 m). It rests conformably and gradationally on the Metralla Sandstone Member and is overlain conformably by the Tecuya Formation. It crops out discontinuously between Black and Metralla Canyons but is absent elsewhere, or, if present, has been mapped as part of the upper part of the Metralla or lower part of the San Emigdio Formation, both of which contain siltstone deposits. It locally contains molluscan fossils and foraminifers, as well as carbonaceous and coal-bearing strata.

TYPE SECTION

The section of the Reed Canyon Siltstone Member measured by Marks (1943, figs. 232 and 233) in Reed Canyon is here designated the type section. It is about one-half mile (0.8 km) south of the mouth of the canyon, in the E½ sec. 25, T. 10 N., R. 20 W., San Bernardino base line and meridian, Grapevine 7½-minute quadrangle (pl. 1, figs. 8 and 12).

	Thickness Feet	Thickness Meters
Tecuya Formation (lower part):		
Conglomerate, cobble and boulder, nonmarine; weathers red; sandstone lenses interbedded.		
Conformable contact.		
Conglomerate, pebble and cobble; weathers gray to brown; clasts mostly quartzite and volcanic fragments; contains fossil oysters, rare.		
Sandstone, fine- to medium-grained, at base; bed 2 in. (0.05 m) thick; contains small-scale cross strata and current ripple marks.		
Tejon Formation (part):		
Reed Canyon Siltstone Member:		
3. Shale, silty; laminated; weathers red; finer at top and coarser at base	3	0.9
2. Sandstone, grayish, silty, fine-grained; massive; extensively bioturbated, some laminated beds at base	2	.6
1. Siltstone and interbedded shale; carbonaceous laminae, black, scattered; contains local calcareous concretions that contain mollusk fragments	99	30.2
Total thickness	104	31.9
Metralla Sandstone Member (upper part):		
Sandstone, silty; massive; bioturbated; contains calcareous concretions; mollusk-rich beds scattered.		
Contact with overlying Reed Canyon Siltstone Member conformable.		

LITHOLOGY, THICKNESS, AND STRATIGRAPHIC RELATIONS

The Reed Canyon Siltstone Member, 0-200 feet (0-61 m) thick, consists of fine-grained sandstone, siltstone, and silty shale. It has not been formally recognized east of Grapevine Creek, although it may be present in the upper part of the Tejon Formation at the Edmonston Pumping Plant east of Pastoria Creek as a sequence of carbonaceous siltstone and shale and in the upper part of small outcrops of the Metralla Sandstone Member on the east side of Grapevine Creek as carbonaceous siltstone and shale.

It can be traced westward from Reed Canyon as a thin, very poorly exposed unit of siltstone and shale overlying the Metralla Sandstone Member; it either may grade laterally into the middle shaly unit of the overlying San Emigdio Formation near Salt Creek or may persist westward below the San Emigdio Formation. It is not mappable west of Salt Creek, although thin siltstone and shale is present locally in the uppermost part of the Metralla Sandstone Member as far west as the area between Pleito and San Emigdio Canyons.

The Reed Canyon Siltstone Member locally is very rich in carbonaceous material, containing very thin beds of poorly consolidated coal. It is extensively bioturbated, locally contains mollusks, and most commonly consists of thinly interlaminated siltstone and shale.

AGE

Marks (1941b) assigned a late Eocene age for the Reed Canyon Siltstone Member from foraminifers collected at the type locality; its age farther west is very poorly known. Pelecypods that I collected from it at Salt Creek (USGS locality M4647) were diagnostic only of an early Tertiary age. It may be at least partly coeval with the San Emigdio Formation (Nilsen and others, 1973, p. H12). The Reed Canyon is therefore here considered to be of middle and late(?) Eocene (late Narizian and Refugian?) age.

STRATIGRAPHIC RELATIONS

The Tejon Formation is conformably overlain by the marine San Emigdio Formation in the western San Emigdio Mountains (pl. 1). In its type section in San Emigdio Creek, it is 1,090 feet (332 m) thick and consists of massive sandstone with some pebble conglomerate in the lower part, sandy shale and mudstone in the middle part, and abundantly fossiliferous, thin- to thick-bedded sandstone in the upper part (DeLise, 1967; Nilsen and others, 1973). Eastward it thins and pinches out near Salt Creek; westward it thickens to a sequence of locally fossiliferous, coarse-grained sandstone that is interbedded with siltstone and shale (Van Amringe, 1957; Hammond, 1958). Foraminiferal studies in its type area by DeLise (1967) indicate that shale in the lower beds of the middle part of the San Emigdio Formation is Narizian in age and was deposited at upper bathyal or lower neritic depths. The age of the San Emigdio is herein considered to be late Eocene (Refugian) on the basis of megafossils from its lower and upper parts. These fossils indicate shallow-marine, locally possibly intertidal deposition (Nilsen and others, 1973).

The Tejon Formation is overlain by the Eocene(?) to Miocene Tecuya Formation in the eastern San Emigdio and western Tehachapi Mountains (pl. 1). The Tecuya, originally named the Tecuya beds by Stock (1920, 1932), later renamed the Tecuya Formation by Marks (1941b, 1943), forms a nonmarine sequence of sedimentary and volcanic rocks. The Tecuya Formation intertongues westward with shallow-marine rocks of the Pleito and Temblor Formations. The Tecuya consists of similar lower and upper units of interbedded conglomerate and sandstone and a middle unit of basalt and dacite. In its type area west of Tecuya Canyon, it is 2,350 feet (717 m) thick (Nilsen and others, 1973). The basal beds of the Tecuya Formation extend westward as a thin nonmarine tongue between the marine San Emigdio and Pleito Formations. The contact between the Tecuya and the underlying Tejon Formation is apparently conformable, although previous workers have suggested that it is unconformable (Marks, 1941a; Harris, 1950). The Tecuya was probably deposited by braided streams as a series of alluvial fans draining source areas to the east and southeast during late Eocene(?), Oligocene, and early Miocene time. As the fans built westward, the late Eocene(?) and Oligocene shoreline retreated progressively to the west, as indicated by westward regression of the Metralla Sandstone Member and San Emigdio Formation through time (Nilsen and others, 1973).

STRATIGRAPHIC SYNTHESIS

Thirteen measured sections through the Tejon Formation from east of the Edmonston Pumping Plant to near Santiago Creek provide the basis for the stratigraphic summary shown in figure 13. The upper datum of the cross section is the top of the Metralla Sandstone Member, except where it is not present near Santiago Creek. The Reed Canyon Siltstone Member, because of its thinness and intermittent presence, is not included in the cross section. In addition to the sections described above, sections were measured (1) about one-half mile (0.8 km) east of the Edmonston Pumping Plant, (2) between Liveoak and Pastoria Creek, (3) Black Canyon, (4) Pleito Creek, and (5) the north limb of the Devils Kitchen syncline. Four measured sections with fossil control were kindly provided by the Atlantic-Richfield Oil Company from unpublished work done in 1939-1940 by M. L. Hill, R. S. Beck, Catinari, Sitzman, L. C. Forest, S. A. Carlson, and J. S. Sheller.

The stratigraphic cross section indicates that the Uvas Conglomerate Member is a persistent basal conglomerate and sandstone that marks the onset of Tejon sedimentation, although it varies considerably in lithology and thickness throughout the area. The overlying Liveoak Shale Member thickens abruptly westward to a maximum thickness of more than 2,000 feet (610 m) in Pleito Creek; west of Pleito Creek, it thins to about 1,000 feet (305 m) in the Devils Kitchen area and at least about 1,000 feet (305 m) near Santiago Creek. The Metralla Sandstone Member also thickens abruptly westward to about 2,000 feet (610 m) near Pleito Creek; west of Pleito Creek, it interfingers with the Liveoak Shale Member. It persists as irregular lenses and fingers of sandstone west of Williams Canyon but is not present near Santiago Creek.

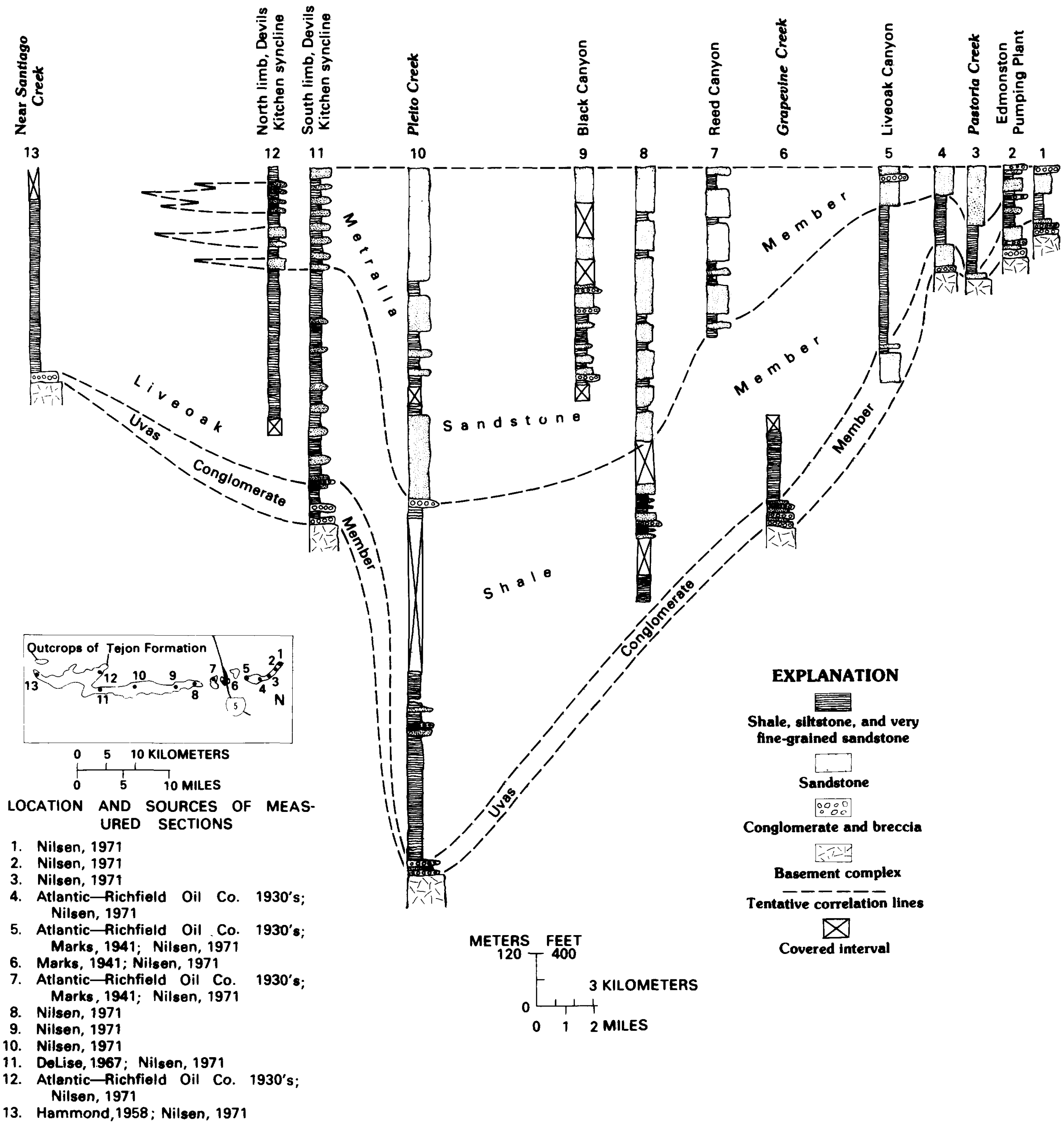


FIGURE 13.—Stratigraphic cross section of the Tejon Formation. Upper datum is top of Metralla Sandstone Member. Years refer to dates when sections were measured. Numbers 1, 4, and 8 are unnamed creeks.

SUBSURFACE STRATIGRAPHY

The Tejon Formation has been penetrated by about 65 wells in and adjacent to the Wheeler Ridge and North Tejon oil fields, and by 26 wells outside the productive limits of these two fields (Weber, 1973). However, very few of these wells have completely penetrated the Eocene sequence to the basement, so the subsurface stratigraphic record of all of the Tejon Formation is incomplete. This is especially true in the southwestern corner of the San Joaquin Valley, where Eocene rocks are deeply buried. In most of the area, almost all oil production from the Tejon is from the Metralla Sandstone Member, so there is little economic incentive to drill deeper. Abrupt facies changes from east to west in both the Metralla Sandstone Member and the overlying San Emigdio Formation, together with the difficulties in distinguishing the nonmarine strata of the Tecuya Formation from adjacent marine rocks, make correlations between the Wheeler Ridge area and well sections to the west difficult.

Weber (1973) investigated subsurface facies changes in the Metralla Sandstone Member in the Wheeler Ridge area, where well control is reasonably good. In this area, the Metralla in subsurface consists of massively bedded fine- to medium-grained sandstone with a minor amount of siltstone and thin interbedded sandstone and siltstone. Shale is uncommon, and massive sandstone beds are as thick as 100 feet (30.5 m). However, the sandstone beds are laterally discontinuous, so that correlation between adjacent wells is difficult.

Weber (1973) prepared maps showing sandstone and siltstone percentages and the drilled thickness of the Metralla in the Wheeler Ridge area. The percentages were determined by counting sandstone beds on available electric logs using conservative techniques (fig. 14). These maps indicate a decrease in thickness to the northwest of the Metralla from a maximum of perhaps 1,000 feet (305 m) southeast of Wheeler Ridge. In addition, the percentage of siltstone increases and the grain size and porosity decrease to the northwest. These data suggest that the productive part of the Metralla Sandstone Member of the Wheeler Ridge area, probably consisting of thick shallow-marine sandstone, grades laterally northwestward into deeper marine fine-grained sandstone, siltstone, and shale. This change corresponds to the westward transition in outcrop of the Metralla to finer grained rocks in the San Emigdio Canyon area. The westward subsurface facies changes in the Tejon Formation are similar to those seen in outcrop, particularly the westward fingering out of the Metralla Sandstone Member into the Liveoak Shale Member (fig. 15).

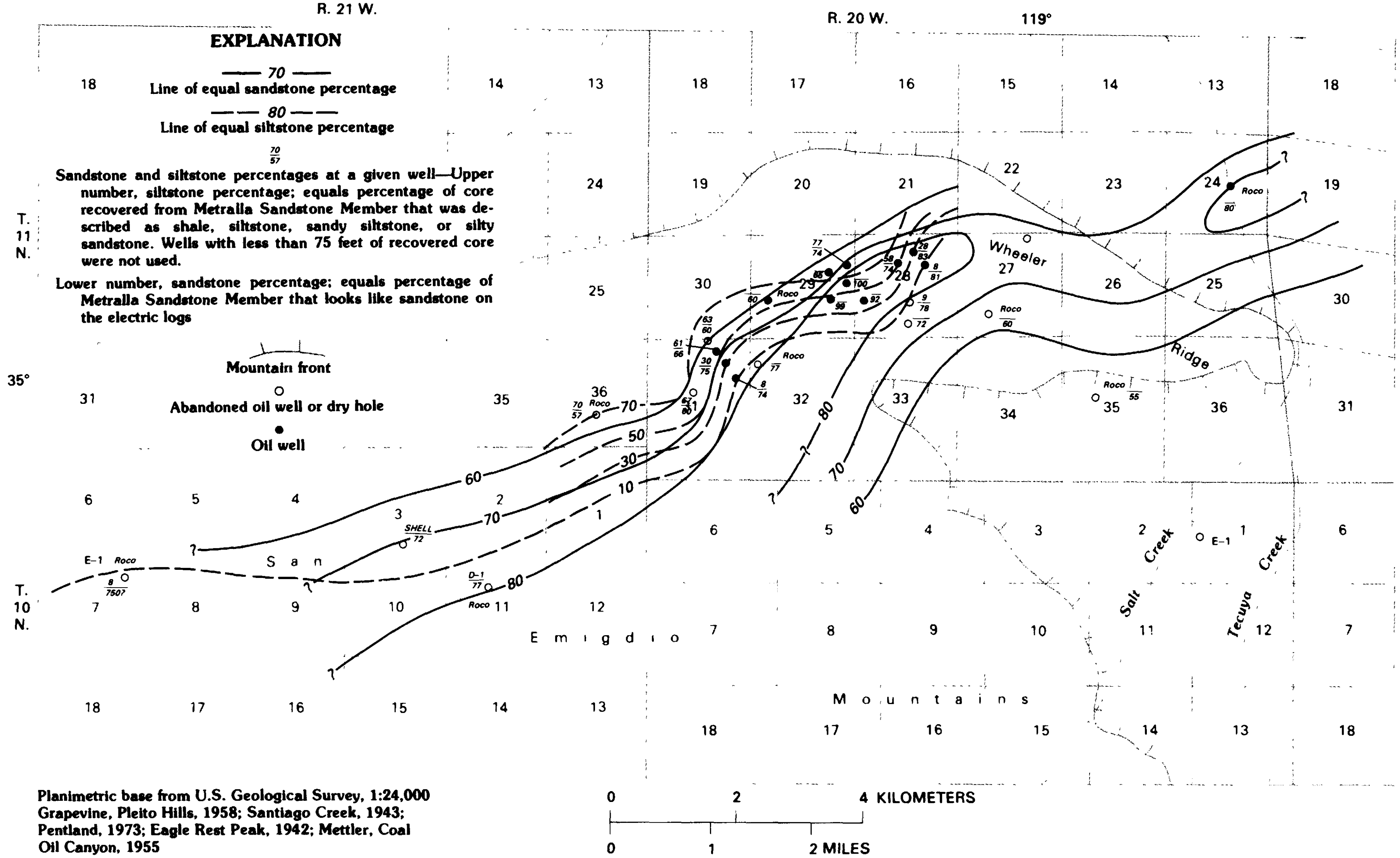
Wells drilled into the Tejon Formation west of the San Emigdio Canyon area have penetrated mostly siltstone and shale but little sandstone. These fine-grained rocks probably correlate laterally with the sandstone-poor sequence of the Liveoak Shale Member west of San Emigdio Canyon, where sandstone of the Metralla apparently pinches out westward. The shelf edge, defined by the transition from shallow- to deep-marine facies and the decrease in both thickness and percentage of sandstone, appears to have trended almost east-west along the north edge of the Wheeler Ridge area and from there southwest across the area of Pleitito and San Emigdio Creeks.

ISOPACH ANALYSIS

An isopach map of the Tejon Formation was prepared from measured sections and well control, using the basal unconformity as the lower datum and the contact with the San Emigdio and Tecuya Formations as the upper datum (fig. 16). Well control, from data kindly supplied by A. H. Warne, formerly with Tenneco Oil Co., permits comparison of surface and subsurface thicknesses. However, no thickness data for the Tejon Formation are available to the northwest, where it is deeply buried beneath younger sediments, and thickness data from wells in the western part of the area may not be completely reliable because of structural complications.

The isopachs have a north-south orientation in the eastern part of the area with the greatest thickness near Pleito Creek. The zero isopach, located near Tunis Creek, extends north-northwest and defines the maximum eastward transgression of the shallow sea in which the Tejon Formation was deposited. Only nonmarine sedimentary rocks of the Tecuya Formation (surface) and the Walker Formation (subsurface) are present east of the zero isopach; the age of these units is poorly known, but their lower parts may be middle Eocene (American Association of Petroleum Geologists, 1957; Hackel, 1966; Nilsen and others, 1973). The northward trend of the isopach lines in the eastern part of the area is presumably parallel to the original shoreline and general orientation of the depositional shelf.

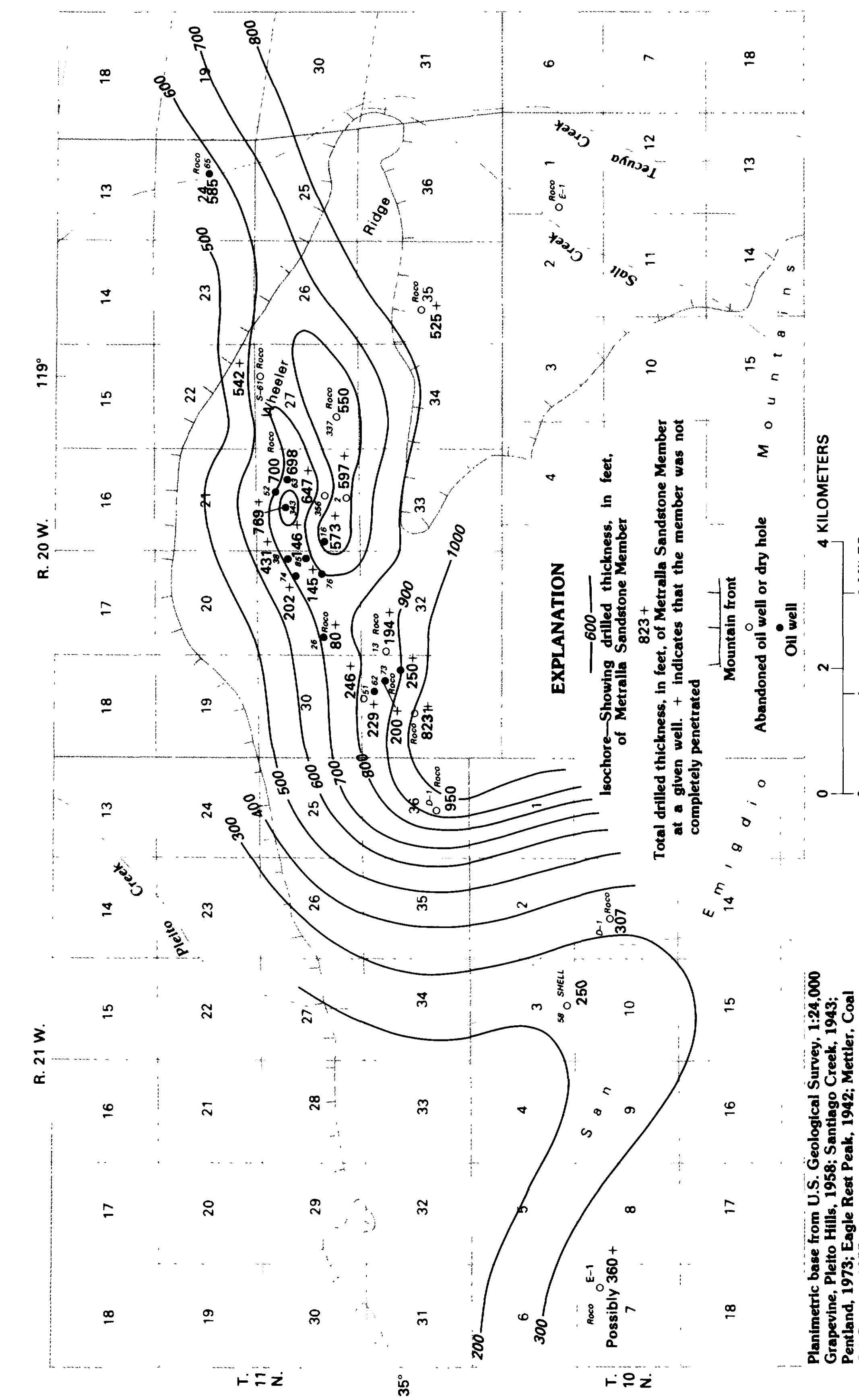
The Tejon Formation is thickest in outcrop near Pleito Creek, where it is more than 4,000 feet (1,220 m) thick (figs. 13 and 16). To the west and north (the subsurface Famosa sand is about 600 feet or 185 m thick), it thins markedly, coinciding with general decreases in amount of sandstone, and changes from mainly shallow to mainly deep-marine facies. The thinner shale-rich sequences to the west and north were characterized by slower rates of sedimentation and probably greater postdepositional compaction, yielding even thinner sections.



Planimetric base from U.S. Geological Survey, 1:24,000 Grapevine, Pleito Hills, 1958; Santiago Creek, 1943; Pentland, 1973; Eagle Rest Peak, 1942; Mettler, Coal Oil Canyon, 1955

A

FIGURE 14.—Maps showing subsurface characteristics of the Metralla Sandstone Member of the Tejon Formation in Wheeler Ridge area (from Weber, 1973, figs. 1 and 2). See plate 1 for location of maps in respect to outcrop area. *A*, Percentage of sandstone and siltstone.



B

FIGURE 14.—Continued. *B*, Variations in drilled thickness.

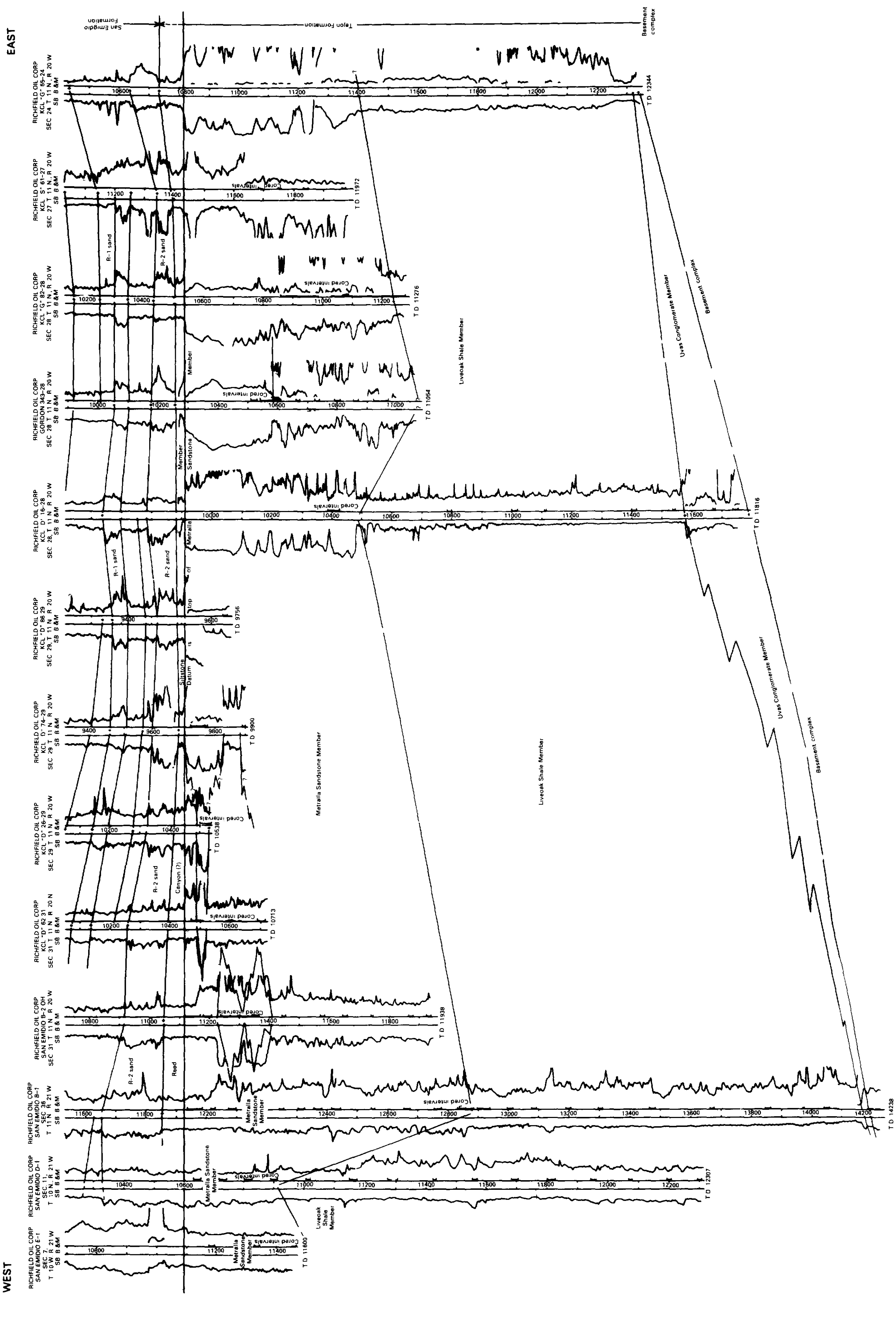


FIGURE 15.—Subsurface east-west cross section of the Tejon Formation in Wheeler Ridge area showing electric-log characteristics and stratigraphic interpretations from Weber (1973, fig. 4). Depth in feet; T.D., total depth.

In summary, the Tejon Formation is a lens-shaped body in east-west cross section. It thins toward the east, north, west, and southwest. Maximum subsidence of the shelf occurred in the Pleito Creek outcrop area, permitting more than 4,000 feet (1,220 m) of sand, mud, silt, and gravel to accumulate. The southward extent and thickness patterns are unclear because of the lack of outcrop and subsurface records of the Tejon Formation.

CONGLOMERATE AND SANDSTONE PERCENTAGES

Lithologic variation in the Tejon Formation is expressed (fig. 17) as the proportion of conglomerate and sandstone combined to shale and siltstone in the total thickness. These data were derived from measured sections and subsurface electric logs. The following trends are apparent: (1) the percentage of sandstone decreases westward from Pleito Creek; (2) the percentage of sandstone increases eastward and is greatest at the east end of the outcrop area; (3) the percentage of sandstone ranges from 40 to 60 percent between Pleito Creek and the Edmonston Pumping Plant. These changing percentages result primarily from the northwestward fingering out of the Metralla Sandstone Member into the Liveoak Shale Member and the north-south trend of the virtually 100 percent conglomerate and sandstone eastern depositional edge or shoreline facies of the Tejon Formation, as suggested by the isopach map (fig. 16).

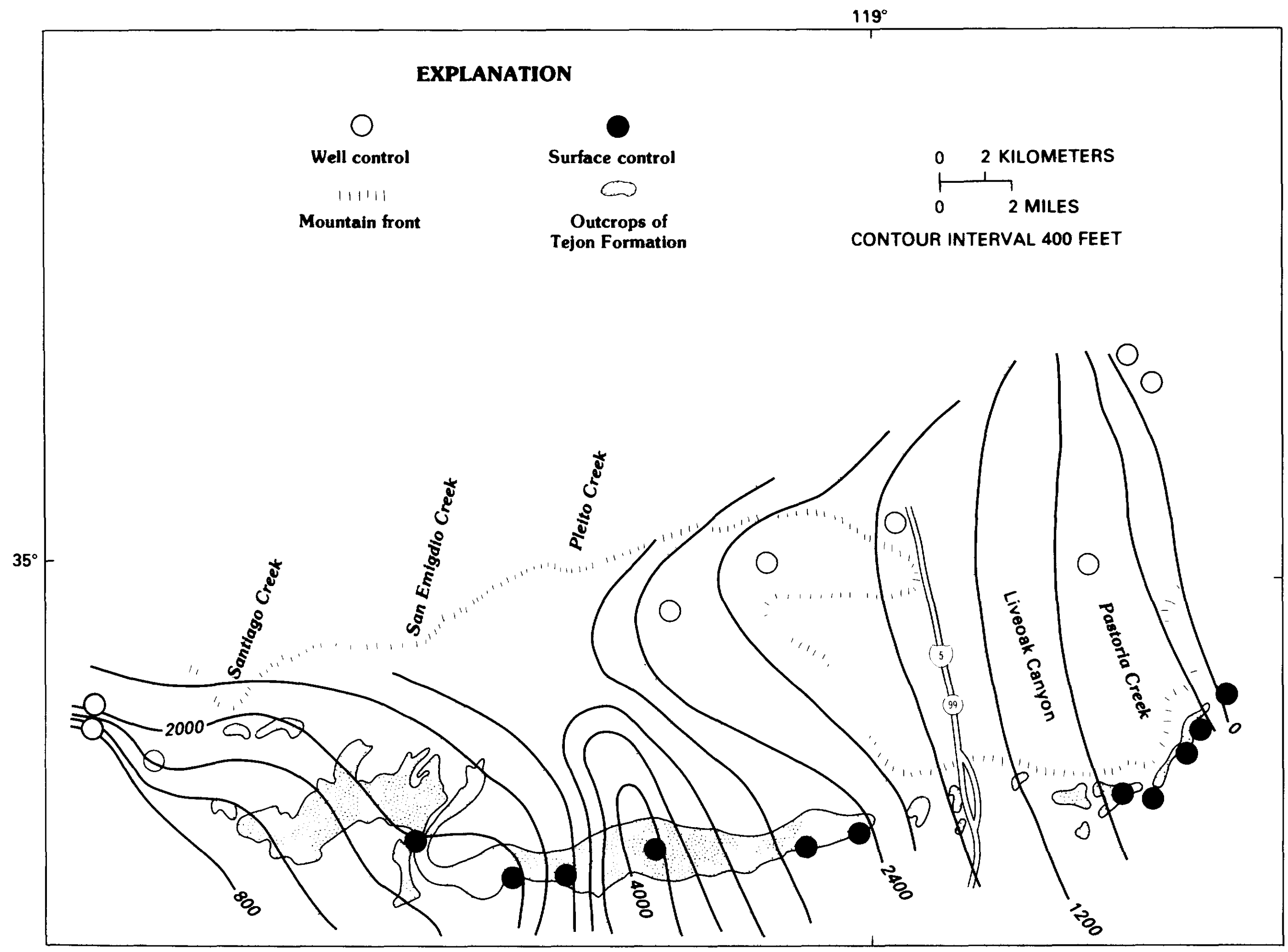


FIGURE 16.—Isopach map of the Tejon Formation. Well control from A.H. Warne, Tenneco Oil Co.; surface control from measured sections shown in figure 13.

SEDIMENTARY STRUCTURES

CROSS STRATIFICATION

Various types of cross-strata are present in sandstone of the Tejon Formation. The most common types are medium- and large-scale cross-strata in the Uvas Conglomerate Member and eastern exposures of the Metralla Sandstone Member, and small-scale cross-strata in the lower and upper parts of the Liveoak Shale Member and the western exposures of the Metralla Sandstone Member.

The medium- and large-scale cross-strata commonly consist of west-dipping foresets that range from 0.5 to 2.0 feet (15-60 cm) in amplitude and to 30° in inclination (figs. 18, 19, and 20). These cross-strata are commonly solitary, consisting of a single set of cross-strata overlain and underlain by other types of deposits. The lower bounding surface is typically eroded into the underlying deposits and curvilinear in shape, locally trough-shaped. Individual cross-strata within a set are typically uniform in grain size and lithology, but many contain scattered pebbles or molluscan shells that in some sets are concentrated in the lower parts or at the base of the cross-strata. These cross-strata fall into Allen's (1963) Groups I and II, interpreted as having been produced in shallow-marine environments as a result of either the migration of solitary banks with curving or linear fronts or the cutting and filling of isolated channels or hollows. Both of these processes may be active during storm conditions.

Small-scale cross-strata are more variable in direction of dip and amount of inclination. They are less than 2 inches (5 cm) in amplitude, occur as solitary or

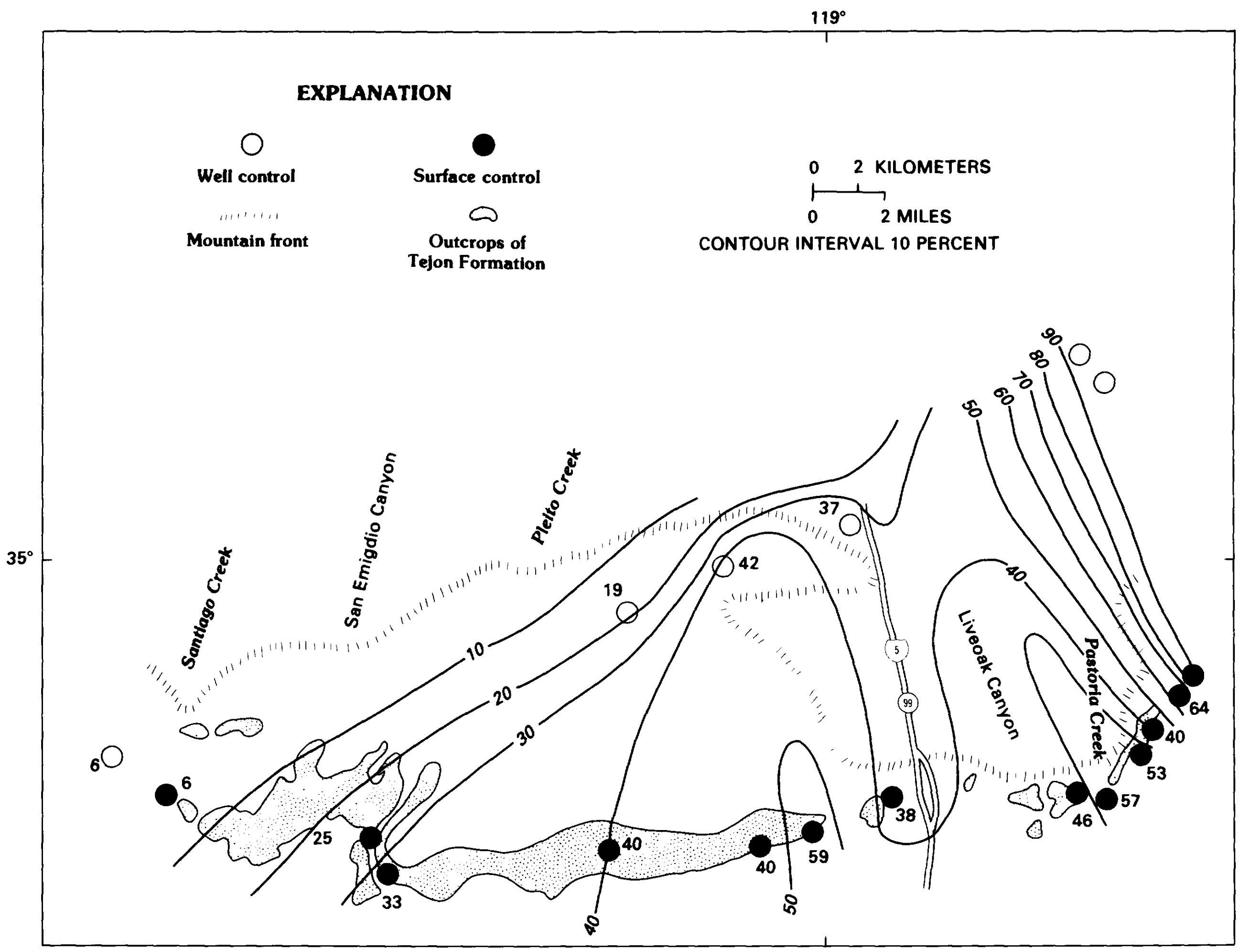


FIGURE 17.—Sandstone-percentage map of the Tejon Formation. Well control from A.H. Warne, Tenneco Oil Co.; surface control from measured sections shown in figure 13.

grouped sets, and commonly have straight depositional lower bounding surfaces. They are found in sandy siltstone to medium-grained sandstone, but most commonly in fine-grained sandstone. These cross-strata fall into Allen's (1963) Group III, and probably result from the migration of current-formed small-scale asymmetrical ripple markings in shallow- to deep-marine conditions. Some cross-strata in the western outcrops of the Metralla are associated with Bouma sequences and probably result from traction-plus-fallout turbidite deposition.

RIPPLE MARKINGS

Only asymmetrical current ripple markings were observed in the Tejon Formation. These have a distribution similar to that of the small-scale cross-strata, to which they are genetically related. The asymmetrical current ripple markings, when viewed in cross section, appear as small-scale cross-strata.

RIPPLE-DRIFT STRATIFICATION

Ripple-drift bedding, or "climbing" ripples, are locally developed within Bouma sequences in the western exposures of the Metralla Sandstone Member. These structures in the Metralla probably result from rapid deposition of a large amount of fine-grained sand from suspension. They are commonly associated with turbidites and also with fluvial sedimentation. They have not been found in the shallow-marine sandstone of the Metralla east of Pleito Creek.

FIGURE 18.—Cross-stratified medium- to coarse-grained sandstone in the Uvas Conglomerate Member of the Tejon Formation at lower Los Lobos Creek. This bed is 9 on figure 64. Upper part of bed 8 to right, beds 10 and 11 on upper left.

FLAT STRATIFICATION

Flat or planar stratification is well developed throughout the Tejon Formation and is one of the most common bedding features. In shallow-marine sandstone in the eastern exposures, it appears as thin, flat, gently undulating or wavy laminations that are best developed in fine- to medium-grained sandstone (figs. 21 and 22). It is also present in coarser grained sandstone as thicker, more irregular flat or planar beds (fig. 23). The structure probably forms in a variety of shallow-marine environments, perhaps primarily in the swash and surf zone. It may also be produced by strong current flows during storm periods or by rip currents.

Flat-stratification is the dominant structure in the flaggy beds of the Metralla Sandstone Member in its western exposures and in the upper and lower parts of the Liveoak Shale Member (fig. 24). In these outcrops, beds of flat-stratified to flat-laminated fine- to medium-grained sandstone are interbedded with shale and siltstone and are commonly organized into Bouma sequences. Other structures of the sequence are present, but flat strata of the Bouma *b* division dominate and generally initiate the sequences rather than the massive Bouma *a* division. Other flat-stratified beds of sandstone are not graded and do not form parts of Bouma sequences (fig. 25).

FIGURE 19.—Medium-scale cross-strata in sandstone of the Tejon Formation at the Edmonston Pumping Plant (see fig. 58). Note erosional lower surface and flat-stratified underlying deposits. Stratigraphic top to right.

SCOUR FEATURES

In addition to the medium- and large-scale cross-strata that fill scours, many other small- and medium-scale scour structures are present in the shallow-marine sandstone. Some of the scour-fill deposits have been subsequently bioturbated and truncated by overlying flat-stratified or cross-stratified deposits (fig. 26). The abundance of scour features having widely dispersed orientations in the shallow-marine deposits indicates the presence of strong current activity, probably flowing in divergent directions.

PRIMARY CURRENT LINEATION

Primary current lineation or parting lineation is strongly developed on bedding surfaces of flat-stratified fine- to medium-grained sandstone of the Metralla Sandstone Member in its western exposures (fig. 27). These structures consist of a series of parallel ridges up to about 1/16 inch (1 mm) in relief that form parallel to current flow (Allen, 1964) and suggest deposition at conditions transitional between lower and upper flow regimes (Harms and Fahnestock, 1965; Allen, 1966).

FLUTE AND GROOVE CASTS

Flute and groove casts are locally well developed on the basal surfaces of fine- to medium-grained sandstone beds in the western exposures of the Metralla Sandstone Member (figs. 28 and 29). These are generally present at the base of incomplete Bouma sequences that commonly start with the *b* rather than *a* division. The flutes are not large, generally being less than 3 inches (7.5 cm) long, 1 inch (2.5 cm) wide, and 0.5 inch (1.8 cm) deep. They are not commonly longitudinally asymmetrical, thus the paleocurrent directions are not easily determined. Groove casts are longer and generally solitary. They show a consistent orientation on any particular bedding surface and are parallel to the orientation of the flute casts. Some groove casts are as wide as an inch (2.5 cm) and resemble elongated flute casts.

CONVOLUTE LAMINATION

Convolute lamination is found locally in the western exposures of the Metralla Sandstone Member (fig. 30). It is common in fine-grained sandstone of Bouma *c* divisions which overlie flat-stratified sandstone of the Bouma *b* division. The convolute lamination is generally useful as a paleocurrent indicator, but is locally very complexly deformed and difficult to interpret. The convolute laminae may reach amplitudes as large as 1 foot (0.3 m) or more, and locally grade laterally into contorted, slumped stratification.

RIP-UP CLASTS

Rip-up clasts of siltstone, shale, and calcareous mudstone are locally abundant in the western exposures of the Metralla Sandstone Member (fig. 31). They are present most commonly in the basal parts of thin Bouma sequences. The clasts are as long as 0.5 foot (0.2 m), but average 1-2 inches (2.5-5.0 cm). They are generally rounded and platy in shape. Admixtures of broken molluscan shell debris and very fine rounded pebbles of quartzite and volcanic rock are present locally. Strata composed of rip-up clasts are typically graded and rarely thicker than 0.5 feet (0.2 m); they generally fine and thin toward the west.

BOUMA SEQUENCES

Graded beds of sandstone and siltstone arranged into Bouma sequences are common in the western exposures of the Metralla Sandstone Member. The beds grade upward from massive medium-grained sandstone with local rip-up clasts at the base to shale at the top (fig. 32). The sequences reflect deposition by turbidity currents, progressively finer grained sediments being deposited

FIGURE 20.—Medium-scale cross-strata in sandstone of the Tejon Formation at Edmonston Pumping Plant (see fig. 58.) Note scattered burrows oriented subparallel to stratification.

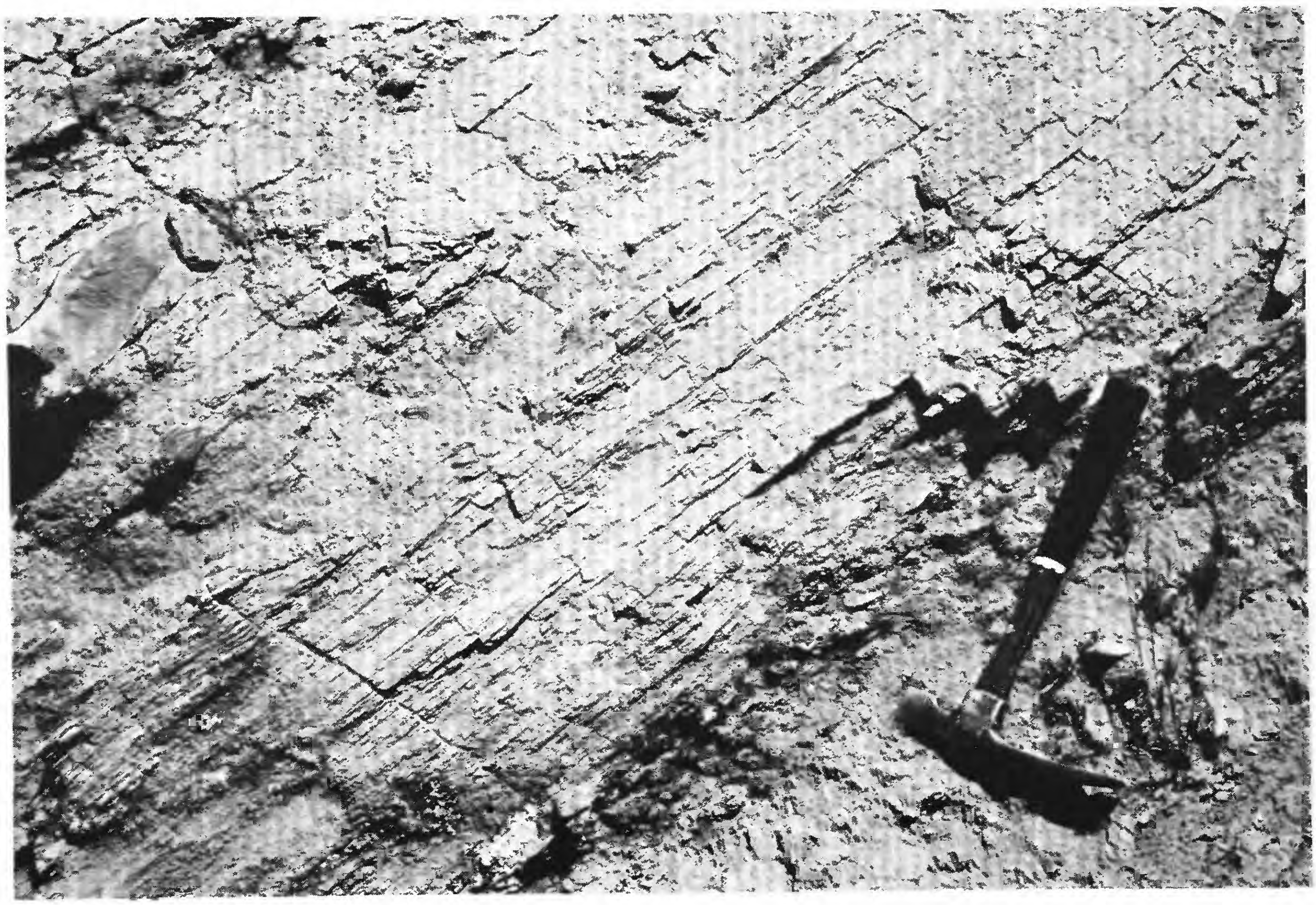


FIGURE 21.—Thinly flat-stratified, well-sorted, fine-grained sandstone in the Tejon Formation, approximately 100 feet (30.5 m) above basal unconformity at Edmonston Pumping Plant (see fig. 58.)

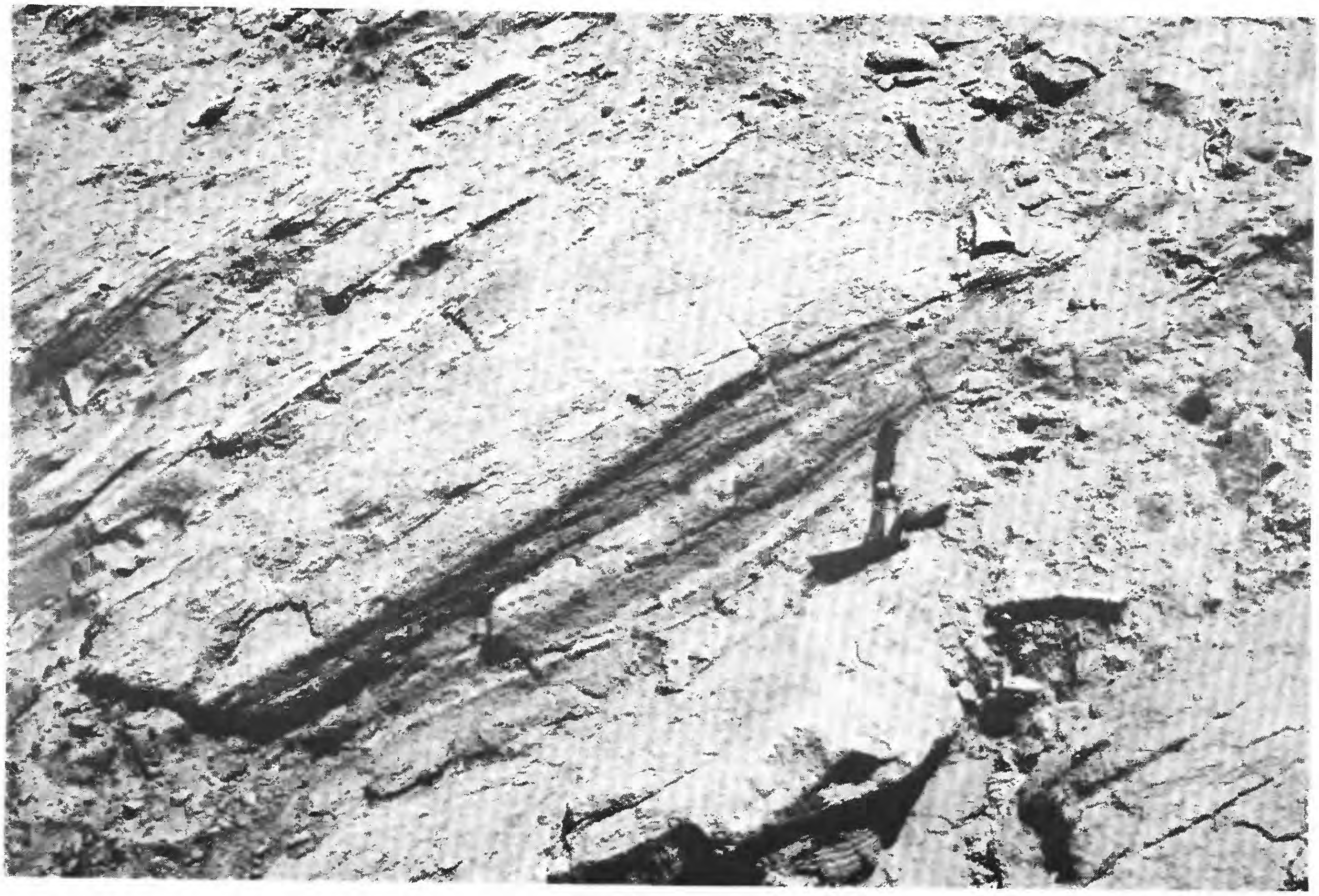


FIGURE 22.—Wavy and gently undulating flat-stratification in fine- to medium-grained sandstone of the Tejon Formation at Edmonston Pumping Plant (see fig. 58.)

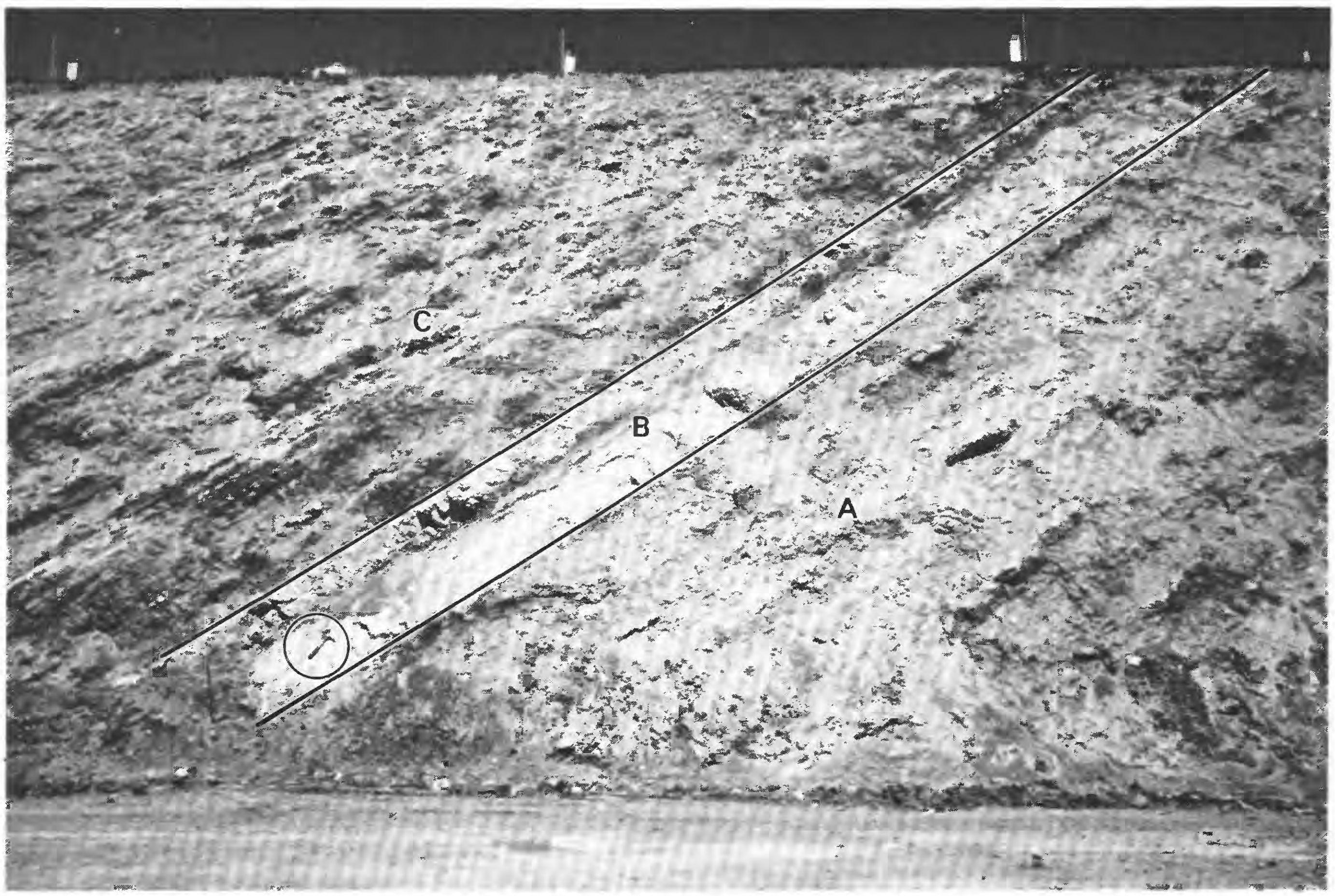


FIGURE 23.—Flat-stratified sandstone in lower part of the Tejon Formation at Edmonston Pumping Plant (see fig. 58). A, Clayey and silty very fine-grained sandstone with abundant irregular lenses of silty fine-grained sandstone rich in carbonaceous matter; B, Conglomeratic coarse-grained sandstone with abundant broken molluscan shell debris (bed situated 92 feet (28 m) above basal unconformity); C, Thinly flat-stratified fine-grained sandstone. Hammer circled for scale.

higher in the sequence as current velocities decreased. The sequences most typically start with the *b* division and end with the *d* division, forming T_{bcd} sequences. Westward, the sequences grade laterally into T_{cde} and T_{de} sequences.

CLASTIC DIKES

Sandstone dikes are locally present in the lower part of the Liveoak Shale Member near its lower gradational contact with the Uvas Conglomerate Member (fig. 33). The dikes are up to 3 feet (0.9 m) wide, terminate abruptly, and are composed of fine- to medium-grained sandstone without internal structures; the dikes commonly intrude interbedded fine-grained sandstone and shale.

SLUMP STRUCTURES

Synsedimentary slump features consist of rotational slumps, contorted strata, and intraformational folds and faults. They are most common in the western exposures of the Metralla Sandstone Member and lower and upper parts of the Liveoak Shale Member. Synsedimentary folds, where clearly exposed, indicate that subaqueous downslope movement of sediment was generally toward the west. The folds reach 5 feet (1.5 m) in amplitude and are commonly overturned. Low-angle rotational slumps commonly have slipped along bedding surfaces and locally can only be recognized with difficulty.

BOULDER BEDS

Beds that include rounded boulders as large as 10 feet (3 m) in diameter are locally present in the basal 100 feet

FIGURE 24.—Thinly flat-stratified flaggy sandstone beds of the Metralla Sandstone Member of the Tejon Formation, east of San Emigdio Creek. These beds form the north limb of an anticline and are slightly overturned toward northwest (left) north of Devils Kitchen syncline; stratigraphic top to left.

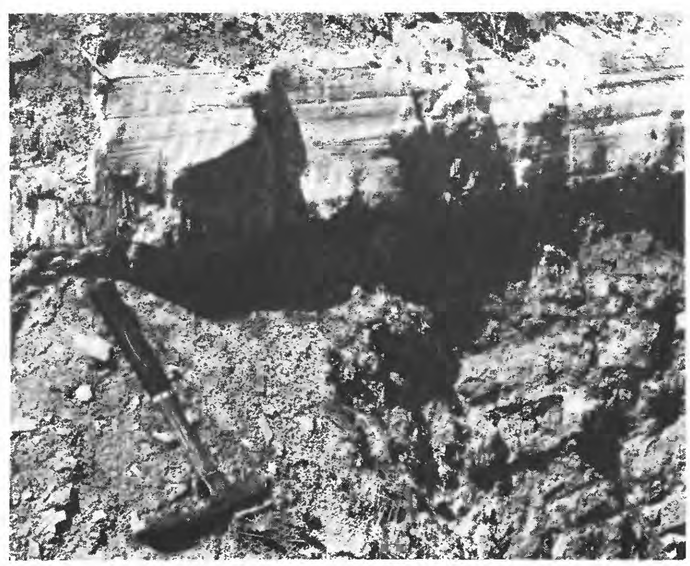


FIGURE 25.—Flat-laminated sandstone bed in shale of lower part of the Liveoak Shale Member of the Tejon Formation, east of San Emigdio Creek. Exposure is in tributary canyon in south limb of Devils Kitchen syncline. Note vertically oriented burrows at base of bed; these are possibly escape burrows.

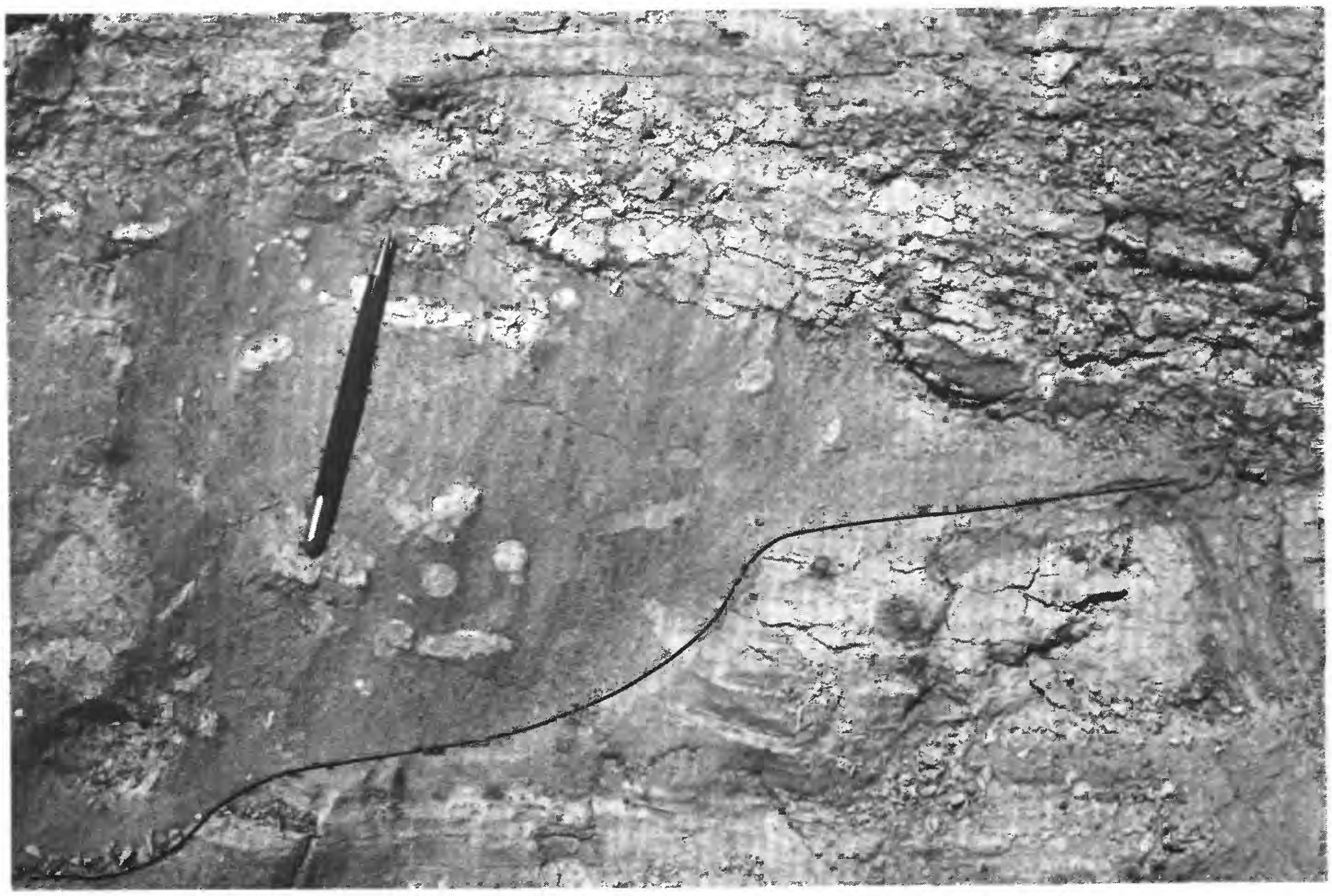


FIGURE 26.—Burrowed channel-fill sandstone in upper part of the Tejon Formation at Edmonston Pumping Plant, about 110 feet (34 m) below the Tecuya Formation (see fig. 58). Inked line traces minor unconformity at base of channel.

FIGURE 27.—Primary current lineation in nearly vertical flat-stratified bed of sandstone of the Metralla Sandstone Member of the Tejon Formation, east of San Emigdio Creek.

(30.5 m) of the Uvas Conglomerate Member. The boulders are particularly conspicuous in outcrops in lower Los Lobos Creek, where the Uvas Conglomerate Member rests on mafic basement rocks (fig. 34). These boulders are suspended in fine- to medium-grained sandstone that locally contains shallow-marine molluscan fossils. The beds of sandstone are locally well sorted, indicating considerable winnowing by currents.

FIGURE 28.—Sole markings on base of a near-vertical bed of sandstone of the Metralla Sandstone Member of the Tejon Formation, east of San Emigdio Creek. Note parallel orientation of large groove casts in center of photograph and flute casts in upper part.

Boulders of basement-complex rocks along the basal contact of the Uvas Conglomerate Member are commonly angular, poorly sorted, and probably represent weathered-out blocks that have not been transported very far (fig. 35); they are lithologically identical to the underlying basement rocks. Boulders of basement rock that are present at higher stratigraphic levels of the Uvas may represent landslide blocks dumped into nearshore or shoreline environments.

CALCAREOUS CONCRETIONS

Postsedimentary calcareous concretions are common in the Uvas Conglomerate Member and are especially abundant in silty fine-grained sandstone of the Metralla Sandstone Member in outcrops east of San Emigdio Canyon. The concretions are hard and dense and range from small spheroids an inch (2.5 cm) or so in diameter (fig. 36) to subspheroidal concretions as large as several feet (0.7 m) in diameter (fig. 37) to large irregular megaconcretions as large as 100 feet (30 m) in length (fig. 38).

BIOTURBATION

Burrowing by marine organisms is common throughout the Tejon Formation, in fine- to coarse-grained sedimentary rocks, deposited in both shallow- and deep-marine deposits. Solitary burrows are present in otherwise well- stratified deposits (fig. 39) and as still-recognizable single burrows in completely bioturbated deposits (fig. 40). Vertical cylindral tubular burrows that include *Ophiomorpha nodosa* are most common in the eastern shallow-marine deposits of the Metralla Sandstone Member and in the Uvas Conglomerate Member (figs. 39 and 40). Farther west, deep-marine fine-grained sandstone, siltstone, and shale are thoroughly bioturbated by smaller, narrow, coiled burrows presumably made by bottom-dwelling worms (fig. 41).

PETROGRAPHY

CONGLOMERATE

Conglomerate is most abundant in the Uvas Conglomerate Member, less common in the Metralla Sandstone Member, and rare in the Reed Canyon Siltstone and Liveoak Shale Members. Conglomerate increases in abundance eastward and is most common at the base and top of the Tejon Formation.

The conglomerates commonly contain clasts of igneous, metamorphic, and sedimentary rocks, megainvertebrate fossils, and, locally, carbonaceous detritus,

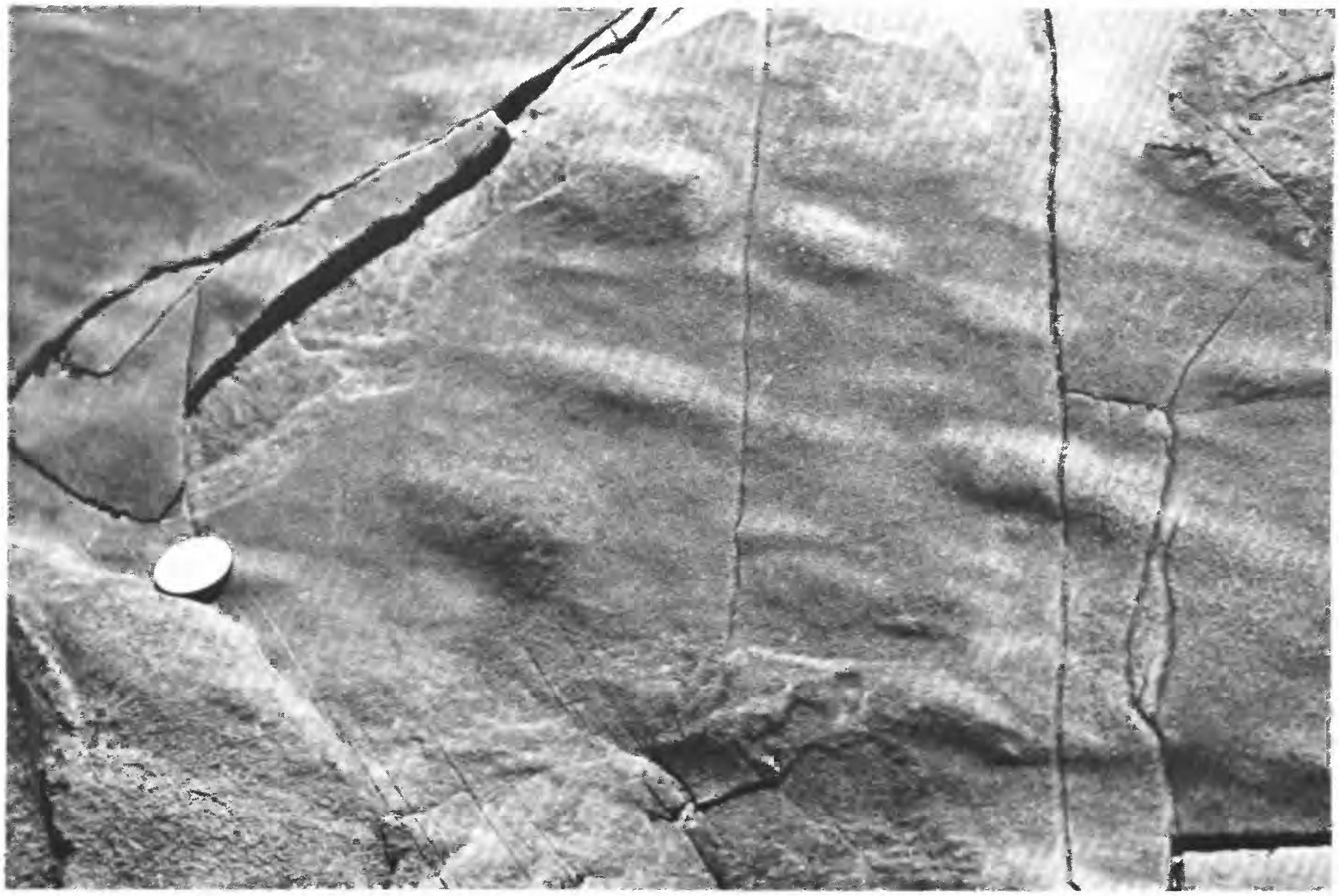


FIGURE 29.—Small flute casts on base of a near-vertical bed of sandstone of the Metralla Sandstone Member of the Tejon Formation, east of San Emigdio Creek.

including wood fragments. The conglomeratic substrate was attractive to certain mollusks, for oyster shells and large clams in growth position are commonly associated with conglomerate beds 1-2 ft (0.3 to 0.6 m) thick in the Metralla and Uvas (fig. 42). Other conglomerates consist of a mixture of pebbles and finely comminuted mollusk shells (fig. 43).

The lithic conglomerate clasts form three distinctive groups: (1) clasts derived from and lithologically similar to the underlying basement complex; (2) clasts derived from more distant sources, generally well rounded, and lithologically dissimilar to the basement rocks; and (3) clasts of sedimentary rocks in intraformational conglomerates that have probably been derived from erosion of previously deposited sediments.

The clasts of group 1 range in composition from gneissic quartz diorite and granodiorite to quartz monzonite, migmatite, gabbro, and metadiabase. Clasts of marble, which could have been derived from nearby outcrops of the basement complex, are locally present. To the east, these clasts are primarily felsic, to the west, primarily mafic. They range in size from small pebbles to boulders as long as 10 feet (3 m) and in roundness from well rounded to angular. This suite is generally restricted to the Uvas Conglomerate Member and originated as blocks weathered in place out of the basement complex, clasts transported relatively short distances by rivers to the sea, and blocks carried to shoreline areas by landsliding.

The clasts of group 2 are lithologically varied and include, in general order of abundance, quartzite, porphyritic volcanic rock, granitic rock, quartz, mafic plutonic rock, and schist. They are well rounded and range from pebble to cobble size. The quartzite and volcanic

FIGURE 30.—Convolute laminations in the Metralla Sandstone Member of the Tejon Formation, east of San Emigdio Creek.

FIGURE 31.—Rounded and abraded calcareous mudstone and siltstone rip-up clasts at base of Bouma sequence in the Metralla Sandstone Member of the Tejon Formation, east of San Emigdio Creek. Some molluscan shell fragments included. View of bottom of near-vertical bed.

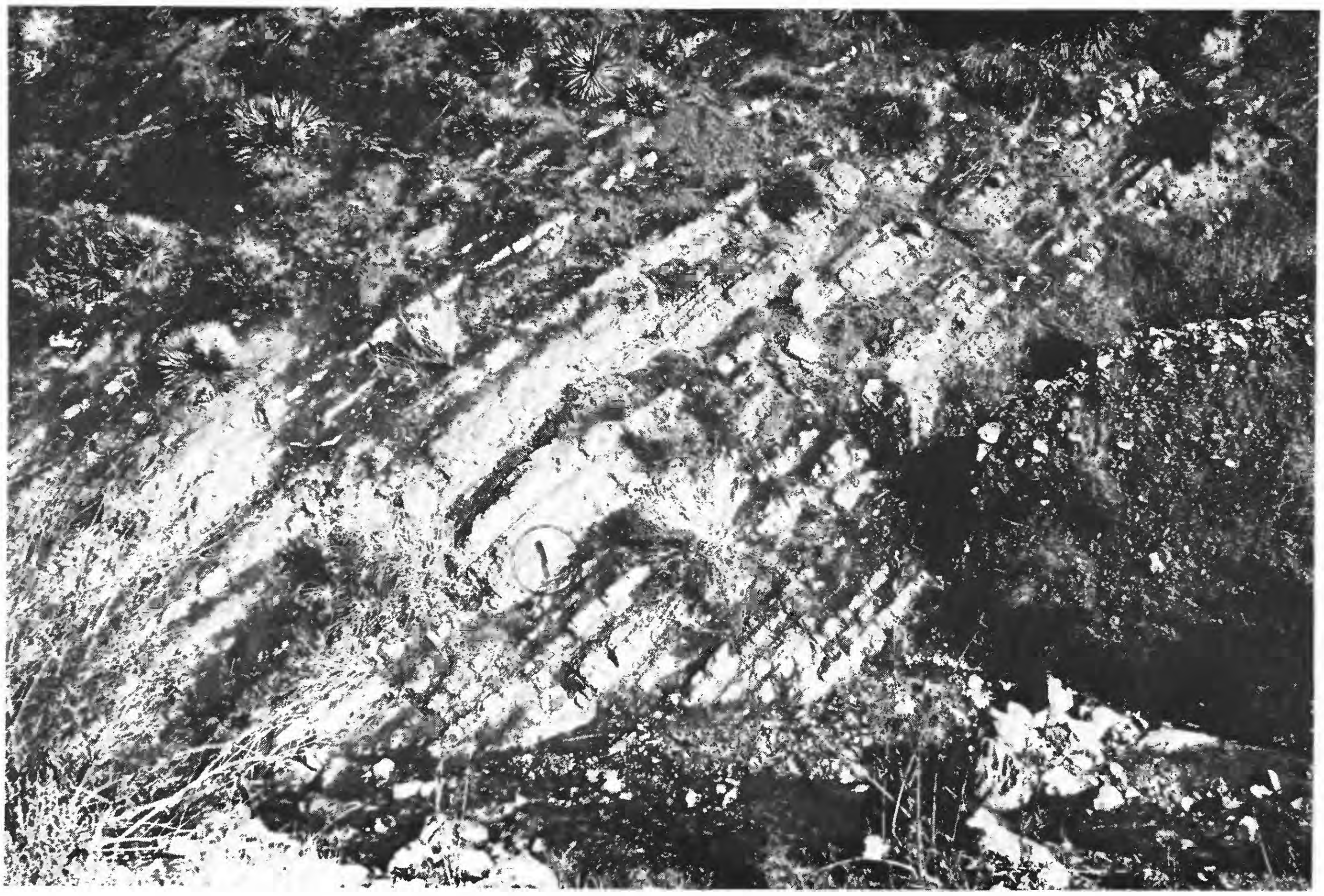


FIGURE 32.—Outcrop of flyschlike sequence of interbedded very fine-grained sandstone, siltstone, and shale of the Metralla Sandstone Member of the Tejon Formation, south limb of the Devils Kitchen syncline, east side of San Emigdio Creek. Hammer circled for scale.

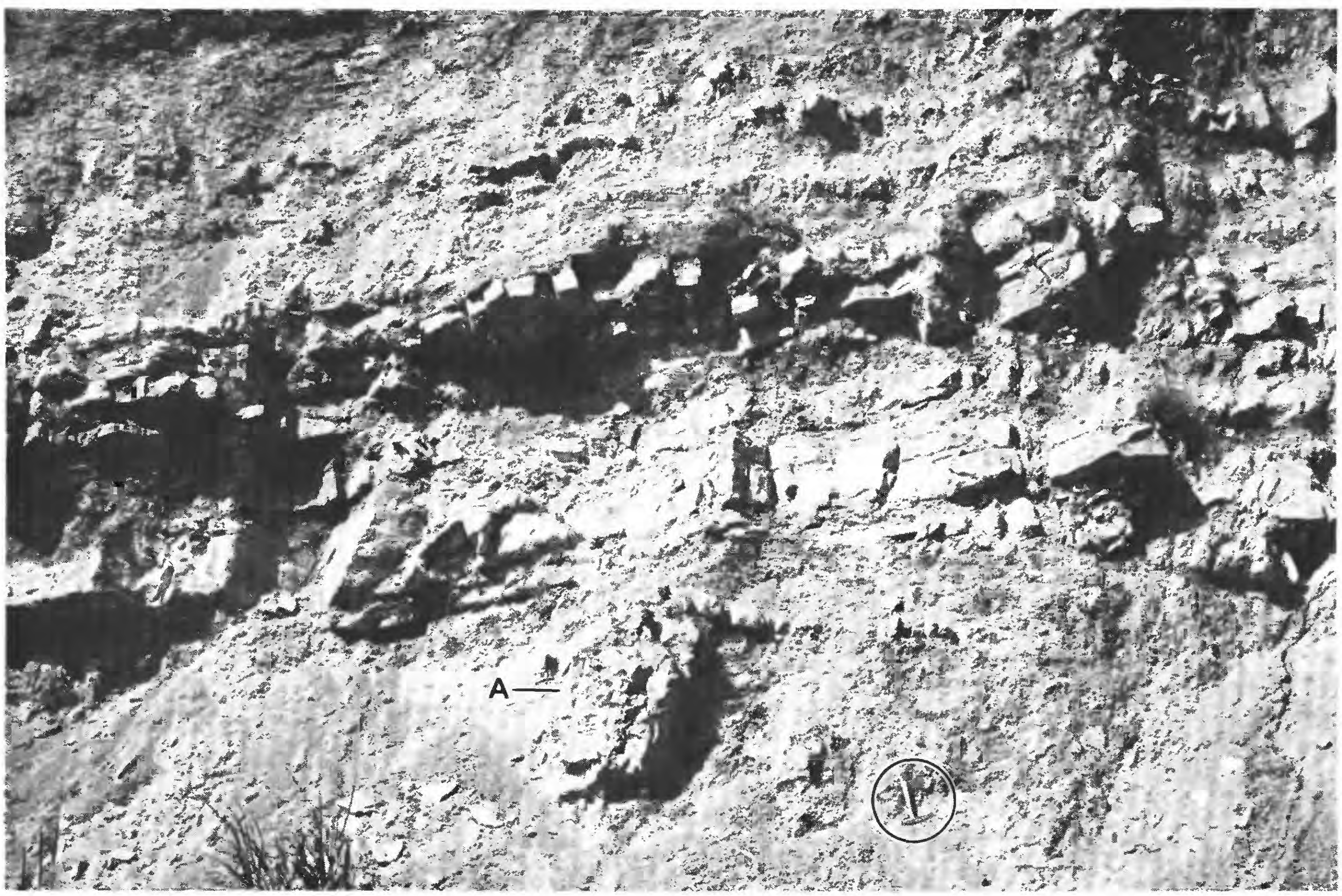


FIGURE 33.—Sandstone dike (A) in flyschlike sandstone, siltstone, and shale of lower part of the Liveoak Shale Member of the Tejon Formation in tributary canyon east of San Emigdio Creek, south limb of Devils Kitchen syncline. Hammer circled for scale.

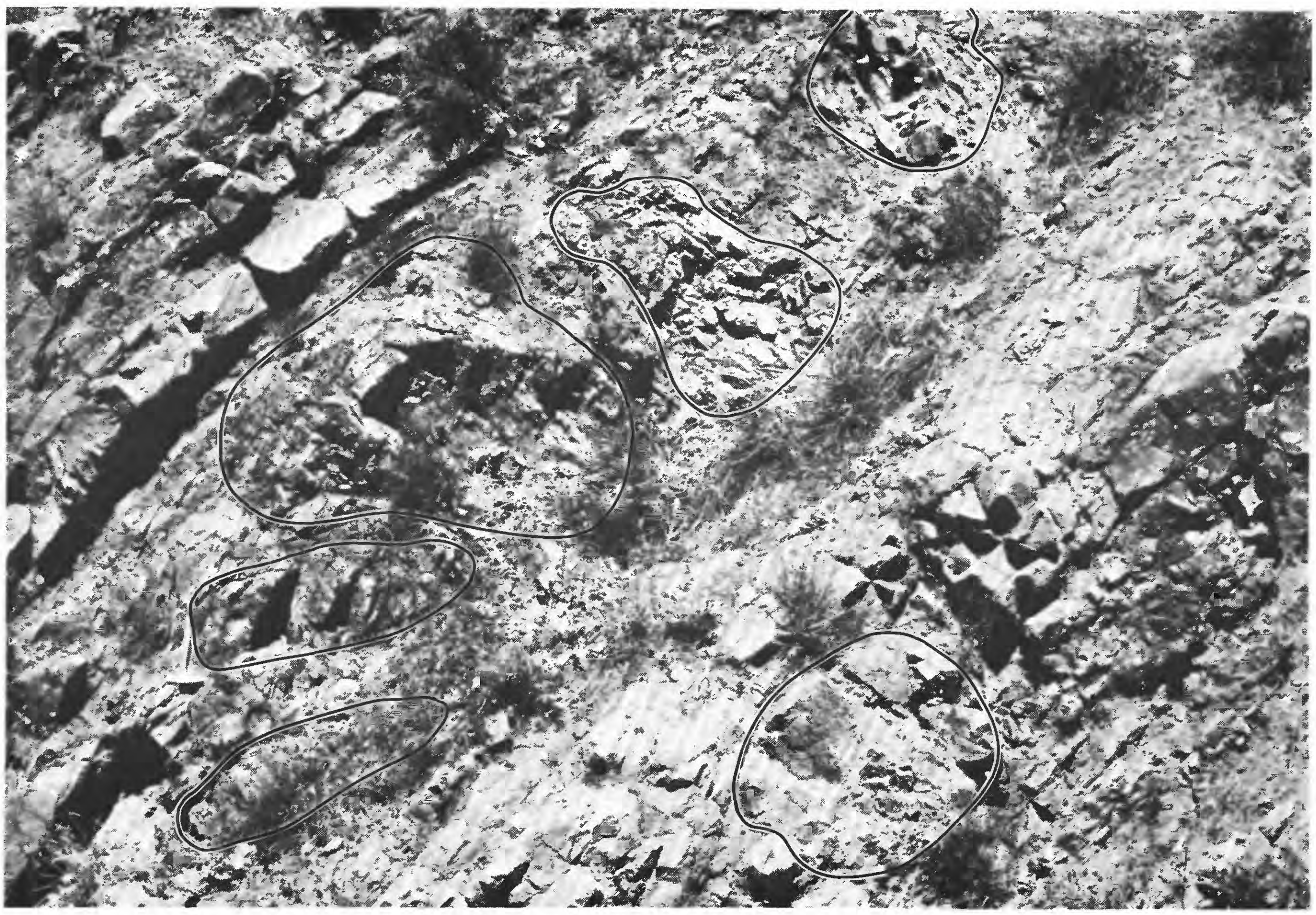


FIGURE 34.—Boulders of metadiabase in bed 7 of Uvas Conglomerate Member of the Tejon Formation, lower Los Lobos Creek (see fig. 64). Lines drawn around large individual boulders. Hammer located at lower left for scale.

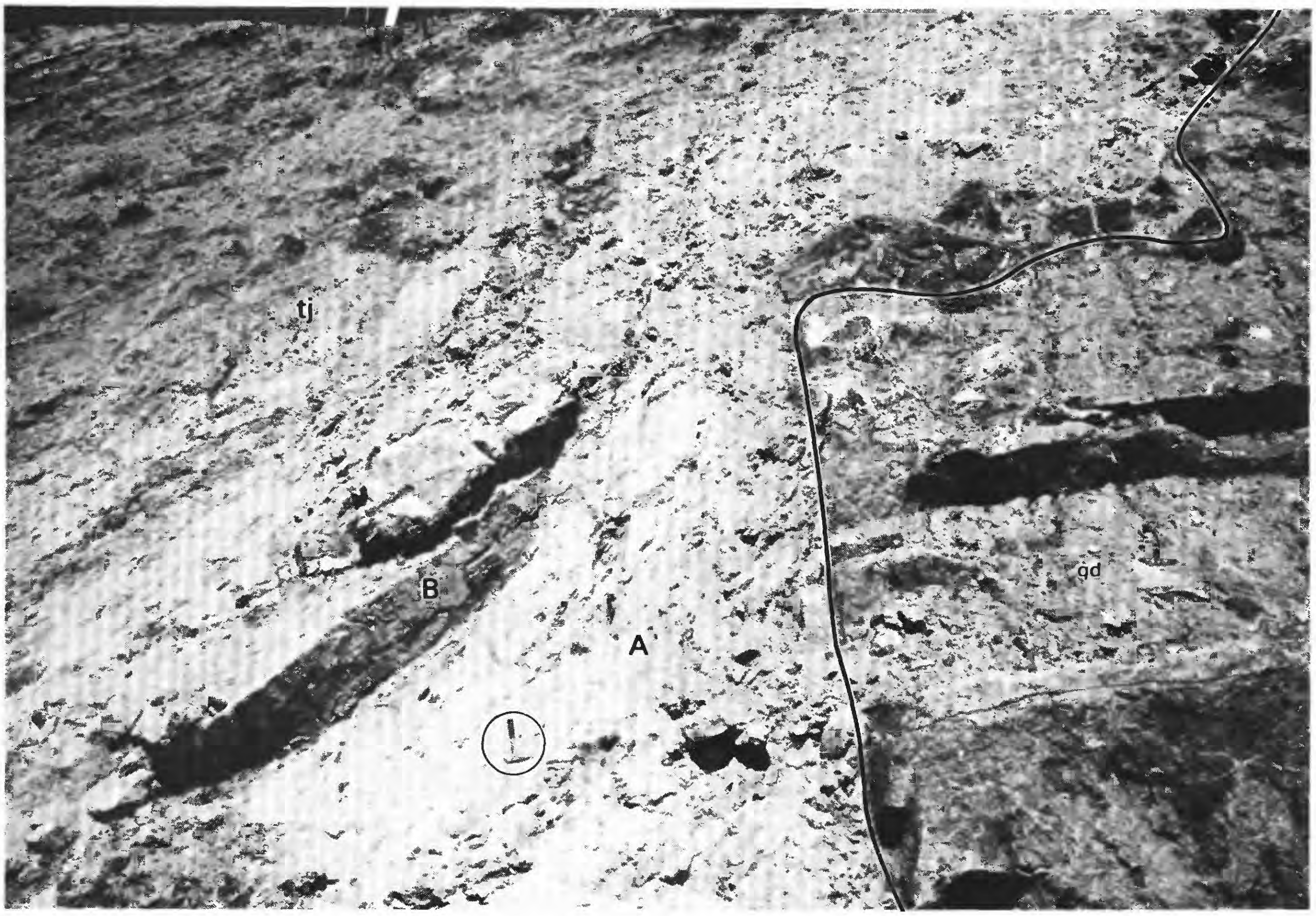


FIGURE 35.—Boulder beds at unconformable contact between gneissic quartz diorite (qd) of basement complex and Tejon Formation(tj), Edmonston Pumping Plant (see fig. 58). Note irregularity of unconformable surface and bench within it covered by boulders. Lowermost beds of the Tejon are characterized by steep initial dips; extremely well sorted and quartzose sandstone A is probably a beach deposit. Sandstone B is an intrusive dike of well-sorted quartzose sandstone. Hammer circled for scale.

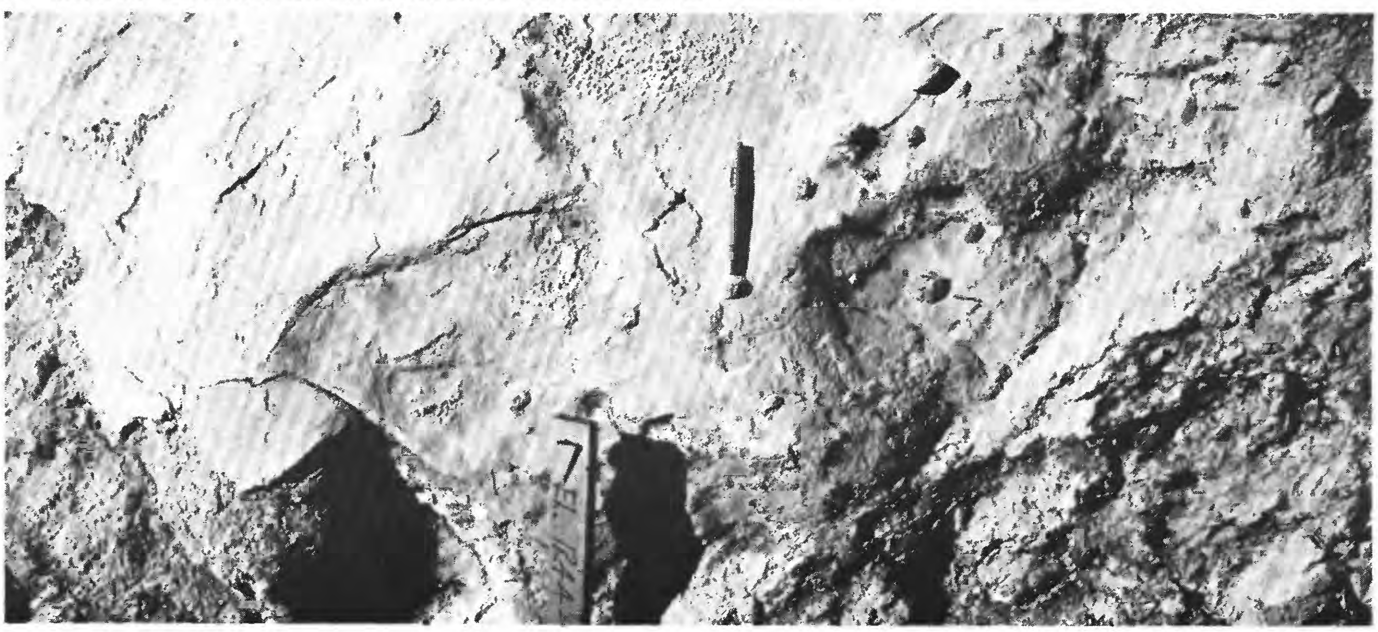


Figure 36.—Small spheroidal calcareous concretions in massively bedded silty fine-grained sandstone of upper part of the Tejon Formation at Edmonston Pumping Plant. Approximately 210 feet (64 m) above basal unconformity (see fig. 58).

clasts are particularly hard and resistant to erosion, are very well rounded, have percussion marks on their surfaces resulting from collisions with other clasts, and have probably undergone a history of considerable abrasion and long distance of transport. They may be second- or third-cycle clasts derived from older, now completely eroded conglomerates.

The rip-up clasts of group 3 are present in small amounts in most conglomerates; they are generally no larger than pebble size, are well rounded, and commonly consist of shale, siltstone, or fine-grained sandstone. To the west, beds of rip-up conglomerate are locally abundant in the Metralla Sandstone Member.

SANDSTONE

Sandstone of the Tejon Formation is arkosic in composition according to the classification system of Williams and others (1954, fig. 96) and based on point counts of 300 grains from stained thin sections (fig. 44*A*). The samples contain an average of about 50 percent quartz, 50 percent feldspar, and minor amounts of rock fragments and accessory minerals. Variable but roughly equal amounts of potassium and plagioclase feldspar are present (fig. 44*B*).

Accessory minerals include abundant biotite and chlorite, and less abundant muscovite and clay minerals. No heavy-mineral determinations were made. Rock fragments include those of the underlying basement rocks, chert, volcanic fragments, quartzite, and shale or mudstone. Quartzofeldspathic gneiss or schist clasts are generally absent and probably broke up before they could be deposited. Calcite forms the cement, and calcareous fossil fragments are present in some thin sections. Representative photomicrographs of sandstone samples from the Uvas Conglomerate and Metralla Sandstone Members are shown in figure 45, which also includes an example of the basement rocks (fig. 45*D*).

There is no major compositional difference between the Uvas Conglomerate and Metralla Sandstone Members, except where the Uvas locally above the basal contact is composed largely of disaggregated rocks of the basement complex or locally is composed of well-rounded and well-sorted quartzose sandstone modified

FIGURE 37.—Typical appearance of "cannonball" concretions in massive sandstone of the Metralla Sandstone Member of the Tejon Formation in Reed Canyon.

FIGURE 38.—Megaconcretions in massive sandstone of the Metralla Sandstone Member of the Tejon Formation in Reed Canyon. Megaconcretion in center of photograph approximately 40 feet (12 m) wide.

FIGURE 39.—Inclined cylindrical burrows in flat-stratified fine-grained sandstone of the undivided Tejon Formation, Edmonston Pumping Plant (see fig. 58).

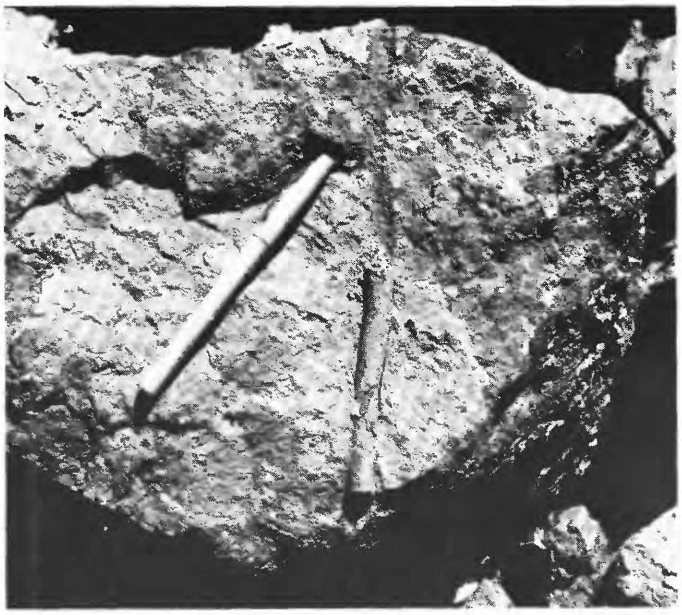


FIGURE 40.—Vertical cylindrical burrow in massive bioturbated sandstone of the Metralla Sandstone Member of the Tejon Formation, Reed Canyon.

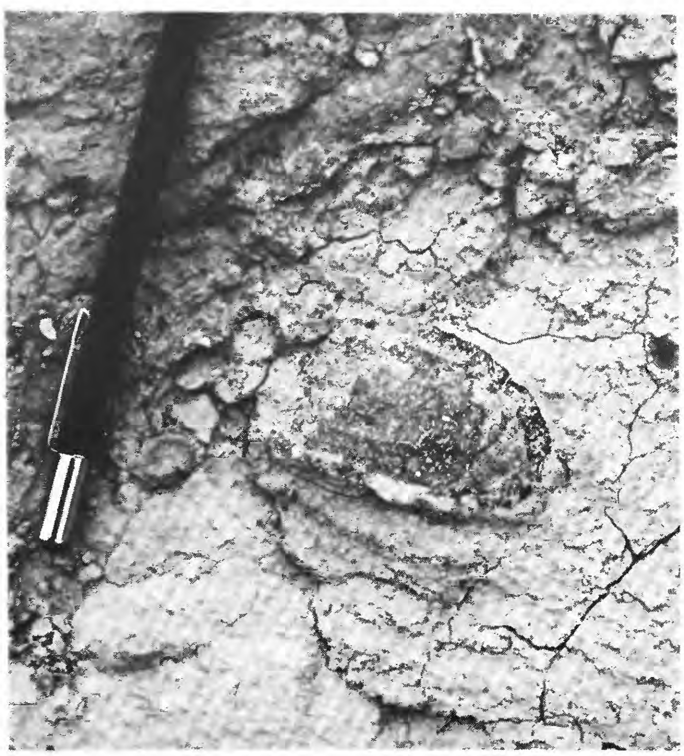


Figure 41.—Bioturbated siltstone concretion in the Liveoak Shale Member of the Tejon Formation, east side of San Emigdio Creek.

by shoreline processes. The sandstones are primarily arenites that contain less than 10 percent interstitial argillaceous material, although some of the finer grained varieties are wackes containing more than 10 percent argillaceous material. Point counts of one sample each from the San Emigdio Formation and Tecuya Formation (fig. 44) indicate a roughly similar sandstone petrology. Comparison of the QFL plot with worldwide examples from Dickinson and Suczek (1979, fig. 1) indicates that the Tejon samples should represent derivation from a continental block provenance, typically uplifted basement, although the samples are oriented toward a less mature and less stable block, plotting close to that indicative of derivation from a dissected magmatic arc. Comparison of the QKP plot with worldwide examples from Dickinson and Suczek (1979, fig. 4) indicates derivation of the sandstones of the Tejon from either an uplifted continental block or a dissected magmatic arc provenance.

GRAIN-SIZE DISTRIBUTION

The grain-size distribution for five easily disaggregated samples of the Uvas Conglomerate Member were determined by S. Bartsch-Winkler of the U.S. Geological Survey by sieving at quarter-phi intervals. Each of the samples was collected from within 15 feet (4.6 m) of the basal contact, at localities (from west to east) near Santiago Creek, Los Lobos Creek, Grapevine Creek, at the Edmonston Pumping Plant, and east of the Edmonston Pumping Plant (pl. 1). Sandstone samples from the Liveoak Shale, Metralla Sandstone, and Reed Canyon Siltstone Members were not sieved for one or more of the following reasons: (1) they were well cemented and forceful disaggregation would have broken some grains, (2) thin-section examination revealed the presence of abundant broken and ruptured quartz and feldspar grains cemented together by calcite, so that the disaggregated grain-size distribution would be different than the original one, and (3) abundant calcareous concretions or deep weathering of outcrops prevented the collection of samples suitable for sieving. Some of these factors affected sampling of the Uvas also, but several good sampling localities were found in its lower part.

Using statistical parameters developed by Folk and Ward (1957), the graphic mean grain size of the five samples collected ranges from 0.35 mm to 0.60 mm (0.80 ϕ to 1.63 ϕ), or medium- to coarse-grained sand. The inclusive graphic standard deviation ranges from 0.82 ϕ to 1.03 ϕ, or moderately sorted. The inclusive graphic skewness ranges from + 0.66 to − 0.49, or strongly fine-skewed to strongly coarse-skewed. The graphic kurtosis ranges from 0.99 to 1.31, or platykurtic to leptokurtic.

Log-probability plots of the five samples indicate the mean grain size of medium- to coarse-grained sand and emphasize the moderate sorting of the samples (fig. 46*A*). Different populations (traction, saltation, and suspension) plot as separate straight-line segments in this type of projection of grain-size distribution, and the length of the segments and location of truncation points are thought to be indicative of depositional processes and environments (Visher, 1969), although these interpretations are controversial. The samples from the Uvas Conglomerate Member most closely resemble plots of modern beach samples because of the location of truncation points, the presence of two distinct saltation populations, and the location of the coarse truncation points within very coarse sandstone.

A plot of standard deviation versus mean grain size (fig. 46*B*) suggests that the grain-size distribution is not indicative of either dune or river deposits according to Friedman (1961). A shallow-marine origin is suggested by other characteristics of the basal part of the Uvas such as the fossil assemblages, sedimentary structures, and regional stratigraphic relations.

PALEOCURRENTS

Paleocurrent analyses made from the measurement in the field of the orientation of current-formed sedimentary structures indicate dominant transport of sediments from east to west (figs. 47 and 48). The attitudes of the sedimentary structures were restored to horizontal orientations using computer programs developed by Parks (1970) for two-tilt restorations. Vector means, using the method of Curray (1956), and standard deviations were computed mathematically by other computer programs. Although standard deviations larger than 60° are invalid for circularly distributed data, they are presented herein where computed. Sufficient data for determining paleocurrent trends were obtained only from the Uvas Conglomerate and Metralla Sandstone Members, although a few paleocurrent directions

FIGURE 42.—Mollusk-rich cobble conglomerate from upper part of the Metralla Sandstone Member of the Tejon Formation in Liveoak Canyon.

FIGURE 43.—Pebble conglomerate in upper part of Tejon Formation at Edmonston Pumping Plant. About 105 feet (32 m) below the base of the Tecuya Formation (see fig. 58).

obtained from the Liveoak Shale Member also indicate sediment transport from east to west. The vector mean and standard deviation for the total of 80 paleocurrent directions determined from all members of the Tejon Formation is 262° ± 80°. In addition, some paleocurrent senses were determined from sedimentary structures such as groove casts and symmetrical ripple markings in the Metralla Sandstone Member; these features do not provide unique orientations, but two possible orientations located 180° apart. They are plotted in addition to paleocurrent directions for the Metralla on figure 48 but were not incorporated in the statistical analysis of the data.

Sedimentary structures useful for paleocurrent analysis are not common in the Tejon Formation, and those measurements obtained may be biased in favor of structures that are well preserved or located in particular areas that contain good, fresh outcrops. Data are scarce because (1) the detailed features of sedimentary structures are destroyed at generally deeply weathered rock surfaces, (2) abundant landslides cover outcrops and yield rotated blocks not suitable for measurement, (3) thick colluvium and slope wash conceal the underlying bedrock, and (4) extensive bioturbation of sandstone has destroyed current-formed sedimentary structures. Most outcrops display primarily flat-stratification, parallel bedding, massive unstructured beds, or irregular wavy bedding that are not amenable to paleocurrent measurements.

The total of 25 paleocurrent directions from the Uvas Conglomerate Member yields an overall vector mean orientation of 293° with a standard deviation of ±81°. The orientations are variable, and some even indicate sediment transport to the east. Most orientations are determined from medium- to large-scale cross-strata; other structures measured include small-scale cross-strata and current ripple markings. Variable paleocurrent directions are to be expected, inasmuch as the Uvas is interpreted as having been deposited in a shallow-marine environment along an irregular shoreline, as indicated by the variety of basal deposits and the marked topographic relief of the basal unconformity. The variable effects of onshore-directed wave transport, offshore-directed rip currents, longshore drift, circular transport within embayments, wave refraction caused by headlands, and different directions of storm waves

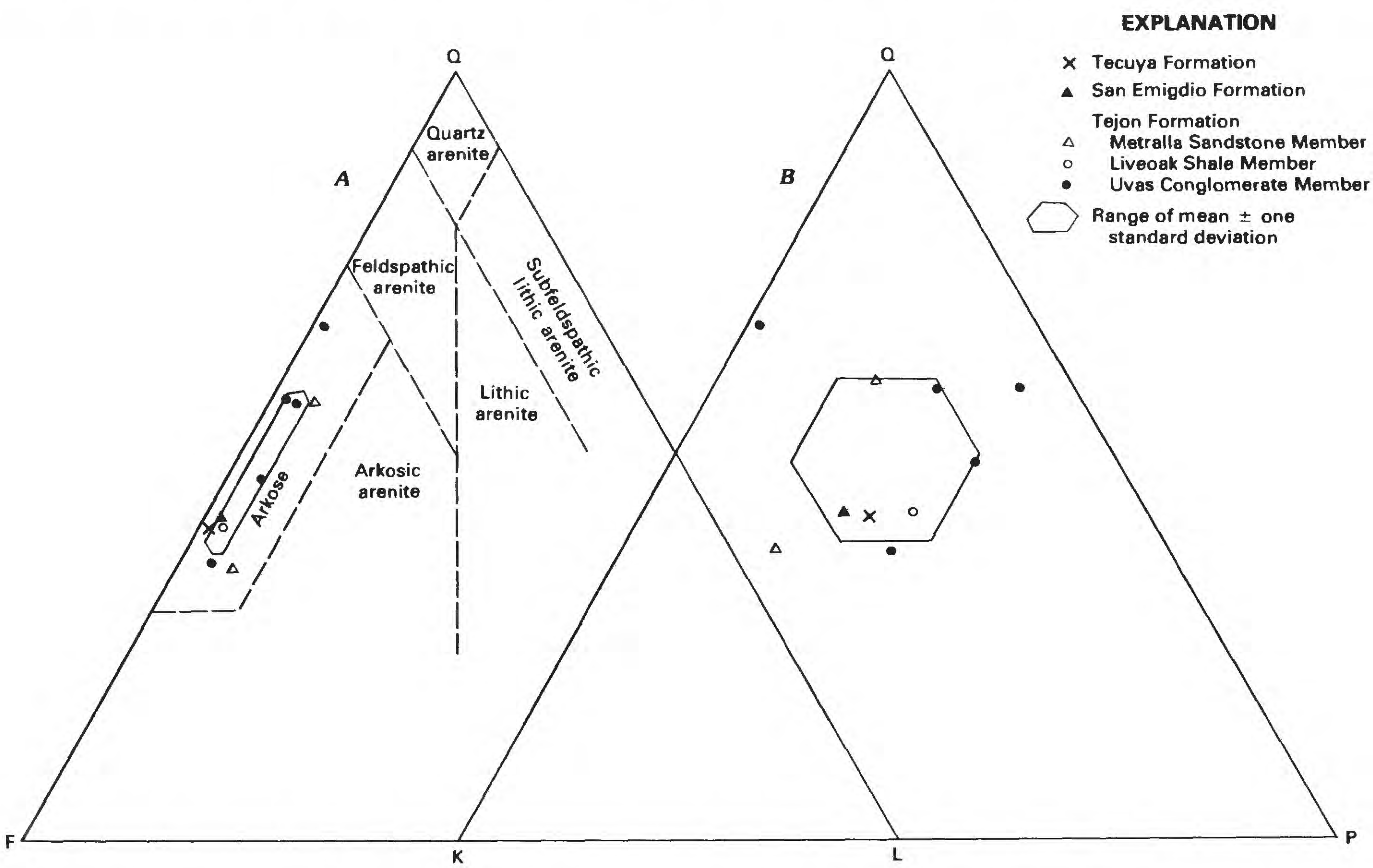


FIGURE 44.—Ternary diagrams showing composition of sandstone samples from the Tejon, Tecuya, and San Emigdio Formations. Based on point counts of 300 grains by T. R. Simoni, Jr. *A*, Quartz (Q) - feldspar (F) - lithic fragment (L) plot showing sandstone classification of Williams and others (1954). *B*, Quartz (Q) - potassium feldspar (K) - plagioclase feldspar (P) plot.

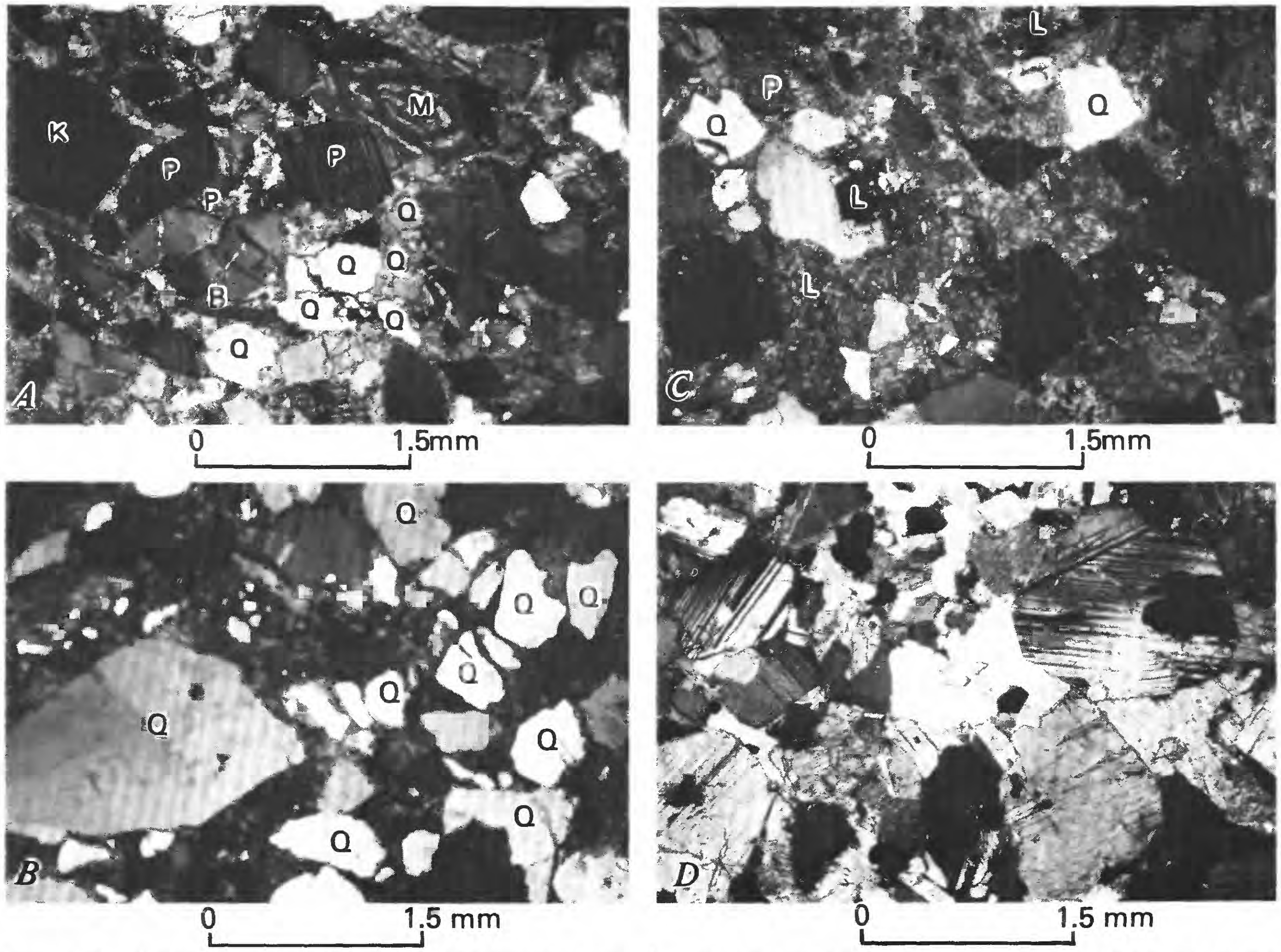


FIGURE 45.—Photomicrographs of the Uvas Conglomerate and Metralla Sandstone Members of the Tejon Formation. Q, quartz; F, feldspar; K, potassium feldspar; P, plagioclase feldspar; L, lithic fragments; B, biotite; M, muscovite; Mf, fossils. All photomicrographs shown under crossed nicols. *A*, Coarse-grained sandstone from type section of the Uvas Conglomerate Member, west side of Grapevine Creek. Poorly sorted angular to partly rounded grains with large foraminifers, abundant biotite, calcite cement. *B*, Very coarse to coarse-grained sandstone from the Uvas Conglomerate Member, west side of Pleito Creek. Poorly sorted and poorly rounded grains with high percentage of quartz, abundant calcite cement. *C*, Coarse-grained sandstone from the Uvas Conglomerate Member, east side of Los Lobos Creek. Clasts of metavolcanic, mafic, and ultramafic rock, amphibole, and epidote, with scattered foraminifers, embayed quartz, plagioclase feldspar, and small amounts of potassium feldspar and biotite; grains very poorly sorted and angular, with abundant calcite matrix. *D*, Coarse-grained plagioclase amphibolite from basement complex directly beneath the Uvas Conglomerate Member, east side of Los Lobos Creek. Contains abundant intermediate plagioclase, pale-olive-green hornblende, magnetite, traces of clinopyroxene; granoblastic texture. *E*, Very coarse to medium-grained sandstone from the Uvas Conglomerate Member, upper East Twin Creek. Large irregular clasts of mafic to ultramafic rock, orbitoidal foraminifers, foraminifers, and scattered quartz and feldspar floating in a dense calcite matrix. *F*, Very coarse to coarse-grained sandstone from the Uvas Conglomerate Member, lower East Twin Creek. Moderately well sorted sandstone containing subrounded grains, very rich in quartz, with abundant potassium feldspar, biotite, and mafic rock fragments; sparse calcite cement. *G*, Medium-grained sandstone from the Metralla Sandstone Member, Pastoria Creek. Poorly sorted angular grains of quartz, potassium feldspar, with some biotite, floating in dense calcite matrix. *H*, Medium-grained sandstone from the Metralla Sandstone Member, Liveoak Canyon. Moderately well sorted, poorly rounded grains of quartz, potassium feldspar, and biotite floating in calcite cement. *I*, Very fine to fine-grained sandstone from the Metralla Sandstone Member, Reed Canyon. Angular, poorly sorted grains of mostly quartz, with calcite cement. *J*, Coarse-grained sandstone from the Metralla Sandstone Member, canyon west of Salt Creek. Angular to poorly rounded and poorly sorted grains of quartz, potassium and plagioclase feldspar, and cherty and volcanic rock fragments in calcite cement.

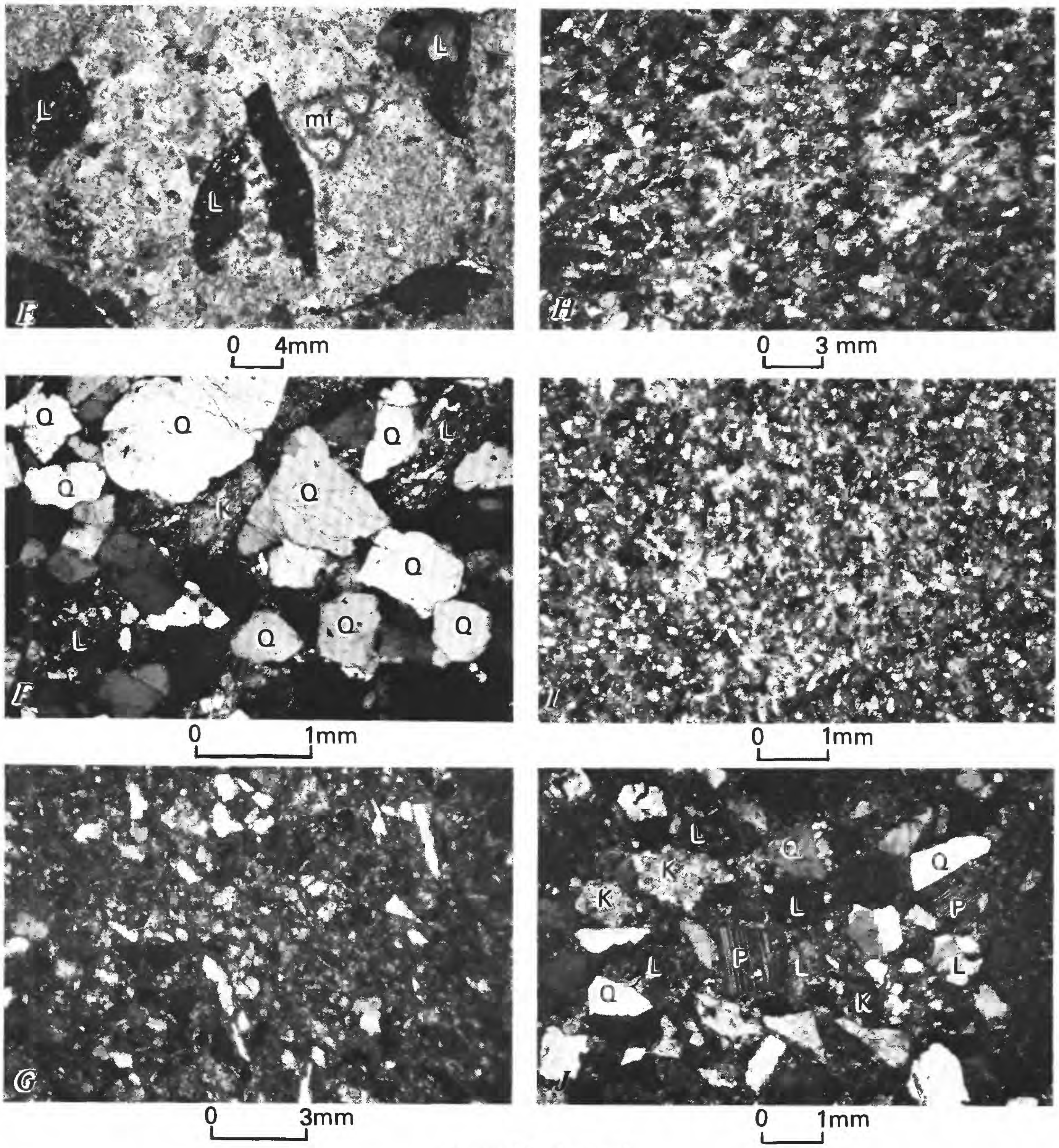


FIGURE 45.—Continued.

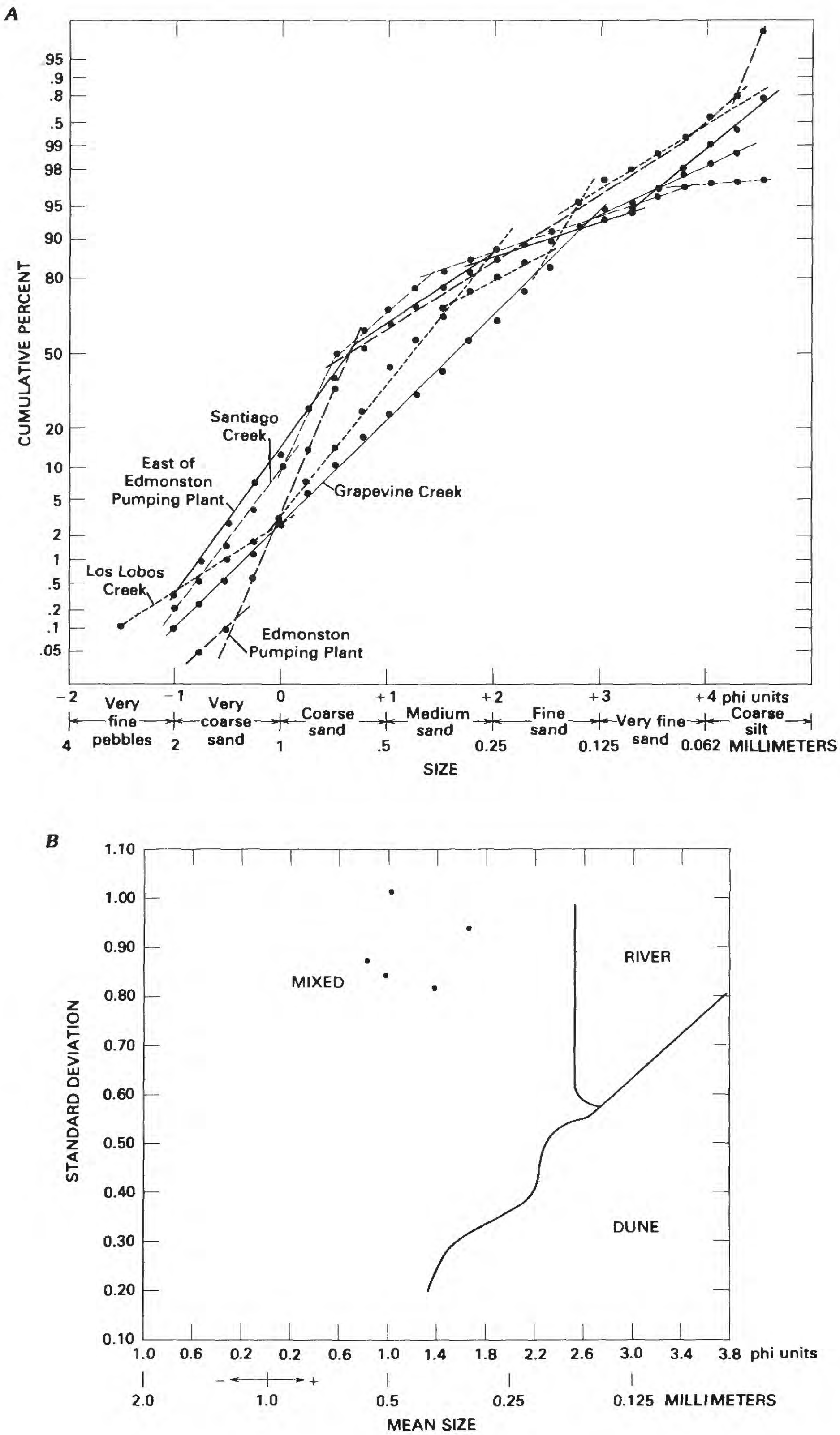


FIGURE 46.—Grain-size distribution plots of five sandstone samples of the Uvas Conglomerate Member of the Tejon Formation. *A*, Log- probability plot. *B*, Mean size plotted against standard deviation.

tend to yield mixed paleocurrent patterns for shallow-marine deposits. The predominance of offshore paleocurrent directions suggests that large amounts of sediment were carried offshore during storm periods, probably by strong rip currents. Sedimentary structures produced during these periods of rapid sedimentation are more easily preserved than structures produced during normal, less energetic intervals. Many of the west-dipping medium- to large-scale cross-strata occur in conglomeratic sandstone beds that are laterally thinner bedded and finer grained to the west, suggesting offshore transport and deposition of the sediments during storm periods. The tops of these beds are bioturbated, probably during more quiescent intervals.

The vector mean of 55 paleocurrent directions from the Metralla Sandstone Member is 250°, with a standard deviation of ±77° (fig. 48). The directions in the eastern outcrops were determined primarily from medium- to large-scale cross-strata, with some directions from small-scale cross-strata and current ripple markings. The paleocurrent pattern for the Metralla is similar to that for the Uvas, although the shoreline may have been more linear in trend during regression of the middle Eocene sea. The dominant westward transport is probably a result of offshore transport during storm periods and preservation of storm-generated sedimentary structures. Almost all of the silty sandstone beds of the Metralla are thoroughly bioturbated, leaving only scattered remnants of current-formed sedimentary structures. Unusual events such as major storms are probably required to deposit beds rapidly and thick enough to preserve the offshore-directed current-produced structures.

Oriented *Turritella* shells were measured in two beds in the lower part of the Metralla Sandstone Member in the Liveoak Canyon area (fig. 49), yielding the rose diagrams and vector means shown in figure 50. The orientation of the pointed or tapered end of the *Turritella* shell was measured in the field and then restored to the horizontal using a stereonet; the plots thus indicate the mean direction, scatter, and number of orientations of the tapered end of the *Turritella* shells. They

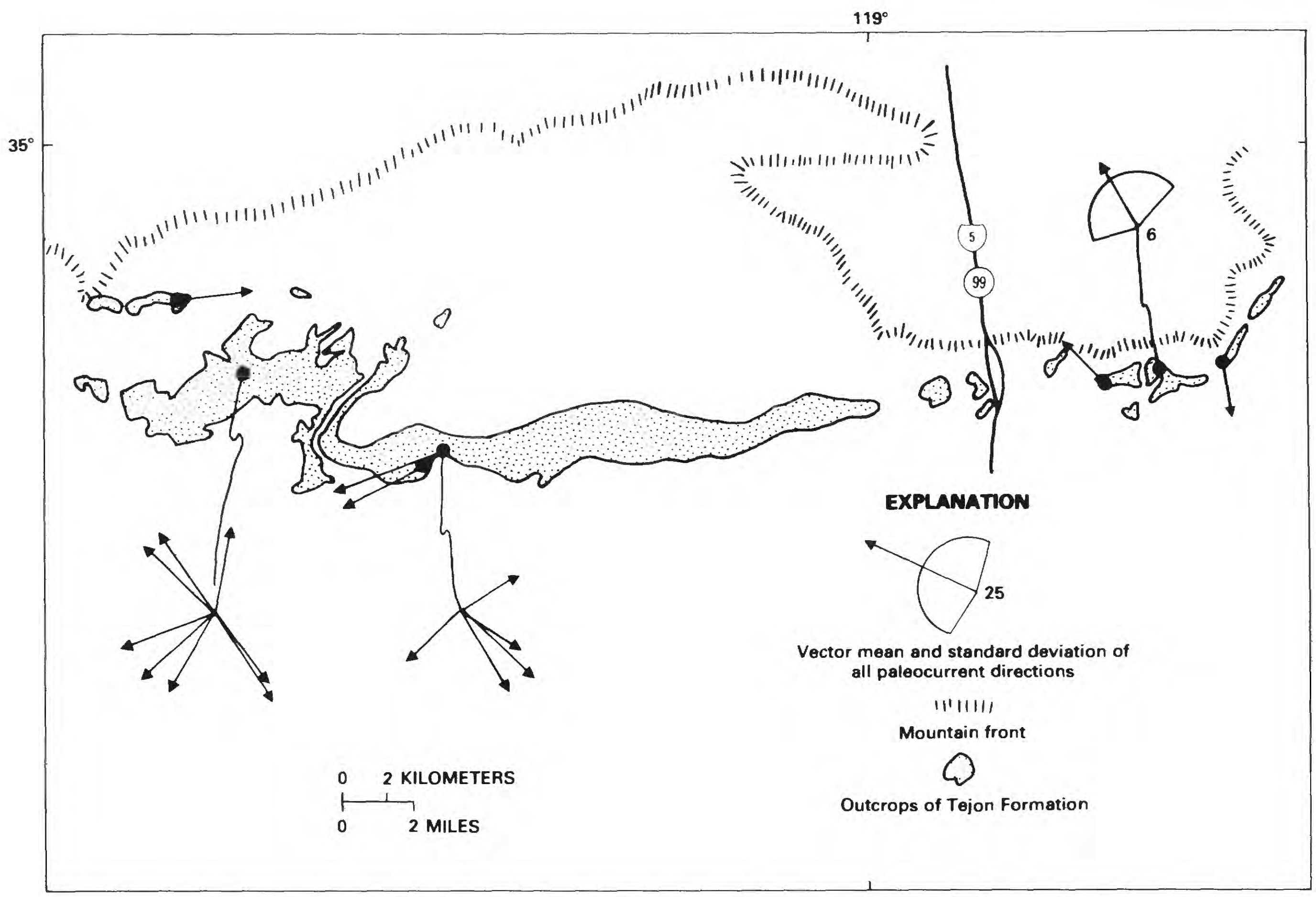


FIGURE 47.—Map showing paleocurrent pattern for the Uvas Conglomerate Member.

generally fell into two east-west-oriented groups about 180° apart, and were thus statistically treated as separate groups divided by the north-south direction. In both beds, the primary orientation seems to be with the tapered end pointed toward the west, which fits well with the other paleocurrent indicators that suggest westward sediment transport.

However, the hydrodynamic interpretation of the orientation of *Turritella* shells is a very complex problem, particularly where the larger end of the shell is hollow, or not filled with sediment. Studies by Nagle (1967) indicate that the shells will orient themselves in various ways, depending upon the nature of the bottom sediments, type and velocity of currents, presence or absence of ripple markings, whether the shells are filled or unfilled, number of additional shells, pebbles or other detritus on the depositional interface, and whether the shells move primarily by rolling about the tapered point or about the blunt end. An additional important factor is whether the animals were still alive; if so, they could have oriented themselves with respect to the current for feeding purposes. The simplest interpretation of the orientations observed here, in view of the other paleocurrent trends, is that the tapered end of the shell is pointing downcurrent. However, beds displaying well-oriented *Turritella* shells are not common, and therefore the interpretation and data should not be relied on too heavily.

The paleocurrent directions from the western outcrops of the Metralla Sandstone Member were derived from a completely different set of sedimentary structures and reflect westward transport by other depositional processes and in other depositional environments than the inferred shallow-marine shelf to the east. The structures include flute casts, convolute laminations, flame structures, small-scale cross-strata, current ripple markings, and ripple-drift lamination. Their organization into Bouma sequences, associated graded bedding, and rhythmic interbedding with shale and mudstone suggests deposition by turbidity currents flowing down a west-facing slope. The beds of sandstone pinch out westward into deep-marine shale. The strong southward component of the paleocurrent directions in the western outcrops suggests that the original slope

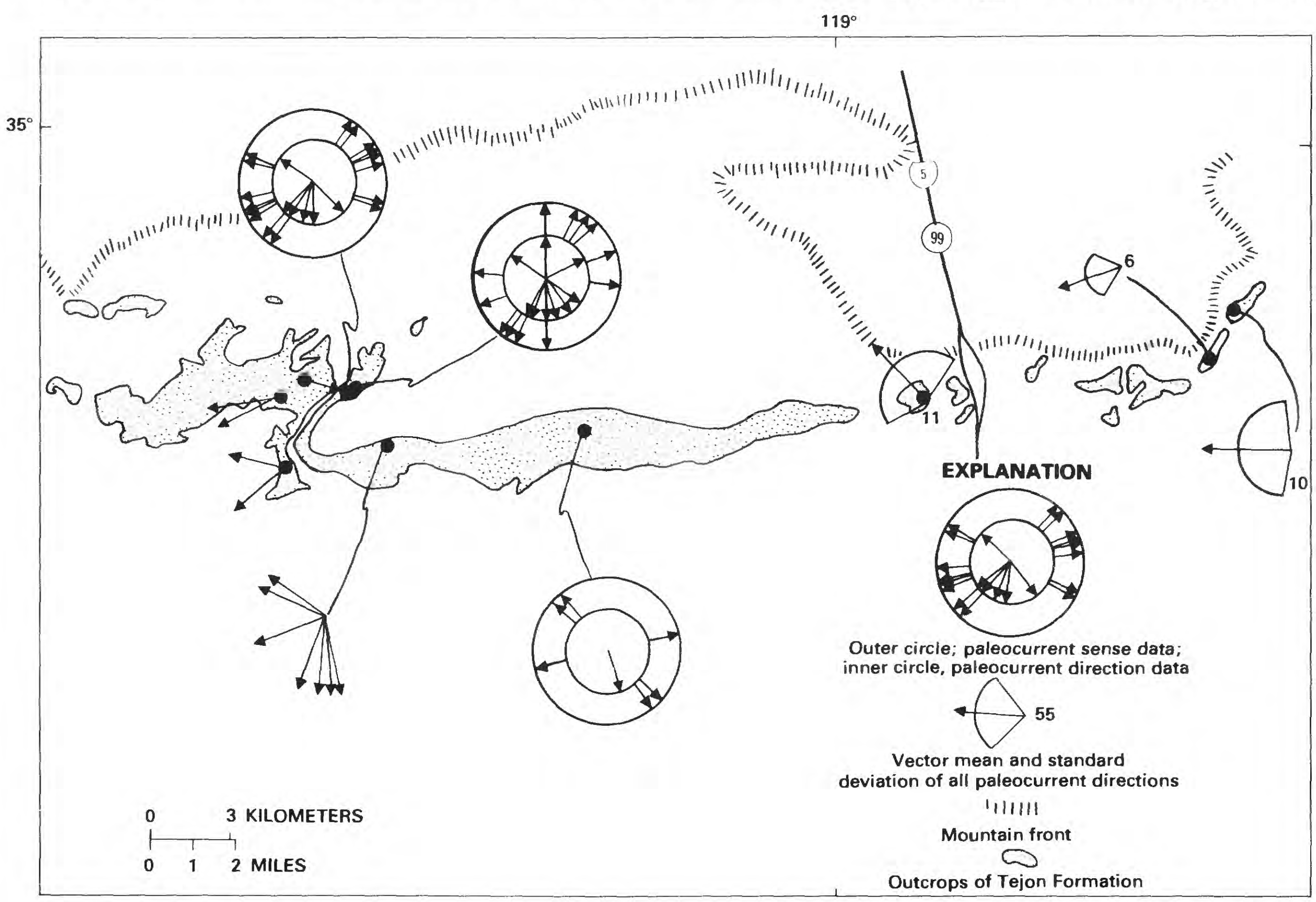


FIGURE 48.—Map showing paleocurrent pattern for the Metralla Sandstone Member.

faced partly southward, the transporting turbidity currents may have hooked leftward downslope, or contour currents flowing parallel to the slope may have influenced the bottom-seeking turbidity currents.

The paleocurrent patterns from cross-strata versus other sedimentary structures are compared in figures 51 and 52. Both sets of structures indicate sediment transport predominantly to the west, with strong southwestward components in the western outcrops.

SEDIMENTARY FACIES

INTRODUCTION

The Tejon Formation includes at least five distinct depositional facies that can be defined by unique assemblages of stratigraphic, sedimentary, and paleontologic characteristics. Although they partly coincide with the formal mapped rock units or members of the Tejon Formation, they are independent of them and are indicative of separate depositional environments.

FIGURE 49.—Oriented *Turritella* shells from near-vertical bed of shallow-marine sandstone in lower part of the Metralla Sandstone Member of the Tejon Formation, east side of Liveoak Canyon. Tapered end of shells point generally to right, or west.

NEARSHORE CONGLOMERATE AND SANDSTONE FACIES

The nearshore conglomerate and sandstone facies was deposited adjacent to or at the migrating Eocene marine shoreline, a high-energy environment where wave, surf, and wind activity was concentrated. This facies is characteristic of the Uvas Conglomerate Member as well as the easternmost outcrops of the Metralla Sandstone Member. It commonly contains abraded and broken rather than whole molluscan shells, although complete shells of oysters and large foraminifers are locally common. This facies is well stratified and contains abundant sedimentary structures. Bioturbation is generally restricted to solitary vertical burrows that disturb only a small part of the beds; only rarely are entire beds completely disrupted by dense networks of burrows and borings.

The conglomerate of this facies generally consists of well-rounded cobbles and pebbles concentrated either in beds 1-8 feet (0.3 m to 2.4 m) thick or scattered along a single horizon in beds of sandstone. The conglomerate is commonly imbricated, both in onshore and offshore directions.

The sandstone is very coarse to medium grained and poorly to well sorted. It is composed primarily of quartz and plagioclase feldspar, and lesser amounts of potassium feldspar and lithic fragments.

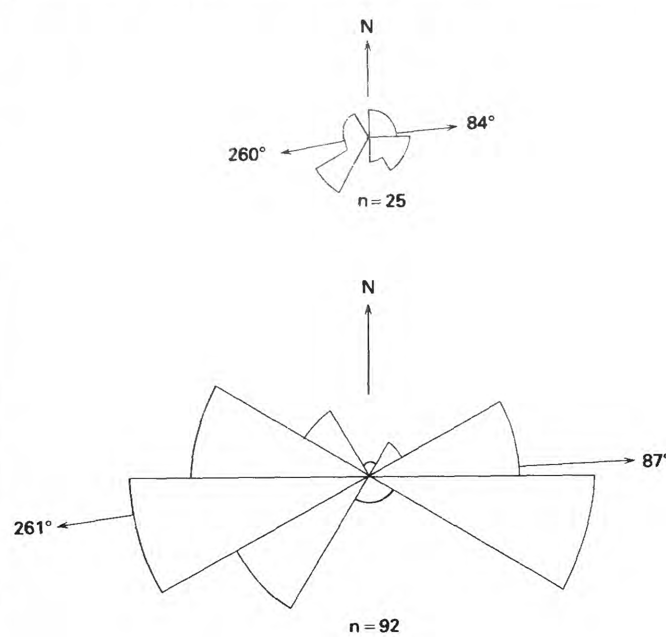


FIGURE 50.—Rose diagrams and vector means for oriented *Turritella* shells on two bedding surfaces from lower part of the Metralla Sandstone Member of the Tejon Formation, east side of Liveoak Canyon; n, number of observations. Tapered ends preferentially point westward.

The two dominant types of stratification are flat, consisting of parallel sandstone laminae probably generated in the foreshore area of beaches, and medium- to large-scale cross-strata, consisting of offshore-dipping foresets probably generated by storm or rip currents transporting sand offshore to the shoreface and farther out, as also inferred by Kumar and Sanders (1976) for some conglomeratic and sandstone layers. Other features include small-scale cross-strata, current ripple markings, megaripples, coarse breccia and boulder beds, oyster reefs, and abrupt lateral and vertical facies changes.

LAGOONAL FACIES

The lagoonal facies was probably deposited behind prominent offshore bars that were present during the retreat of the middle Eocene sea. It is present in the Reed Canyon Siltstone Member, the upper part of the Metralla Sandstone Member in its eastern outcrops, and rarely in the Uvas Conglomerate Member. It generally consists of interbedded sandstone, siltstone, and shale that are extensively bioturbated and include abundant carbonaceous material, locally preserved in thin coaly beds. The sediments of this facies were apparently derived from both onshore and offshore directions. Microfaunal and megafaunal remains from areas beyond the offshore bars were probably swept into the lagoons during storm periods, while other sediments were probably carried into the lagoons by westward-flowing streams. This twofold derivation of sediment may explain some of the controversial interpretations of the depositional environment of the Reed Canyon Siltstone Member, which has been considered to be a deeper marine deposit by some micropaleontologists and a shallow-marine to intertidal deposit by others. The lagoonal facies may encompass other environments, including coastal marshlands, estuaries, tidal flats, and possibly a variety of intra-delta environments. Unfortunately, information regarding its lateral variation is limited by the small extent and poor exposures, so that a definitive interpretation of this depositional environment is conjectural.

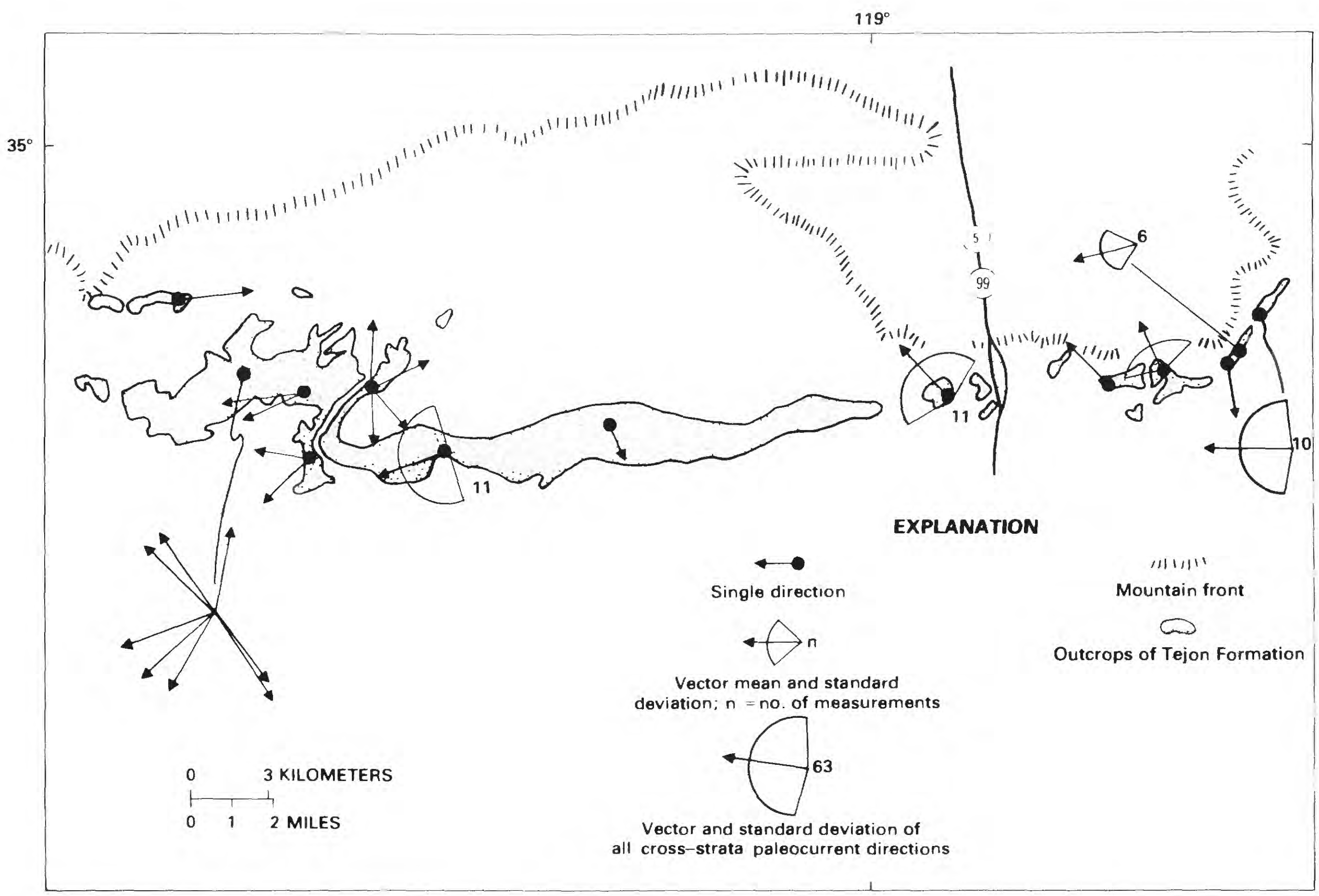


FIGURE 51.—Paleocurrent pattern from measured cross-strata in the Tejon Formation.

SHALLOW-MARINE SANDSTONE FACIES

The shallow-marine sandstone facies was deposited on the shelf offshore from the nearshore conglomerate and sandstone facies, but still in shallow-marine conditions above wave base. It is characteristic of the upper part of the Uvas Conglomerate Member and exposures of the Metralla Sandstone Member east of Pleito Creek (pl. 1). It consists almost wholly of generally fine- to medium-grained sandstone. Molluscan shells are locally abundant and indicate sandy, level bottoms at depths ranging from low tide to about 300 feet (91 m) (W. O. Addicott, written commun., Feb. 18, 1972). The sandstone is generally poorly sorted and contains abundant silt-sized matrix material.

Sedimentary structures and bedding are generally absent, probably as a result of extensive bioturbation. Most of this facies consists of massive, irregularly bedded sandstone with abundant medium to large spheroidal calcareous concretions. The few preserved sedimentary structures present include current ripple markings and small-scale cross-strata, and more rarely, medium- and large-scale cross-strata and planar bedding. Movement of sand and current activity must have been generally minimal, with low energy characterizing the offshore environment, a situation favorable for burrowing organisms.

DEEP-MARINE SANDSTONE FACIES

The deep-marine sandstone facies is represented by the western outcrops of the Metralla Sandstone Member and in the upper and lower parts of the Liveoak Shale Member. It was deposited by turbidity currents that flowed westward down a submarine slope located west of the shelf area. The facies consists of interbedded sandstone, siltstone, and shale organized into graded beds that contain Bouma sequences; each bed represents the deposit of a single turbidity current.

Sandstone of this facies is fine grained. No conglomerates composed of igneous or metamorphic clasts are present, although rip-up clasts of mudstone and

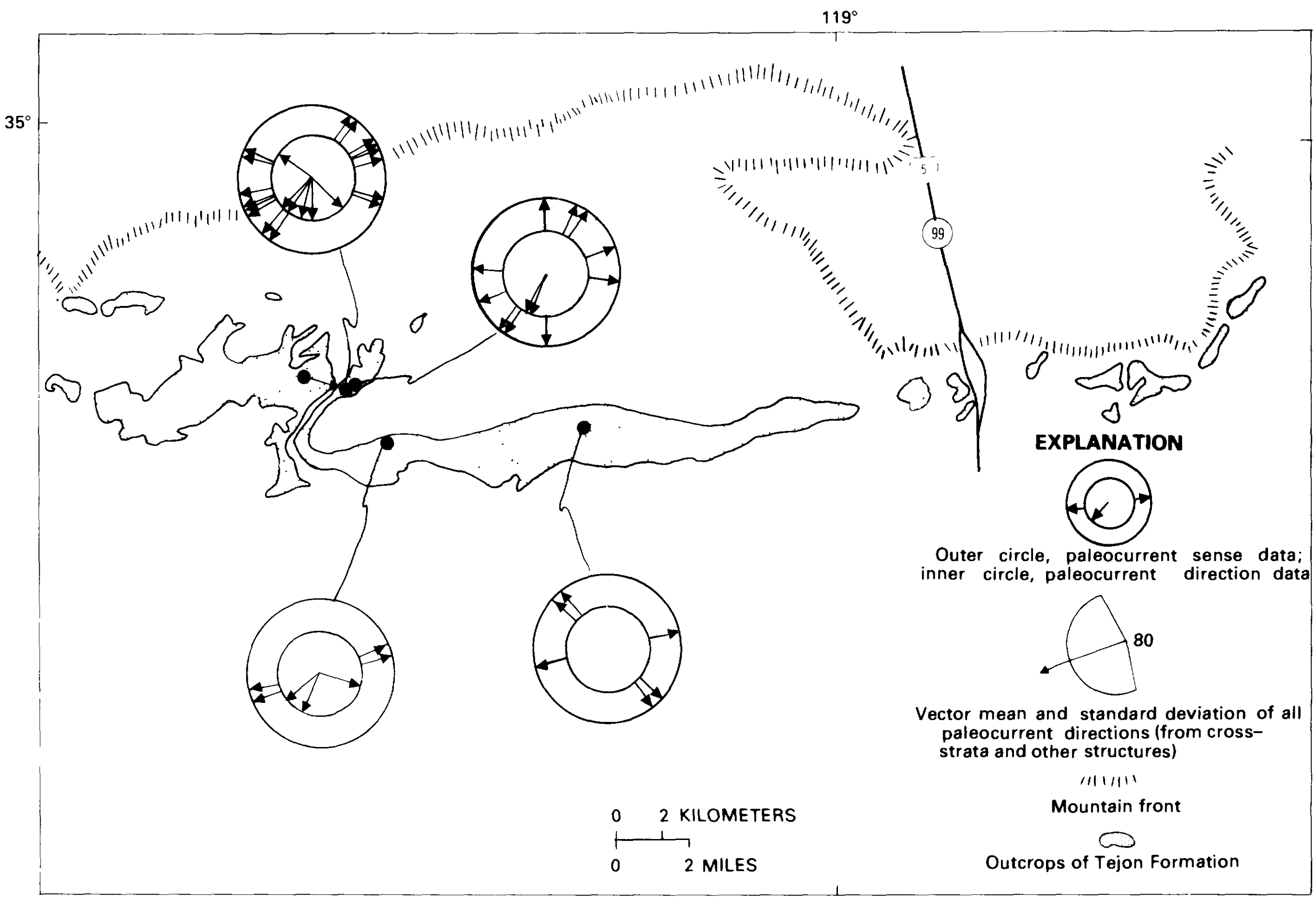


FIGURE 52.—Paleocurrent pattern from sedimentary structures other than cross-strata in the Tejon Formation. The data include measurements of ripple markings, primary current lineation, flute casts, flame structures, and convolute laminations.

siltstone are common in places. The beds of sandstone were derived from sands deposited on the shelf to the east, and they thicken eastward. Sparse megafossils consisting of minute, apparently dwarf pelecypods indicative of middle or outer sublittoral depths are present.

Sedimentary structures indicative of turbidite sedimentation are common, particularly parallel stratification of the Bouma *b* division (Bouma, 1962). Evidence for synsedimentary slumping is common, such as contorted stratification, and dikes of sandstone are present in this facies. The combination of Mutti and Ricci Lucchi (1972, 1975) facies D turbidites (base-cut-out Bouma sequences), low sandstone-to-shale ratios, slumping, stratigraphic setting west of the shelf facies, and absence of deep-sea fan features within these turbidites suggests deposition on a submarine slope.

DEEP-MARINE SHALE FACIES

The deep-marine shale facies is represented by most of the Liveoak Shale Member. It was deposited in offshore bathyal to abyssal environments as indicated by foraminifers. The deepest environments were located at the western outcrop areas of the Liveoak, particularly west of San Emigdio Canyon. Here the Liveoak Shale Member is characterized by scattered foraminifers and a lack of megafossils. It consists dominantly of micaceous and argillaceous shale or claystone, but includes interbedded siltstone and some fine-grained sandstone.

Outcrops are either shaly or massive and blocky; bioturbation is widespread and strongly developed, and in most outcrops only remnants of stratification are visible. Some of the interbeds of siltstone and shale contain thin, irregular, very small scale cross-strata and irregular current ripple markings. Coarser grained beds of turbidite sandstone are locally present and are typically of Mutti and Ricci Lucchi facies D, containing $T_{c\text{-}e}$ sequences.

The deep-marine shale facies is probably composed of pelagic microfaunal shell detritus that has slowly settled out of the oceanic water column plus fine-grained terrigenous detritus transported to deep water from the continental shelf to the east. Turbid-layer flows, nepheloid layers, and flood-generated overflows and interflows of sediment may have also contributed fine-grained sediment to this facies.

DEPOSITIONAL HISTORY AND PALEOGEOGRAPHY

The Tejon Formation was deposited primarily on part of the continental shelf that existed along the western border of North America during Eocene time. It records a major transgression from west to east that began in the early Eocene (the megainvertebrate "Capay" Stage) and reached its maximum extent with deposition of the Liveoak Shale Member during middle Eocene time (the megainvertebrate "Domengine," "Transition," and "Tejon" Stages) (fig. 7). During the late middle Eocene, the shallow sea covering the shelf regressed westward as the regressive shallow-marine Metralla Sandstone and Reed Canyon Siltstone Members were deposited (fig. 53). A prominent inferred paleogeographic feature of the western part of the depositional area was the west- and northwest-facing submarine slope on which the deep-marine turbidite sandstone facies of the Metralla was deposited. This slope was probably part of the early Tertiary continental slope at the western edge of North America and was presumably located at the transition between basement rocks of granitic character to the east and gabbroic character to the west. Ross (1970) postulated that this basement contact represents a Mesozoic subduction zone; if so, it persisted in Eocene time as a submarine slope rather than an active zone of subduction or faulting, because the Uvas Conglomerate Member uniformly covers with unconformity both the mafic and felsic basement rocks.

In the western part of the range during late Eocene and early Oligocene time, the deep-marine sandstone and shale facies of the Liveoak Shale and Metralla Sandstone Members were covered by thick shallow-marine deposits of the San Emigdio Formation. This succession indicates that the west-facing Eocene submarine slope had disappeared as a paleogeographic feature in that area, most probably as a result of uplift in the area of the western San Emigdio Mountains.

Farther west, a continental borderland or peninsula underlain by granitic basement rocks of the Salinian block is inferred to have been present (Nilsen and Clarke, 1975); it may have been sheared off from the southern end of the Sierra Nevada by pre-Eocene right-lateral slip along the proto-San Andreas fault (Clarke and Nilsen, 1973; Nilsen and Clarke, 1975; Nilsen and Link, 1975; Clarke and others, 1975; Nilsen, 1977; Nilsen and McKee, 1979) or have been transported even greater distances. This inferred peninsula or borderland was presumably the source area for deep-sea fans such as the Point of Rocks Sandstone Member of the Kreyenhagen Formation, located in the southwestern San Joaquin Valley northwest of the Tejon Formation.

The inferred regional Eocene paleogeography for the southern San Joaquin Valley is indicated by figure 54. At the eastern end of the Tejon Formation outcrop belt where the Tejon thins and consists almost wholly of shallow- marine and nearshore sandstone, it is impossible to stratigraphically separate transgressive sandstone of the Uvas Conglomerate Member from regressive sandstone of the Metralla Sandstone Member. Both units are conglomeratic and both grade laterally eastward into nonmarine facies similar to the Tecuya Formation. This facies persists northward in the subsurface as the Walker Formation, a nonmarine sequence ranging from possibly middle or late Eocene to early Miocene in age (Addicott, 1970a, b). The Walker also crops out along the southeast margin of the San Joaquin Valley (Bartow and Doukas, 1978). The Tejon Formation also extends northward in subsurface as the Famosa sand of Hackel (1966) (American Association of Petroleum Geologists, 1957).

The north-south-trending paleogeography during Tejon sedimentation suggests that the southern parts of the east-west-trending San Emigdio and western Tehachapi Mountains were covered by marine waters during the Eocene. Sedimentologic data and composition of conglomerate clasts suggest that both the Tejon Formation and the Tecuya Formation were derived from source areas to the east, possibly including the Mojave Desert region to the southeast. No evidence for southerly or westerly source areas exists for either formation. Subsurface facies relations to the north in the Metralla Sandstone Member of the Tejon Formation suggest that the Eocene submarine slope separating the shelf area to the east from the deep-sea basin to the west trended northeast (Weber, 1973).

The overlying San Emigdio and Pleito Formations were apparently derived from the south or southeast, as suggested by subsurface studies by Tipton (1971) and Tipton and others (1973, 1974). These units may have been partly if not wholly derived from source areas south of the present San Andreas fault. If one assumes 200 miles (320 km) of post-Eocene right-lateral slip along the San Andreas fault (Clarke and Nilsen, 1973), a likely source area is the Gabilan Range. The earliest evidence of uplift in the area of the present San Emigdio

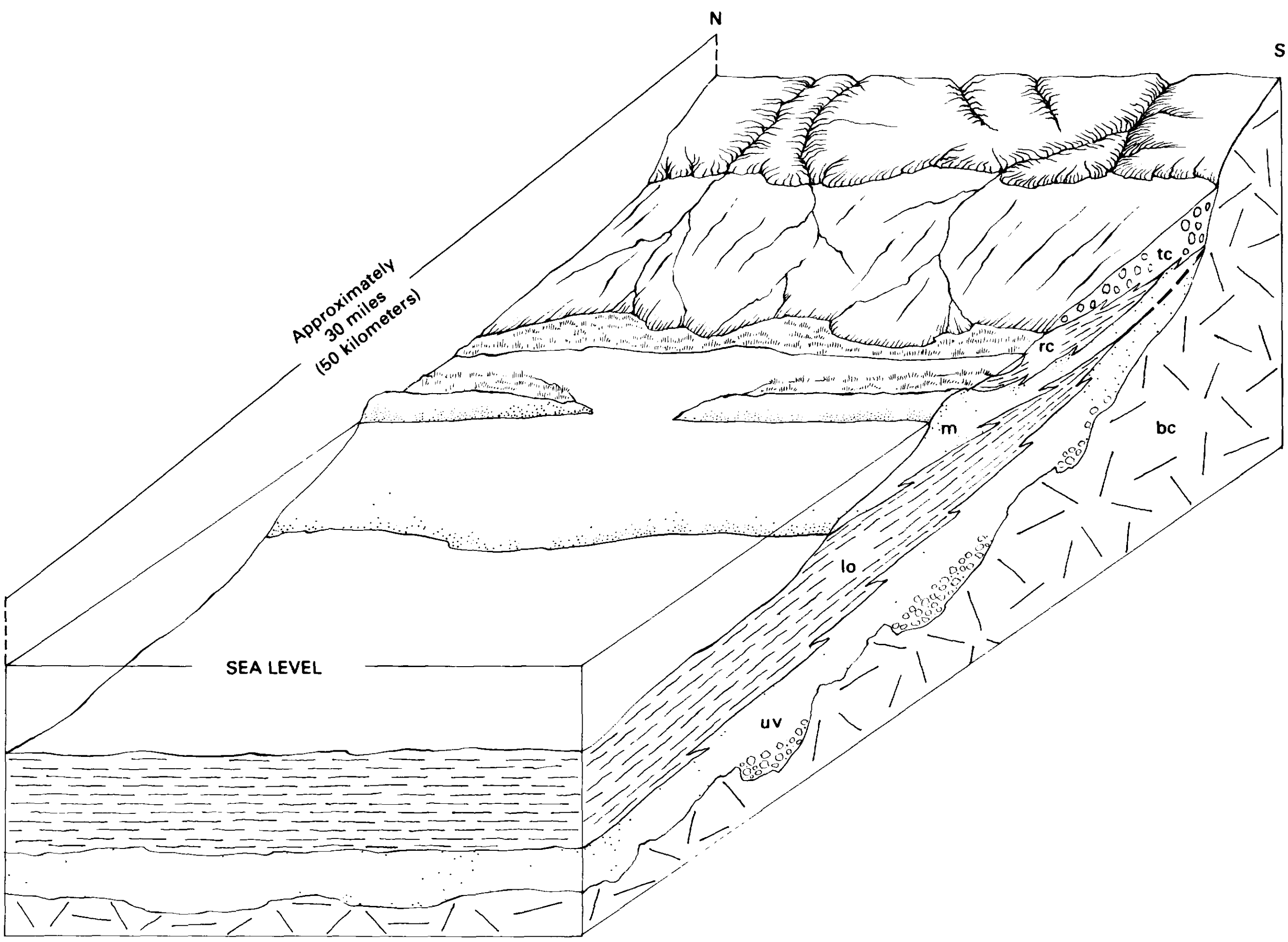


FIGURE 53.—Simplified paleogeographic model of the Uvas Conglomerate (uv), Liveoak Shale (lo), Metralla Sandstone (m) and Reed Canyon (rc) Members of the Tejon Formation. Other abbreviations: bc, basement complex; tc, Tecuya Formation.

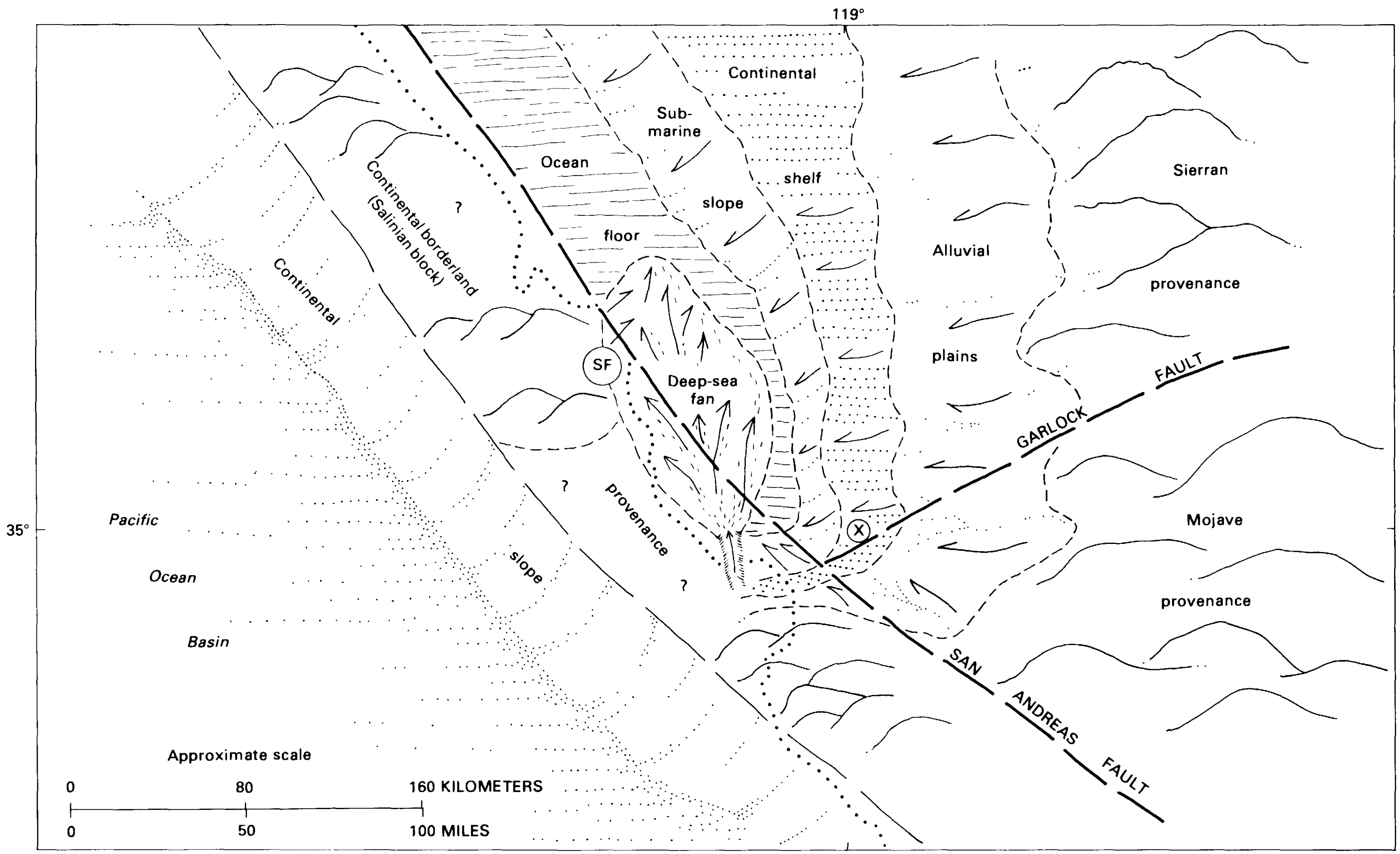


FIGURE 54.—Inferred middle Eocene paleogeography of south end of San Joaquin Valley. X = location of Tejon Formation. Arrows indicate directions of sediment transport. Post-Eocene right-lateral offset of approximately 200 miles (310 km) along San Andreas fault has been restored in diagram. Large deep-sea fan in center of map comprises the Butano Sandstone of the Santa Cruz Mountains and the Point of Rocks Sandstone Member of the Kreyenhagen Formation in the Temblor Range, as restored by Clarke and Nilsen (1973). Dotted line in continental borderland represents present trace of coastline, with San Francisco (SF).

Range is in extreme southwestern part, near Brush Mountain, as indicated by the unconformable relation of the Temblor Formation on older Tertiary units (fig. 8; Nilsen and others, 1973). The main uplift of the mountains, however, must have taken place much later, during Pliocene or Pleistocene time, when thick nonmarine deposits were shed northward into the southern San Joaquin Valley (pl. 1). This period of uplift was accompanied by or followed by major northward thrusting of the basement complex and the Tertiary sequence along a series of imbricate thrust slices, primarily during Quaternary time.

ECONOMIC ASPECTS

The Metralla Sandstone Member is a reservoir rock for petroleum and has been extensively drilled at Wheeler Ridge and adjacent areas north of the outcrop belt. The oil has been produced only east of Pleito Creek, where the Metralla consists chiefly of the shallow-marine sandstone facies. North of the western San Emigdio Mountains between Maricopa and Santiago Creek, the Tejon Formation lies deeply buried beneath structurally complex younger sedimentary rocks and has not been penetrated by wells. Attempts to find additional oil fields in the deeply buried Metralla Sandstone Member in the southern San Joaquin Valley west of Wheeler Ridge have thus far been unsuccessful.

The data presented herein, based on surface geology and attempted subsurface correlation, indicate that the Metralla Sandstone Member fingers out northwestward and westward in outcrop and probably in subsurface into the Liveoak Shale Member. This fingering out corresponds to a change from shelf to slope to deep-marine depositional environments. Because the sandstone becomes finer grained, thinner bedded, and less porous westward and northwestward, it is less suitable as an oil reservoir. Consequently, exploration in the Metralla should probably be confined to the areas where it was deposited on the middle Eocene shelf, approximately southeast of a line connecting the north edge of the Wheeler Ridge oil field and the Eagle Rest Peak area (pl. 1). Northwest of that line, the Tejon Formation probably consists largely of shale and siltstone with some thin interbeds of fine-grained sandstone in the subsurface as well as in outcrop. There is no evidence to indicate that a deep-sea fan was deposited to the west or northwest, although if one were present, it might provide a suitable reservoir, as later Miocene deep-sea fans have yielded large amounts of petroleum in the southern San Joaquin Valley (MacPherson, 1977), and the area has been subjected to repeated shoaling and deepening episodes (Bandy and Arnal, 1969).

In subsurface to the northwest, the equivalent of the Liveoak Shale Member is called the Kreyenhagen Formation of the Temblor Range and subsurface western San Joaquin Valley. There are probably no significant age differences between these units, as the foraminiferal samples from the westernmost outcrops of the Liveoak Shale Member indicate. Suitable reservoirs for oil are present on the west edge of the San Joaquin Valley in the coeval Point of Rocks Sandstone Member of the Kreyenhagen Formation of the Temblor Range, which fingers out eastward into shale of the Kreyenhagen Formation and probably southeastward into the Liveoak Shale Member. Suitable Eocene exploration targets in the area, then, consist of the Point of Rocks to the northwest (probably northwest of Maricopa) and the Metralla Sandstone Member to the east. In the intervening area, Eocene strata consist primarily of shale.

SUMMARY AND CONCLUSIONS

The Tejon Formation was deposited on crystalline basement rocks of the San Emigdio and western Tehachapi Range as a result of an eastward early Eocene transgression of a shallow-marine sea followed by a westward middle Eocene regression. The Tejon consists of a basal shallow-marine transgressive conglomerate, breccia and sandstone (Uvas Conglomerate Member), an overlying deeper marine shale (Liveoak Shale Member), and an upper regressive sandstone (Metralla Sandstone Member). Locally a fourth member, thought to be a lagoonal siltstone (Reed Canyon Siltstone Member), can be mapped. The regressive sandstone-siltstone association grades laterally westward into turbidite sandstone and shale deposited in slope environments. The regressive deposits are overlain in the east by braided-stream conglomerate of the Tecuya Formation and in the west by shallow-marine sandstone and conglomerate of the San Emigdio Formation. Abundant megafossils and foraminifers in the Tejon Formation provide correlation between deep- and shallow-marine facies.

The absence in the San Emigdio and western Tehachapi Mountains of Cretaceous forearc basin deposits of the Great Valley sequence, which are extremely thick and widespread to the north in the San Joaquin Valley and to the south and west in the Transverse and Peninsular Ranges, and the absence of Paleocene strata, which are abundant in regions to the north, south, and west, suggest tectonic uplift of the area during part or all of Cretaceous and Paleocene time. Whether the Great Valley sequence had been deposited and then eroded, perhaps during latest Cretaceous or Paleocene uplift, is not known. During early Eocene time, the entire area must have undergone gradual subsidence and associated transgression, perhaps as a tilted block, and the western part of the area subsided to at least lower bathyal depths. The basal Eocene conglomerates were deposited on both mafic basement rocks of the western San Emigdio Range and granodioritic basement rocks of the main part of the San Emigdio Range and the western Tehachapi Range. The Eocene basin of deposition deepened westward as well as northward toward the present San Joaquin Valley. At the west end of the outcrop area, the Tejon Formation is overlain with angular unconformity by the late Oligocene and early Miocene Temblor Formation.

Full understanding of the paleotectonic and paleogeographic history of the area bordering the south end of the San Joaquin Valley requires reconstruction of rocks and terranes presently situated west of the San Andreas fault. The Eocene Point of Rocks Sandstone Member of the Kreyenhagen Formation of the Temblor Range and subsurface portion of the southwestern San Joaquin Valley has been equated with the Eocene Butano Sandstone of the Santa Cruz Mountains by Clarke and Nilsen (1973), an offset along the San Andreas fault of about 190 miles (305 km). Mafic basement rocks from the Logan Quarry area 6.5 miles (10.5 km) northwest of San Juan Bautista have been equated with similar mafic basement rocks in the western San Emigdio Range by Ross (1970), also an offset of about 190 miles (305 km). Nilsen and Link (1975) concluded that the basal conglomerate resting on mafic basement rocks near Logan Quarry and overlying shale with thin turbidite sandstone interbeds of the lower part of the San Juan Bautista Formation of Kerr and Schenck (1925) or the unnamed Eocene formation as mapped by Dibblee and others (1979) are equal to the Uvas Conglomerate and overlying Liveoak Shale Members of the Tejon Formation in the East Twin Creek area of the western San Emigdio Range and indicate a similar offset of 190 miles (305 km), Cretaceous and Paleocene strata are also absent from the San Juan Bautista area.

The offsets along the San Andreas fault are considered by most workers to be the result of late Miocene to Holocene right-slip movement (Dickinson and others, 1972; Blake and others, 1978; Crowell, 1979). Because offsets of Eocene, Oligocene, lower Miocene, and middle Miocene units along the San Andreas fault appear to be the same 190 miles (305 km), indicating the absence of movement along the San Andreas fault between Eocene and late Miocene time (Nilsen and Link, 1975), both the erosion of possible pre-Tejon Formation deposits and development of the angular unconformity between the Tejon Formation and Pleito Formation in the western San Emigdio Range must be related to tectonic activity not associated with lateral movements along the San Andreas fault.

The pre-Tejon Formation erosion could be related to uplifts associated with a decrease in subduction angle (Coney and Reynolds, 1977; Keith, 1978), lateral movement along a proto-San Andreas fault (Nilsen, 1978), or other effects not now clearly understood. The angular unconformity may be related to initial movements associated with the development of the plate boundary between the Pacific and North American plates following initial contact between these plates in southern California at 29 m.y. ago (Atwater, 1970; Atwater and Molnar, 1973; Blake and others, 1978).

The marine Eocene basin occupying the southern San Joaquin Valley extended at least in part west of the San Andreas fault to the San Juan Bautista area, and also connected northwestward with the La Honda basin of the Santa Cruz Mountains area. Northward the basin extended almost the entire length of the Great Valley area, interrupted by two west-protruding arches near Bakersfield and Stockton. To the east the basin was bounded by the uplifted southern Sierra Nevada, and to the southeast by uplifted terranes of the Tehachapi Mountains and northern Mojave Desert areas, in which some smaller early Tertiary basins were filled with fluvial deposits (Dibblee, 1967; Nilsen and Clarke, 1975; Cox, 1979).

However, the extension of the basin southward is poorly known. Nilsen and Link (1975) and Link and Nilsen (1979) suggested that it extended southward across the Salinian block to the northern Santa Lucia basin, whereas Graham (1976, 1978) inferred the presence of a land barrier in the vicinity of the northern mountains between the two basins. Access to the open ocean was available, in either case, to the north and northwest.

The Tejon Formation represents a classic example of a continental-margin onlap-offlap sequence over a shelf width of 25 miles (40 km). Deposition occurred during an interval of relative quiescence, at least in comparison to other parts of the Tertiary of California. Alternating marine sandstones and shales were deeply buried, folded, and faulted, yielding stratigraphic and structural traps for petroleum, particularly in the upper regressive facies.

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MEASURED SECTIONS

INTRODUCTION

I measured sections through the Tejon Formation along most of the major north-flowing creeks and canyons in the San Emigdio and western Tehachapi Mountains (fig. 13). A section was measured near Pleito Creek along the adjacent ridge crest to the west because exposures along the creek were poor. Four measured sections with fossil control from Pastoria Creek, Liveoak Canyon, Reed Canyon, and the north limb of the Devils Kitchen syncline adjacent to San Emigdio Creek were kindly provided by the Atlantic-Richfield Oil Company. Other measured sections of varying detail had been prepared by Marks (1941a) for Liveoak Canyon, Grapevine Canyon, and Reed Canyon; by DeLise (1967) for the south limb of the Devils Kitchen syncline along San Emigdio Creek; and by Hammond (1958) for his informally named East Twin Creek, located east of Santiago Creek. Some of these sections are substantially revised here on the basis of the new stratigraphic, structural, and paleontologic work presented in this paper and a reinterpretation of the distribution of landslide and colluvial deposits. For almost every section, I have taken independent measurements of thicknesses of various units, re-described the lithology and characteristics of various units, and made new collections of both megafossils and microfossils.

Detailed measured sections for each member of the Tejon Formation are presented in the stratigraphy section of this paper and are not repeated here. The overall stratigraphy of the Tejon Formation is summarized in the stratigraphic cross section shown in figure 13. The measured sections are presented in geographic order from east to west across the outcrop area, and from the top of the section to the base.

EDMONSTON PUMPING PLANT SITE

The Edmonston Pumping Plant, located between Pastoria and Tunis Creeks, lifts water almost 2,000 feet (610 m) from the floor of the San Joaquin Valley to near the top of the Tehachapi Mountains, where it flows to the coastal plains of southern California through a series of tunnels, pipelines, and canals (fig. 55). The four-story deep excavation for the Edmonston Pumping Plant is in the Tejon Formation and the underlying granitic basement rocks, and their contact was exposed in great detail during construction. However, because of subsequent construction and fill, the contact is now visible only in narrow cuts along the sides of the plant. The large cut face behind and south of the main building exposes basement rocks; cuts on the sides to the east and west expose a complete section of the Tejon Formation, which dips approximately 45° to the northwest. At the north end of the plant, conglomerates of the overlying Tecuya Formation are exposed. Although a variety of rock types and sedimentary facies are exposed at the plant sites, the four members of the Tejon Formation cannot be differentiated either here or farther east.

The three-dimensional geologic map of the excavation site shows the extreme irregularity and high, steep relief of the unconformable contact between the Tejon Formation and the basement complex (figs. 35 and 56). Relief on the basal contact can locally be measured in meters, and in several places conglomerate and sandstone fill deep, narrow crevices that extend into the basement complex. Numerous isolated outliers of basal sandstone and conglomerate of the Tejon must have filled topographically low areas on the basement complex.

Abrupt facies changes take place within the Tejon Formation between the east and west sides of the pumping plant. The middle part of the Tejon on the west side consists of a thick section of siltstone and shale, whereas the middle part on the east side consists dominantly of sandstone. Stratigraphic relations exposed when the excavation site was uncovered indicate that the sandstone intervals pinch out westward into the shale. Thus, within the width of the excavation site the Liveoak Shale Member becomes differentiable as a discrete mappable body between the basal conglomerate (Uvas Conglomerate Member) and the upper sandstone (Metralla Sandstone Member).

The entire thickness of the Tejon Formation, approximately 400 feet (122 m), is exposed in the main cut along the east side of the pumping plant (figs. 57 and 58). However, there is no clear division between the Uvas Conglomerate, Liveoak Shale, and Metralla Sandstone Members here because the entire section consists primarily of sandstone.

The lower 60 feet (18 m) of the section consists primarily of well-sorted and rounded, quartzose sandstone and conglomerate, and is characterized by medium- to large-scale cross-strata, thin flat strata, scattered shell fragments, and a small sandstone dike near the basal contact (see fig. 35). The basal beds rest with relatively high initial dips of as much as 15° on the basement complex.

Above this is a sequence of brown-weathering, bioturbated, clayey and silty very fine grained sandstone that includes lenses of fine-

FIGURE 55.—Aerial photograph of Edmonston Pumping Plant and Tehachapi Crossing.

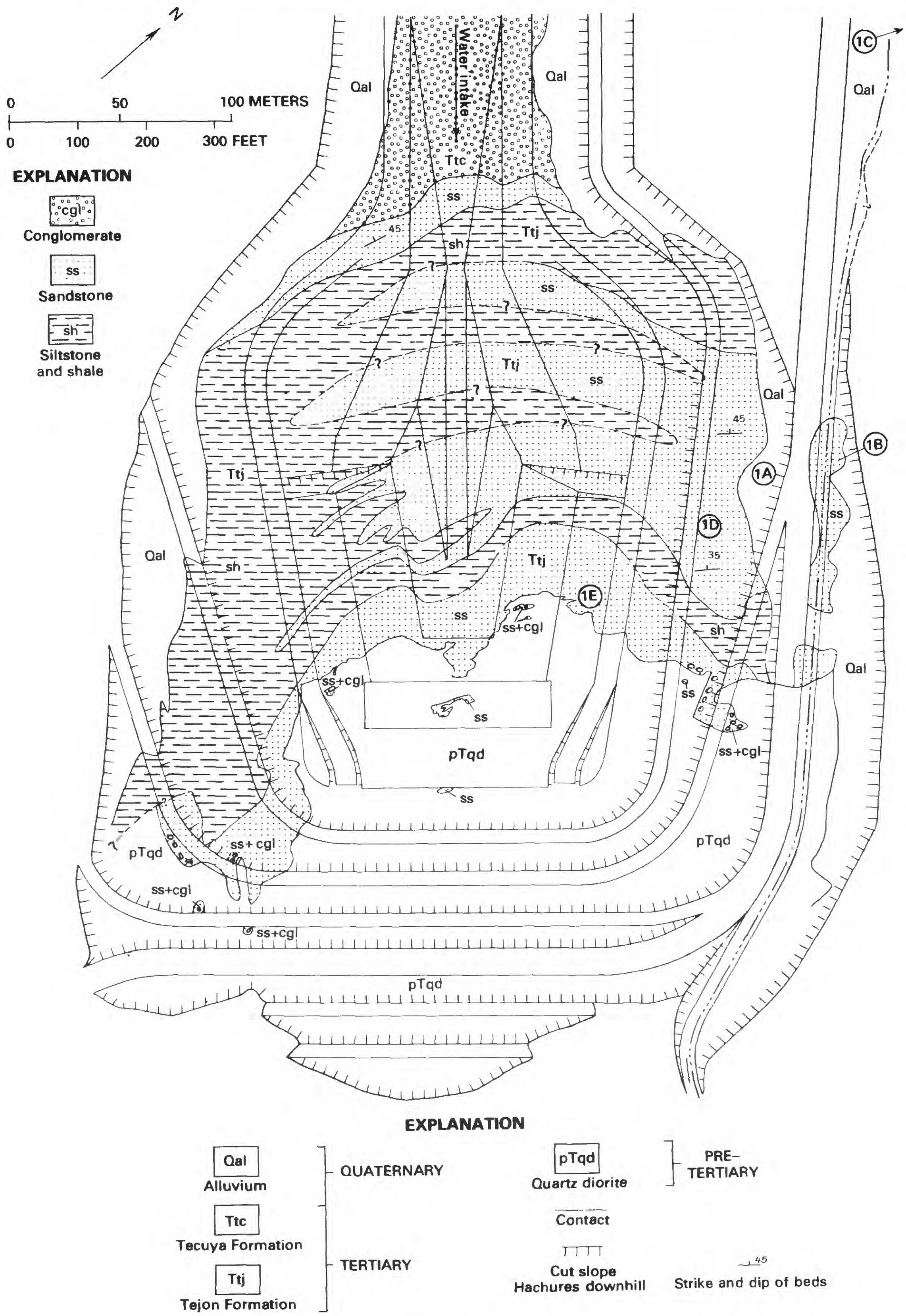

FIGURE 56.—Geologic map of Edmonston Pumping Plant excavation showing stratigraphy and lithology of Tejon Formation (modified from Bacon and Cochran, 1970). Numbers and letters refer to figure 57.

grained carbonaceous sandstone. Much of the section is rich in carbonaceous matter, commonly in the form of scattered plant fragments and wood. These rocks, because of the amount of bioturbation, lack of current-formed sedimentary structures, and abundance of carbonaceous matter, represent deposition in a low-energy marine environment.

A conglomeratic, coarse-grained sandstone with abundant broken shell debris overlies this unit and is in turn overlain by thinly flat-stratified and laminated fine-grained sandstone (figs. 57 and 58). Both of these sandstone units, because of their well-developed stratification, conglomerate clasts, and shell debris, probably represent shoreline sedimentation or a sequence of storm deposits.

Most of the middle part of the section, from about 140 to 260 feet (43-79 m) above the base, consists of massive-bedded, extensively bioturbated silty fine-grained sandstone. These beds are overlain by mottled, extensively bioturbated siltstone that contains abundant carbonaceous fragments. These deposits may have been deposited in lagoonal environments.

The uppermost part of the section consists of interbedded conglomerate, sandstone, and siltstone that contains abundant channel-fill conglomerate, flat strata, cross-strata, solitary burrows with various orientations, some shell debris, and well-sorted sandstone. These deposits represent relatively high energy marine and shoreline deposition.

PASTORIA CREEK

Harris (1950) measured a 610-foot (186-m) section of the Tejon Formation on the east side of Pastoria Creek (fig. 59) and collected megafossils from the basal beds and from 600 feet (183 m) above the base of the section (CAS locality 816), as well as from the basal beds on the west side of Pastoria Creek (CAS locality 815). He did not divide the sequence into members; however, his section shows three distinct units, which I recognize as the Uvas Conglomerate, Liveoak Shale, and Metralla Sandstone Members.

The Uvas Conglomerate Member is 9 to 17 feet (3-5 m) thick and consists of (1) a basal conglomerate containing cobbles and boulders of schist, gneiss, and granitic rocks as large as about 3 feet (0.9 m) in diameter in a matrix of poorly sorted sandstone that resembles granite in texture and composition, and (2) a medium- to coarse-grained poorly sorted arkosic sandstone containing scattered molluscan fossils. This sandstone thickens and becomes conglomeratic toward the northeast.

The Liveoak Shale Member is mostly a massive, silty fine-grained sandstone in irregular beds a few inches to 8 feet (5 cm to 2.4 m) thick interbedded with siltstone and shale. It contains foraminifers, casts of mollusks, pyrite, and glauconite. Generally poorly exposed, the Liveoak is deeply weathered and forms slopes that are covered with debris from the Tecuya Formation.

The Metralla Sandstone Member consists of richly fossiliferous calcareous sandstone with minor interbedded shale and siltstone that crops out as narrow ridges on steep slopes. The beds coarsen eastward, where they contain thin conglomeratic beds and scattered boulders up to 8 feet (2.4 m) in length.

LIVEOAK CANYON

Liveoak Canyon is one of the most famous localities for collecting Eocene mollusks on the west coast of North America and is the source

FIGURE 57.—Exposures of the Tejon Formation at Edmonston Pumping Plant; viewed toward northeast, alluvium in foreground. Abbreviations: qd, quartz diorite of basement complex; tj, Tejon Formation; tc, Tecuya Formation. See figure 56 for map locations of 1A, 1C, 1D, and 1E.

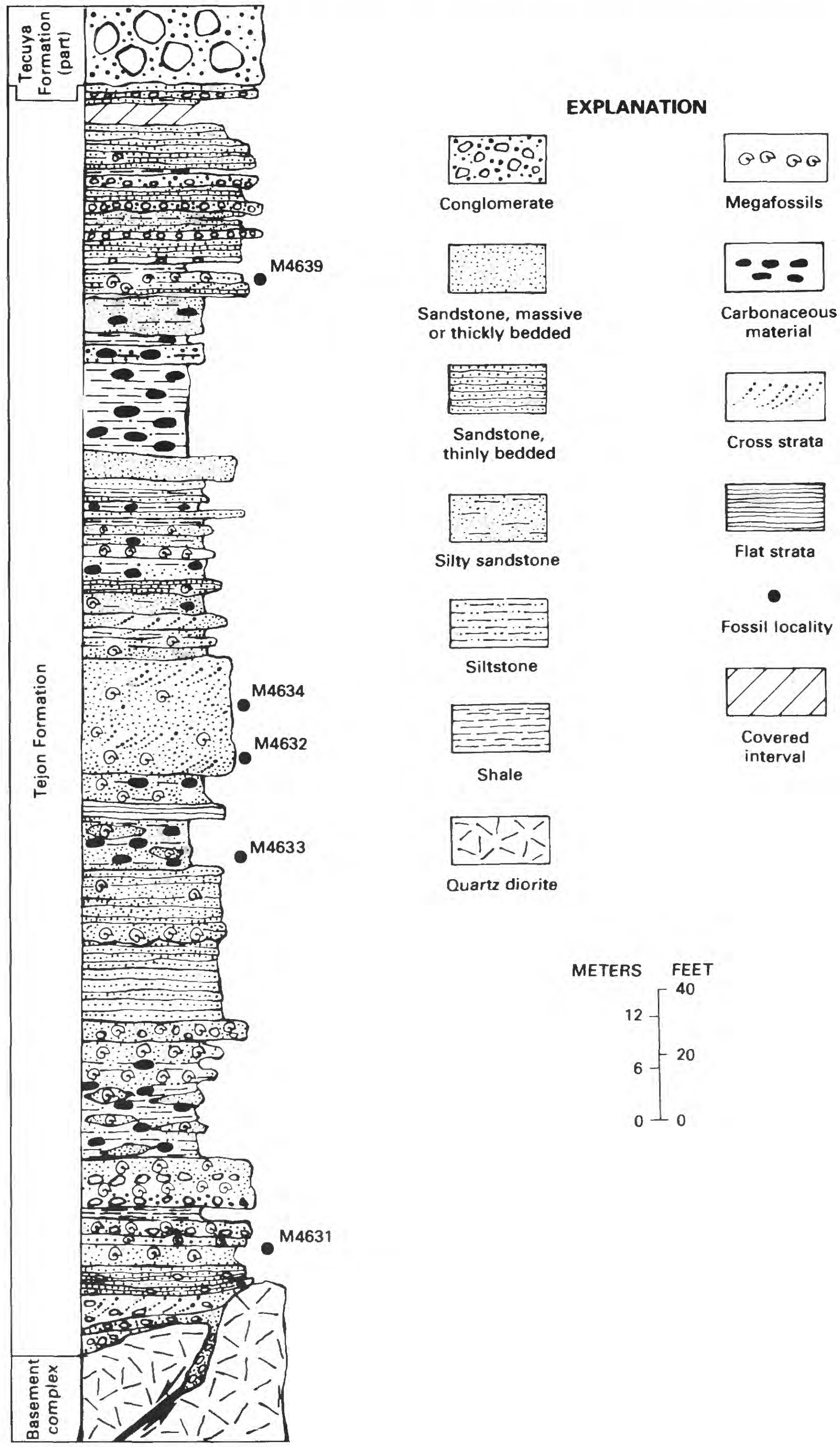

FIGURE 58.—Measured section of the Tejon Formation along east side of Edmonston Pumping Plant, about 1 mile (1.6 km) east of Pastoria Creek.

of collections by Gabb (1869), Dickerson (1915), Anderson and Hanna (1925), Ralph Stewart (unpub. data), and Marks (1941a) among others. It is also the type section of the Liveoak Shale Member and provides good exposures of the Uvas Conglomerate and Metralla Sandstone Members.

The Tejon Formation is about 1,270 feet thick (386 m) in the canyon, a figure consistent with its thickness in wells drilled for oil and gas a few miles to the north, but thinner than the 1,970 feet (600 m) determined by Marks (1941b). The upper part of the canyon contains many landslide deposits, especially on the west side (Dibblee, 1961; Dibblee and Nilsen, 1973). These were not recognized by Marks (1941b, pl. 6), whose thickness for the Eocene section is greater because he continued his measured section through these landslide deposits. In fact,

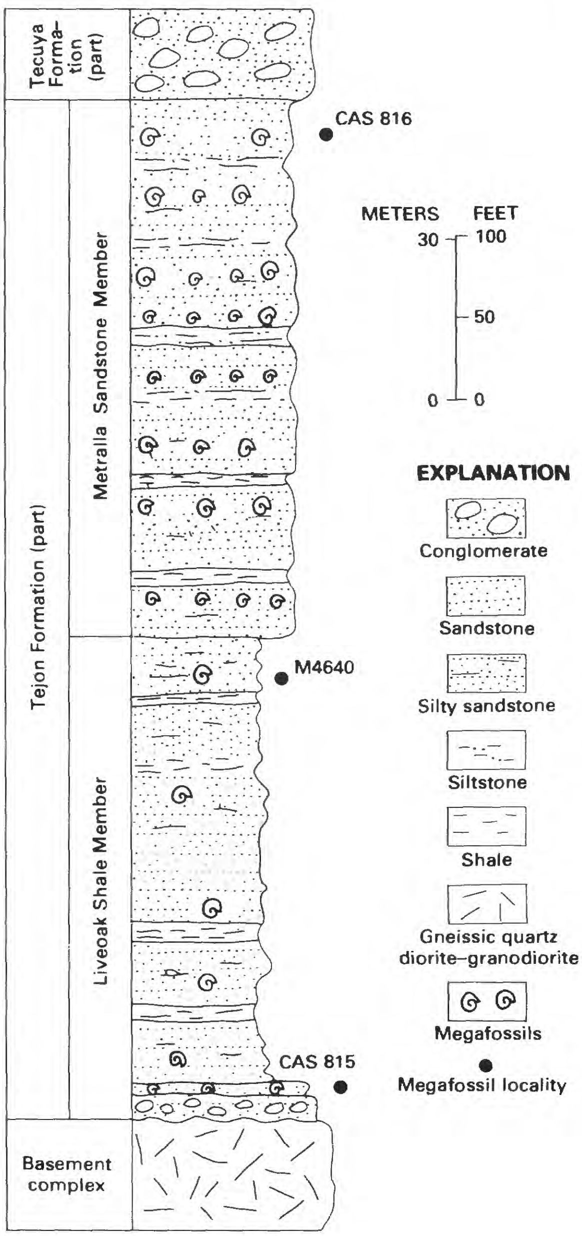

FIGURE 59.—Measured section of the Tejon Formation on east side of Pastoria Creek, modified from Harris (1950).

the landslide deposits conceal the basal contact between the Tejon Formation and the basement complex of gneissic quartz diorite, so that a complete section of the Tejon is not exposed. The exposed section dips steeply and is partly overturned to the north. The Pleito thrust fault crosses the canyon and forms the boundary between the basement rocks to the south and the Tertiary sequence to the north (pl. 1).

South of the main exposures of the Uvas are many landslides that cover the trace of the Pleito fault, gneissic quartz diorite basement complex, and some thin outliers of the Uvas Conglomerate Member that rest on the basement complex. These outliers are very poorly exposed and consist mostly of sandstone deposited in topographically low areas on the unconformable surface at the base of the Tejon Formation.

The lowest exposed strata of the Uvas that are in place consist of medium- to coarse-grained sandstone containing abundant cross-strata, flat strata, some carbonaceous beds, and locally abundant molluscan fossils (USGS locality M4645). Above these strata is a sequence of bioturbated, silty fine-grained sandstone and siltstone interbedded with more resistant fine- to medium-grained sandstone containing abundant molluscan fossils.

The uppermost 6-foot- (1.8-m) thick bed of the Uvas contains abundant molluscan fossils and coiled tubules of annelid worms (USGS locality M4644). These fossils appear to be in growth position as they have not been broken or abraded from transport and most of the mollusk shells are articulated.

The overlying Liveoak Shale Member is 470 feet (143 m) thick and consists mostly of thin-bedded bioturbated siltstone and shale with thin fine-grained beds of sandstone in the upper and lower parts. The sandstone is commonly flaggy and contains abraded and broken molluscan fossil debris (USGS locality M4643). It is well exposed only on the ridge crest east of the canyon.

The lower part of the Metralla Sandstone Member consists of a thick sequence of alternating beds of flat-stratified, fine-grained sandstone and resistant calcareous sandstone with abundant molluscan fossil remains. Some beds contain oriented *Turritella* shells on bedding surfaces and "cannonball" concretions. These fossiliferous sandstones were deposited in shallow-marine conditions (USGS locality M4642).

The upper part of the Metralla commences with 10 feet (3 m) of interbedded carbonaceous siltstone, pebbly sandstone, and conglomerate containing molluscan fossils (USGS locality M4541). A bed of massive, white to buff, medium-grained sandstone 2 feet (0.6 m) thick containing scattered mudstone clasts and large plant fragments crops out above this. This bed is overlain by a sequence of bioturbated, thinly interbedded finer grained sandstone and siltstone 38 feet (12 m) thick containing abundant carbonaceous material. These strata represent lagoonal facies in the Tejon Formation and are presumably correlative with the Reed Canyon Siltstone Member exposed farther to the west, and with the carbonaceous siltstone in the upper part of the Tejon Formation at the Edmonston Pumping Plant. The uppermost bed of the Metralla is a well-sorted, irregularly flat-stratified, very coarse grained pebbly sandstone 3 feet (0.9 m) thick that was probably deposited at the Eocene shoreline. The Metralla contains pebbles and cobbles locally in its upper part that are lithologically and texturally identical to those in the overlying nonmarine Tecuya Formation.

Above the Tejon Formation, nonmarine conglomerate in the lower unit of the Tecuya Formation is characterized by medium- and large-scale cross-strata, flat strata, anisotropic fabrics, imbricated pebbles and cobbles, lens-shaped beds of both conglomerate and sandstone that undergo abrupt lateral pinchouts and changes in thickness, and red to brown colors on weathered surfaces. Paleocurrent directions, although few in number, are generally oriented toward the west. Conglomerate clast types in the Tecuya Formation include sandstone, quartzite, porphyritic volcanic rock, and granitic rock. The contact with the underlying Tejon Formation appears to be gradational.

TECUYA CREEK

The Tecuya Formation was named for thick nonmarine conglomerate exposed on the west side of Tecuya Creek. Sandstone, conglomerate, and volcanic rock of this formation are also very well exposed in tributary canyons to Tecuya Creek. The Tejon Formation in Tecuya Creek is about 2,000 feet (610 m) thick, and all four members are exposed, although the basal member—Uvas Conglomerate Member—is very thin or locally absent. The Liveoak Shale Member is generally covered by thick colluvium, plant cover, or landslides and is poorly exposed. The east side of the canyon consists almost wholly of landslide deposits, some of which have been recently active. The Metralla Sandstone Member is similar in appearance to exposures in Reed and Metralla Canyons, although in Tecuya Creek only the most

FIGURE 60.—Geologic map of Devils Kitchen area plotted on an aerial photograph.

resistant beds or beds containing abundant calcareous concretions are well exposed. The Reed Canyon Siltstone Member of the Tejon Formation is generally covered by landslide debris and is very poorly exposed.

SAN EMIGDIO CREEK

The Tejon Formation is very well exposed on the north and south limbs of the Devils Kitchen syncline on the east side of San Emigdio Creek. Younger Tertiary units also are well exposed in the spectacular outcrops formed by the sheer rock walls of the syncline (fig. 60).

The stratigraphic sequence from the south limb of the syncline or east side of the canyon (fig. 61) is modified from DeLise (1961). DeLise did not distinguish the members of the Tejon Formation, but his section enables the differentiation of all but the Reed Canyon Siltstone Member. The contacts between the Uvas Conglomerate and Liveoak Shale Members and between the Liveoak Shale and Metralla Sandstone Members are gradational; the former has tentatively been placed above the lowest and the latter below the highest occurrence of abundant sandstone beds in the dominantly shale and siltstone sequence (fig. 61). Here only the basal beds of the Uvas are conglomeratic, and the Metralla contains more siltstone and shale than sandstone. In the San Emigdio Canyon area, sandstone beds in the Metralla are flyschlike and begin to pinch out westward into the Liveoak (fig. 13).

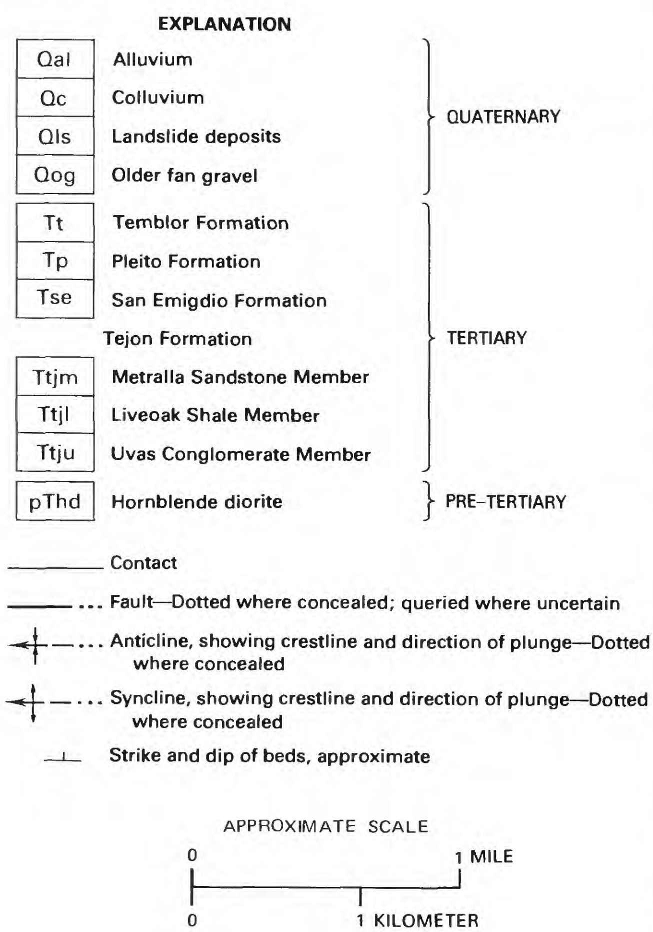

FIGURE 60.—Continued.

The following descriptions of the measured section (fig. 60) apply to outcrops visible along the floor of the canyon. The lettered localities are shown on figure 60.

Locality A.—Basal conglomeratic sandstone beds of the San Emigdio Formation. The lower beds are generally finer grained, massively bedded, and contain abundant burrows up to 0.8 inch (2 cm) wide and 6 inches (15 cm) long. Overlying beds are coarser grained, better sorted, and characterized by flat strata and cross-strata with amplitudes ranging from 4 inches to 2 feet (10-60 cm). Paleocurrent directions are generally oriented from south to north.

Locality B.—Uppermost slabby sandstone beds of the San Emigdio Formation overlain by massive basal sandstone beds of the Pleito Formation near the axis of the Devils Kitchen syncline. Both sandstones contain pebbly and fossiliferous beds. The San Emigdio contains abundant flat strata, medium- to large-scale cross-strata, and alternating thin to thick beds. The Pleito generally is thoroughly bioturbated, lacks current-formed sedimentary structures, and is very thick bedded.

Locality C.—Lower sandstone unit of the Pleito Formation on the south limb near the Devils Kitchen syncline. These very thick beds consist of thoroughly bioturbated silty fine-grained sandstone with some fossiliferous pebbly lenses. A great variety of trace fossils can be seen here, many apparently formed by smooth-shelled pelecypods that in places can be found in the burrows. This unit resembles the shallow-marine sandstone of the Metralla Sandstone Member in Reed Canyon.

Locality D.—Upper sandstone unit of the San Emigdio Formation (same stratigraphic interval as locality B). The sandstone here is thin bedded, pebbly, and fossiliferous. South of here is the middle black shale unit of the San Emigdio Formation, which is well exposed only on the ridge crest to the east.

Locality E.—Basal conglomeratic sandstone of the San Emigdio Formation (same stratigraphic interval as locality A). Here the basal beds consist of very coarse grained sandstone with pebbles as long as 2 inches (5 cm). The sandstone is fairly well sorted and fossiliferous; it consists of beds ranging from 1 inch to 12 feet (2.5 cm to 3.7 m) in thickness. Flat strata and medium- to large-scale cross-strata are common.

Locality F.—Flyschlike very fine grained sandstone, siltstone, and shale of the Metralla Sandstone Member (see fig. 32). The sandstone and siltstone beds are almost rhythmically interbedded with shale in thicknesses ranging from 1 inch to 3 feet (2.5 cm to 0.9 m). Many beds are graded. Foraminifers collected by DeLise (1967, p. 15) from this and the underlying Liveoak Shale Member suggest a deep, cool-water, bathyal depositional environment for these strata. The siltstone is extensively bioturbated by small burrows presumably formed by worms (see fig. 41). Calcareous concretions are abundant.

Locality G.—Outcrops of Liveoak Shale Member in stream bank. This is a monotonous sequence of bioturbated mudstone and shale.

Locality H.—Uppermost sandstone beds of the Uvas Conglomerate Member. Cyclic deposits of thick, massive, medium- to coarse-grained sandstone grade upward through thinly flat-stratified, fine-grained sandstone with some small-scale cross-strata to thinly laminated shale. At least seven repetitions of this cycle are present, and each cycle is 1 to 4 feet (0.3 to 1.2 m) thick. The massive basal sandstone generally rests unconformably on the underlying shale. Other features present include mudstone clasts and carbonaceous plant fragments in the basal part, hematitic concretions, and scattered medium-scale cross-strata. The origin of these cyclically arranged beds is not clear, but they do not appear to be of turbidite origin.

Locality I.—Unconformable contact between the basement complex and the Uvas Conglomerate Member. The basement complex here consists of complexly folded and faulted gneissic hornblende diorite with inclusions of hornblende and mica schist. The contact is irregular

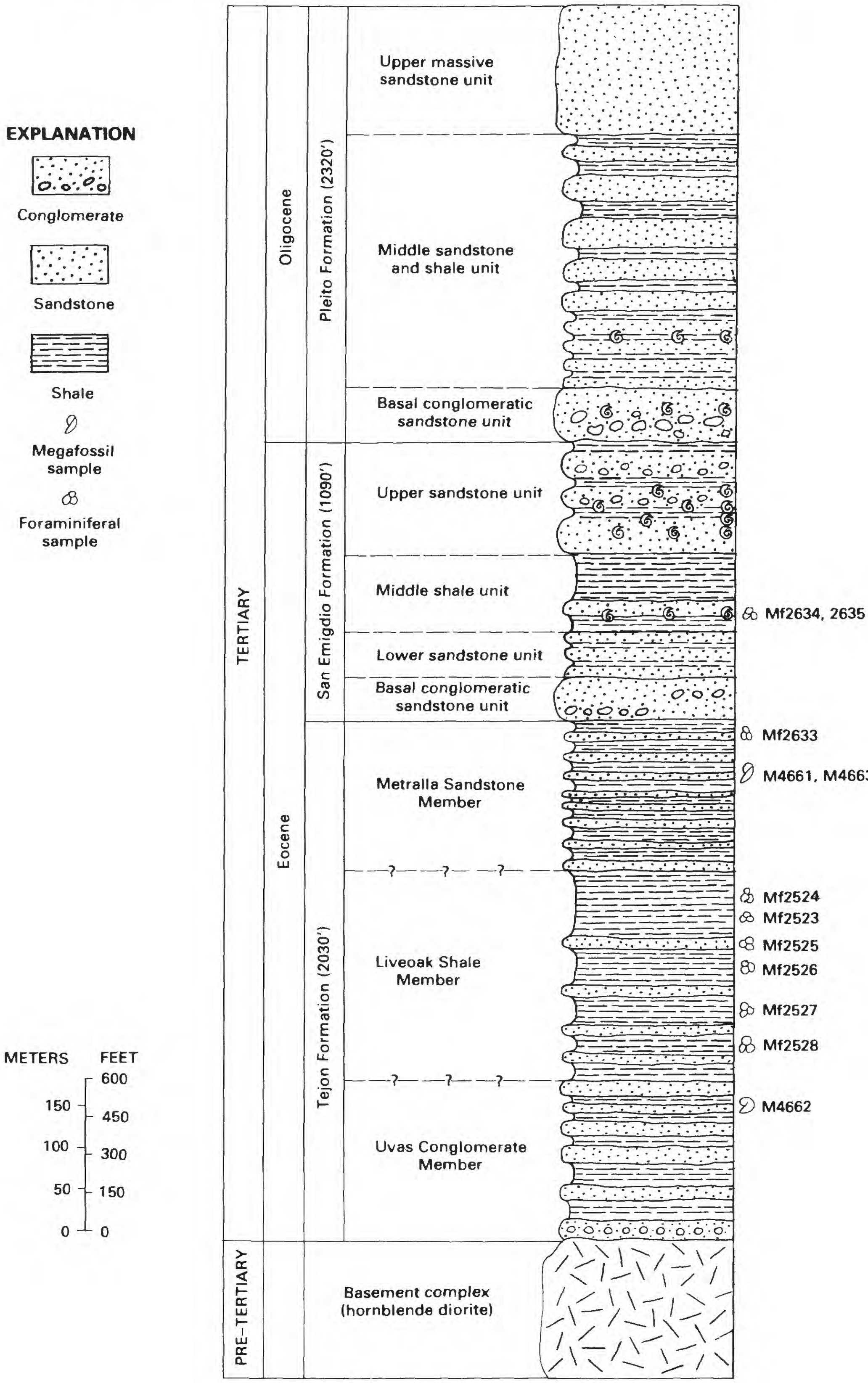

FIGURE 61.—Measured section from south limb of Devils Kitchen syncline, east side of San Emigdio Creek (modified from DeLise, 1967, fig. 5).

but with relief no higher than about 6 feet (2 m). The basal beds of the Uvas consist of medium- to coarse-grained sandstone, and, in contrast with many other exposures of this basal contact, no large blocks or fragments of the basement rock lie just above the contact. However, conglomerate beds up to 2 feet (0.6 m) thick containing well-rounded pebbles of quartzite, porphyritic volcanic rock, and other resistant clasts as long as 3 inches (8 cm) are common. The basal sandstone beds range from 6 inches to 3 feet (15 cm to 0.9 m) in thickness and overlap topographically high parts of the basement. The conglomerate and sandstone beds form cyclically repeating units that consist of (1) coarse, massive, locally conglomeratic sandstone at the base that grades upward into (2) flat-stratified fine-grained sandstone with megaripples and some cross-strata, that grades upward into (3) interbedded shale and very fine grained sandstone. The cycles are increasingly thinner, finer grained, and less sandy higher in the sequence.

Locality J.—View of south limb of the Devils Kitchen syncline (fig. 62), toward the east. From the clearing at the junction of the tributary canyon to the east, the entire Tejon sequence can be seen for several miles. The Uvas Conglomerate and Liveoak Shale Members are traceable eastward with little change in thickness or lithology, but the Metralla Sandstone Member grades laterally eastward from a flyschlike sequence to one dominated by thick-bedded sandstone with little interbedded shale. This transition results from the westward pinching out of sandstone in the Metralla, and separates the shallow-marine sandstone facies to the east from the deep-marine sandstone facies to the west.

Locality K.—Interbedded flyschlike sandstone and shale from the lower part of the Liveoak Shale Member (see fig. 33). Sandstone and shale are well exposed in the narrow tributary canyon to the east. Visible features include small sandstone channels, lenticular beds of sandstone, sandstone dikes (fig. 33), possible escape burrows (fig. 25), syndepositional contorted and folded strata, slump blocks, flute and groove casts, load casts, small-scale cross-strata, and convolute laminations.

Locality L.—Unconformable contact between the basement complex and the Uvas Conglomerate Member. Here the basal sandstone beds of the Uvas are exposed in an entrenched meander of an east-flowing tributary to San Emigdio Creek. A thick sequence of the Liveoak Shale Member is exposed on the slope to the north. The Uvas is thinner here than on the east side of the creek and grades abruptly upward into shale of the Liveoak. The basal beds contain abundant medium- to large-scale cross-strata.

Locality M.—View toward the west of the Tejon, San Emigdio, and Pleito Formations forming the south limb of the Devils Kitchen on the west side of San Emigdio Creek (fig. 63). The Metralla Sandstone Member consists of thinly interbedded fine-grained sandstone and shale and is poorly exposed. The four informal divisions of the San

FIGURE 62.—View northeast of south limb of Devils Kitchen syncline from San Emigdio Creek showing Uvas Conglomerate (uv), Liveoak Shale (lo), and Metralla Sandstone (m) Members of the Tejon Formation. Note westward pinchout of sandstone beds in the Metralla Sandstone Member. bc, basement complex; se, basal beds of San Emigdio Formation.

Emigdio Formation of DeLise (1967) can be distinguished; the basal conglomeratic sandstone and the middle black shale are particularly conspicuous and form a gentle slope in the middle of the sequence. The massively bedded basal sandstone, the middle sandstone and shale, and the lower part of the massive, pebbly upper sandstone of the Pleito Formation are also well exposed.

Locality N.—Basal beds of conglomeratic sandstone of the San Emigdio Formation. These strata are lithologically similar to beds at locality E.

Locality O.—Contact between the San Emigdio and Pleito Formations. The upper beds of the San Emigdio are here abundantly fossiliferous, pebbly, and cross-stratified. The beds in the Pleito are pebbly, fossiliferous, massive, and extensively bioturbated (see descriptions of localities B, C, and D).

LOWER LOS LOBOS CREEK

GENERAL

Almost all of the Uvas Conglomerate Member and a small part of the overlying Liveoak Shale Member are exposed on the east side of lower Los Lobos Creek north of the main unpaved road connecting San Emigdio Canyon with Santiago Creek (pl. 1). A photograph and measured section of this exposure are shown on figure 64. The basal contact with metadiabase is not exposed, but the metadiabase is well exposed below this 100-foot (30 m) covered interval. Exposures of the Liveoak Shale Member are truncated on the north by the Pleito thrust fault, along which the Tejon Formation and the western mafic basement complex have been thrust northward over younger sedimentary rocks. A smaller exposure of the Uvas Conglomerate Member is present on the west side of the creek.

MEASURED SECTION

	Thickness Feet	Thickness Centimeters
Tejon Formation (part):		
Liveoak Shale Member (part):		
Shale, siltstone, and sandstone, fine-grained, thin bedded.		
Uvas Conglomerate Member:		
11. Sandstone, medium- to coarse-grained, irregularly bedded; upper part cross-bedded; top calcareous, resistant	3.4	105
10. Conglomerate and sandstone. Sandstone, very coarse grained and pebbly at base, grades up to fine- to medium-grained sandstone; top irregularly bedded	6.1	190
9. Sandstone, medium- to coarse-grained, crossbedded at base, grades up to fine-grained sandstone, laminated, crossbedded; bioturbated in upper 3.0 ft (90 cm). Vertical and horizontal burrows in lower 1.4 ft (42 cm).......	4.4	132

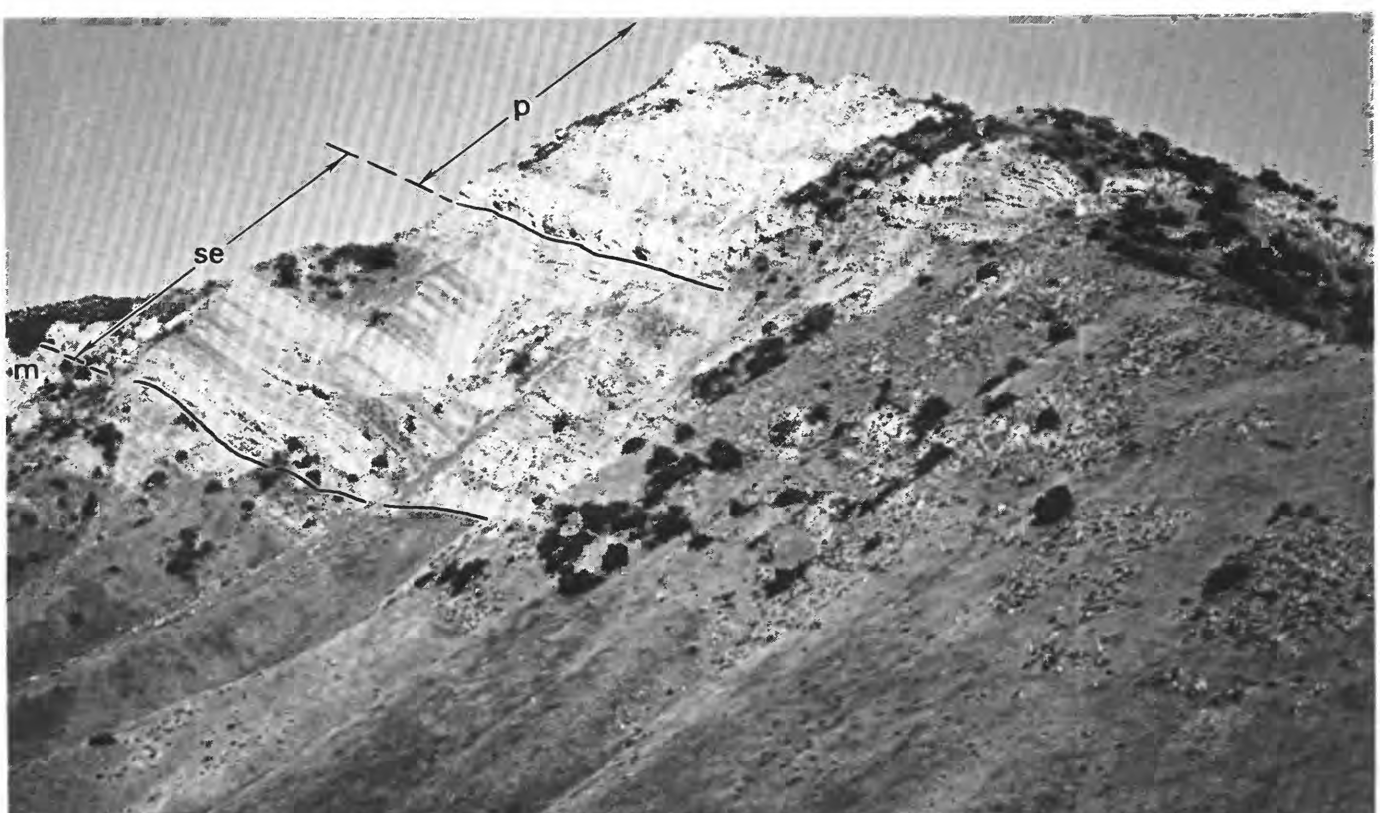

FIGURE 63.—Lower and middle Tertiary sequence exposed on south limb of Devils Kitchen syncline, west side of San Emigdio Creek. Photograph clearly shows various units of the San Emigdio (se) and Pleito (p) Formations as designated in measured section of DeLise (fig. 61) and shaly character of the Metralla Sandstone Member (m) of the Tejon Formation.

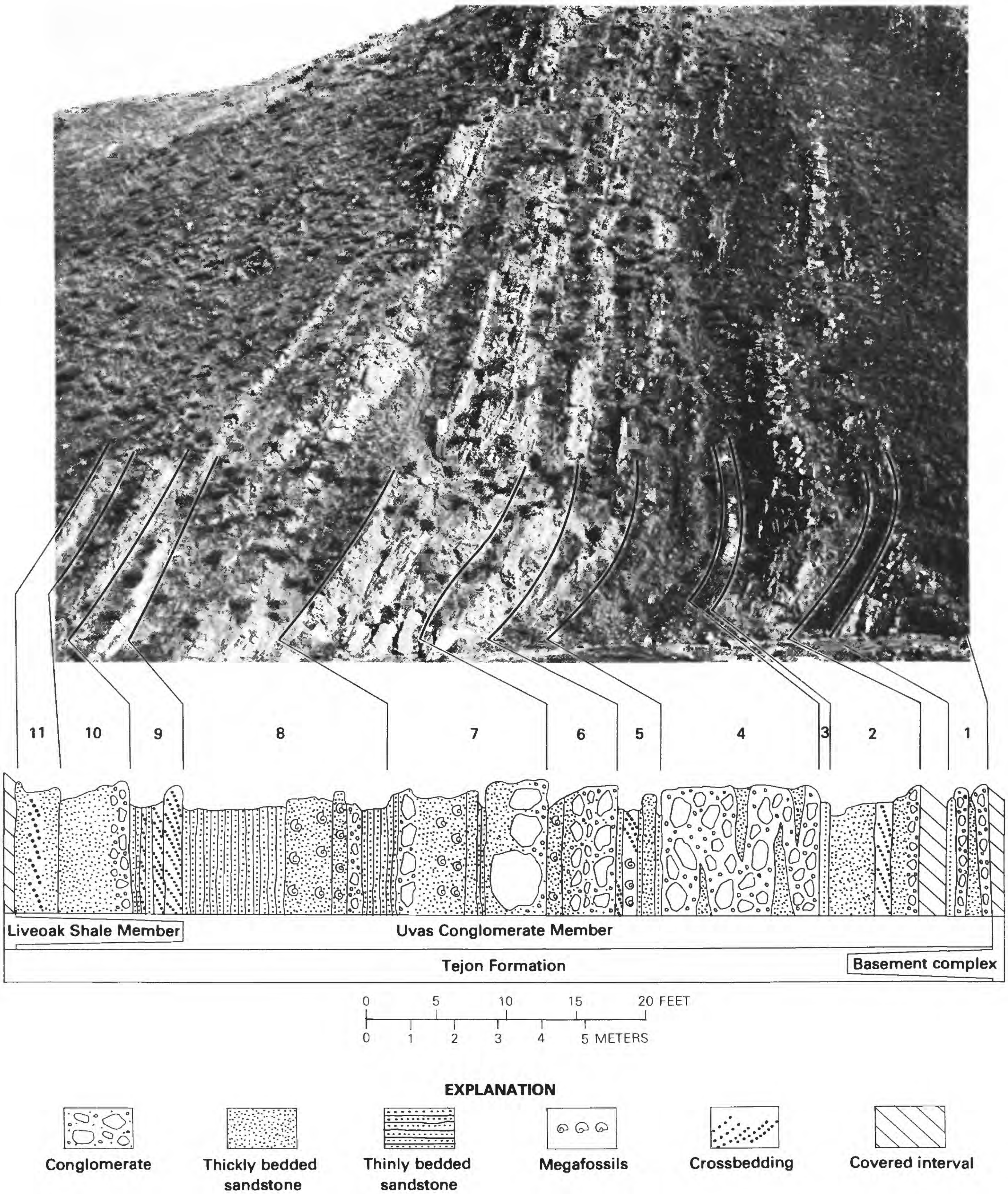

FIGURE 64.—Photograph, measured section, and description of boulder beds in the Uvas Conglomerate Member of the Tejon Formation at lower Los Lobos Creek. Numbers refer to beds described in measured section on pages 84 and 86.

	Thickness Feet	Thickness Centimeters
Uvas Conglomerate Member—Continued:		
8. Conglomerate and sandstone. Sandstone, fine-grained, thin-bedded; contains very small pebbles in basal 0.9 ft (26 cm). In overlying 1.1 ft (33 cm), sandstone very coarse to coarse-grained, massive; concretionary; contains abundant shell debris. In overlying 4.2 ft (127 cm), sandstone, fine- to medium-grained, irregularly bedded; contains abundant molds and casts of gastropods, pelecypods, and scaphopods (USGS Cenozoic locality M4649). In uppermost 8.9 ft (270 cm), sandstone, fine-grained, laminated, unfossiliferous	15.1	456
7. Boulder conglomerate interbedded with coarse-grained sandstone; longest clasts 6.6 ft (200 cm) in diameter; contains abundant mollusk shells and burrows. Some sandstone, fine-grained, laminated, in middle and upper part	13.7	420
6. Boulder conglomerate grading up into coarse- and medium-grained sandstone. Clasts as long as 5.5 ft (165 cm). Coarse-grained sandstone, massive. Medium-grained sandstone, irregularly bedded, slightly fossiliferous....................	5.3	170
5. Sandstone. At base, sandstone, silty, fine- to medium-grained, wavy laminated. In middle, sandstone, coarse-grained, massive, some thin beds. At top, sandstone, fine-grained, thin-bedded, interbedded with some siltstone; locally, small-scale crossbedding, very small pebbles and mollusk shells..............	4.0	123
4. Boulder conglomerate, largest clasts 3.5 ft (110 cm) in diameter; irregularly bedded; framework, open-to-closed with finer conglomerate and sandstone matrix; not imbricated; some sandstone lenses, thin, interbedded	13.1	400
3. Sandstone, coarse-grained, massive........	1.2	37
2. Conglomerate and sandstone. At base, conglomerate bed, clasts as long as 0.9 ft (26 cm) in diameter; mudstone clasts scattered throughout bed. In lower part, sandstone fine- to coarse-grained, massive; in middle, cross-bedded sandstone; in upper part, sandstone laminated	6.0	185
Covered interval	2.4	75
1. Conglomerate and sandstone. Conglomerate, irregularly bedded, imbricated; clasts as long as 0.4 ft (12 cm) in diameter; contains lens of coarse-grained sandstone, pebbly; abundant rip-up clasts in basal 3.0 ft (90 cm). Sandstone, medium- to coarse-grained, massive, thin-bedded; crossbedding and mudstone rip-up clasts scattered throughout upper 0.6 ft (20 cm)	3.6	110
Total thickness..............................	78.3	24
Covered interval	100	30
Basement complex (top):		
Metadiorite, strongly foliated.		

SUMMARY

The exposed 78-foot (24-m) sequence of the Uvas Conglomerate Member is not characteristic of the Uvas and probably represents deposition under atypical conditions. The rounded aspect of even the largest clasts indicates that considerable abrasion occurred even though the clasts, which are all composed of metadiorite identical to the underlying basement complex, were probably not transported far from their place of origin. A nearshore, high-energy environment seems likely—perhaps near a steep headland or cliff eroded into the metadiabase, which may have been more resistant to erosion than the surrounding coarser grained hornblende-pyroxene gabbros (pl. 1). Large blocks or fragments of metadiabase may have broken loose periodically and fallen or slid toward the shoreline, where they were pounded by surf and abraded by silt, sand, pebbles, and cobbles. Although close packing of the conglomerates is common, many large boulders are isolated and completely enclosed by sandstone. The headland may have had considerable relief because it continued to supply large fragments to the shoreline area during deposition of almost the entire 70-foot (21-m) sequence. Similar shoreline deposits have been described in the Eocene Maniobra Formation of Crowell and Susuki (1959) in the Orocopia Mountains and in middle Eocene strata of the Pine Mountain area (Howell, 1975).

Pelecypod, gastropod, and scaphopod remains collected from this sequence (USGS Cenozoic locality M4649) are too poorly preserved to be diagnostic of either the age of the sedimentary rocks or the bathymetry of the depositional environment. The medium- and large-scale cross-strata in some beds suggest relatively high-energy conditions.

The limited outcrop of Uvas on the west side of Los Lobos Creek is thinner bedded and contains smaller clasts of metadiabase, a maximum length of about 30 inches (75 cm). The main rock type is well-sorted coarse-grained quartzose sandstone that contains medium- to large-scale inclined cross-strata, festoon cross-strata, vertical cylindrical trace fossils, and rare molluscan fossils. Abrupt lateral changes in bed thickness and lithology apparently prevent correlation of these beds with those exposed on the west side of the creek.

EAST OF SANTIAGO CREEK

GENERAL

This section (fig. 65) is well exposed in a north-northwest-flowing tributary of Santiago Creek informally called East Twin Creek by Hammond (1958). It is the westernmost measured section of the Tejon Formation. Along the banks of Santiago Creek, the oldest exposed strata belong to the San Emigdio Formation (USGS Cenozoic megafossil localities M4596, M4597, and M4598; pl. 1).

The basal contact of the Uvas Conglomerate Member is exposed both in the lower part of East Twin Creek, where it rests on hornblende quartz-diorite-gabbro, and in the upper part of the East Twin Creek, where it rests on metadiabase. An exposed thickness of about 1,000 feet (305 m) of Liveoak Shale Member can be seen in the upper part of the creek (as shown by Hammond, 1958, p. 26), and a thinner section in the lower part of the creek. The upper part of the Liveoak Shale Member is covered by alluvium in the lower part of the creek and is truncated with angular unconformity by the Temblor Formation in the upper part of the creek (figs. 7, 65); as a result, the complete thickness of the Tejon Formation is not exposed in this area. However, it may not have been much more than about 1,000 feet (305 m) inasmuch as it thins progressively westward from Pleito Creek (fig. 13), and foraminifers from near the top of the exposed sequence of Liveoak Shale Member indicate late Ulatisian and Narizian ages (USGS Cenozoic foraminiferal localities Mf2515, 2516, and my field locality TNF-21), the probable or expected age of the top of the Liveoak Shale Member if exposed in this area.

MEASURED SECTIONS

LOWER PART OF EAST TWIN CREEK

	Thickness Feet	Thickness Meters
Alluvial gravel (Quaternary).		
Contact with Liveoak Shale Member unconformable.		
Tejon Formation (part):		
Liveoak Shale Member:		
Shale interbedded with fine-grained sandstone. Shale, foraminiferal. Sandstone, turbiditic, beds 1-2 in. (2-5 cm) thick; locally silty. Unit very poorly exposed; shoe-peg weathering	245	75
Uvas Conglomerate Member:		
5. Sandstone interbedded with siltstone. Sandstone, coarse-grained, well-sorted; grains well-rounded; becomes finer grained, siltier, and less resistant toward the top; massive to laminated; beds as thick as 8 ft (2.5 m); beds contain abundant orbitoidal foraminifers and a few small quartzite pebbles scattered throughout. Siltstone, gritty, laminated, bioturbated	60	18.2
4. Siltstone, massive, bioturbated; contains abundant orbitoidal foraminifers	10	3.5
3. Sandstone, very coarse to coarse-grained, well-sorted; crossbedding, medium- to large-scale; contains abundant metadiorite clasts along stratification surfaces in upper parts of beds; few pebbles of quartzite and metadiorite scattered throughout unit	15	4.6
2. Conglomerate, pebble to cobble, clasts rounded, quartzite and volcanic; imbricated, clast-supported	5	1.5
1. Megabreccia, metadiabase fragments as long as 10 feet (3 m) in matrix of finer breccia; matrix-supported; fragments become finer upward; contains a few rounded quartzite clasts scattered throughout. Lower contact grades into basement; possibly weathered subaerially	20	6.1
Total	355	108
Basement complex:		
Hornblende-quartz gabbro and diorite, metamorphosed; strongly foliated (average orientation 85/80S); contains abundant hornblende prisms and chlorite.		
Contact with Uvas Conglomerate Member unconformable.		

UPPER PART OF EAST TWIN CREEK

	Thickness Feet	Thickness Meters
Temblor Formation (part):		
Conglomeratic sandstone.		
(Covered interval)		
Tejon Formation (part):		
Liveoak Shale Member:		
2. Shale, greenish-gray, argillaceous; contains interbedded sandstone, fine-grained, laminated, 1-2 in (2-5 cm) thick, very rare	600	184
1. Shale, greenish gray, argillaceous; shoe-peg weathered. Unit contains less than 2 percent interbedded sandstone; beds 1-2 ft (0.3-0.6 m) thick; sandstone, two types: fine- to medium-grained, graded, shale rip-up clasts; fine-grained, flaggy, parallel-laminated	347	105

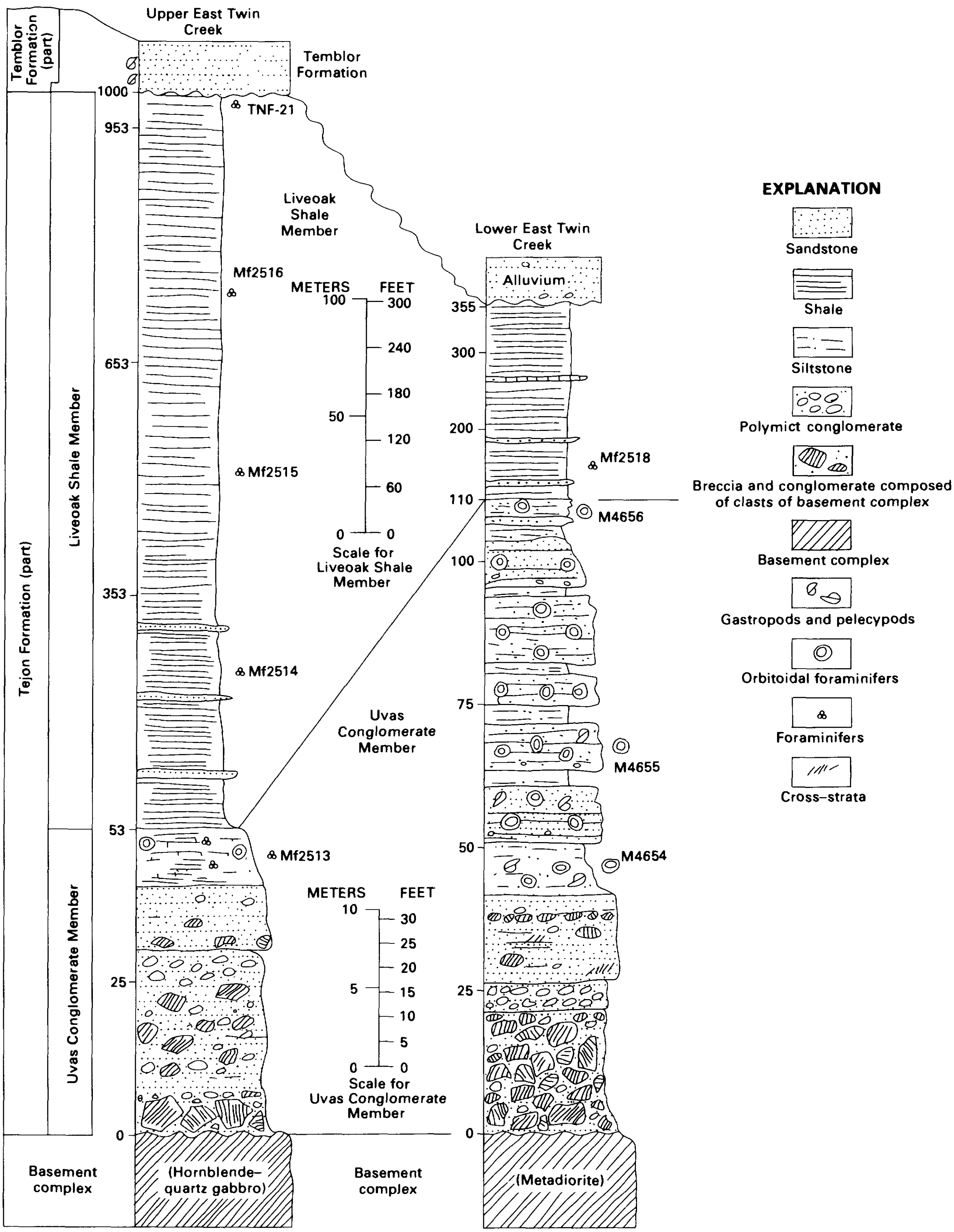

FIGURE 65.—Measured sections of the Uvas Conglomerate and Liveoak Shale Members of the Tejon Formation in East Twin Creek, an informally named tributary to Santiago Creek (see pl. 1). Upper part of measured section in part from Hammond (1958). Note that a larger scale has been used for the Uvas Conglomerate Member (to show details of those parts of the sections) than for the Liveoak Shale Member.

	Thickness Feet	Thickness Meters
Uvas Conglomerate Member:		
4. Claystone, greenish-brown, silty and sandy, massive; contains foraminifers and quartz grains scattered randomly	10	3
3. Sandstone, quartzose, calcareous, quartz grains rounded, well-sorted, partly frosted; thick-bedded to massive, unstratified, resistant; cobbles of gneiss and schistose metadiorite scattered throughout unit	6	1.8
2. Breccia, partly stratified, blocks of subrounded schistose metadiorite as long as 4 ft (1.2 m) set in calcareous quartzose sandstone matrix, very coarse to coarse-grained; weathers white. Basal contact irregular	5	1.5
1. Megabreccia, unstratified; matrix of sandstone and siltstone, calcareous, quartzose, greenish, contains randomly oriented blocks of schistose metadiorite. Blocks as long as 10 ft (3 m), most very angular, some partly rounded; contain pebbles and cobbles of quartzite, granite, chert, schist, and gneiss, well rounded, as large as 1 ft (0.3 m) intermixed within megabreccia. Some orbitoidal foraminifers scattered throughout unit	32	9.8
Total thickness	1,000	305

Basement complex:
Metadiorite, strongly foliated (average orientation 110/85S); much folding, mesoscopic, commonly recumbent; hornblende prisms and chlorite crystals large.
Contact with Uvas Conglomerate Member unconformable.

SUMMARY

The irregular angular blocks of basement rock as long as 10 feet (3 m) within the brown-weathering sandy micaceous matrix just above the basal unconformity show no evidence of rounding. These irregular beds of breccia are as much as 25 feet (7.6 m) thick and have been interpreted by Hammond (1958) as rotten zones developed in place by weathering of the basement rocks. On the other hand, they may also represent talus, colluvium, or landslide deposits; the continued presence of a limited number of clasts from the basement complex in overlying strata suggests the persistence of a local exposed source for these rocks. The minor amounts of well-rounded pebbles of quartzite, granitic rock, chert, schist, and gneiss scattered in the upper parts of the breccia were presumably derived from more distant sources.

The polymict conglomerate and quartzose sandstone that overlies the breccia contains an abundant megafauna of pelecypods and gastropods, including *Turritella merriami,* that are indicative of a "Capay" age (USGS Cenozoic locality M4654). The upper part of this sandstone unit contains orbitoidal foraminifers and annelid worm tubules (USGS Cenozoic locality M4655) and grades upward into gritty silty shale that also contains orbitoidal foraminifers (USGS Cenozoic locality M4656) indicative of deposition in warm, shallow, aerated water. These beds mark the top of the Uvas Conglomerate Member.

The overlying Liveoak Shale Member contains some thin beds of sandstone in its lower part. The sandstone beds are of two types: the first is massive, medium-grained sandstone that grades upward to fine-grained sandstone and shale; these commonly contain randomly oriented rip-up clasts of shale, carbonized plant fragments, and local trace fossils. The second type is flat-laminated, flaggy, fine-grained sandstone that is characterized by primary current lineation and small sole markings that resemble flute casts. The Liveoak in its middle and upper parts contains rare interbeds of fine-grained, flat-stratified sandstone 1-2 inches (2.5-5 cm) thick. Foraminifers in the sequence indicate a Penutian age and neritic depths near the base of the Liveoak (USGS Cenozoic foraminiferal locality Mf2513) and a Ulatisian to Narizian age and upper to lower bathyal depths for the middle and upper parts (USGS Cenozoic foraminiferal localities Mf2514, 2515, and 2516), respectively.

LIST OF INVERTEBRATE MEGAFOSSILS COLLECTED FROM THE TEJON FORMATION AND ADJACENT OVERLYING STRATA

[See plate 1 for locations; identifications and age determinations by W. O. Addicott unless otherwise specified]

USGS Cenozoic loc. M4595.—Knoll on prominent northwest-trending ridge between Pleitito and San Emigdio Creeks in unsurveyed land 2,050 ft (625 m) N., 2,500 ft (762 m) W. of SW. cor. sec. 19, T. 10 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle, from upper 30 ft (9 m) of fossiliferous section below yellow sandstone, near base of San Emigdio Formation. Collectors: T. H. Nilsen and W. O. Addicott, 1971.

Gastropods:
- *Bruclarkia columbiana* (Anderson and Martin)?
- *Bullia clarki* Wagner and Schilling
- *Epitonium* sp.
- *Exilia*?
- *Neverita* sp. aff. *N. thomsonae* Hickman
- *Olequahia lorenzana* (Wagner and Schilling)?
- *Perse* sp.
- *Siphonalia merriami* Wagner and Schilling
- Undetermined internal molds

Pelecypods:
- *Amiantis*?
- Cardiid

Modiolus sp.
Spisula sp. cf. S. *packardi* Dickerson
Spisula sp. cf. *S. rushi* Wagner and Schilling
Yoldia ?

USGS Cenozoic loc. M4596.—Ridgetop west of Santiago Creek, 1,500 ft (460 m) N., 1,700 ft (520 m) E. of SW. cor. sec. 23, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle, *Heteromacoma* bed of San Emigdio Formation. Collectors: T. H. Nilsen and W. O. Addicott, 1971.
Pelecypod:
Heteromacoma rostellata (Clark)

USGS Cenozoic loc. M4597.—Hillside exposure on west side of Santiago Creek, about 50-80 ft (15-24 m) stratigraphically above M4596, 1,500 ft (460 m) N., 1,700 ft (520 m) E, of SW. cor. sec. 23, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle, San Emigdio Formation. Collector: T. H. Nilsen and W. O. Addicott, 1971.
Gastropods:
Epitonium sp.
Neverita sp.
Pelecypods:
Acila shamardi (Dall)
Amiantis sp. cf. *A. mathewsoni* (Gabb)
Chlamys?—fragments
Here exavata (Carpenter)
Spisula sp. cf. *S. rushi* Wagner and Schilling

USGS Cenozoic loc. M4598.—Hillside exposure on west side of Santiago Creek, 700 ft (210 m) east of SW. cor. sec. 3, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle, San Emigdio Formation. Collectors: T. H. Nilsen and W. O. Addicott, 1971.
Gastropods:
Neverita sp. aff. *N. thomsonae* Hickman
Siphonalia?
Undetermined internal molds
Pelecypods:
Amiantis? sp.
Spisula sp. cf. *S. packardi* Dickerson
Yoldia?

NOTE: *Turritella variata lorenzana* Wagner and Schilling and *Epitonium* cf. *E. condoni* Dall were observed in the field at isolated exposures in the stratigraphic interval between M4598 and M4596.

Summary of USGS Cenozoic Localities M4595, M4596, M4597, M4598

Age and correlation: Late Eocene, Refugian. Localities on the west side of Santiago Creek include species restricted to the Refugian Stage of Schenck and Kleinpell (1936) such as *Acila shumardi*. Other species including *Here excavata* and *Heteromacoma rostellata* are now known to occur in older strata. Although the stratigraphically lowest collection, loc. M4598, consists of doubtfully identified species, *A. shumardi* has been previously reported from approximately the same stratigraphic position at a nearby locality (Hammond, 1958). The biozone of *A. shumardi* is restricted to the Refugian Stage, the lower stratigraphic occurrence being in the lowest part of the Refugian but not at the base. The biozone of *A. shumardi* has been long regarded by molluscan paleontologists as indicative of an early to middle Oligocene provincial age, but recent work by foraminiferal specialists suggests that the Refugian Stage, and the biozone of *A. shumardi*, are of late Eocene age. The collection from between San Emigdio and Pleitito Creeks, M4595, also contains species restricted in stratigraphic occurrence to the Refugian Stage. Suggested environment: Upper part of the inner sublittoral (neritic) zone, 30-120 feet (9-35 m deep). The *Heteromacoma* bed, loc. M4596, may represent even shallower depths.

The following localities are from (1) a measured section in the undifferentiated Tejon Formation at the Edmonston Pumping Plant (M4631 to M4634 and M4639) about 1 mile (1½ km) east of Pastoria Creek (see fig. 16) and (2) from an isolated exposure (M4630) of the undifferentiated Tejon Formation and about 0.5 mile (0.8 km) farther east.

USGS Cenozoic loc. M4630.—Hillside exposure 9,250 ft (2,820 m) E., 3,400 ft (1,030 m) S., of BM 1040 (in SE¼ proj. sec. 12, T. 10 N., R. 19 W.), Pastoria Creek 7½-minute quadrangle, Tejon Formation. Collectors: T. H. Nilsen and W. O. Addicott, 1971.
Gastropods:
Amauropsis alveata (Conrad)
Calyptraea sp. cf. C. *diegoana* (Conrad)
Conus sp. cf. *C. remondi* Gabb
Fissurella n. sp.? aff. *F. behri* Dickerson
Naticid?
Olivella?
Pseudoperrisolax blakei (Gabb)
Pelecypods:
Brachydontes ornatus (Gabb)?
Corbula sp.
Crassatella sp.—large
Gari sp. aff. *G. diegoensis* (Hanna)
Gari horni (Gabb)?
Halonanus horni (Gabb)?
Lima sp.—large
Macrocallista sp.
Ostrea?
Schedocardia breweri (Gabb)
Spisula sp. cf. *S. acutirostrata* Packard
Spondylus carlosensis Anderson?
Tellina sp.
Venericardia sp.
Brachiopod:
Discinisca sp. with fine radial sculpture
Coral:
Undetermined solitary branching species

USGS Cenozoic loc. M4631.—Edmonston Pumping Plant measured section, about 40 ft (12 m) stratigraphically above base of undivided Tejon Formation, 7,900 ft (2,400 m) N., 6,900 ft (2,100 m) E. of SW. cor. T. 10 N., R. 18 W., Pastoria Creek 7½-minute quadrangle. Collectors: T. H. Nilsen and W. O. Addicott, 1971.
Gastropod:
Calyptraea sp.
Pelecypods:
Barbatia sp.
Brachydontes ornatus (Gabb)?
Ostrea sp. cf. *O. idriaensis* Gabb
Schedocardia breweri (Gabb)?
Spondylus carlosensis Anderson
Brachiopod:
Terebratulina tejonensis waringi Hertlein and Grant

USGS Cenozoic loc. M4632.—Edmonston Pumping Plant measured section, about 215 ft (65 m) stratigraphically below top of undivided

Tejon Formation, 7,900 ft (2,400 m) N., 6,900 ft (2,100 m) E. of SW. cor. T. 10 N., R. 18 W., Pastoria Creek 7½-minute quadrangle. Collectors: T. H. Nilsen and W. O. Addicott, 1971.

Gastropods:
- *Bonellitia paucivaricata* (Gabb)?
- *Calyptraea* sp.
- *Ectinochilus*?—same taxon as in M4639
- *Ficopsis remondi* (Gabb)
- Naticid
- *Turritella* sp.—internal mold with straight whorl profile

Pelecypods:
- Cardiid—possibly *Schedocardia breweri* (Gabb)
- *Corbula* sp.
- *Macrocallista* sp. cf. *M. horni* (Gabb)
- *Musculus*? sp.—possibly *Brachydontes ornatus* (Gabb)? of authors
- *Mytilus* or *Modiolus*—fragment
- *Pitar californiana* (Conrad)?
- *Semele diabloi* Dickerson?
- *Solen*?
- *Spisula* sp. cf. *S. acutirostrata* Packard
- *Spisula* sp. cf. *S. bisculpturata* Anderson and Hanna
- *Spisula merriami* Packard
- *Tellina* sp. cf. *T. lebecki* Anderson and Hanna
- *Tellina* sp. cf. *T. jollaensis* Dickerson

USGS Cenozoic loc. M4633.—Edmonston Pumping Plant measured section, about 250 ft (75 m) stratigraphically below top of undivided Tejon Formation, 7,900 ft (2,400 m) N., 6,900 ft (2,100 m) E. of SW. cor. T. 10 N., R. 18 W., Pastoria Creek 7½-minute quadrangle. Collectors: T. H. Nilsen and W. O. Addicott, 1971.

Gastropods:
- Acmaeid—internal mold with marginal "slit" and radial sculpture, same taxon occurs in M4634
- *Amauropsis*?—minute specimen
- *Bonellitia* sp.
- *Calyptraea* sp.—fragment
- *Fissurella* n. sp.? aff. *F. behri* Dickerson

Pelecypods:
- Arcid
- *Brachydontes*?
- *Corbula*?
- *Pitar* sp.—minute internal molds
- *Pteria* sp.
- *Schedocardia*?
- *Spisula merriami* Packard
- *Spondylus carlosensis* Anderson
- *Tellina castacana* Anderson and Hanna
- *Tellina* sp. cf. *T. jollaensis* Dickerson
- *Tellina* sp. cf. *T. longa* Gabb (Clark and Woodford)

Scaphopod:
- *Dentalium*?

Brachiopod:
- *Discinisca* sp.

USGS Cenozoic loc. M4634.—Edmonston Pumping plant measured section, about 190 ft (58 m) from the top of the undivided Tejon Formation, 7,900 ft (2,400 m) N., 6,900 ft (2,100 m) E. of SW. cor. T. 10 N., R. 18 W., Pastoria Creek 7½-minute quadrangle. Collectors: T. H. Nilsen and W. O. Addicott, 1971.

Gastropods:
- *Acmaea* sp. cf. *A. ruckmani* Dickerson
- Acmaeid—species occurring in collection from M4633
- *Amauropsis alveata* (Conrad)
- *Bonellitia paucivaricata* (Gabb)?
- *Calyptraea* sp.
- *Exilia* sp. A
- *Exilia* sp. B
- *Exilia fausta* Anderson and Hanna?
- Naticids
- *Neverita* sp.—minute specimens
- *Olivella mathewsoni* Gabb
- *Pyramidella mucronis* Anderson and Hanna
- *Turbonilla*?
- Turrid
- *Turritella buwaldana* Dickerson
- *Turritella uvasana* Conrad
- *Turritella uvasana sargeanti* Anderson and Hanna
- Undetermined minute internal molds—three taxa
- *Whitneyella sinuata* (Gabb)?

Pelecypods:
- *Barbatia* sp. cf. *B. suzzalloi* (Weaver and Palmer)
- *Halonanus horni* (Gabb)
- *Macoma viticola* Anderson and Hanna
- *Macrocallista*?
- *Musculus* sp.—possibly *Brachydontes ornatus* (Gabb) of authors
- *Nemocardium linteum* (Conrad)
- *Nuculana* sp. cf. *N. gabbi* (Gabb)
- *Pitar uvasana* (Conrad)?
- *Schedocardia breweri* (Gabb)
- *Spisula* sp. cf. *S. bisculpturata* (Anderson and Hanna)
- *Spisula merriami* Packard?
- Tellinid—fragment

Scaphopod:
- *Dentalium*?

USGS Cenozoic loc. M4639.—Edmonston Pumping Plant measured section, 43 ft (13 m) stratigraphically below top of the undivided Tejon Formation, 6,850 ft (2,090 m) E. of NW. cor. T. 10 N., R. 18 W., Pastoria Creek 7½-minute quadrangle. Collector: T. H. Nilsen, 1971.

Gastropods:
- *Acmaea* sp. cf. *A. tejonensis* Gabb
- Acmaeid
- *Amauropsis alveata* (Conrad)
- *Calyptraea* sp. cf. *C. diegoana* (Conrad)
- *Ectinochilus*?—same taxon as in M4632
- *Ficopsis horni* (Gabb)
- *Ficopsis remondi* (Gabb)
- *Mayena*? sp. cf. *M.? kewi* (Dickerson)
- *Molopophorus tejonensis* Dickerson
- Naticid
- *Olivella* sp.
- *Pyramidella*?
- *Surculites isoformis* (Anderson and Hanna)?
- *Turritella* sp. cf. *T. buwaldana* Dickerson
- Undetermined internal molds—three or four taxa

Pelecypods:
- Cardiid
- *Corbula* sp. cf. *C. horni* Gabb
- *Gari horni* (Gabb)
- *Glycymeris* sp.
- *Nuculana* sp.
- *Pitar* sp. cf. *P. tejonensis* (Dickerson)
- *Schedocardia breweri* (Gabb)?
- *Spisula* sp.
- *Tellina castacana* Anderson and Hanna?
- *Venericardia* sp.—fragment

Scaphopod:
Dentalium sp.

Summary of USGS Cenozoic Localities M4630, 4631, 4632, 4633, 4634, and 4639

Practically all of the species from the Edmonston Pumping Plant section have been previously reported from the type Tejon Formation of the San Emigdio Mountains. The collections are probably all referable to the "Tejon Stage."

The three highest localities (M4632, M4634, and M4639) are clearly referable to the "Tejon Stage." The occurrence of *Turritella uvasana sargeanti* at locality M4634 suggests a stratigraphic position in the upper part of the "Tejon Stage."

The two relatively small collections from the lowest localities (M4631 and M4633) do not contain stratigraphically diagnostic species. They represent either the "Transition Stage" or the "Tejon Stage" and contain many rock-dwelling epifaunal mollusks and differ, therefore, from the large "Tejon" assemblages from Liveoak Canyon to the west.

The progressive faunal change indicated on the above stratigraphic check lists of invertebrate taxa is probably more a matter of gradually deepening bathymetric facies than of any significant temporal change in this section. There are, however, a few species in the collections from the lower part that seem to be restricted in occurrence to the "Domengine Stage" and others in the collections from the upper part that have been previously reported only from the "Tejon Stage."

The assemblage from locality M4631 near the base is composed almost entirely of epifaunal elements indicative of a hard substrate—probably rocky—depositional environment. The composition further suggests a fully marine but extremely shallow-water environment, possibly intertidal.

The proportion of epifaunal elements is noticeably smaller in the assemblage collected from locality M4633. A number of infaunal elements (burrowing) such as the tellinids suggests the development of appreciable areas of sandy level bottom in addition to the continued presence of rocky or gravelly areas to support the epifaunal mollusks. The indicated bathymetric environment is still very shallow but definitely subtidal.

The assemblages from localities M4632, M4634, and M4639 are representative of sandy, level bottom communities and somewhat greater depths in the inner sublittoral zone (low tide to about 300 ft (90 m).

USGS Cenozoic loc. M4637.—On south wall of east-trending tributary to Tecuya Creek at an altitude of about 2,500 ft (750 m), 1,900 ft (580 m) N., 1,250 ft (380 m) W. of SE. cor. sec. 26, T. 10 N., R. 20 W., Grapevine 7½-minute quadrangle, Metralla Sandstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Pelecypod:
Undetermined fragments

Age and correlation: Middle Eocene, "Tejon Stage." These mollusks are represented by incomplete external molds preserved in a spheroidal concretion. The doubtfully identified *Turritella* is similar to the subspecies used by Weaver and Kleinpell (1963) to characterize molluscan assemblages of the Coldwater Sandstone of the Santa Ynez Mountains. They indicate that *T. schencki delaguerrae* is restricted in stratigraphic occurrence to strata assigned to the upper part of the Narizian Stage of the benthic foraminiferal sequence. This subspecies has not previously been recorded from the Tejon Formation of the San Emigdio Mountains.

USGS Cenozoic loc. M4638.—East wall of San Emigdio Canyon, 1.95 mi. (3.14 km) N., 100 ft (30 m) W. of SE. cor. sec. 25, T. 10 N., R. 22 W., Eagle Rest Peak 7½-minute quadrangle, San Emigdio Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
Bruclarkia columbiana (Anderson and Martin)
Ficus gesteri Wagner and Schilling
Neverita thomsonae Hickman
Polinices sp. cf. *P. washingtonensis* (Weaver)
Siphonalia merriami Wagner and Schilling

Pelecypods:
Acila shumardi Dall
Cardium sp.
Solen sp.
Spisula sp. cf. *S. pittsburgensis* Clark
Spisula sp. cf. *S. ramonensis* Packard
Spisula sp. cf. *S. rushi* Wagner and Schilling
Yoldia n. sp.? aff. *Y. tenuissima* Clark

Scaphopod:
Dentalium n. sp.?

Age and correlation: Late Eocene, Refugian.

USGS Cenozoic loc. M4640.—Approximately 2,000 ft (600 m) east of Pastoria Creek at an altitude of about 1,550 ft (470 m) (in proj. sec. 29, T. 10 N., R. 18 W.), 2.58 mi (4.15 km) S., 3,750 ft (1,140 m) east of NW. cor., T. 10 N., R. 18 W. (in unsectioned Rancho lands), Pastoria Creek 7½-minute quadrangle, Liveoak Shale Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
Calyptraea sp.—internal mold
Polinices sp. cf. *P. horni* Gabb
Turritella uvasana Conrad
Turritella sp. cf. *T. uvasana neopleura* Merriam
Undetermined internal mold

Pelecypods:
Callista?—fragment
Musculus sp.
Ostrea sp.
Tellina tehachapi Anderson and Hanna
Venericardia?—fragment
Undetermined fragments

Coral:
Undetermined fragments

Echinoid:
Spatangoid—fragment

Age and correlation: Middle Eocene, "Tejon Stage."

USGS Cenozoic loc. M4641.—On northeast side of Liveoak Canyon about 200 ft (60 m) east of west boundary of Pastoria Creek quadrangle at an altitude of about 1,725 ft (525 m), 4,330 ft (1,320 m) N., 200 ft (60 m) E. of lat 34°55' N., and long 118°52.5', Pastoria Creek 7½-minute quadrangle. Near the top of the Metralla Sandstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
Bonellitia?
Calyptraea diegoana (Conrad)
Crepidula pileum (Gabb)
Conus horni Gabb
Ectinochilus sp.
Ficopsis remondi (Gabb)
Ficus mammilatus Gabb
Molopophorus striatus (Gabb)
"Murex" beali Anderson and Hanna?
Neverita?
Olequahia horni (Gabb)
Olivella mathewsoni Gabb
Polinices horni (Gabb)
Pyramidellid
Ranellina pilsbryi (Gabb)?

Strepsidura ficus (Gabb)?
Turritella uvasana sargeanti Anderson and Hanna
Undetermined internal molds—two taxa

Pelecypods:
Acanthocardia breweri (Gabb)
Callista sp. cf. *C. conradiana* (Gabb)
Callista sp. cf. *C. horni* (Gabb)
Corbula horni Gabb
Nemocardium?
Nuculana sp. cf. *N. gabbi* (Gabb)
Nuculana uvasana (Dickerson)
Pitar sp. cf. *P. uvasana* Conrad
Solen?
Spisula sp. cf. *S. acutirostrata* Packard
Spisula sp. cf. *S. merriami* Packard
Tellinid—fragments
Venericardia sp.—minute specimens

Age and correlation: Middle Eocene, "Tejon Stage."

USGS Cenozoic loc. M4642.—On west-trending ridge on east side of Liveoak Canyon at an altitude of about 1,925 ft (587 m), 4,700 ft (1,430 m) N., 850 ft (260 m) E. of lat 34°55' N., long 118°52.5' W., Pastoria Creek 7½-minute quadrangle. At the base of the Metralla Sandstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
Amauropsis alveata (Conrad)
Architectonica sp.
Bonellitia sp.
Calyptraea diegoana (Conrad)
Crepidula pileum (Gabb)
Cymatium n. sp.?
Ectinochilus canalifera (Gabb)
Ferminoscala sp.
Olivella mathewsoni Gabb
Pseudoperrisolax blakei (Conrad)
Ranellina pilsbryi Stewart
Sinum obliquum (Gabb)
Strepsidura ficus (Gabb)?
Surculites?
Turritella uvasana sargeanti Anderson and Hanna

Pelecypods:
Acanthocardia breweri (Gabb)
Callista sp. cf. *C. andersoni* Dickerson
Crassatella sp. cf. *C. uvasana* Conrad
Gari sp.
Glycymeris saggitata (Gabb)
Glycymeris sp.—minute specimens
Nuculana parkei (Anderson and Hanna)
Pitar sp. cf. *P. tejonensis* (Dickerson)
Pitar sp. cf. *P. quadratus* (Gabb)
Spisula sp. cf. *S. acutirostrata* Packard
Spisula merriami Packard
Tellina lebecki Anderson and Hanna
Undetermined tellinid
Venericardia sp.—fragment

Scaphopod:
Dentalium sp.

Age and correlation: Middle Eocene, "Tejon Stage."

USGS Cenozoic loc. M4643.—Top of ridge east of Liveoak Canyon at an altitude of 2,000 ft (610 m), 4,450 ft (1,350 m) N., 1,300 ft (400 m) east of lat 34°55' N., long 118°52.5' W., Pastoria Creek 7½-minute quadrangle. Liveoak Shale Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
Epitonium (*Boreoscala*?) sp.
Euspira nuciformis (Gabb)
Ficopsis horni (Gabb)
Ficopsis remondi crescentensis Weaver and Palmer
Galeodea sp.
Polinices horni (Gabb)
Turrid
Turritella uvasana neopleura Merriam
Turritella uvasana Conrad subsp.?
Undetermined internal mold

Pelecypods:
Acanthocardia breweri (Gabb)
Crassatella sp.—fragment
Gari sp.
Glycymeris?
Pitar sp.
Tellina lebecki Anderson and Hanna
"*Teredo* borings"
Venericardia sp.—decorticated giant specimens

Scaphopods:
Dentalium sp. cf. *D. stentor* Anderson and Hanna
Dentalium sp.—coarsely ribbed

Age and correlation: Middle Eocene, "Transition Stage" or "Tejon Stage." The co-occurrence of the two species of *Ficopsis* is suggestive of a "Transition" age, *F. remondi crescentensis* being characteristic of the "Tejon Stage." *Turritella uvasana neopleura* seems to be characteristic of the lower part of the Liveoak Shale Member and appears to range from the lower part of the "Tejon Stage" downward into the "Transition Stage." The affinities of this assemblage are decidedly with the fauna of the "Tejon Stage" rather than that of the "Domengine Stage."

USGS Cenozoic loc. M4644.—East bank of Liveoak Canyon at an altitude of about 1,700 ft (520 m), 3,500 ft (1,070 m) N., 900 ft (275 m) east of lat 34°55' N., long 118°52.5' W., Pastoria Creek 7½-minute quadrangle. Uvas Conglomerate Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
Amauropsis alveata (Conrad)
Bonellitia?—internal molds
Cylichnina tantilla (Gabb)
Ficopsis horni (Gabb)
Ectinochilus canalifera supraplicatus (Gabb)
"Gyrineum" horni (Gabb)?
Polinices horni (Gabb)?
Pseudoperrisolax blakei (Conrad)
Turritella buwaldana Dickerson
Turritella uvasana neopleura Merriam

Pelecypods:
Acanthocardia breweri (Gabb)
Macoma?
Pitar sp. cf. *P. uvasanus* (Dickerson)
Spisula merriami Packard?
Venericardia sp.—internal mold

Scaphopods:
Cadulus?
Dentalium sp.

Annelid:
Tubulostium? *tejonense* (Arnold)

Age and correlation: Middle Eocene, "Transition Stage." The *Ectinochilus* appears to be ancestral to the "Tejon" species *E. canalifera* and is generally recognized as an index to the "Transition Stage." *Turritella uvasana neopleura* appears to range from the "Transition Stage" into the lower part of the "Tejon Stage."

USGS Cenozoic loc. M4645.—East bank of Liveoak Canyon at an altitude of about 2,275 ft (693 m), 1,100 ft (335 m) N., 3,425 ft (1,045 m) E. of lat 34°55' N., long 118°52.5' W., Pastoria Creek 7½-minute quadrangle. Uvas Conglomerate Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- *Amauropsis?*
- *Crepidula?*
- *Ficopsis horni* (Gabb)
- *Galeodea* sp.—fragment
- Naticid
- *Neverita secta* (Gabb)
- *Turritella buwaldana* Dickerson
- *Turritella uvasana* Conrad subsp.?

Pelecypods:
- *Acanthocardia breweri* (Gabb)
- *Crassatella?*
- *Macoma?*
- *Spisula acutirostrata* Packard?
- *Spisula* cf. *S. merriami* Packard
- *Venericardia* sp. internal molds

Age and correlation: Middle Eocene, "Transition Stage" or "Tejon Stage."

USGS Cenozoic loc. M4646.—In first unnamed creek east of Tecuya Creek at an altitude of about 2,350 ft (715 m), 2,650 ft (810 m) N., 250 ft (75 m) W. of NE. cor. sec. 25, T. 10 N., R. 20 W., Grapevine 7½-minute quadrangle. Metralla Sandstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Pelecypods:
- *Glycymeris* sp.
- *Lima* sp.
- *Nuculana* n. sp.?
- *Ostrea* sp.
- *Pitar quadratus* (Gabb)
- *Pitar* sp.—minute, articulated specimens

Scaphopod:
- *Dentalium* cf. *D. stramineum* Gabb

Age and correlation: Eocene, "Domengine Stage," "Transition Stage," or "Tejon Stage."

USGS Cenozoic loc. M4647.—In bed of east fork of Salt Creek at an altitude of about 2,600 ft (790 m), 2,200 ft (670 m) N., 1,200 ft (365 m) W. of SE. cor. sec. 27, T. 10 N., R. 20 W., Grapevine 7½-minute quadrangle. Reed Canyon Siltstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Pelecypods:
- *Pinna* cf. *P. barrowsi* Dickerson
- *Venericardia?*

Age: Early Tertiary.

USGS Cenozoic loc. M4648.—In bed of east fork of Salt Creek about 300 ft (90 m) upstream from M4647, 1,900 ft (580 m) N., 1,050 ft (320 m) W. of SE. cor. sec. 27, T. 10 N., R. 20 W., Grapevine 7½-minute quadrangle. Upper part of the Metralla Sandstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- Turrids—2 undetermined taxa
- *Turricula cohni* (Dickerson)
- *Turritella buwaldana* Dickerson

Pelecypods:
- *Corbula?*
- *Gari* cf. *G. horni* (Gabb)
- *Nemocardium linteum* (Conrad)
- *Pinna* sp.
- *Pitar* cf. *P. quadratus* (Gabb)
- *Pitar* sp.

Scaphopod?—smooth, slender specimens

Age and correlation: Middle Eocene, "Tejon Stage."

USGS Cenozoic loc. M4649.—Los Lobos Creek, nearly ¼ mile (0.4 km) downstream from San Emigdio Canyon-Santiago Canyon road, 6,000 ft (1,830 m) N., 150 ft (46 m) E. of SW. cor. sec. 21, T. 10 N., R. 22 W. (in unsectioned Rancho lands), Eagle Rest Peak 7½-minute quadrangle. Uvas Conglomerate Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- Ampullospirid or Naticid
- *Turritella?*—internal molds
- Undetermined specimens—at least four taxa

Pelecypods:
- *Ostrea* sp.
- *Venericardia?*
- Undetermined specimens—two or more taxa

Scaphopod:
- *Dentalium* sp.

Age: Indeterminate. These mollusks are represented by incomplete molds and casts in soft, crumbly sandstone. The preservation is such that even generic determinations are uncertain.

USGS Cenozoic loc. M4651.—On west side of Pleito Creek at Neasons Flat (altitude about 3,350 ft, 1,020 m), 3,000 ft (915 m) N., 200 ft (61 m) W. of SE. cor. sec. 35 T. 10 N., R. 21 W., Pleito Hills 7½-minute quadrangle. Metralla Sandstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- *Amauropsis alveata* (Conrad)
- *Strepsidura ficus* (Gabb)?
- *Turritella uvasana sargeanti* Anderson and Hanna

Pelecypod:
- *Venericardia* cf. *V. horni* (Gabb)

Age and correlation: Middle Eocene, "Tejon Stage." *Turritella uvasana sargeanti* is restricted in stratigraphic occurrence to the uppermost part of the Tejon Formation; it also occurs at or near the top of the Eocene sequence in the Pine Mountain area in the Transverse Ranges west of the San Andreas fault.

USGS Cenozoic loc. M4652.—In saddle a few hundred feet (about 100 m) north of 4,472-ft (1,363-m) peak between Lost Canyon and Pleito Creek, 1,400 ft (425 m) S., 500 ft (150 m) W. of NE. cor. sec. 34, T. 10 N., R. 21 W., Pleito Hills 7½-minute quadrangle. San Emigdio Formation. Collector: T. H. Nilsen, 1971.

Gastropod:
- Naticid

Pelecypods:
- *Pseudocardium?*
- *Spisula* sp.

Age: Indeterminate.

USGS Cenozoic loc. M4653.—East side of Pleito Creek near head of Neasons Flat, 200 ft (61 m) S., 1,300 ft (400 m) E. of NW. cor. sec. 36, T. 10 N., R. 21 W., Pleito Hills 7½-minute quadrangle. At or near base of San Emigdio Formation. Collector: T. H. Nilsen, 1971.

Gastropod:
- Naticid

Pelecypods:
- *Pitar?*
- *Spisula* spp.

Age: Indeterminate.

USGS Cenozoic loc. M4654.—On northeast side of East Twin Creek (informal local name), 1,150 ft (350 m) S., 400 ft (120 m) W. of NE. cor. sec. 26, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle. Uvas Conglomerate Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- *Amaurellina?*
- *Ectinochilus macilentus* (White)
- *Eocernina?*
- *Ficopsis* cf. *F. meganosensis packardi* Merriam and Turner
- *Lyria andersoni* Waring
- *Neverita globosa* Gabb
- *Pachycrommium clarki* (Stewart)?
- *Turritella merriami* Dickerson

Pelecypods:
- *Nemocardium linteum* (Conrad)?
- *Pitar joaquinensis* Vokes
- *Pitar* sp.
- *Solen?*
- *Venericardia?*—minute specimen

Age and correlation: Early Eocene, "Capay Stage." The distinctive species *Turritella merriami* is restricted in stratigraphic occurrence to assemblages correlated with the "Capay." Most of the gastropods range from the "Capay" to the "Domengine Stage." The occurrence of *Pitar joaquinensis* in this assemblage seems to be a range extension; previous records are from faunas correlated with the "Domengine Stage."

USGS Cenozoic loc. M4655.—On northeast side of East Twin Creek (informal local name), stratigraphically above M4654, 1,150 (350 m) ft S., 250 ft (75 m) W. of NE. cor. sec. 26, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle. Uvas Conglomerate Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Foraminifer:
- Undetermined orbitoid—samples sent to USNM for identification

Annelid:
- *Tubulostium?* sp.—this is the *"Spiroglyphus"* of earlier reports

Age and correlation: Eocene. Species referred to *Spiroglyphus* or *Tubulostium?* are known from the early, middle, and late Eocene in California; they are especially common and characteristic of faunal assemblages of "Domengine" age. They were once believed to be vermetid gastropods.

USGS Cenozoic loc. M4656.—On northeast side of East Twin Creek (informal local name), stratigraphically above M4655, 1,200 ft (370 m) S., 50 ft (15 m) W. of NE. cor. sec. 26, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle. Uvas Conglomerate Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Foraminifer:
- Undetermined orbitoid—samples sent to USNM for identification

Gastropods:
- *Muricopsis* cf. *M. whitneyi* var. Vokes
- *Turritella* cf. *T. andersoni susannae* Merriam

Pelecypods:
- *Spondylus?*
- *Venericardia* sp.—small specimen

Age and correlation: Possibly early Eocene. The doubtfully identified *Turritella* ranges from the upper Paleocene "Meganos Stage" to the lower Eocene "Capay Stage." Correlation with the "Capay" is suggested by the fact that this assemblage overlies an undoubted "Capay" locality (USGS loc. M4654). Large foraminifers identified by K. N. Sachs, Jr., from the same locality (written commun., Feb. 15, 1972):
- *Pseudophragmina (Proporocyclina) flintensis* (Cushman)
- *Asterocyclina aster* (Woodring)
- *Nummulites* (= *Camerina* of Cole) sp.

Age: This association suggests a middle Eocene age, thus a bit younger than that determined by W. O. Addicott on the basis of the mollusks. Could also be early Eocene, but not Paleocene or late Eocene.

USGS Cenozoic loc. M4657.—In north fork of small northwest-trending tributary to San Emigdio Creek about 150 ft (46 m) west of boundary between R. 21, 22 W., (in unsectioned Rancho lands), Eagle Rest Peak 7½-minute quadrangle. Metralla Sandstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- *Turritella uvasana* Conrad subsp.?
- Undetermined fragments

Pelecypods:
- *Acila* sp.
- *Cyclopecten* sp.
- *Nuculana* sp.
- *Venericardia?*

Scaphopod:
- *Dentalium* cf. *D. lighti* Vokes—common

Foraminifers:
- several taxa

Age and correlation: Middle Eocene, "Domengine Stage," "Transition Stage", or "Tejon Stage."

USGS Cenozoic loc. M4658.—Near base of east wall of San Emigdio Creek at mouth of small tributary 5,550 ft (1,690 m) N., 750 ft (230 m) W. of SE. corner sec. 25, T. 10 N., R. 22 W., Eagle Rest Peak 7½-minute quadrangle. San Emigdio Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- *Crepidula* cf. *C. ungana* Dall
- *Epitonium condoni* Dall s.l.
- Naticids (possibly representing only one species)
- *Olequahia lorenzana* (Wagner and Schilling)
- *Polinices?*
- *Siphonalia merriami* Wagner and Schilling
- *Turritella* aff. *T. variata* Conrad—specimen with accentuated posterior spiral

Pelecypods:
- Cardiid—minute specimen
- *Crassatella?*
- *Here* aff. *H. excavatus* (Carpenter)
- *Pitar* sp.
- *Spisula* cf. *S. pittsburgensis* Clark
- *Spisula* cf. *S. ramonensis* Packard
- *Spisula* cf. *S. rushi* Wagner and Schilling
- Undetermined specimen

Scaphopod:
- *Dentalium* n. sp.?

Age and correlation: Late Eocene, Refugian.

USGS Cenozoic loc. M4659.—On northeast-trending ridge on west side of Los Lobos Creek (altitude 3,700 ft, 1,130 m), 1,300 ft. (400 m) N., 450 ft (135 m) W. of SE. cor. sec. 29, T. 10 N., R. 22 W., Eagle Rest Peak 7½-minute quadrangle. Same as UCLA loc. 3552. Liveoak Shale Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- Acmaeid?
- *Cylichnina tantilla* (Gabb)
- *Ectinochilus macilentus* (White)
- Naticid or Ampullospirid
- Undetermined specimens—two taxa

Pelecypods:
- *Acanthocardia breweri* (Gabb)?
- *Barbatia* sp.—internal mold
- *Pitar* sp.
- *Septifer* sp. cf. *S. dichotomous* (Gabb) Arnold (1909)
- *Venericardia* sp.—minute specimen

Age and correlation: Early or middle Eocene, "Capay Stage" or "Domengine Stage."

Ectinochilus macilentus is of common occurrence in strata of "Domengine" age along the western margin of the San Joaquin Valley at Reef Ridge and near Coalinga. It has recently been reported from strata correlated with the lower Eocene "Capay Stage" in southern California.

USGS Cenozoic loc. M4660.—At prominent right-angle bend in west wall of San Emigdio Canyon north of mouth of Williams Canyon, 5,900 ft (1,800 m) N., 2,400 ft (730 m) W. of SE. cor. sec. 26, T. 10 N., R. 22 W. (in unsectioned Rancho lands), Eagle Rest Peak 7½-minute quadrangle. San Emigdio Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- *Calyptraea* sp. cf. *C. diegoana* (Conrad)
- *Epitonium condoni* Dall s.l.
- Naticid
- *Polinices* sp. cf. *P. washingtonensis* (Weaver)
- *Siphonalia merriami* Wagner and Schilling?

Pelecypods:
- *Heteromacoma rostellata* (Clark)
- *Pitar* sp.
- *Spisula packardi* Dickerson
- *Spisula* sp. cf. *S. ramonensis* Packard
- *Spisula* sp.?

Scaphopod:
- *Dentalium* n. sp.?

Age and correlation: Late Eocene, Refugian.

USGS Cenozoic loc. M4661.—In San Emigdio Creek, 200 ft (61 m) N., 1,050 ft (320 m) W. of SE. cor. sec. 31, T. 10 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Metralla Sandstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropod:
- Undetermined fragment

Age: Indeterminate.

USGS Cenozoic loc. M4662.—In small west-trending tributary to San Emigdio Creek about a mile southwest of Eagle Rest Peak and south of Devils Kitchen, 2,550 ft (775 m) S., 1,750 ft (530 m) E. of NW. cor. sec. 5, T. 9 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Uvas Conglomerate Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- *Amauropsis* cf. *A. alveata* (Conrad)
- *Calyptraea* cf. *C. diegoana* (Conrad)
- *Conus horni* Gabb
- *Ectinochilus* sp.
- *Olivella mathewsoni* Gabb
- *Sinum obliquum* (Gabb)
- Turrid?
- *Turritella buwaldana* Dickerson

Pelecypods:
- *Acanthocardia breweri* (Gabb)
- *Corbula horni* Gabb
- *Nuculana* sp.
- *Pitar*

Scaphopod:
- *Dentalium* sp.

Coral:
- Undetermined fragment

Age and correlation: Eocene, "Domengine Stage," "Transition Stage," or "Tejon Stage."

USGS Cenozoic loc. M4663.—On wall of northwest-trending tributary to San Emigdio Creek about 100 ft (30 m) south of north line of T. 9 N. (altitude about 4,125 ft, 1,257 m), 7,150 ft (2,180 m) N., 4,150 ft (1,265 m) W. of SE. cor. sec. 6, T. 9 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Metralla Sandstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

This sample consists of an undetermined pelecypod, a plant fragment, and what appear to be skeletal remains of fish. The material is too poorly preserved to permit an age determination.

USGS Cenozoic loc. M4664.—Knoll on west side of Los Lobos Creek about 850 ft (260 m) N., 200 ft (61 m) E. of SW cor. sec. 33, T. 10 N., R. 22 W., Eagle Rest Peak 7½-minute quadrangle. San Emigdio Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- Naticid
- *Olequahia*?
- Undetermined internal mold

Pelecypods:
- *Lucinoma*?—fragment
- *Spisula* sp. cf. *S. ramonensis* Packard
- *Spisula* sp. cf. *S. rushi* Wagner and Schilling

Age: Probably late Eocene (based upon the doubtfully identified *Spisulas*).

USGS Cenozoic loc. M4665.—West side of Los Lobos Creek at an altitude of about 3,875 ft (1,180 m), 1,550 ft (470 m) S., 1,300 ft (400 m) E. of NW. cor. sec. 33, T. 10 N., R. 22 W., Eagle Rest Peak 7½-minute quadrangle. Metralla Sandstone Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.

Pelecypods:
- *Acila* sp.
- *Nuculana* sp.
- *Venericardia*?
- Undetermined fragments

Age: Eocene(?).

USGS Cenozoic loc. M4666.—East wall of Los Lobos Creek Canyon, 1,850 ft (560 m) N., 2,200 ft (670 m) E. of SW cor. sec. 33, T. 10 N., R. 22 W., Eagle Rest Peak 7½-minute quadrangle. San Emigdio Formation. Collector: T. H. Nilsen, 1971.

Gastropods:
- *Olequahia lorenzana* (Wagner and Schilling)
- Undetermined molds

Pelecypods:
- *Amiantis*?
- *Pitar*?
- *Pseudocardium*?
- *Spisula* sp. cf. *S. ramonensis* Packard
- *Spisula* sp. cf. *S. rushi* Wagner and Schilling

Age and correlation: Late Eocene, Refugian.

USGS Cenozoic loc. M5785.—Ridge flank east of Doc Williams Canyon at 4,100 ft (1,250 m) elevation along boundary between sec. 35, T. 10 N., R. 22 W., and sec. 2, T. 9 N., R. 22 W., Eagle Rest Peak 7½-minute

quadrangle. Metralla Sandstone Member of Tejon Formation. Collector: T. H. Nilsen and T. W. Dibblee, Jr., 1972.
Gastropod:
?Molopophorus
Pelecypods:
Pitar sp.
Undetermined fragment
Scaphopod:
Dentalium sp. cf. *D. laneensis* Hickman
Age and correlation: Possibly late Eocene.

USGS Cenozoic loc. M5786.—Ridge flank west of Doc Williams Canyon in NW¼SW¼ sec. 2, T. 9 S., R. 22 W., Eagle Rest Peak 7½-minute quadrangle. Elevation 4,700 ft (1,635 m). San Emigdio Formation. Collector: T. H. Nilsen and T. W. Dibblee, Jr., 1972.
Gastropod:
Polinices sp.
Pelecypods:
Acila shumardi Dall
Amiantis or *Antigona*
Pitar sp.
Age and correlation: Late Eocene, Refugian. *Acila shumardi* ranges through the middle and upper part of this stage.

USGS Cenozoic loc. M5787.—In Rancho San Emigdio land grant on east side of San Emigdio Canyon where spur road to the east takes first sharp turn toward the northwest in SW¼SW¼ sec. 9, T. 10 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. San Emigdio Formation. Collectors: T. H. Nilsen and T. W. Dibblee, Jr., 1972.
Gastropods:
Epitonium condoni Dall s.l.
Epitonium sp.
?Olequahia
?Sinum
Age and correlation: Late Eocene, Refugian.

USGS Cenozoic loc. M5788.—On ridge crest east of San Emigdio Creek near center of sec. 20, T. 10 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. San Emigdio Formation. Collectors: T. H. Nilsen and T. W. Dibblee, Jr., 1972.
Gastropods:
Olequahia lorenzana (Wagner and Schilling)
Neverita sp.
Siphonalia merriami Wagner and Schilling
Undetermined naticid
Pelecypods:
Amiantis or *Antigona*
Spisula muliniaformis Wagner and Schilling
Spisula sp.
Age and correlation: Late Eocene, Refugian.

USGS Cenozoic loc. M5789.—In canyon due west of 4,666-ft (1,422-m) hill in SW¼ NE¼ sec. 34, T. 10 N., R. 22 W., Eagle Rest Peak 7½-minute quadrangle. San Emigdio Formation. Collectors: T. H. Nilsen and T. W. Dibblee, Jr., 1972.
Pelecypods:
Amiantis or *Antigona*
Solen sp.
Spisula sp. cf. *S. ramonensis* Packard
Spisula sp. cf. *S. rushi* Wagner and Schilling
Undetermined fragments
Age and correlation: Probably late Eocene.

Summary of Collections From the Tejon and San Emigdio Formations (by W. O. Addicott)

Tejon Formation

Assemblages from exposures of the Uvas Conglomerate Member of the Tejon Formation represent shallow-water deposition, generally less than about 90 feet (27 m). The poorly preserved assemblage from M4649 appears to be transported; some of the taxa are suggestive of very shallow water while others appear to represent middle sublittoral or possibly greater depths.

One collection from the Metralla Sandstone Member (locality M4657) may represent outer sublittoral or upper bathyal depths based upon the small pelecypods including *Cyclopecten*; the other collections are of inner sublittoral aspect.

Mollusks from the Metralla Sandstone Member are also of inner sublittoral aspect and probably represent deposition in relatively shallow water—less than about 90 feet (27 m). One locality, however, may represent middle or even outer sublittoral depths (locality M4646) based upon the abundance of minute, relatively deep-water pelecypod genera.

San Emigdio Formation

Collections from the San Emigdio Formation probably represent deposition in the upper part of the inner sublittoral zone (depths of less than about 90-120 ft, 27-36 m). The two poorly preserved assemblages from exposures near Pleito Creek (M4652 and M4653) suggest extremely shallow-water deposition, possibly in the intertidal zone.

LIST OF FORAMINIFERS COLLECTED FROM THE TEJON FORMATION AND ADJACENT OVERLYING STRATA

[See plate 1 for locations; identifications, summaries, and age determinations by W. V. Sliter and R. Z. Poore unless otherwise specified]

Localities east of Santiago Creek near head of East Twin Creek (informal name not shown on 1943 ed. of Santiago Creek 7½-minute quadrangle). Samples from localities 2513-2516 to TNF-21 were collected from near the base of the Liveoak Shale Member (2513) upward to the uppermost exposed part of the Liveoak Shale Member (TNF-21). Sample TNF-21 was not examined by Sliter or Poore. See figure 65 for measured sections.

USGS Cenozoic loc. Mf2513.—Creek bottom about 1,000 ft (300 m) N., 2,000 ft (600 m) E. of SW. cor. sec. 25, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle. Collector: T. H. Nilsen, 1971.
Benthic foraminifers:
Gaudryina sp. cf. *G. sandiegensis* Cushman and Hanna
Lenticulina sp. cf. *L. convergens* (Bornemann)
Pseudophragmina (Proporocyclina) psila (Woodring)
Saracenaria sp.
Age and comments: Early Eocene (Penutian) based on rare, poorly preserved foraminifers. Neritic water depths are suggested by this assemblage. Foraminifers identified by R. Stanley Beck (written commun., June 4, 1971) from collections by T. H. Nilsen at the same locality:

Vaginulinopsis saundersi
Robulus inornatus
Eponides yeguaensis
Amphistegina? sp.
Anomalina sp. cf. *A. garzaensis*
Trifarina? sp.
Cibicides sp. cf. *C. macmastersi*
Uvigerina sp. cf. *U. garzaensis*
Valvulineria? cf. *V. involuta*
Nonion sp. cf. *N. inflatum*

USGS Cenozoic loc. Mf 2514.—Creek bottom about 800 ft (240 m) N., 2,100 ft (640 m) E. of SW. cor. sec. 25, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle. Collector: T. H. Nilsen, 1971.
Benthic foraminifers:
Bathysiphon eocenica Cushman and Hanna
Rhabdammina eocenica Cushman and Hanna
Haplophragmoides eggeri Cushman
Epistomina sp. cf. *E. partschiana* (d'Orbigny)
Lenticulina sp. cf. *L. pseudovortex* Cole
Dentalina soluta Reuss
Gyroidina sp. cf. *G. guayabalensis* Cole
Age and comments: Middle Eocene (early Ulatisian) based on rare, poorly preserved foraminifers. Increased water depths of upper bathyal range are indicated.
Foraminifers identified by R. Stanley Beck (written commun., June 4, 1971) from collections by T. H. Nilsen at the same locality:
Vaginulinopsis sp. cf. *V. asperuliformis*
Bathysiphon spp.
Robulus inornatus
Dentalina? spp.
Haplophragmoides spp.
Nodosarella? sp. cf. *N. ignora*
Globigerina sp. cf. *G. triloculinoides*
limonitized radiolaria?

USGS Cenozoic loc. Mf 2515.—Creek bottom about 600 ft (180 m) N., 2,200 ft (670 m) E. of SW. cor. sec. 25, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle. Collector: T. H. Nilsen, 1971.
Planktic foraminifers:
Globigerina eocaena Gumbel (s.l.)
Subbotina patagonica (Todd and Kniker)
"S." senni (Beckmann)
?*Catapsydrax* sp.
Morozovella sp. aff. *M. dolobrata* (Jenkins) (one specimen)
M. aragonensis aragonensis (Nuttall)
M. sp. aff. *M. broedermanni* (Cushman and Bermudez)
M. spp.
Truncorotaloides bullbrooki (Bolli)
T. sp. aff. *Acarinina rotundimarginata* Subbotina
T. spp.
Planorotalites sp. aff. *P. pseudoscitula* (Glaessner)
?*Hantkenina* sp. (one small fragment)
Pseudohastigerina micra (Cole)
Age and comments: Middle Eocene. Most likely zones P10-P11. Fauna is poorly preserved, and many specimens are deformed.
Benthic foraminifers:
Rhabdammina eocenica Cushman and Hanna
Spiroplectammina tejonensis Mallory
Vaginulinopsis asperuliformis (Nuttall)
Dorothia principiensis Cushman and Bermudez
Textularia sp. cf. *T. recta* Cushman
Cyclammina pacifica Beck
Quadrimorphina allomorphinoides (Reuss)
Gyroidina planata Cushman
Eponides umbonata (Reuss)
Eponides sp. cf. *E. dorfi* Toulmin
Valvulinaria involuta Cushman and Dusenbury
Bulimina macilenta Cushman and Parker
Gyroidina condoni (Cushman and Schenck)
Cibicides sp. cf. *C. cocoaensis* (Cushman)
Bulimina guayabalensis Cole
B. sp. cf. *B. cowlitzensis* Beck
Dentalina colei Cushman and Dusenbury
Lagena sp.
Stilostomella spinescens (Montagu)
Lenticulina convergens Bornemann
Age and comments: Middle Eocene (late Ulatisian or early Narizian) based on relatively abundant calcareous and agglutinated fauna. Middle bathyal water depths are indicated by this assemblage (equals middle Eocene, European standard).
Foraminifers identified by R. Stanley Beck (written commun., June 4, 1971) from collections by T. H. Nilsen at the same locality:
Globigerina triloculinoides
Robulus inornatus
Cibicides macmastersi
Dorothia principiensis
Bathysiphon spp.
Cyclammina sp. cf. *C. samanica*
Haplophragmoides spp.

USGS Cenozoic loc. Mf 2516.—Creek bottom about 400 ft (120 m) N., 2,400 ft (730 m) E. of SW. cor. sec. 25, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle. Collector: T. H. Nilsen, 1971.
Planktic foraminifers:
Globigerina eocaena Gumbel (s.l.) (specimens deformed)
Globorotaloides wilsoni Cole (one partially crushed specimen)
Age and comments: Eocene, probably middle Eocene. One partially crushed specimen might be *"Globigerina" wilsoni*. If correct, this suggests a middle Eocene age.
Benthic foraminifers:
Bathysiphon eocenica Cushman and Hanna
Rhabdammina eocenica Cushman and Hanna
Haplophragmoides sp. cf. *H. coalingensis* Cushman and Hanna
Cyclammina samanica Berry
Cyclammina sp. cf. *C. pacifica* Beck
Dentalina soluta Reuss
Cibicides sp. cf. *C. laimingi* Mallory
Gaudryina sp. cf. *G. trinitatensis* Nuttall
Age and correlation: Middle Eocene (late Ulatisian) based on rare, poorly preserved foraminifers. Middle to lower bathyal water depths are indicated.
Foraminifers identified by R. Stanley Beck (written commun., June 4, 1971) from collections by T. H. Nilsen at the same locality:
Haplophragmoides spp.
Globigerina triloculinoides
Vaginulinopsis sp. cf. *V. saundersi lewisensis*
Tritaxilina colei
Verneuilina sp.
Bulimina ovata cowlitzensis
Chilostomella sp.
pyritized and limonitized radiolarians abundant
Summary by R. Stanley Beck (written commun., June 4, 1971) of age and correlation of foraminifers identified by him from localities Mf 2513 to Mf 2516: "Late Eocene; *Uvigerina churchi* zone equals undifferentiated Tejon and Kreyenhagen Formations. The facies is closer to that of the Kreyenhagen Formation than that of the Tejon Formation."

Field locality TNF-21.—Creek bottom about 300 ft (90 m) N., 2,500 ft (760 m) E. of SW. cor. sec. 25, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle. Top of section of Liveoak Shale Member of Tejon Formation in East Twin Creek. Collector: T. H. Nilsen, 1971.
Foraminifers identified by R. Stanley Beck (written commun., 4 June 1971):

Haplophragmoides sp.
Verneuilina? sp.
Globigerina? sp.
pyritized radiolarian

Age and comments: Age uncertain but possibly middle Eocene as at USGS Cenozoic loc. Mf 2516.

USGS Cenozoic loc. Mf 2517.—Exposure on ridge flank west of Pleito Creek about 1,000 ft (300 m) E., 2,200 ft (670 m) S. of NW. cor. sec. 2, T. 9 N., R. 21 W., Pleito Hills 7½-minute quadrangle. Lower part of Liveoak Shale Member of the Tejon Formation. Collector: T. H. Nilsen, 1971.
Benthic foraminifers:

Rhabdammina eocenica Cushman and Hanna

Age and comments: Paleocene or Eocene based on single benthic specimen.

USGS Cenozoic loc. Mf 2518.—East wall of lower East Twin Creek (informal name not shown on 1943 ed. of Santiago Creek 7½-minute quadrangle), 500 ft (150 m) W., 800 ft (240 m) S. of NE. cor. sec. 26, T. 10 N., R. 23 W., Santiago Creek 7½-minute quadrangle. Lower part of Liveoak Shale Member of Tejon Formation. Collector: T. H. Nilsen, 1971.
Benthic foraminifers:

Rhabdammina eocenica Cushman and Hanna
Cyclammina pacifica Beck
Trochamminoides contortus Mallory
Eggerella sp. cf. *E. subconica* Parr
Lenticulina turbinata (Plummer)

Age and comments: Middle Eocene (late Ulatisian or early Narizian) based on rare, poorly preserved, mostly agglutinated fauna. Middle bathyal water depths are suggested.

USGS Cenozoic loc. Mf 2520.—Exposure on ridge flank west of Los Lobos Creek about 700 ft (210 m) W., 900 ft (270 m) N. of SE. cor. sec. 32, T. 10 N., R. 22 W., Eagle Rest Peak 7½-minute quadrangle. Liveoak Shale Member of Tejon Formation. Collector: T. H. Nilsen, 1971.
Benthic foraminifers:

Rhabdammina eocenica Cushman and Hanna

Age: Paleocene or Eocene.

USGS Cenozoic loc. Mf 2523.—Exposure on ridge flank of east side of tributary to San Emigdio Creek, 2,300 ft (700 m) W., 2,000 ft (600 m) S. of NE. cor. sec. 6, T. 9 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Middle part of Liveoak Shale Member of Tejon Formation. Collector: T. H. Nilsen, 1973.
Benthic foraminifers:

Cyclammina sp. cf. *C. samanica* Berry
Eggerella sp. cf. *E. subconica* Parr

Age and comments: Middle Eocene (Narizian) based on very rare agglutinated fauna. Bathyal water depths are indicated.

Localities near intersection of Cloudburst Canyon and San Emigdio Canyon

Samples Mf 2524 to 2528 were collected from the lower part of the Liveoak Shale Member of the Tejon Formation, with sample Mf 2528 being the lowest stratigraphically, a few meters above the Uvas Conglomerate Member, and sample Mf2523 the highest stratigraphically, about 500 feet (150 m) above sample Mf 2528.

USGS Cenozoic loc. Mf 2524.—Exposure near ridge crest west of Cloudburst Canyon, about 2,100 ft (640 m) W., 3,200 ft (975 m) S. of NE. cor. sec. 6, T. 9 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Collector: T. H. Nilsen, 1973.
Benthic foraminifers:

Cyclammina pacifica Beck
Haplophragmoides sp. cf. *H. obliquicameratus* Marks
Trochamminoides contortus Mallory
Eggerella sp. cf. *E. elongata* Blaisdell

Age and comments: Middle Eocene (early Narizian) based on rare poorly preserved fauna. Faunal assemblage indicates bathyal water depths.

USGS Cenozoic loc. Mf 2525.—Exposure on ridge flank west of Cloudburst Canyon, about 1,900 ft (580 m) W., 3,300 ft (1,000 m) S. of NE. cor. sec. 6, T. 9 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Collector: T. H. Nilsen, 1973.
Benthic foraminifers:

Bathysiphon eocenica Cushman and Hanna
Cyclammina pacifica Beck
Trochamminoides contortus Mallory
Eggerella elongata Blaisdell

Age and comments: Middle Eocene (early Narizian) based on rare agglutinated foraminifers. Assemblage indicates bathyal water depths.

USGS Cenozoic loc. Mf 2526.—Exposure on ridge flank west of Cloudburst Canyon, about 1,800 ft (550 m) W., 3,500 ft (1,070 m) S. of NE. cor. sec. 6, T. 9 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Collector: T. H. Nilsen, 1973.
Benthic foraminifers:

Bathysiphon eocenica Cushman and Hanna
Cyclammina pacifica Beck
Haplophragmoides sp. cf. *H. obliquicameratus* Marks
Eggerella sp. cf. *E. elongata* Blaisdell

Age and comments: Middle Eocene (early Narizian) based on rare, poorly preserved, agglutinated foraminifers. Assemblage indicates bathyal water depths.

USGS Cenozoic loc. Mf 2527.—Exposure on ridge flank west of Cloudburst Canyon, about 1,700 ft (520 m) W., 3,600 ft (1,100 m) S. of NE. cor. sec. 6, T. 9 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Collector: T. H. Nilsen, 1973.
Benthic foraminifers:

Bathysiphon eocenica Cushman and Hanna
Rhabdammina eocenica Cushman and Hanna
Cyclammina samanica Berry
Lenticulina carolinianus Cushman

Age and comments: Middle Eocene (late Ulatisian or early Narizian) based on very rare, poorly preserved, mostly agglutinated fauna. Assemblage indicates bathyal water depths.

USGS Cenozoic loc. Mf 2528.—Exposure on ridge flank west of Cloudburst Canyon, about 1,500 ft (460 m) W., 3,800 ft (1,160 m) S. of NE. cor. sec. 6, T. 9 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Collector: T. H. Nilsen, 1973.
Benthic foraminifers:

Haplophragmoides sp.
Eggerella sp. cf. *E. elongata* Blaisdell

Age and comments: Middle Eocene (late Ulatisian or early Narizian) based on very rare, poorly preserved, agglutinated fauna.

USGS Cenozoic loc. Mf 2529.—Roadcut on ridge flank east of East Fork of Los Lobos Creek, about 2,200 ft (670 m) E., 1,200 ft (370 m) S. of NE. cor. sec. 28, T. 10 N., R. 22 W., Eagle Rest Peak 7½-minute quadrangle. Shale from lower part of Liveoak Shale Member of Tejon Formation. Collector: T. H. Nilsen, 1973.

Benthic foraminifers:

Trochamminoides contortus Mallory
Cyclammina sp. cf. *C. samanica* Berry
Eggerella sp. cf. *E. elongata* Blaisdell

Age and comments: Middle Eocene (probably early Narizian) based on very rare, poorly preserved, agglutinated fauna. Bathyal water depths are suggested.

USGS Cenozoic loc. Mf 2531.—Exposure on ridge flank on west side of tributary to San Emigdio Creek, 2,500 ft (760 m) W., 1,700 ft (520 m) S. of NE. cor. sec. 34, T. 10 N., R. 22 W., Eagle Rest Peak 7½-minute quadrangle. Shale from uppermost part of Liveoak Shale Member. Collector: T. H. Nilsen, 1973.

Benthic foraminifers:

Cyclammina pacifica Beck
Rhabdammina eocenica Cushman and Hanna
Haplophragmoides obliquicameratus Marks
Eggerella elongata Blaisdell

Age and comments: Middle Eocene (late Narizian) based on rare, poorly preserved fauna. Assemblage suggests bathyal water depths.

USGS Cenozoic loc. Mf 2633.—Ridge flank east of San Emigdio Creek, 600 ft (180 m) W., 500 ft (460 m) N. of SE. cor. sec. 31, T. 10 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Upper part of Liveoak Shale Member of Tejon Formation, about 75 ft (22 m) below contact with overlying San Emigdio Formation. Collector: E. E. Brabb, 1975.

Planktic foraminifers:

Pseudohastigerina micra (Cole)
P. sp.
Truncorotaloides collacteus (Finlay)
T. sp. aff. *T. bullbrooki* (Bolli)
Subbotina patagonica (Todd and Kniker)
Globigerina eocaena Gumbel (s. l.)
G. spp.
"Globigerinoides" higginsi Bolli
Morozovella sp. aff. *M. subbotinae* (Morozova)

Age and comments: Middle Eocene. Most likely zones P10-P11. Planktic foraminifers are rare and poorly preserved.

USGS Cenozoic loc. Mf 2634.—Creek bottom of tributary to San Emigdio Creek, about 600 ft (180 m) W., 800 ft (240 m) N. of SE. cor. sec. 31, T. 10 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Middle part of San Emigdio Formation. Collector: E. E. Brabb, 1975.

Planktic foraminifers:

?Subbotina sp. (one extremely poorly preserved specimen)

Age and comments: Middle(?) Eocene. Age determination based on adjacent samples. Foraminifers are rare. The benthic assemblage exhibits two types of preservation. Most individuals are poorly preserved and stained, and the chambers of many calcareous forms are filled with pyrite. A few individuals on the picked slide submitted with this sample exhibit much better preservation.

USGS Cenozoic loc. Mf 2635.—Creek bottom of tributary to San Emigdio Creek, about 1,000 ft (300 m) W., 2,400 ft (730 m) N. of SE. cor. sec. 31, T. 10 N., R. 21 W., Eagle Rest Peak 7½-minute quadrangle. Middle part of San Emigdio Formation. Collector: E. E. Brabb, 1975.

Planktic foraminifers:

Hantkenina dumblei Weinzierl and Applin
Pseudohastigerina sp. aff. *P. micra* (Cole)
P. sp. aff. *P. sharkriverensis* Berggren and Olsson
Globigerina eocaena Gumbel (s.l.)
?*Globorotaloides* sp.

Age and comments: Middle Eocene. Planktic foraminifers are rare and poorly preserved. Benthic foraminifers are common. As in the previous sample, two types of preservation are evident in the benthic foraminiferal assemblage. The majority of specimens are poorly preserved and stained and contain pyrite within chamber voids. A few individuals, however, exhibit much better preservation. The most probable explanation for the preservational differences seen in this sample and in Mf 2634 is laboratory contamination.

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