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By DAVID L. DURHAM *and* WARREN O. ADDICOTT

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A study of stratigraphy and paleontology of Pliocene marine strata in southern Salinas Valley, California

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PANCHO RICO FORMATION, SALINAS VALLEY, CALIFORNIA

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ABSTRACT

The Pancho Rico Formation of Pliocene age comprises sandy marine strata and interbedded finer grained rocks. It generally overlies the marine Monterey Shale of Miocene age and underlies the nonmarine Paso Robles Formation of Pliocene and Pleistocene(?) age in southern Monterey County, Calif. Locally it lies on the basement complex or on the Santa Margarita Formation of upper Miocene age. It crops out from north of King City southeastward for more than 50 miles to beyond the Nacimiento River and Vineyard Canyon. The Pancho Rico contains sandstone, mudstone, porcelaneous mudstone, porcelanite, diatomaceous mudstone, and conglomerate. Where the Pancho Rico overlies the Monterey Shale, its lower contact is at the base of the stratigraphically lowest sandstone unit above the typically finer grained Monterey. Where the Pancho Rico overlies the Santa Margarita Formation, its lower contact is at the top of the stratigraphically highest bed that contains *Ostrea titan*, a giant oyster characteristic of the Santa Margarita. The upper contact of the Pancho Rico is at the top of the stratigraphically highest lithologic unit that contains marine fossils. Both the upper and lower contacts are conformable and gradational. At some localities the unit probably intertongues with the Paso Robles Formation, and at others, with the Monterey Shale. The thickness of the Pancho Rico ranges from less than 20 feet to more than 1,000 feet.

The molluscan fauna of the Pancho Rico Formation consists principally of species not previously reported from the Salinas Valley area. Among the 141 larger invertebrate taxa recorded in this paper are many species indicative of Pliocene age, as that epoch is recognized in the Pacific Coast megafossil chronology. Faunal correlation is made with the type Jacalitos Formation—exposed near Coalinga—a biostratigraphic unit that has been traditionally regarded as the standard for the lower Pliocene of the Pacific Coast.

The molluscan fauna of the Pancho Rico implies a shallow-water marine environment considerably warmer than exists today at comparable latitudes and similar to that off the west coast of Baja California, Mexico. The wide distribution of several warm-water indicators in the early Pliocene of the Salinas Valley area and the absence of these indicators from contemporaneous strata to the north and northwest suggest that a Pliocene seaway connected the Salinas Valley area to the Santa Maria basin to the south. Local moderate-depth assemblages in exposures of the Pancho Rico Formation in the northwestern part of the area are of a northern, cool-water type and may indicate interchange with Pliocene faunas to the north through a northwest-trending marine trough.

INTRODUCTION

Sandy marine strata succeed mudstone, porcelanite, and chert beds of the Monterey Shale at most places in the Salinas Valley, southern Monterey County, Calif. These sandy strata, together with interspersed finer grained rocks, constitute the Pancho Rico Formation (Durham and Addicott, 1964). The following discussion of the lithologic character, stratigraphic relations, and thickness of the Pancho Rico Formation is by Durham, and is based on geologic mapping and related studies (Durham, 1963, 1964, 1965). Paleontologic determinations, correlation of strata, and discussion of molluscan paleoecology and paleogeography are by Addicott. The Pancho Rico was referred to as an unnamed formation of Pliocene age in three previous reports (Durham, 1963, 1964, 1965).

ACKNOWLEDGMENTS

E. J. Moore studied collections of fossil mollusks from 18 localities (see list of fossil locs., M902–M1067) in 1960 and 1961. These collections were rexamined and additional fossils were collected during preparation of this paper. Most of the echinoid identifications were made by J. Wyatt Durham. C. L. Rice made the initial collections from localities between San Lucas and Pancho Rico Creek in 1960. J. G. Vedder and C. A. Repenning collected the fossils from locality M982, northwest of Bradley, in 1960. A. Myra Keen provided access to the Stanford University collections and lent some specimens figured herein. J. H. Peck, Jr., arranged a loan of specimens from the Pliocene collections in the University of California Museum of Paleontology.

DEFINITION OF THE PANCHO RICO FORMATION

Reed (1925, p. 606) "grouped together as the Poncho Rico [1] formation" marine "diatomite * * * clastic shale, yellowish sandstone, and conglomerate beds" on the east side of the Salinas Valley. He presumably intended that the marine strata exposed along Pancho Rico Creek should be considered typical of the formation, although he later (Reed, 1933, p. 231) admitted that the unit had "never yet been adequately defined." To help overcome this need, we defined the Pancho Rico Formation as comprising the sandy marine strata and interbedded finer grained rocks that generally overlie the marine Monterey Shale and underlie the nonmarine Paso Robles Formation in the Salinas Valley area, southern Monterey County (Durham and Addicott, 1964). Locally the Pancho Rico overlies units other than the Monterey, as northeast of King City, where it lies nonconformably on the basement complex, and about 35 miles farther southeast near Vineyard Canyon, where it apparently lies conformably on the Santa Margarita Formation. Where the Pancho Rico overlies the Monterey, the contact is conformable and is at the base of the stratigraphically lowest sandstone unit above the typically finer grained Monterey. Sandstone beds occurring locally in the Monterey Shale in the subsurface near the Salinas River (Gribi, 1963, p. 19) are distinguished from lithologically similar beds in the Pancho Rico by their lower stratigraphic position and their proximity to the sloping surface of the basement complex. The contact of the Pancho Rico with the overlying nonmarine Paso Robles Formation is conformable and is placed at the top of the stratigraphically highest lithologic unit containing marine fossils. The Pancho Rico Formation, as so defined, includes beds in the lower part that are lithologically identical with those in the Monterey Shale, and beds in the upper part that are lithologically similar to those in the Paso Robles Formation. In this sense, both upper and lower contacts of the Pancho Rico are gradational and probably intertonguing.

Strata exposed along Pancho Rico Creek are considered typical of the Pancho Rico Formation for the purpose of definition, but designation of a particular sequence of beds as typical of the unit must be qualified by recognition of lateral variation in lithologic character, thickness, and stratigraphic relations.

Many geologists have assigned part or all of the Pancho Rico Formation, as here defined, to the Santa Margarita Formation (fig. 2). However, use of the name Santa Margarita in the Salinas Valley is considered appropriate only at the type area, near the town of Santa Margarita, and in adjacent areas where beds occur that are similar to typical Santa Margarita in both lithologic character and stratigraphic position (Durham and Addicott, 1964). At the type area, the Santa Margarita overlies the Monterey Shale and is light-colored massive coarse-grained arkosic sandstone that locally contains numerous large fossil oysters. The concept that the Santa Margarita is progressively younger northward from the type area is commonly accepted, mainly on the basis of including in the Santa Margarita at least some beds that here are considered part of the Pancho Rico. The concept of a northward time transgression by the Santa Margarita is rejected in favor of the idea that in the southern part of the Salinas Valley the Santa Margarita overlies the Monterey but that farther north it intertongues with the uppermost part of that formation (Durham and Addicott, 1964). Accordingly, the Santa Margarita in southern Monterey County is considered to be a lenticular sandstone unit at or near the top of the Monterey, whereas the Pancho Rico Formation overlies both.

AREAL DISTRIBUTION

The Pancho Rico Formation crops out on the east side of the Salinas Valley from north of King City southeastward for about 50 miles to beyond Vineyard Canyon. It crops out at places along the west side of the valley from north of the Arroyo Seco southeastward for about 50 miles to beyond the Nacimiento River. It also crops out farther west, in the San Antonio River Valley, north and northwest of Jolon and south of Lockwood (fig. 1).

PREVIOUS NOMENCLATURE

Names previously applied to strata of late Miocene and Pliocene age in the Salinas Valley and the nomenclature used in this paper are shown in figure 2. Intertonguing relations are omitted from the diagram, and correlation of unit boundaries from column to column may be inexact. Figure 2 illustrates the divergence of opinion among previous investigators as to classification of strata here assigned to the Pancho Rico Formation. However, as indicated in the following discussion, all previous investigators have recognized the generally sandy nature of the sequence of strata that succeeds the Monterey Shale.

[1] Authors' note: Maps available to Reed—for example, the 1915 edition of the Priest Valley 30-minute quadrangle—have the "Poncho Rico" Creek joining the Salinas River at San Ardo. Later maps, including the 1927 reprint of the Priest Valley 30-minute quadrangle, have the differently spelled name "Pancho Rico" for the same stream. Gudde (1949, p. 269) listed the name "Poncho Rico," but stated that it "probably commemorates Francisco ('Pancho') Rico, grantee of San Lorenzo grant, November 16, 1842." The U.S. Board on Geographic Names (1961, p. 13) favored the spelling "Pancho Rico" for the stream, and this is obviously the proper form for the name of the formation. However, in this discussion of the work of others, the spelling employed by each investigator is used where reference is made to his work.

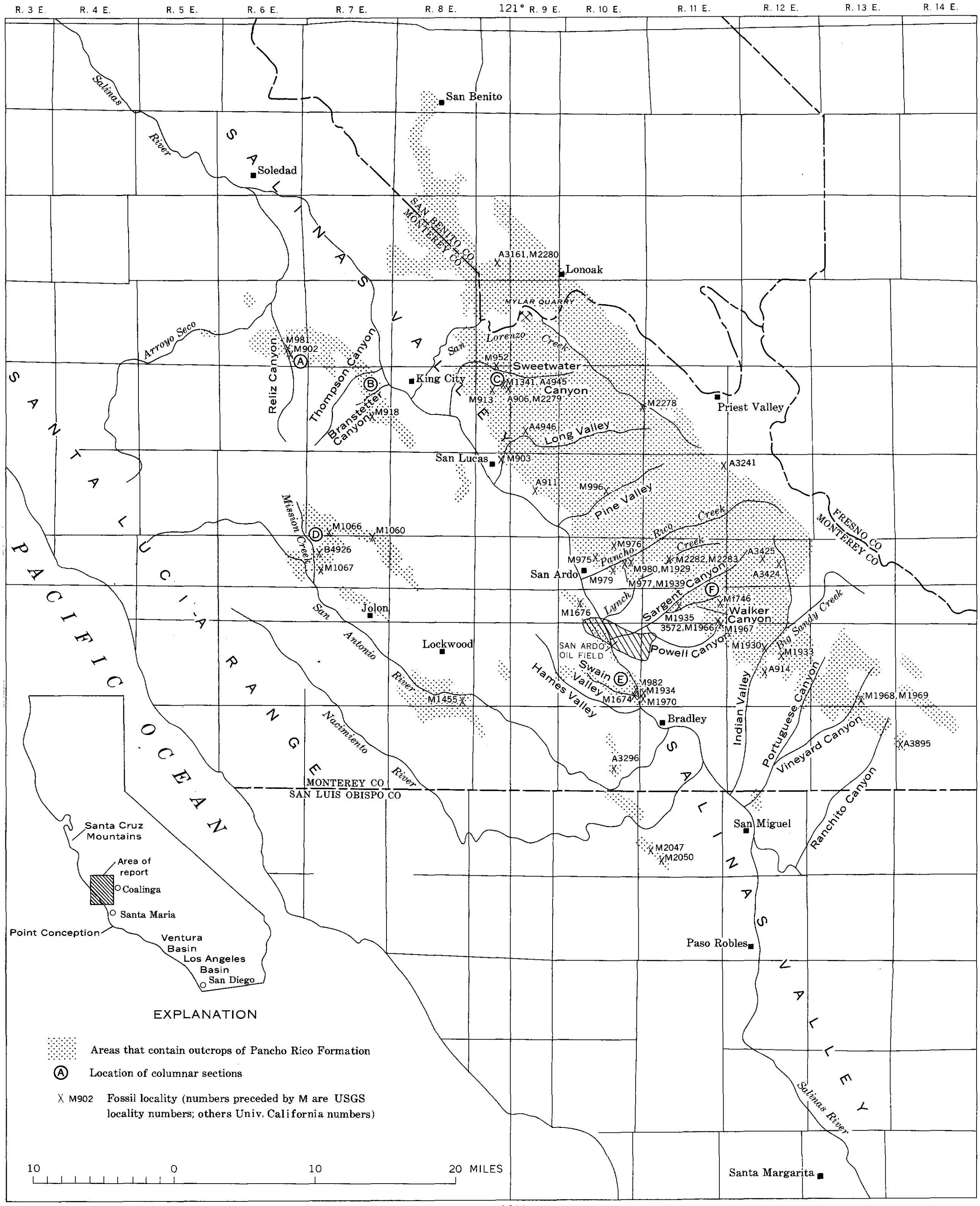

FIGURE 1.—Fossil and columnar-section localities and Pancho Rico Formation outcrop areas.

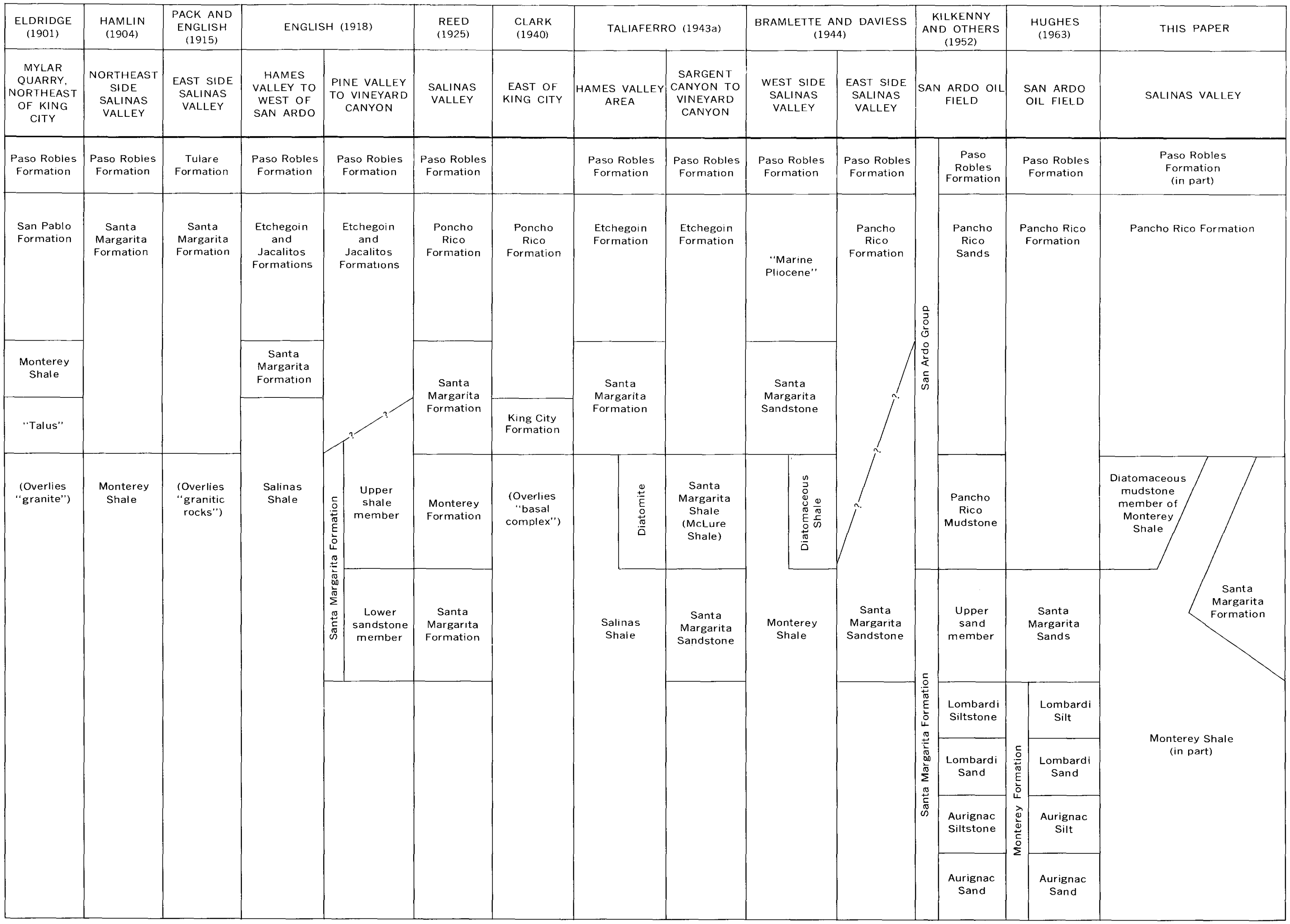

FIGURE 2.—Stratigraphic nomenclature of strata of late Miocene and Pliocene age in the southern Salinas Valley area.

EAST SIDE OF SALINAS VALLEY

Marine strata exposed east of King City have a complex nomenclatural history but are assigned to the Pancho Rico Formation in this report. Eldridge (1901, p. 408–409) listed, in ascending order, the following three units (here all assigned to the Pancho Rico) above the basement complex near Mylar Quarry, northeast of King City:

1. A basal unit of bituminous sandstone and coarser debris that he considered to be talus material associated with an old topographic high on the surface of the basement complex.
2. An intermediate unit 400–500 feet thick that he assigned to the "softer, chalky variety" of "Monterey Shales."
3. An upper unit about 150 feet thick that he regarded as "shales of the San Pablo" Formation.

Hamlin (1904, p. 17) also considered "soft chalky shale" that overlies bituminous beds at Mylar Quarry as "probably a portion of the Monterey Shale." He (Hamlin, 1904, p. 15) considered the succeeding beds to be in the Santa Margarita Formation, which he represented as "sandstone at the base, grading upward into soft chalk-like shale and clay shale." Waring (1914, p. 422) also assigned fossiliferous beds east of King City to the Santa Margarita. Pack and English (1915, p. 133) designated the entire sequence of marine strata exposed east of King City as Santa Margarita. They noted that beds near Lonoak—equivalent to those called Monterey Shale by Eldridge—are "largely of diatomaceous and clay shale," including "relatively little interstratified sand," and form a unit that is locally sandy, grades laterally into sandstone, and contains fossils which indicate that it should be grouped with the overlying more sandy beds.

Nomland (1917a, p. 207) recorded fossils that he considered "indicative of middle Etchegoin" in "light-colored shale and volcanic ash" near Lonoak. Clark (1935, p. 1050) once believed that all the marine strata east of King City belonged to the Santa Margarita Formation. Later he (Clark, 1940; 1943, p. 190) gave the name King City Formation to sandy marine beds that overlie the basement complex and assigned the succeeding marine beds to the Poncho Rico Formation. Bramlette and Daviess (1944) speculated that conglomeratic sandstone overlying the basement complex east of King City is Clark's King City Formation, but they concluded that more likely his "formation" simply represents a faunal division of the Pancho Rico. They also indicated that along the north side of San Lorenzo Creek, diatomaceous mudstone beds of the Pancho Rico Formation grade eastward into porcelaneous mudstone. Kilkenny (1948, p. 2260) considered the bituminous sandstone beds at Mylar Quarry to be in the Santa Margarita Formation. Turner (1963, p. 37), however, reported that sandstone beds overlying the basement complex along San Lorenzo Creek, and superadjacent shale, siltstone, and sandstone beds, belong to the Pancho Rico Formation.

The Pancho Rico Formation farther south on the east side of the Salinas Valley has an equally confused history of nomenclature. Strata discussed here are assigned to the Pancho Rico unless otherwise noted. Waring (1914, p. 422, 423) designated sandy marine strata exposed near Vineyard Canyon, Indian Valley, and Big Sandy Creek as Jacalitos and Etchegoin Formations, names originally applied to units in the Coalinga district of the San Joaquin Valley. Pack and English (1915, pl. 5) mapped rocks exposed along Pancho Rico Creek as "diatomaceous and clay shale, sandy shale, sandstone, and shale-pebble beds, regarded as equivalent to Santa Margarita Formation." Nomland (1917a, p. 215) noted that beds of "lower Etchegoin" age crop out in Vineyard Canyon and Indian Valley. English (1918, p. 230–232) pointed out that sandy beds in this area "corresponding to the Jacalitos and Etchegoin Formations" range considerably in thickness, lithologic character, and faunal content. He also mentioned that these beds conformably overlie a unit (here considered a diatomaceous mudstone member of the Monterey Shale) that he called a shale member of the Santa Margarita Formation, and are in turn overlain conformably by the Paso Robles Formation. Reed (1925, p. 591, 606) casually introduced the name "Poncho Rico Formation" for beds in the eastern part of the Salinas Valley area, obviously including strata exposed along Pancho Rico Creek. Taliaferro (1943a, fig. 189) mapped as Etchegoin Formation sandy marine beds that crop out between Sargent and Vineyard Canyons. Bramlette and Daviess (1944) listed the following three lithologic units each about 200 feet thick, exposed along Pancho Rico Creek: (a) A lower unit of sandstone, exposed in the headwaters of the creek, (b) an intermediate unit of "somewhat siliceous" mudstone, and (c) an upper unit of "generally rusty-orange" sandstone. They pointed out that the sandstone and mudstone are commonly interbedded, and that the proportion of sandstone to mudstone varies laterally. They considered the "light-colored diatomaceous mudstone and interbedded sandstone" exposed between Pancho Rico and San Lorenzo Creeks to the north to be typical of the Pancho Rico Formation. Baldwin (1950, p. 1988) assigned "diatomaceous and silty mudstones" in the San Ardo oil-field area to the Pancho Rico Formation (probably equivalent to beds assigned to the diatomaceous mudstone member of the Monterey Shale).

These were described as occurring above a local unconformity and underlying "ochre-brown, dirty and pebbly fossiliferrous sands which are locally called Etchegoin." He also said that "Etchegoin sands * * * finger out in diatomaceous Pancho Rico shale."

WEST SIDE OF SALINAS VALLEY

Most of the sandy strata exposed between King City and the Arroyo Seco were regarded as the Santa Margarita Formation by previous investigators, but those discussed below are assigned to the Pancho Rico Formation unless otherwise noted. Hamlin (1904, p. 18) assigned bituminous sandstone beds exposed northwest of King City, near the mouth of Thompson Canyon, to the basal part of the Santa Margarita. Reed (1925, p. 593) assigned these sandy strata to the Santa Margarita, together with sandy beds that overlie the Monterey Shale in the Arroyo Seco and in Reliz Canyon. Clark (1929, p. 25; 1930, p. 767) recognized that beds equivalent to the "Jacalitos horizon" occur in the Arroyo Seco area. Kleinpell (1930, p. 30) stated that "a series of gritty, white, fine, calcareous sandstones" overlying the Monterey Shale in Reliz Canyon are "generally classified as Santa Margarita because of the apparently similar field relations to the south at the 'type Santa Margarita.'" He later (Kleinpell, 1938, p. 7) described the contact of the Monterey with the overlying sandstone unit in Reliz Canyon as "typicaly gradational." Nickell (1931) relegated beds that overlie the Monterey Shale near the Arroyo Seco to the Santa Margarita Sandstone. Clark (1930, p. 781–782), in a discussion of the area west and northwest of King City, claimed that "unconformably on the Salinas [Monterey] shales are several hundred feet of sandstones and shales referable to the Santa Margarita horizon (upper Miocene) and unconformably on the latter beds is * * * the continental Paso Robles formation. * * * between the Paso Robles and the Santa Margarita formations are several hundred feet of sandstones containing a lower Pliocene fauna. * * * these marine Pliocene deposits are cut out as the result of the overlapping of the Paso Robles." Taliaferro (1943b, p. 140) described as "gradational and conformable" the contact between the Monterey Shale and overlying sandy beds in Reliz Canyon that he designated Santa Margarita Formation. Schombel (1943, p. 467) listed a sequence of five stratigraphic units (the second, third, and fourth are here assigned to the Pancho Rico) in the Soledad 15-minute quadrangle, including the area along the Arroyo Seco: (a) Monterey Shale, (b) Santa Margarita, Miocene sandstone, (c) Poncho Rico, Pliocene? sandstone, (d) Jacalitos, Pliocene sandstone and shale, and (e) Paso Robles, Pliocene-Pleistocene continental beds. Bramlette and Daviess (1944) believed that the sandy beds overlying the Monterey near the Arroyo Seco belong to the Santa Margarita Sandstone, but they recognized that the beds are probably of early Pliocene age. They also stated that bituminous sandstone beds northwest of King City form a "transitional zone from the Monterey siliceous rocks to the overlying Santa Margarita sandstone." Kilkenny (1948, p. 2260) referred these beds to the Santa Margarita.

Many investigators have studied the Pancho Rico Formation exposed west of the Salinas River between San Ardo and the San Antonio River, chiefly because the unit in that area contains bituminous sandstone beds. Strata discussed below are assigned to the Pancho Rico, unless otherwise noted. Eldridge (1901, p. 410) placed sandy marine beds exposed west of San Ardo in the "middle Neocene [San Pablo] Series." He described the stratigraphic sequence as shale at the base, "overlain by 125 feet of sandstone varyingly impregnated with bitumen, * * * followed by about 400 feet of shale, which is in turn overlain by a succession of shale and [bituminous] sandstone, a half dozen beds each." Hamlin (1904, p. 16) placed the bituminous beds exposed west of San Ardo in the Monterey Shale but pointed out that they differ from the more typical Monterey: "some beds are soft and chalk-like, others contain an unusual percentage of fine sand and mica flakes, interstratified with beds of quartzose sandstone." In addition, he indicated that "the upper 770 feet of this formation consists of alternating beds of chalk-like shale and sandstone." Waring (1914, p. 434) also assigned the bituminous sandstone beds west of San Ardo to the Santa Margarita Formation. English (1918, p. 229) stated that the basal beds in the unit west of San Ardo that he considered Santa Margarita Formation are "shaly and are overlain by the typical sandstone, followed by more shale and interbedded sandstone." Kew (1920, p. 104) considered echinoid-bearing beds at the mouth of Swain Valley to be part of the Santa Margarita Formation. Reed (1925, p. 593, 594) assigned sandstone beds exposed in the bank of the Salinas River, 6¼ miles south of San Ardo, to the Santa Margarita Formation. Taliaferro (1943b, p. 140) stated that the contact between the Salinas (Monterey) Shale and the overlying Santa Margarita Formation in the area north of Bradley and west of the Salinas River is "gradational and conformable." Bramlette and Daviess (1944) regarded bituminous sandstone beds southwest of San Ardo as part of a "transitional zone from the Monterey siliceous rocks to the overlying Santa Margarita sandstone." Mandra (1963, p. 104) favored the name Pancho Rico for sandy beds exposed southwest of Hames Valley.

Bituminous sandstone beds that crop out near the San Antonio River, about 6 miles southwest of Bradley, are probably part of the Paso Robles Formation. Eldridge (1901, p. 411) considered them "perhaps of a formation younger than the Monterey Series." Fairbanks (1900, p. 144) referred them to the base of the San Pablo Formation. Hamlin (1904, p. 19) described them as the basal beds of the Santa Margarita Formation, and Waring (1914, p. 435) also placed them in the Santa Margarita Formation. English (1918, p. 240) called them Paso Robles Formation. Taliaferro (1943a, p. 460) assigned them to "the base of the Etchegoin where it rests unconformably on organic Salinas [Monterey] Shale." Bramlette and Daviess (1944) termed these beds "basal Pliocene strata" and described them as lying unconformably on the Monterey Shale. Kilkenny (1948, p. 2260) placed them "at the base of the Poncho Rico."

The Pancho Rico Formation farther west in the San Antonio River valley has received scant attention. Reed (1925, p. 593) assigned the sandy beds overlying the Monterey Shale to the Santa Margarita Formation. These beds are now assigned to the Pancho Rico.

LITHOLOGIC CHARACTER

The Pancho Rico Formation contains fine- to coarse-grained sandstone, mudstone, porcelaneous mudstone, porcelanite, diatomaceous mudstone, and conglomerate. The abundance of sandstone in the Pancho Rico distinguishes it from the Monterey Shale, which contains lenticular sandstone beds only. Diatomaceous mudstone is more common in the Pancho Rico on the east side of the Salinas Valley than on the west side. Porcelaneous rocks are common on the west side but are scarce on the east side. Larger invertebrate fossils with shell material preserved are most abundant in beds of medium- and coarse-grained sandstone, but molds and casts of fossils occur in both coarse- and fine-grained rocks. Figure 3 shows the generalized lithologic character of the Pancho Rico at six representative localities.

SANDSTONE

The sandstone most characteristic of the Pancho Rico Formation is fine or very fine grained, massive, arkosic, noncalcareous, and yellowish gray or very pale orange (fig. 4). It consists of angular grains in a matrix of silt and clay, and in places it contains a few scattered medium or coarse sand grains. Fine-grained and very fine grained sandstone on the east side of the Salinas Valley is generally friable, but ordinarily on the west side it is well indurated.

Medium- and coarse-grained sandstone is interbedded with finer grained rocks in the upper part of the Pancho Rico Formation (fig. 5). It forms massive beds as much as 10 feet thick and is generally arkosic, poorly sorted, yellowish gray, dusky yellow, or yellowish brown, and ranges from friable to well indurated. Some of it is calcareous; most of it has a matrix of very fine grained sand, silt, and clay. Fossil mollusks and echinoids are abundant in some beds (fig. 6).

Sandstone at the base of the Pancho Rico Formation east of King City in Sweetwater Canyon (fig. 3, col. C), where the unit lies on the basement complex, is medium grained, massive, arkosic, noncalcareous, friable, and yellowish gray. The grains are angular to subrounded and range from 0.15 to 1 mm in length, although most are about 0.3 mm long.

MUDSTONE

Mudstone in the Pancho Rico Formation on the east side of the Salinas Valley, and locally in the lower part of the Formation on the west side of the valley, is typically massive, noncalcareous, and white or yellowish gray, and consists of a few scattered very fine sand grains and mica flakes in a matrix of silt and clay (fig. 7). Diatom frustules are abundant in the rock, and molds of pelecypods and fish scales are locally common. Mudstone in the Pancho Rico on the west side of the valley ordinarily resembles that in the underlying Monterey Shale. It is generally massive, noncalcareous, yellowish gray or very pale orange, and well indurated. It is commonly porcelaneous, and in some places it grades into porcelanite.

CONGLOMERATE

Distinctive conglomerate that occurs in the upper part of the Pancho Rico Formation contains pebbles, granules, molds of small mollusks, fish teeth and bones, echinoid spines, and other organic debris scattered in a matrix of mudstone or very fine grained sandstone. The larger pebbles are generally porcelanite or porcelaneous mudstone, presumably derived from the Monterey Shale; some smaller clasts are quartz or basement rock. The beds are 1–2 feet thick and are pale orange or dark yellowish orange, in marked contrast to the lighter colored enclosing rock. The pebbles, granules, and organic remains are commonly coated or discolored by grayish-brown phosphatic material.

Pebble and cobble conglomerate beds, generally similar to those in the overlying Paso Robles Formation, occur in the upper part of the Pancho Rico Formation on the east side of the Salinas Valley, especially south of Pine Valley. These beds contain fossil marine mollusks and echinoids in some places.

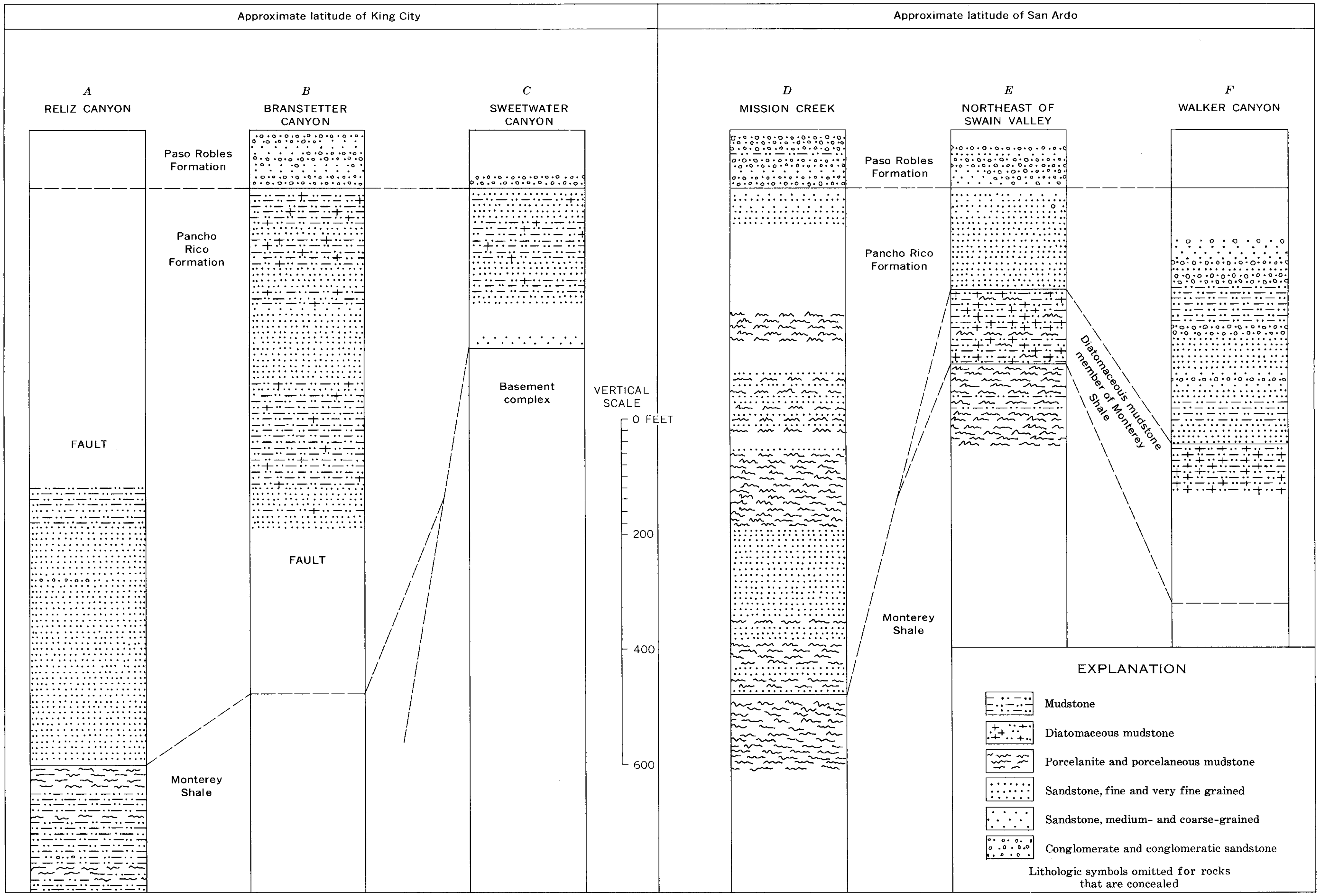

Figure 3.—Representative columnar sections of the Pancho Rico Formation.

FIGURE 4.—Massive very fine grained sandstone containing molds and casts of clam shells exposed in roadcut about 5 miles northwest of Jolon. Nearly all the visible surfaces are joints.

FIGURE. 5.—Medium- and coarse-grained sandstone, locally pebbly, and interbedded mudstone at fossil locality M1935, east of San Ardo oil field in Walker Canyon. The ledge-forming bed at the top of the outcrop contains abundant fossil echinoids.

FIGURE 6.—Sandstone containing *Balanus gregarius* (Conrad) and *Lyropecten terminus* (Arnold) at fossil locality M913, 5 miles north of San Lucas. The fossiliferous bed is about 3 feet thick. Fossils are scarce in adjacent beds.

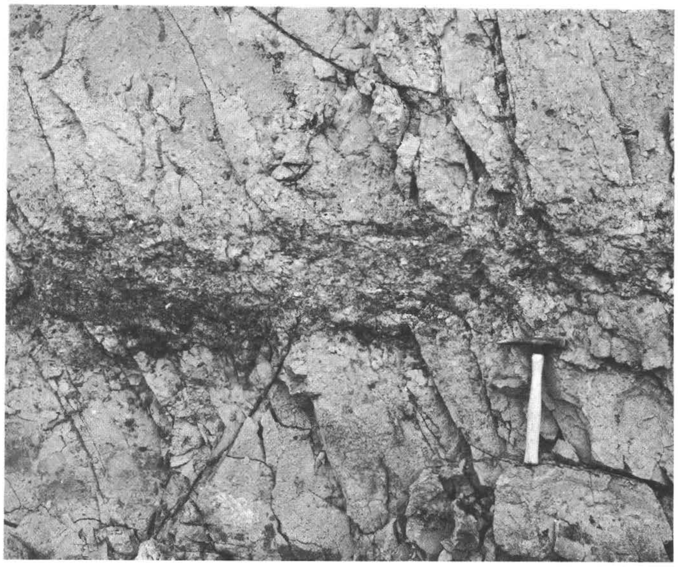

FIGURE 7.—Massive diatomaceous mudstone at fossil locality M977, on south bank of Pancho Rico Creek. Dark band just above pick is sandy fossiliferous layer that grades into the adjacent mudstone. The beds are nearly flat.

STRATIGRAPHIC RELATIONS

East of King City the Pancho Rico Formation lies nonconformably on the basement complex. Southeastward, toward Pancho Rico Creek, the base is concealed. In Sargent Canyon, and from there southeastward to Indian Valley, the Pancho Rico overlies a diatomaceous mudstone unit that is correlated, on the basis of lithologic character and stratigraphic position, with the diatomaceous mudstone member of the Monterey Shale, which is exposed west of the Salinas River around Hames Valley (fig. 3, col. E, F). The lower contact of the Pancho Rico from Sargent Canyon to Indian Valley is at the base of the stratigraphically lowest sandstone unit above the diatomaceous mudstone member of the Monterey. The contact is gradational, for some diatomaceous mudstone beds occur above the sandstone beds that mark the base of the Pancho Rico; and it is intertonguing, for the base is not at the same stratigraphic horizon throughout the area. In both Indian Valley and nearby valleys, and for a short distance southeast of that vicinity, the diatomaceous mudstone member either pinches out or grades laterally into porcelaneous rocks, and the Pancho Rico lies conformably on porcelaneous rocks assigned to the Monterey Shale. The lower contact of the Pancho Rico in this area is at the base of the stratigraphically lowest sandstone beds above the finer grained rocks typical of the Monterey. Farther southeastward, in Vineyard Canyon, the Pancho Rico lies on the Santa Margarita Formation, apparently conformably. In this area the lower part of the Pancho Rico is massive friable noncalcareous fine-grained grayish-yellow or yellowish-gray sandstone that contains scattered coarser grains and locally abundant fossil mollusks. Some beds of porcelaneous rock occur stratigraphically above the basal sandstone. The underlying Santa Margarita Formation in Vineyard Canyon is sandstone that is massive, friable, noncalcareous, well sorted, fine grained, and grayish orange, and locally contains numerous large fossil oysters. The contact is at the top of the stratigraphically-highest giant oyster-bearing bed.

On the west side of the Salinas Valley, the Pancho Rico Formation lies conformably on the Monterey Shale. The contact is gradational—rocks like those in the Monterey also occur in the Pancho Rico—and it is probably not at the same stratigraphic horizon throughout the area owing to lateral change in the lithologic character of the sandstone beds that define the base of the Pancho Rico. West of King City and in the San Antonio River Valley, the lower contact of the Pancho Rico Formation is at the base of the stratigraphically lowest unit of fine-grained sandstone above the Monterey Shale (fig. 3, col. A, D). Northeast of Hames Valley (fig. 3, col. E) the lower contact of the Pancho Rico is at the base of the stratigraphically lowest sandstone beds above the diatomaceous mudstone member of the Monterey, but mudstone identical with that in the Monterey locally occurs above the basal sandstone beds in the Pancho Rico. Near the Nacimiento River the lower contact of the Pancho Rico is at the base of the stratigraphically lowest marine sandstone beds above porcelaneous, cherty, or diatomaceous rocks of the Monterey.

The Pancho Rico underlies the nonmarine Paso Robles Formation with apparent conformity. The upper contact of the Pancho Rico is placed at the top of the stratigraphically highest marine fossil-bearing beds. East and west of King City, the contact coincides with the base of the stratigraphically lowest prominent conglomerate bed (fig. 3, col. B, C), which generally consists of pebbles of porcelaneous rock and chert in a matrix of sand and opaline cement. This conglomerate and the overlying strata are unfossiliferous. Farther south, conglomerate occurs in the Pancho Rico as well as in the Paso Robles. The upper contact of the Pancho Rico may not be at the same stratigraphic horizon throughout the area because of possible intertonguing of marine and nonmarine beds.

THICKNESS

The Pancho Rico Formation is about 275 feet thick in Sweetwater Canyon, where it lies on the basement complex (fig. 3, col. C), and is more than 500 feet thick 10 miles farther southeast, near Pine Valley, where the base is concealed. It is 450–550 feet thick 10 miles southeast of Pine Valley, near Sargent Canyon, where both the base and the top are exposed (fig. 3, col. F), and it is about 650 feet thick near Indian Valley. Structure sections between Sargent Canyon and Indian Valley suggest that thickening of the Pancho Rico between the two areas is due to intertonguing of the unit with the underlying diatomaceous mudstone member of the Monterey Shale. The Pancho Rico is about 850 feet thick west of Reliz Canyon and may be more than 1,000 feet thick between Reliz Canyon and the Salinas River. It is about 850 feet thick at the mouth of Thompson Canyon. The Pancho Rico is nearly 900 feet thick north of Jolon (fig. 3, col. D), but it is only about 200 feet thick near the San Antonio River south of Lockwood and is even thinner nearby. The unit is 100–200 feet thick northeast of Hames Valley (fig. 3, col. E) but is only about 20 feet thick at places along the Nacimiento River. Variation in the thickness of the Pancho Rico Formation is partly due to intertonguing caused by lack of coevality of deposition and is probably partly related to unlike sedimentation rates.

FAUNAL COMPOSITION

The fauna of the Pancho Rico Formation consists of 141 larger marine invertebrate taxa (table 1), principally mollusks, but includes locally abundant echinoids, barnacles, and brachiopods. As it is now known, the Pancho Rico fauna is larger than any other invertebrate fauna from Pliocene formations in central California, but it is smaller than faunas of this age from the Santa Maria basin, Ventura basin, Los Angeles basin and, presumably, the San Diego area, all in southern California. Although the number of taxa might be increased by additional collecting, the taxa enumerated in table 1 are considered representative of at least the more common faunal elements.

In earlier reports, the only invertebrate class in the Pancho Rico Formation that received more than passing attention was the Echinoidea (Kew, 1920; Grant and Hertlein, 1938; Hall, 1962). The large representation of Pliocene mollusks in the Pancho Rico was not apparent from the few species listed by Arnold (1906, p. 64, 67), Woodring and Bramlette (1950, p. 102, 106), Hertlein (in Mandra, 1963, p. 104), and Taggart and Kraetsch (1963). Most mollusks listed in table 1 are named species that have not been previously reported from the Salinas Valley area. About 10 percent of the mollusks are undescribed.

Taxa other than muricids, ostreids, pectinids, barnacles, brachiopods, and echinoids were, in large part, identified from casts made from external molds of the original shells. The generally poor preservation of shell material is probably the reason that this fauna has not been extensively studied. Approximately one-fourth of the larger invertebrates now known from the Pancho Rico Formation are figured in plates 1–5. Among the figured specimens are a majority of the taxa regarded as diagnostic of Pliocene age as well as other characteristic but longer ranging species.

Clypeasteroid echinoids are represented by abundant *Astrodapsis* locally and by *Dendraster* at several localities between Sweetwater Canyon and Walker Canyon. Brachiopods of the genus *Terebratalia* are very abundant in an area near the mouth of Reliz Canyon. Barnacles of the genus *Balanus* are widespread and abundant. Specimens of *B. gregarius* attain a length of at least 198 mm (Pilsbry, 1916, p. 127). In some areas they form biostromal units composed almost exclusively of articulated barnacle plates (fig. 6). Opercular valves of *B. gregarius*, abundant at many localities, are illustrated on plates 1 and 2.

The invertebrate fauna of the Pancho Rico Formation is largest in the area between King City and Bradley, east of the Salinas River. Characteristic shallow-water taxa in collections from that area include *Astrodapsis* spp., *Forreria belcheri* (Hinds), *Calicantharus kettlemanensis* (Arnold), *Crucibulum* (*Dispotaea*) n. sp., *Ostrea atwoodi* Gabb, *Lyropecten terminus* (Arnold), *Protothaca tenerrima* (Carpenter), *Florimetis biangulata* (Carpenter), and *Balanus gregarius* (Conrad). A moderate-depth [2] assemblage consisting of several species not found elsewhere in the Pancho Rico Formation occurs in the upper San Antonio River valley and in Reliz Canyon. Among these distinctive species are *Terebratalia arnoldi* Hertlein and Grant, *Turcica caffea brevis* Stewart, *Crepidula* n. sp., an apparently undescribed species of *Chlamys*, and *Macoma brota* Dall.

[2] Moderate depth is here regarded as greater than about 10–15 fathoms and less than 100 fathoms. It includes part of the inner sublittoral zone (low tide to 50 fathoms), and all of the outher sublittoral zone (50–100 fathoms) as defined by Hedgpeth (1957, p. 18).

Foraminifera from a few localities in the Pancho Rico Formation have been reported by Cushman and Grant (1927, p. 75), Hughes (1963, p. 95), and Gribi (in Taggart and Kraetsch, 1963). Taxa listed by these investigators include *Elphidium hughesi* Cushman and Grant, *E. hannai* Cushman and Grant, *Buliminella elegantissima* (d' Orbigny), *Eponides* cf. *E. peruvianus* (d' Orbigny), and *E. exigua* (Brady). A small assemblage collected during this investigation and identified by Patsy J. Smith (this report, p. A17) contains a few additional species.

AGE AND CORRELATION

Identifiable fossils have not been recovered from porcelaneous and diatomaceous rocks of the Monterey Shale that underlie basal sandstone beds of the Pancho Rico Formation. However, megafossils indicative of a late Miocene age occur in arenaceous strata mapped as Santa Margarita Sandstone by Taliaferro (1943a, p. 457) between Portuguese and Ranchito Canyons, northeast of San Miguel. In Vineyard Canyon the Santa Margarita Formation underliés fossiliferous Pancho Rico Formation (mapped as Etchegoin Formation by Taliaferro, 1943a). Collections from a giant-oyster biostrome at the top of the Santa Margarita in Vineyard Canyon (USGS loc. M1968 [12 ft. stratigraphically below M1969]) include the following taxa which suggest a Miocene age:

Mytilus sp.
Ostrea titan Conrad
Ostrea cf. *O. vespertina* Conrad
Lyropecten cf. *L. estrellanus* (Conrad)
Chione cf. *C. temblorensis* (Anderson)
Cryptomya? sp. (internal molds)
Balanus gregarius (Conrad)

Two other species that are reported from near Vineyard Canyon, *Forreria perelegans* (Nomland) (Nomland, 1917b, p. 312) and *Aequipecten discus* (Conrad) (Taggart and Kraetsch, 1963), are known only from strata of Miocene age.

A foraminiferal assemblage from the middle fork of Vineyard Canyon, nearly 2 miles northwest of locality M1968, identified as upper Delmontian (by Standard Oil Co., in Taggart and Kraetsch, 1963, loc. 2259), includes the following species:

Nonion montereyanum Cushman and Galliher
Elphidium hughesi Cushman and Grant
Eponides exigua (Brady)
Nonionella miocenica Cushman
Nonionella cushmani (Cushman)
Nonionella cf. *N. belridgensis* (Barbat and Johnson)

This locality seems to be stratigraphically lower in Taliaferro's Santa Margarita Sandstone (1943a, p. 457) than is megafossil locality M1968.

TABLE 1.—*Larger invertebrates from the Pancho Rico Formation*

[Identifications by W. O. Addicott unless otherwise noted. ×, present as identified; ?, doubtful identification; cf., similar form, specimen(s) incomplete or too poorly preserved for definite identification; aff., comparable but apparently different form; sp., species not determinable; ?sp., genus questionably identified]

	West of Salinas River												East of Salinas River																								
	M902	M981	M918	M1060	M1066	M1067	M1455	M982	M1676	A3296	M2047	M2050	M2280	M952	A906	M913	A4946	M903	M2278	A3241	M996	M2282	M2283	M975	M977	M979	M980	A3425	M1935	M1934	M1970	M1930	M1966	M1967	A914	M1969	A3895
ECHINOIDS:[1]																																					
Astrodapsis arnoldi Pack (pl. 1, fig. 9)																				cf.		×					×[2]	sp.[3]									
crassus Kew																								×[4]													
aff. *A. cuyamanus* Kew								×[5]																													
fernandoensis Pack								×										cf.																			
salinasensis Richards								×								×[6]																					
spatiosus Kew																		cf.											×				cf.				
sp. [*A. whitneyi*-*A. jacalitosensis* group]																		?											×								
Dendraster sp															×			×				×							×								
BRACHIOPODS:																																					
Discinisca cumingi Broderip	sp.																																			×	
Terebratalia arnoldi Hertlein and Grant (pl. 2, figs. 3, 4)	×	×																																			
GASTROPODS:																																					
Diodora n. sp.? aff. *D. inaequalis* (Sowerby) (pl. 5, fig. 5)	?sp.																						×		×												
Calliostoma? aff. *C. cammani* Dall																											×[2]										
Calliostoma coalingense Arnold (pl. 5, figs. 6, 7)								sp.	cf.									×								×	sp.					×		×			
etchegoinense Nomland																			×		cf.							×				×					
cf. *C. ligatum* (Gould)																														×							
Margarites cf. *M. condoni* Dall												×																									
aff. *M. pupillus* (Gould)																					?sp.				×[7]				×								
Turcica cf. *T. caffea brevis* Stewart	×	×																																			
Epitonium (*Nitidiscala*) cf. *E. eelense* Durham																		×																			
Epitonium (*Cirsotrema*?) sp									×																												
Turritella cooperi Carpenter (pl. 5, fig. 9)							×			×		×						×				×	×		×		×[2]				×						×
cooperi forma *nova* Nomland (pl. 4, fig. 3)									×																												
gonostoma hemphilli Applin, in Merriam (pl. 5, figs. 18, 19)								×		×		×												×												×	
vanvlecki Arnold (pl. 5, figs. 11, 14)																								×	×[7]		×	×	×	×		×					
n. sp. [*T. broderipiana* stock]	×																		×						?		×[2]			×							
Bittium cf. *B. attenuatum multifilosum* Bartsch							sp.												sp.								sp.			×							
Bittium casmaliense Bartsch (pl. 5, fig. 10)			cf.					×				?		cf.													×		×	sp.							
casmaliense Bartsch. Strongly sculptured form (pl. 5, fig. 15)								×																					?					×			
Calyptraea filosa (Gabb)	×	sp.	sp.			×	sp.	sp.	sp.	sp.	sp.	×						sp.	×		×				×		sp.[2]			×		×	×				
Crepidula adunca Sowerby							×					×							cf.				cf.	sp.							sp.						
nummaria Gould (pl. 3, fig. 4)																							×				×[2]		cf.								
cf. *C. onyx* Sowerby																									×[7]		×[2]		×	×							
cf. *C. princeps* Conrad									×																		sp.					?					
n. sp. aff. *C. aculeata* (Gmelin)	×	×																																			
Crucibulum (*Dispotaea*) n. sp																					×			×	×		×[2]		×			×					
Neverita recluziana (Deshayes)				?sp.			sp.		sp.										×	×			×		×[7]		×	×[3]	cf.	×							sp.
Polinices lewisi (Gould)												×											sp.														
Sinum scopulosum (Conrad)																							?sp.			×			cf.								
Ceratostoma foliatum (Gmelin) (pl. 2, figs. 6, 8)	?																	×																			
nuttalli (Conrad)?																		×																			
Forreria belcheri (Hinds) (pl. 4, figs. 5, 8; pl. 5, fig. 22)											sp.					×[6]		?			?sp.		×		×	sp.	×[2]		×	?	×						
cf. *F. coalingensis* (Arnold) (pl. 5, fig. 13)															×			×				×						×									
Jaton (*Shaskyus*) *festivus* (Hinds)		cf.																										×[3]									
Ocenebra cierboensis (Grant and Eaton)																		×																			
cf. *O. tenuisculpta* (Carpenter)	sp.															×					sp.				sp.		?sp.										
cf. *O. tethys* (Nomland)																									?				×	×							

n. sp. A																		X																			
Acanthina n. sp.																		X																			
Thais etchegoinensis Arnold. Ribbed form [8] (pl. 3, fig. 6)																																					
collomi Carson (pl. 4, figs. 6, 7)																	X	X																			
Calicantharus cf. *C. fortis* (Carpenter) (pl. 5, fig. 8)			X					sp.				X													X		X [2]	X				?sp.	?sp.				
cf. *C. fortis* forma *angulata* (Arnold) (pl. 5, fig. 3)																											X		X								
cf. *C. humerosus* (Gabb)																													X				?				
kettlemanensis (Arnold) (pl. 5, fig. 2)									X	X			X							?	cf.				X		X [2]		X		?						
kettlemanensis (Arnold). Weakly noded form (pl. 5, fig. 4)																											X [2]										
Kelletia cf. *K. kelleti* (Forbes) (pl. 3, fig. 5)																														X							
Mitrella gausapata (Gould)																			sp.								?sp.		sp.			sp.		X			
Nassarius (*Caesia*) *coalingensis* (Arnold) (pl. 5, fig. 21)	sp.		?sp.											sp.											sp.	X											
(*Caesia*) *grammatus* (Dall)													cf.						?	X			cf.					cf. [3]					X [9]				?
cf. *N. californianus* (Conrad)																													X								
aff. *N. californianus* (Conrad) (pl. 5, (fig. 12)							X	X				X									X					X											
salinasensis Addicott (pl. 5, fig. 20)																			cf.						X												
Olivella sp.							X																														
Cancellaria cf. *C. fernandoensis* Arnold	?sp.						X												X							?sp.	? [2]		X								
tritonidea Gabb (pl. 4, fig. 4)																												X									
Clavus coalingensis (Arnold)			?									X															X	? [3]									
Megasurcula n. sp. aff. *M. wynoocheensis* (Weaver)								X										?								X	X		X								
Turricula aff. *T. piercei* (Arnold)																			X			X				X											
Crassispira n. sp.? aff. *C. martinensis* Dall								sp.				X							X		sp.						sp.										
Elaeocyma empyrosia (Dall)?																											X										
Scaphander aff. *S. jugularis* (Conrad)							X																														
SCAPHOPOD:																																					
Dentalium? sp.								X																													
PELECYPODS:																																					
Nuculana taphria (Dall)										X																											
Yoldia sp.																													X [10]								
Anadara (*Anadara*) *trilineata* (Conrad) (pl. 2, fig. 2)	X	X					cf.														X		X		cf.		X	X [3]					sp.	sp.		cf.	
(*Anadara*) *trilineata* forma *canalis* (Conrad) (pl. 5, fig. 1)								X					cf.																								
(*Larkinia*) *camuloensis* (Osmont) Reinhart (1943, p. 65)																																					
Arca cf. *A. santamariensis* Reinhart																																				X	
Glycymeris cf. *G. grewinki* Dall	sp.											sp.						sp.											X								
Modiolus cf. *M. capax* (Conrad)				X [11]								sp.									sp.																
rectus (Conrad)																												X [3]					X				
Mytilus coalingensis Arnold							cf.											sp.						sp.											X		
Atrina n. sp?					X													sp.																			
Ostrea atwoodi Gabb (pl. 3, figs. 3, 7)	X							X					X	sp.	X	X	X		X			X	X	X	X [7]		X	X	X		sp.	X	X [10]		X		
Chlamys cf. *C. hodgei* (Hertlein)	X	sp.																sp.																			
n. sp. aff. *C. nipponensis* Kuroda	X																																				
n. sp.?				X [11]											X																						
Hinnites giganteus (Gray)													X											X				X [3]									
Lyropecten cerrosensis (Gabb) (pl. 3, fig. 8) [12]																																					
estrellanus (Conrad) (pl. 1, fig. 5)											cf.	X		cf.	X			cf.																			
terminus (Arnold) (pl. 1, figs. 1, 10; pl. 2, figs. 1, 10)			?sp.	cf.	?sp.		sp.	cf.	X	sp.			X		X	X	X						X		X [7]		X		X	?sp.	?		X			X	
Patinopecten lohri Hertlein [13] (pl. 1, fig. 4; pl. 3, fig. 1; pl. 4, fig. 1)													X		X													X							X		
Lima cf. *L. hemphilli* Hertlein and Strong																		X																			
?*Anomia* sp.																		X																			
Pododesmus cepio (Gray)													X			X																					
Cyclocardia californica (Dall) (pl. 5, figs. 16, 17)							cf.	X						cf.															X			sp.					
Glans n. sp. aff. *G. radiata* (Sowerby)																													X								
Here excavata (Carpenter)							X																				X [2]										X
Lucinisca n. sp.? aff. *L. nuttalli* (Conrad)	X					X	X		X										X		X	X			X		X									X	
Lucinoma cf. *L. annulata* (Reeve)																																				X	
Miltha sp.											X							X																			
Diplodonta sp.								X	X																												
Trachycardium quadragenarium (Conrad)								?	sp.	?										X					?sp.				X				cf.			?	

See footnotes at end of table.

TABLE 1.—*Larger invertebrates from the Pancho Rico Formation*—Continued

	West of Salinas River												East of Salinas River																								
	M902	M981	M918	M1060	M1066	M1067	M1455	M982	M1676	A3296	M2047	M2050	M2280	M952	A906	M913	A4946	M903	M2278	A3241	M996	M2282	M2283	M975	M977	M979	M980	A3425	M1935	M1934	M1970	M1930	M1966	M1967	A914	M1969	A3395
PELECYPODS—Continued																																					
?*Clinocardium* sp							X																														
Transenella tantilla (Gould)									sp.																?sp.		?sp.		X								
Amiantis n. sp.? aff. *A. stalderi* (Clark)																										sp.					X						
Dosinia cf. *D. ponderosa* Gray (pl. 1, fig. 7)											X																										
Saxidomus nuttalli Conrad									X																												
?*Compsomyax* sp						X																															
Chione cf. *C. fernandoensis* English																		X																			
aff. *C. gnidia* (Broderip and Sowerby)							X																														
Protothaca cf. *P. lacinata hannibali* Howe	sp.								X			sp.										X					X		X	?sp.			?	X			
cf. *P. staminea* (Conrad)							X																														
tenerrima (Carpenter)			X	X [11]			X		X													X			X [7]		X		?					X			
Cumingia californica Conrad?																									X												
Spisula mercedensis Packard							sp.		sp.			sp.	sp.														X			cf.							
hemphilli (Dall)?																													X				X			X	
Tresus nuttalli (Conrad)									?sp.														?sp.				X	sp.[3]		?						?sp.	
Tellina cf. *T. aragonia* Dall																													X								
idae Dall																		cf.					X													cf.	
cf. *T. lutea* Wood									?																				X								
Macoma affinis Nomland (pl. 2, fig. 6)	sp.																		sp.			sp.				cf.				X							
cf. *M. arnheimi* Dall																														X							
brota Dall					X																																
indentata Carpenter												?													X [7]					cf.			cf.				
nasuta (Conrad)			X				X	?	X	cf	?	X															X [2]		X	X	?	?	X			?	
secta (Conrad)																													X	X	X						
Macoma? aff. *M. arctata* (Conrad)				X	X																															X	
Florimetis biangulata (Carpenter) (pl. 4, fig. 2)							X		X	X	X	X										X	X		X [7]	?	X	X [3]	X	X	X	X		X		X	
Sanguinolaria cf. *S. nuttalli* Conrad																													X								
n. sp.?																							X														
Solen perrini Clark							cf.					?								X			X		X [7]	sp.	?		sp.	X	cf.					cf.	cf.
Siliqua cf. *S. media* (Sowerby) of Woodring [and Bramlette], 1950								X																									X				
Cryptomya californica Conrad			?sp.				X					X							X	X						X	X [2]									cf.	
Mya arenaria Linné (pl. 3, fig. 2)			?sp.																								cf.			X							
cf. *M. truncata* Linné																														X							
Panope abrupta (Conrad)				X														X		X							X										?
Zirfaea pilsbryi Lowe																				X						sp	X [2]										
BARNACLES:																																					
Balanus gregarius (Conrad) (pl. 1, figs. 2, 3, 6, 8; pl. 2, figs. 4, 7)	?	?						X	cf.							X		X					sp.	X			?	X	X		X	sp.	sp.				
n. sp.?																X [14]																					
sp. (small)																													X								

[1] Echinoid identifications from USGS collections, excepting loc. M1966, by J. Wyatt Durham.
[2] Occurrence in collection numbered M1966 from same locality.
[3] Occurrence in collection from UCMP loc. A3424, about 1 mile ESE.
[4] Occurrence at loc. M976 almost 2 miles NNE of M975.
[5] Occurrence at loc. M1674 about 500 feet S. of M982 and somewhat higher stratigraphically. *Astrodapsis salinasensis* and *Astrodapsis* cf. *A. fernandoensis* have also been identified from loc. M1674 by J. Wyatt Durham.
[6] Occurrence in University of California Museum of Paleontology (UCMP) collection from USGS loc. M1341 which is about ½ mile SE of M913.
[7] Occurrence in collection numbered M1939 from same locality.
[8] Present in Stanford University collection from loc. C1001, "3 miles E. of San Lucas, Calif." R. B. Moran, collector.
[9] Occurrence in collection from UCMP loc. 3572, which is equivalent to M1966.
[10] Field identification.
[11] Occurrence at loc. M1064 about ½ mile WSW of M1066.
[12] Occurrence in collection from UCMP loc. A911, 500 feet N. of W¼ cor. sec. 14 T. 21 S., R. 9 E., MDB&M, with *Lyropecten terminus* Arnold.
[13] Also recorded with *Lyropecten terminus* Arnold from "2 miles S. of San Lucas" (Arnold, 1906, p. 64 as *Pecten oweni* Arnold) and from "1½ miles SW of Lonoak post office" (Nomland, 1917a, p. 215, also as *P. oweni*).
[14] Occurrence in collection from loc. M2279 from same gully. Species represented by large, concentrically sculptured scuta and terga which lack radial sculpture.

Larger invertebrate fossils from the Pancho Rico Formation that are diagnostic or strongly suggestive of Pliocene age, as that epoch is used in the standard Pacific Coast provincial megafossil chronology (Weaver and others, 1944; Durham. J. Wyatt, 1954) are:

Gastropods:
- *Calliostoma coalingense* (Arnold)
- *Calliostoma etchegoinense* (Nomland)
- *Turritella cooperi* forma *nova* Nomland[3]
- *Turritella gonostoma hemphilli* Applin, in Merriam
- *Turritella vanvlecki* Arnold
- *Bittium casmaliense* Bartsch
- *Thais etchegoinensis* (Arnold) ribbed form
- *Thais collomi* Carson
- *Calicantharus* cf. *C. humerosus* (Gabb)
- *Calicantharus kettlemanensis* (Arnold)
- *Nassarius coalingensis* (Arnold)
- *Nassarius grammatus* (Dall)
- *Clavus coalingensis* (Arnold)[3]

Pelecypods:
- *Arca* cf. *A. santamariensis* Reinhart
- *Anadara camuloensis* (Osmont)
- *Mytilus coalingensis* Arnold
- *Ostrea atwoodi* Gabb
- *Lyropecten terminus* (Arnold)[3]
- *Lyropecten cerrosensis* (Gabb)
- *Patinopecten lohri* (Hertlein)
- *Cyclocardia californica* (Dall)
- *Macoma affinis* Nomland
- *Spisula mercedensis* Packard
- *Mya arenaria Linné*

Echinoids:
- *Astrodapsis arnoldi* Kew[3]
- *Astrodapsis fernandoensis* Pack[3]

Brachiopod:
- *Terebratalia arnoldi* Hertlein and Grant

An arcid pelecypod, identified as *Arca* cf. *A. santamariensis*, is abundant at USGS locality M1969 in Vineyard Canyon. This species was previously recorded only from the type locality in the Pliocene Careaga Sandstone of the Santa Maria basin and from Pliocene strata in the northern Whittier Hills, on the east side of the Los Angeles basin, Calif.[4] *Anadara camuloensis* was reported from a locality about 2½ miles south of San Ardo by Reinhart (1943, p. 65). *Patinopecten lohri*, a common species at USGS locality M2280, is also represented in collections at the University of California and at Stanford University. It was reported from strata included in the Pancho Rico Formation by Woodring and Bramlette (1950, p. 102), and as "*Pecten oweni* Arnold" both by Arnold (1906, p. 64) from "2 miles south of San Lucas," and by Nomland (1917a, p. 215) from Lonoak, northeast of King City. *Mya arenaria*, although reintroduced in historic time on the Pacific Coast, became locally extinct by the end of the Pliocene in California. It is in a collection from USGS locality M1934, near the top of the Pancho Rico Formation, and has been tentatively identified from USGS locality M980 at the type area on Pancho Rico Creek.

Brachiopods identified as *Terebratalia arnoldi* on the basis of a very weak medial sulcus on the pedicle valve and a corresponding low fold on the brachial valve are abundant at localities M902 and M981 in Reliz Canyon. A deformed specimen from UCMP locality 3953 (M902 of this report) that Hertlein and Grant (1944, p. 142) stated "appears related to *Terebratalia transversa caurina* Gould," a species characterized by an opposite arrangement of mesial flexures, probably is this species. *Terebratalia arnoldi*, here reported from the Salinas Valley area for the first time, is known only from Pliocene strata (Hertlein and Grant, 1944, p. 120); yet it appears to be closely related to the living *T. occidentalis* Dall and has been treated as a synonym of that species by some paleontologists (Woodring and Bramlette, 1950, p. 86).

Lyropecten terminus,[5] perhaps the most characteristic mollusk in the Pancho Rico Formation, is generally recognized as an early Pliocene "Jacalitos Stage" species in central California, although it is reported from a single locality (UCMP 2096) in the "lowest invertebrate fossiliferous zone" north of Coalinga, a unit that was included in the Etchegoin Formation by Nomland (1917a, p. 228 and table facing p. 230). However, Arnold and Anderson's (1910, p. 125–133) more comprehensive list of fossils from the Etchegoin does not include *L. terminus*. Neither is this species reported from the Etchegoin Formation at Kettleman Hills nor in the Kreyenhagen Hills-Jacalitos Creek area, south of Coalinga.

At least 10 species or subspecies of *Astrodapsis* have been reported from the Pancho Rico Formation (Kew, 1920; Richards, 1935; Mandra, 1963). Although the majority are considered Pliocene guides, some species that also occur in the Miocene have been identified: *A. tumidus*, *A. whitneyi*, and *A. margaritanus*. Another

[3] Considered diagnostic of an early Pliocene age.

[4] Stark, H. E., 1949, Geology and paleontology of the northern Whittier Hills, California: Claremont, Calif., Claremont Graduate School unpub. M.A. thesis.

[5] On the basis of collections from the Salinas Valley area, *Lyropecten terminus* (pl. 1, figs. 1, 10; pl. 2, figs. 1, 10) is here differentiated from *L. estrellanus* (pl. 1, fig. 5), its precursor, by its fewer and broader primary ribs (about 14 or 15 as contrasted with 17 or more on *L. estrellanus*); broader interspaces that are incompletely filled with an interrib; and generally flatter, less inflated valves. Because *L. terminus* can be satisfactorily discriminated from *L. estrellanus* and because it has a stratigraphic range that is almost entirely exclusive of that of *L. estrellanus*, it is here treated as a separate species as a matter of stratigraphic utility. The occurrence of *L. estrellanus* with Pliocene mollusks at locality M2050 and at a few other localities near the base of the Pancho Rico Formation is evidence of a local range that extends upward into the lowest part of the Pliocene, as that term is customarily used in the provincial molluscan chronology. A comprehensive discussion of the genus *Lyropecten* and its Miocene and Pliocene species, including *L. estrellanus* and *L. terminus*, was made by Woodring (1938, p. 33–35).

species, *A. salinasensis* (*A. antiselli*, of authors), has been treated as a Miocene or Pliocene taxon, although it occurs at the type locality and elsewhere with Pliocene mollusks including *Patinopecten lohri*, *Lyropecten terminus*, and *Ostrea atwoodi*. Mollusks of undoubted Pliocene age also occur at the type locality of *A. spatiosus*, in Powell Canyon (UCMP loc. 3572). The varying identifications of echinoids are difficult to reconcile with stratigraphic ocurrence and tend to cast some doubt on the utility of these echinoids for biostratigraphic correlation, at the species level, without supporting molluscan evidence. Hall (1962) proposed a reduction of the large number of available echinoid names into species groups, which could be used for biostratigraphic correlation. To his recognition of two species of *Astrodapsis* from the Pancho Rico Formation, *A. arnoldi* and *A. spatiosus*, however, should be added at least one species referable to his *A. whitneyi-A. jacalitosensis* lineage (represented by *Astrodapsis* aff. *A. cuyamanus* (this report), *A. margaritanus* (Kew, 1920), *A. whitneyi* (Mandra, 1963), and *Astrodapsis* sp. (this report)). Another seemingly distinct species, here reported for the first time from the Pancho Rico Formation, is *A. fernandoensis*, from USGS localities M982 and M903. Hall's (1962) assignment of a Miocene age to the Pancho Rico Formation can be disregarded on the basis of the large representation of Pliocene mollusks. The echinoids listed in table 1 were identified by J. Wyatt Durham (oral commun., January 1964), who, contrary to the view of Hall, believed that the early echinoid names of Kew (1920) should be retained, at least in large part.

A tripartite chronostratigraphic division of the Pliocene strata in California based upon larger invertebrates from the Jacalitos, Etchegoin, and San Joaquin Formations in the Coalinga district has been used at least since Woodring and others (1940, p. 104, correlation chart opposite p. 106) informally designated these units as lower, middle, and upper Pliocene, respectively. Clark (1929, p. 24–28, correlation chart) seemingly had the concept of chronostratigraphic units of approximate stage magnitude in mind when he employed a threefold division of the Pliocene of California, although he used the inappropriate term "horizon" for these units. He recognized that knowledge was insufficient, at that time, to permit satisfactory definition of his Jacalitos and Etchegoin "horizons" and "upper Pliocene." Later, Gale (in Grant and Gale, 1931, p. 21, 61) advocated a threefold division of Pliocene strata in coastal southern California. Although Gale did not specifically denote standard sections and faunas, he used the names "Jacalitos zone," "San Diego zone," and "Santa Barbara zone" (p. 69–70) for the lower, middle, and upper Pliocene, respectively. The "Santa Barbara zone" was considered early Pleistocene, in part. Recognition of these series subdivisions in other California basins on strictly biostratigraphic data is difficult and is commonly subjective or predicated entirely on stratigraphic position.[6]

Faunal data for the Jacalitos Formation date back to Nomland's (1917a) early work, which by modern standards must be considered generalized. More refined stratigraphic studies by Woodring and others (1940) at Kettleman Hills are the basis for recognition of the Etchegoin and San Joaquin "Stages." Aside from the difficulty of equating older paleontologic data classified by faunal assemblages with modern determinations that are documented stratigraphically, there is the problem of correlating the base of the incompletely exposed section of the Etchegoin Formation at Kettleman Hills with the type section of the Jacalitos Formation in the Kreyenhagen Hills area to the west.

The Jacalitos fauna listed by Nomland (1917a, p. 211–213) in his summary treatment of the Pliocene stratigraphy of the Coalinga district is the best standard available for lower Pliocene biostratigraphic correlation. Nomland's list includes his *Chione elsmerensis* zone and *Turritella nova* zone, both of which were originally included in the informal definition of the Jacalitos as a "stage" by Clark (1943, p. 190). However, Gale (in Grant and Gale, 1931, p. 52) equated the *Chione elsmerensis* zone with the Jacalitos and considered the overlying *Turritella nova* zone to be middle Pliocene in age. Woodring, Stewart, and Richards (1940, p. 104) observed that the presence of *Ficus* (*Trophosycon*) in the *Turritella nova* zone is suggestive of the Jacalitos. From Nomland's list, *Turritella cooperi* forma *nova*, *Clavus coalingensis*, and *Lyropecten terminus*, which occur in the Pancho Rico, are considered to be early Pliocene species. Additional evidence of the early Pliocene age of the Pancho Rico is the joint occurrence of the echinoid genera *Astrodapsis* and *Dendraster*, late Miocene–early Pliocene and Pliocene–Recent taxa, respectively. Two species of *Astrodapsis*—*A. arnoldi* and *A. fernandoensis*—in the Pancho Rico are generally regarded as early Pliocene forms.

A number of species that occur in both the Jacalitos and Etchegoin Formations do not range above the lower part of the Etchegoin exposed at Kettleman Hills. These would seemingly be useful in a twofold division of the central California Pliocene strata, and such a partition might be more realistic than division into lower, middle, and upper Pliocene. Species that would

[6] Problems with this chronology have led some geologists to imply that a twofold division of the Pliocene would be more realistic, at least in certain areas of southern California (Vedder, 1960, p. B327; Winterer and Durham, 1962, p. 322).

be early Pliocene guides are *Calicantharus kettlemanensis*, *Ostrea atwoodi*, and *Patinopecten lohri*. All these species are present in the Pancho Rico Formation, and the first two are sufficiently abundant and widespread to be considered characteristic.

As previously mentioned, the fauna of the Pancho Rico Formation compares most closely with that of the Jacalitos Formation in the Coalinga district. Of the 95 species of larger invertebrates listed by Nomland (1917a, p. 211–213), more than half are represented by very closely related or identical taxa in the Pancho Rico Formation. The similarity of the Pancho Rico and Jacalitos faunas led earlier investigators (Nomland, 1917b, p. 305; Clark, 1943, p. 190; Woodring and Bramlette, 1950, p. 102) to correlate these formations and to classify the Salinas Valley strata as lower Pliocene. However, evaluation of this long-standing interpretation has been difficult in the absence of faunal documentation. The evidence for an early Pliocene age, in the traditional provincial usage, is occurrence of five species regarded as early Pliocene guides, faunal similarity with the standard lower Pliocene section in the San Joaquin Valley, and the joint occurrence of the echinoid genera *Astrodapsis* and *Dendraster*.

Strata included by Wilson (1943) in the Etchegoin Group in the San Benito quadrangle, about 20–25 miles due north of King City and on the northeast side of the San Andreas fault, are correlative with the Pancho Rico Formation. The presence of *Lyropecten terminus* and the joint occurrence of species of *Astrodapsis* and *Dendraster* in the basal 400 feet of the marine part of the group are evidence of a Jacalitos age. Because the fauna of these beds was not segregated stratigraphically from those of the overlying strata, which contain assemblages comparable to those in the younger part of the Coalinga Pliocene sequence (Wilson, 1943, p. 245), detailed comparison and correlation with the Pancho Rico Formation are not made.

The megafossils in the upper part of the Sisquoc Formation of the Santa Maria basin and in the Pancho Rico Formation are similar. More than half of 42 taxa listed from the basin facies of the Sisquoc Formation by Woodring and Bramlette (1950, table opposite p. 34) are represented by identical or closely related forms in the Pancho Rico Formation. At least 20 of the 25 larger invertebrates from the marginal facies of the Sisquoc, the Tinaquaic Sandstone Member, are represented in the Pancho Rico Formation. In the absence of distinctive early Pliocene guides, the upper parts of both facies of the Sisquoc were considered middle Pliocene by Woodring and Bramlette. Because the Pancho Rico Formation does contain early Pliocene invertebrate fossils, it may be older, at least in part, than the Sisquoc, in spite of considerable similarity in the faunas of the Pancho Rico and the upper part of the Sisquoc. Woodring and Bramlette (1950, p. 100–101) observed that the Foraminifera from the upper part of the basin facies of the Sisquoc "have more of a late Miocene than a Pliocene aspect," whereas the lower and middle parts of the basin facies contain "a few megafossils that have Pliocene affinities." This condition is similar to that in the Pancho Rico Formation, where Foraminifera suggestive of Delmontian age and megafossils that are clearly of Pliocene age occur together.

Units similar in age to the Pancho Rico Formation are present in the Ventura and Los Angeles basins of southern California. The lower Pliocene strata in those areas accumulated predominantly at bathyal depths, and for that reason the larger invertebrates and Foraminifera have little similarity to the shallow-water assemblages from the Pancho Rico. A notable exception is the Pliocene fauna of the Towsley Formation of late Miocene and early Pliocene age in the eastern Ventura basin (Winterer and Durham, 1962, p. 296–306); this fauna contains shallow-water mollusks and echinoids that suggest correlation with the Pancho Rico Formation.[7]

Problems of interbasinal correlation of Pliocene strata based on larger invertebrates were discussed in considerable detail by Woodring, Stewart, and Richards (1940) and by Woodring and Bramlette (1950). Little can be added to their conclusions other than documentation of the early Pliocene age of the Pancho Rico Formation and reiteration of the difficulty in recognition and correlation of a threefold division of the Pliocene on biostratigraphic evidence alone.

Foraminifera from the Pancho Rico Formation have been interpreted as indicating either a Miocene or a Pliocene age. Kleinpell (1938, fig. 14) assigned a foraminiferal faunule from the Pancho Rico Formation in Long Valley to his upper Delmontian Stage, which he equated with echinoid zones listed as *Astrodapsis salinasensis* and *A. spatiosus*. Foraminifera identified by Patsy J. Smith (written commun. 1963) as *Elphidium hughesi* (abundant), *Ammonia beccarii* (common), *Buliminella elegantissima* (abundant), *Bolivina* cf. *B. girardensis* (rare), *Bolivina* cf. *B malagensis* (rare), and *Bolivina obliqua* (rare), from USGS locality Mf746, between Walker and Powell Canyons, are regarded as indicative of "an upper Mohnian or 'Delmontian' age." On the other hand, Hughes (1963, p. 95) regarded Foraminifera from the Pancho Rico in the

[7] Many shallow-water assemblages in the Towsley Formation were displaced into much deeper water, as is indicated by their occurrence with bathyal mollusks at several localities (Winterer and Durham, 1962, p. 306–307).

San Ardo oil-field area as Pliocene, and younger than Delmontian. Taggart and Kraetsch (1963) listed E. A. Gribi, Jr., as the source of a Pliocene determination of a foraminiferal assemblage from Long Valley that is about the same as that listed by Hughes from the San Ardo oil-field area.

MOLLUSCAN PALEOECOLOGY AND PALEOGEOGRAPHY

The molluscan fauna of the Pancho Rico Formation consists of taxa whose living representatives or modern analogs are usually found in the shallow nearshore areas of the northeastern Pacific Ocean. Many of the still-living species are known to range into water deeper than 10–15 fathoms, but exclusively moderate-depth taxa are found only in collections from USGS localities M902 and M981 in Reliz Canyon. These localities are near the northwestern end of the outcrop area of the Pancho Rico and have an unusual faunal composition with respect to assemblages from the type area on Pancho Rico Creek and elsewhere on the east side of Salinas Valley. Water depths of 30 fathoms or more are suggested by the presence of *Turcica* sp. and abundant *Terebratalia arnoldi* Hertlein and Grant. *Turcica* has a bathymetric range of from 10 to 35 fathoms off the Pacific Coast (Coan in Keen, 1963, p. 104); *Terebratalia arnoldi* is represented in the northeastern Pacific by a modern analog, *T. occidentalis* (Dall), which ranges from 30 to 75 fathoms (Woodring and Bramlette, 1950, p. 95). Many other taxa in these collections have shallow to moderate depth ranges, but some, such as *Crepidula* n. sp., *Ostrea atwoodi*, and *Balanus gregarius*? suggest relatively shallow depths in the sublittoral zone. It is possible that these taxa may have been displaced downslope from their original habitat. The genus *Patinopecten* may indicate moderate depths, according to the bathymetric range of from 20 to more than 100 fathoms listed by Grau (1959, p. 148) for the modern *P. caurinus*. However, extinct Pliocene species of *Patinopecten* may possibly have ranged into somewhat shallower water, as is indicated by their frequent occurence in assemblages of shallow-water aspect.

The shallow-water aspect of the coarser grained strata in the Pancho Rico Formation, suggested by the larger invertebrates, is confirmed by foraminifera from a few localities in the interbedded finer grained rocks. Foraminiferal assemblages from the Pancho Rico are characterized by *Elphidium* and *Buliminella elegantissima*, taxa generally considered to be reliable indicators of shallow-water, nearshore shelf environments (Bandy and Arnal, 1960, p. 1927; Bandy, 1964, p. 141).

The occurrence in the Pancho Rico Formation of several taxa now known only from lower latitudes suggests that the local early Pliocene marine climate was generally warmer than modern marine climates at comparable latitudes off the central California coast. In terms of the modern distribution of living species and modern analogs, the fauna of the Pancho Rico Formation is suggestive of the modern Californian molluscan province, as recognized by Valentine (1961), which extends from Point Conception (lat 34.5° N.) to Cedros Island (lat 28° N.). Taxa with southern affinities that are sufficiently abundant to be termed "common" are *Crucibulum* (*Dispotaea*), *Turritella* (three species referable to the *T. broderipiana* stock: *T. gonostoma hemphilli*, *T. vanvlecki*, and *Turritella* n. sp.), *Anadara*, *Lyropecten*, and a *Chione* allied to *C. gnidia*. Taxa perhaps more suggestive of the Panamic molluscan province than of Valentine's (1961) adjoining Californian molluscan province include *Diodora* n. sp?, the three turritellas of the *T. broderipiana* stock, *Crassispira* n. sp., *Dosinia*, *Arca*, and an undescribed species of *Glans* comparable to the modern *G. radiata* (Sowerby). However, modern analogs of these taxa range northward into a zone of overlap between the Panamic and Californian molluscan provinces (lat 22° N.–28° N.), an area that is usually regarded as subtropical. The only exclusively Panamic or tropical taxon known from the Pancho Rico Formation is *Miltha* sp. from locality M903, near San Lucas, and from locality M2047, west of San Miguel near the southernmost exposures of the formation. The living representative of this genus in the northeastern Pacific Ocean *Miltha xantusi* (Dall), was found as far north as the south end of Baja California and has been dredged from a more northern locality in the Gulf of California near Guaymas (D. R. Shasky, oral commun., June 1964). With the possible exception of some of the turritellas, these warm-water taxa occur near the base of the Pancho Rico Formation in assemblages of shallow-water aspect.

Both faunal similarity with the Pliocene of the Santa Maria basin and the presence of a small element of warm-water mollusks in the widespread shallow-water facies of the Pancho Rico Formation imply interchange of marine life between the southern Salinas Valley area and the Santa Maria basin, to the southeast, during early Pliocene time. A westward shoaling and possible depositional limit of the Pancho Rico Formation, at least in the southwestern part of the outcrop area, is suggested by the relatively thin sequence of coarse-grained clastic rocks containing abundant mollusks indicative of shallow water. Scattered exposures of this facies occur from near Lockwood (USGS loc. M1455) southward to the Nacimiento River area (USGS loc. M2050), the southernmost known exposure of the formation. Farther south nonmarine strata of the Paso Robles Formation overlap marine beds of early to late Miocene age and rest on granitic basement (Jennings, 1958). Although subsurface relations of the Pancho Rico Formation to the overlying Paso Robles Formation in this area are not adequately known, it is possible that the nonmarine strata may conceal evidence of a marine depositional basin that may have extended much farther southeast. If the Pliocene marine basin of the Salinas Valley area was once connected to the western oceanic area through the Santa Maria basin, as is suggested by faunal evidence, the seaway must have crossed the present crest of the Santa Lucia Range and possibly passed through the Huasna basin southeast of San Luis Obispo. Strata of probable early Pliocene age are exposed in the Huasna syncline near Saucelito and Phoenix Creeks (Jennings, 1958), about 40 miles southeast of the southernmost known occurrence of the Pancho Rico Formation. A small collection of mollusks from UCLA locality 4159 in the Phoenix-Saucelito area, identified by Hall (1962, p. 61), includes the following: *Astrodapsis spatiosus* Kew, *A. whitneyi* Remond, *Mytilus coalingensis* Arnold, *Ostrea atwoodi* Gabb, and *Pecten* (*Lyropecten*) *estrellanus* Conrad, n. subsp. (?) This collection is from a unit that Hall (1962) included in the Santa Margarita Formation and considered to be Miocene. He compared it on echinoid evidence with the Pancho Rico Formation, a unit which he also considered to be Miocene but on the basis of a foraminiferal assemblage. Certainly the mollusks, if not the echinoids, are suggestive of Pliocene age as that term is used in this report.

The alternate possibility that there was no marine connection to the south and that the warm-water taxa are merely Miocene relicts, or are directly evolved from Miocene species, cannot be entirely discounted. This idea seems less probable, however, because some of the taxa with southern affinities, such as *Crucibulum* (*Dispotaea*), *Glans* n. sp., and *Crassispira* n. sp., made their initial appearance in the Pliocene strata of this central California area.

Faunal similarity to presumably contemporaneous molluscan assemblages from the lower part of the Purisima Formation in the southern Santa Cruz Mountains, some 60–70 miles to the northwest, is less apparent. Comparable depth assemblages from the Purisima (Arnold, 1908; Martin, 1916; Cummings and others, 1962), although containing fewer species than those of the Pancho Rico Formation, seem to represent markedly cooler water conditions. Thickening of the Pancho Rico to a maximum measured thickness greater than 1,000 feet in the northwestern part of the outcrop area, local deepening of the depositional basin suggested by the benthonic mollusks from that area, and the diminution of grain size of strata might be taken as evidence of a seaway or marine trough leading northwestward toward the present position of Monterey Bay. Such a marine connection would provide a direct path of migration for some of the cool water, northern forms that are locally abundant and characteristic of the northwestern exposures of the Pancho Rico Formation. Some of the taxa with northern affinities in the Pancho Rico are *Chlamys* n. sp. aff. *C. nipponensis*, *Mya arenaria*, *M. truncata*, *Tellina* cf. *T. lutea*, *Macoma brota*, and *Siliqua* cf. *S. media*. For the most part these species are represented by isolated individuals and are not characteristic of the formation.

A more circuitous route by which northern species could have migrated into the Salinas Valley area during deposition of the Pancho Rico Formation was through the San Benito trough, a linear Pliocene depositional basin immediately east of the San Andreas fault and extending southward from near Hollister to the Coalinga area. The northernmost known occurrence of early Pliocene species characteristic of the so-called Jacalitos Stage are near San Benito (Wilson, 1943, p. 245), but the biostratigraphy of Pliocene strata northwest of that area is not well known. The presence of *Dosinia* with Pliocene species in the Purisima Formation of the Sargent oil field in the north end of the San Benito trough (Martin, 1916, p. 245) is suggestive of an early Pliocene age at that latitude, and of the existence of a seaway bordering the east side of the San Andreas fault in the Hollister-San Benito area.

COLLECTION-LOCALITY DESCRIPTIONS

U.S. Geological Survey (USGS) Cenozoic Localities

M902. East side of Reliz Canyon, 650 ft S., 1,875 ft W. of NE cor. sec. 35, T. 19 S., R. 6 E., Reliz Canyon quadrangle. Collector: D. L. Durham, 1960.

M903. Sandstone bluff on west side of State Highway 198, 425 ft S., 425 ft W. of NE cor. sec. 5, T. 21 S., R. 9 E., San Lucas quadrangle. Collectors: D. L. Durham, 1959; W. O. Addicott and D. L. Durham, 1964.

M913. North side of Wildhorse Canyon, 2,650 ft N., 1,075 ft E. of SW cor. sec. 8, T. 20 S., R. 9 E., San Lucas quadrangle. Collector: D. L. Durham, 1960.

M918. Ridge northwest of Pine Canyon, 2,000 ft N., 1,475 ft W. of SE cor. sec. 23, T. 20 S., R. 7 E., Thompson Canyon quadrangle. Collector: D. L. Durham, 1959.

M952. North of Sweetwater Canyon, 800 ft N., 2,250 ft E. of SW cor. sec. 32, T. 19 S., R. 9 E., San Lucas quadrangle. Collector: D. L. Durham, 1959.

M975. About 1 mile north of San Ardo, 300 ft S., 1,000 ft E. of NW cor. sec. 9, T. 22 S., R. 10 E., San Ardo 15-minute quadrangle. Collector: C. L. Rice, 1960.

M976. North of Pancho Rico Creek, 2,600 ft S., 600 ft W. of NE cor. sec. 3, T. 22 S., R. 10 E., San Ardo 15-minute quadrangle. Collector: C. L. Rice, 1960.

M977. Base of bluff on south side of Pancho Rico Creek, 1,000 ft N., 3,100 ft W. of SE cor. sec. 11, T. 22 S., R. 10 E., San Ardo 15-minute quadrangle. Collector: D. L. Durham, 1960. Same as USGS locality M1939.

M979. South side of Pancho Rico Creek, 700 ft S., 1,200 ft W. of NE cor. sec. 15, T. 22 S., R. 10 E., San Ardo 15-minute quadrangle. Collector: D. L. Durham, 1960.

M980. Base of bluff on south side of Pancho Rico Creek, 1,600 ft N., 1,400 ft W. of SE cor. sec. 11, T. 22 S., R. 10 E., San Ardo 15-minute quadrangle. Collector: D. L. Durham, 1960. Same as USGS locality M1929.

M981. East side of Reliz Canyon, 650 ft N., 1,950 ft W. of SE cor. sec. 26, T. 19 S., R. 6 E., Reliz Canyon quadrangle. Collector: D. L. Durham, 1960.

M982. Roadcut on west side of U.S. Highway 101, 150 ft N., 2,525 ft W. of SE cor. sec. 25, T. 23 S., R. 10 E., Wunpost quadrangle. Collectors: J. G. Vedder and C. A. Repenning, 1960.

M996. Ridge between Mooney Canyon and Pine Valley, 900 ft S., 150 ft E. of NW cor. sec. 15, T. 21 S., R. 10 E., San Ardo 15-minute quadrangle. Collector: C. L. Rice, 1960.

M1060. West of Jolon Road, 2,325 ft west along section line from NE cor. sec. 2, T. 22 S., R. 7 E., Cosio Knob quadrangle. Collector: D. L. Durham, 1960.

M1064. Ridge east of Mission Creek, 19,550 ft N., 2,100 ft E. of SW cor. Cosio Knob quadrangle, on Hunter Liggett Military Reservation. Collector: D. L. Durham, 1961.

M1066. Between Mission Creek and Sulphur Spring Canyon, in unsurveyed land, 20,350 ft N., 4,575 ft E. of SW cor. of Cosio Knob quadrangle, on Hunter Liggett Military Reservation. Collector: D. L. Durham, 1961.

M1067. On ridge between Mission Creek and Sulphur Spring Canyon, in unsurveyed land, 9,275 ft N., 2,475 ft E. of SW cor. of Cosio Knob quadrangle, on Hunter Liggett Military Reservation. Collector: D. L. Durham, 1961.

M1341. North side of Wildhorse Canyon, in NW¼SE¼ sec. 8, T. 20 S., R. 9 E., San Lucas quadrangle. Collectors: J. A. Wolfe and V. A. Zullo, 1961.

M1455. Roadcut on west side of San Antonio River road, 2,975 ft N., 650 ft E. of SW cor. sec. 36, T. 23 S., R. 8 E., Williams Hill quadrangle. Collector: D. L. Durham, 1962.

M1674. In bed of Swain Creek on west side of U.S. Highway 101, 475 ft S., 2,525 ft E. of NW cor. sec. 36, T. 23 S., R. 10 E., Wunpost quadrangle. Collector: D. L. Durham, 1962.

M1676. On first ridge west of Salinas River, 1,050 ft N., 2,500 ft W. of SE cor. sec. 29, T. 22 S., R. 10 E., Hames Valley quadrangle. Collectors: D. L. Durham and D. C. Wiese, 1962.

M1929. Same as locality M980. Collectors: W. O. Addicott and D. L. Durham, 1963.

M1930. On west side of Indian Valley, 2,175 ft S., 2,100 ft W. of NE cor. sec. 9, T. 23 S., R. 12 E., Valleton quadrangle. Collector: D. L. Durham, 1963.

M1933. 225 ft S., 950 ft W. of NE cor. sec. 15, T. 23 S., R. 12 E., Valleton quadrangle. Collector: D. L. Durham, 1963.

M1934. Railroad cut east of Salinas River, just north of Sarah Canyon, 550 ft N., 175 ft W. of SE cor. sec. 25, T. 23 S., R. 10 E., Wunpost quadrangle. Collectors: W. O. Addicott and D. L. Durham, 1963.

M1935. North side of Walker Canyon, 900 ft N., 850 ft W. of SE cor. sec. 28, T. 22 S., R. 11 E., Wunpost quadrangle. Collectors: W. O. Addicott and D. L. Durham, 1963.

M1939. Same as locality M977. Collectors: W. O. Addicott and D. L. Durham, 1963.

M1966. North side of Powell Canyon, 50 ft N., 1,550 ft E. of SW cor. sec. 36, T. 22 S., R. 11 E., Valleton quadrangle. Collectors: W. O. Addicott and D. L. Durham, 1964.

M1967. Top of ridge between Powell Canyon and Cañada Montuosa, 500 ft N., 1,550 ft E. of SW cor. sec. 36, T. 22 S., R. 11 E., Valleton quadrangle. Collectors: W. O. Addicott and D. L. Durham, 1964.

M1969. Near top of ridge southeast of Vineyard Canyon road, about 12 ft stratigraphically above USGS locality M1968 (Santa Margarita Formation), 2,625 ft N., 1,850 ft E. of SW cor. sec. 34, T. 23 S., R. 13 E., Stockdale Mountain quadrangle. Collectors: W. O. Addicott and D. L. Durham, 1964.

M1970. Railroad cut at mouth of first small gully south of USGS locality M1934; approximately 20 ft stratigraphically below M1934, 425 ft N., 175 ft W. of SE cor. sec. 25, T. 23 S., R. 10 E., Wunpost quadrangle. Collectors: W. O. Addicott and D. L. Durham, 1964.

M2047. 550 ft N., 225 ft W. of SE cor. sec. 19, T. 25 S., R. 11 E., Adelaida quadrangle. Collectors: W. O. Addicott, D. L. Durham, and R. J. McLaughlin, 1964.

M2050. 2,225 ft N., 1,250 ft W. of SE cor. sec. 29, T. 25 S., R. 11 E., Adelaida quadrangle. Collectors: W. O. Addicott, D. L. Durham, and R. J. McLaughlin, 1964.

M2278. Cut on grade between San Lorenzo Creek and summit of State Highway 198, 11,300 ft E., 1,200 ft N. of SW cor. sec. 14, T. 20 S., R. 10 E., San Ardo 15-minute quadrangle. Alt. 1,325 ft. Collector: W. O. Addicott, 1964.

M2279. Float collection near head of small gully on north side of Wildhorse Canyon, 2,500 ft N., 300 ft W. of SE cor. sec. 8, T. 20 S., R. 9 E., King City 15-minute quadrangle. Collector: W. O. Addicott, 1964.

M2280. In southwestern trending canyon near center of SW¼ sec. 29, T. 18 S., R. 9 E., Greenfield quadrangle. Alt. about 1,350 ft. Collector: W. O. Addicott, 1964.

M2282. North side of Lynch Canyon, 300 ft N., 1,600 ft E. of SW cor. sec. 8, T. 22 S., R. 11 E., San Ardo 15-minute quadrangle. Collector: W. O. Addicott, 1964.

M2283. East side of road from Lynch Canyon to abandoned well location, 2,300 ft S., 2,200 ft E. of NW cor. sec. 8, T. 22 S., R. 11 E., San Ardo 15-minute quadrangle. Collector: W. O. Addicott, 1964.

Mf746. Between Walker and Powell Canyons, 3,250 ft N., 750 ft E. of SW cor. sec. 25, T. 22 S., R. 11 E., Valleton quadrangle. Collector: D. L. Durham, 1963.

University of California Museum of Paleontology (UCMP) localities

A906. North wall of Wildhorse Canyon, 1,000 ft S. of E cor. sec. 8, T. 20 S., R. 9 E., King City quadrangle. 100 ft below base of barren Paso Robles gravels. Collector: J. Kirby, 1931.

A911. In steep hill slope 150 ft north of State Highway, 500 ft N. of W¼ cor. sec. 14, T. 21 S., R. 9 E., Priest Valley quadrangle. Collector: J. Kirby, 1931.

A914. Southeast side of Indian Valley, 1 mile north of Eagle School, in NE¼NE¼ sec. 21, T. 23 S., R. 12 E., San Miguel quadrangle. 100–150 ft below base of Paso Robles Formation. Collector: J. Kirby, 1931.

A3161. In canyon on east side of Bitterwater-King City road, in NE¼SW¼ sec. 29, T. 18 S., R. 9 E., Metz quadrangle. Collector: N. R. Park, 1939.

A3241. East of Peachtree Valley in center of sec. 1, T. 21 S., R. 11 E., Priest Valley quadrangle. Collectors: N. L. Taliaferro and class, 1937.

A3296. Center of south line of SW¼NW¼ sec. 26, T. 24 S., R. 10 E.

A3424. Middle of sec. 10, T. 22 S., 12 E., Priest Valley 30-minute quadrangle.

A3425. On ridge at head of Sargent Canyon, NW¼ cor. sec. 9, T. 22 S., R. 12 E., Priest Valley 30-minute quadrangle.

A3572. Same as USGS Cenozoic locality M1966.

A3895. East side of Hog Canyon, 17 miles northeast of San Miguel, center of sec. 18, T. 24 S., R 14 E.

A4945. Same as USGS Cenozoic locality M1341.

A4946. In cut of farm road about 100 yds south of Highway 198 in center of E½ sec. 33, T. 20 S., R. 9 E., Priest Valley 30-minute quadrangle. Collector: Paleo 137 class, 1949.

B4926. About 190 ft above base of undifferentiated marine Pliocene and Paso Robles Formation in SE¼SE¼ projected sec. 8, T. 22 S., R. 7 E., King City quadrangle. Collector: R. Weidman, 1953–1956.

Stanford University (SU) locality

C1001. Three miles east of San Lucas, Monterey County, Calif. Collector: R. B. Moran.

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PLATES 1–5

PLATE 1

FIGURES 1, 10. *Lyropecten terminus* (Arnold).

USGS Cenozoic loc. M1935, Walker Canyon.

1. Left valve. Length 90 mm, height 82 mm. USNM 649083.

10. Right valve. Length 116 mm, height 101 mm. USNM 649084.

2, 3, 6, 8. *Balanus gregarius* (Conrad).

USGS Cenozoic loc. M903, ¾ mile northeast of San Lucas.

2, 8. Scutum. Length 26 mm, width 16.5 mm. USNM 649171.

3, 6. Scutum. Length 29.5 mm, width 22 mm. USNM 649172.

4. *Patinopecten lohri* (Hertlein).

Left valve. Length 61 mm, height 68 mm. SUPTC 9753. Long Valley, Monterey County.

5. *Lyropecten estrellanus* (Conrad).

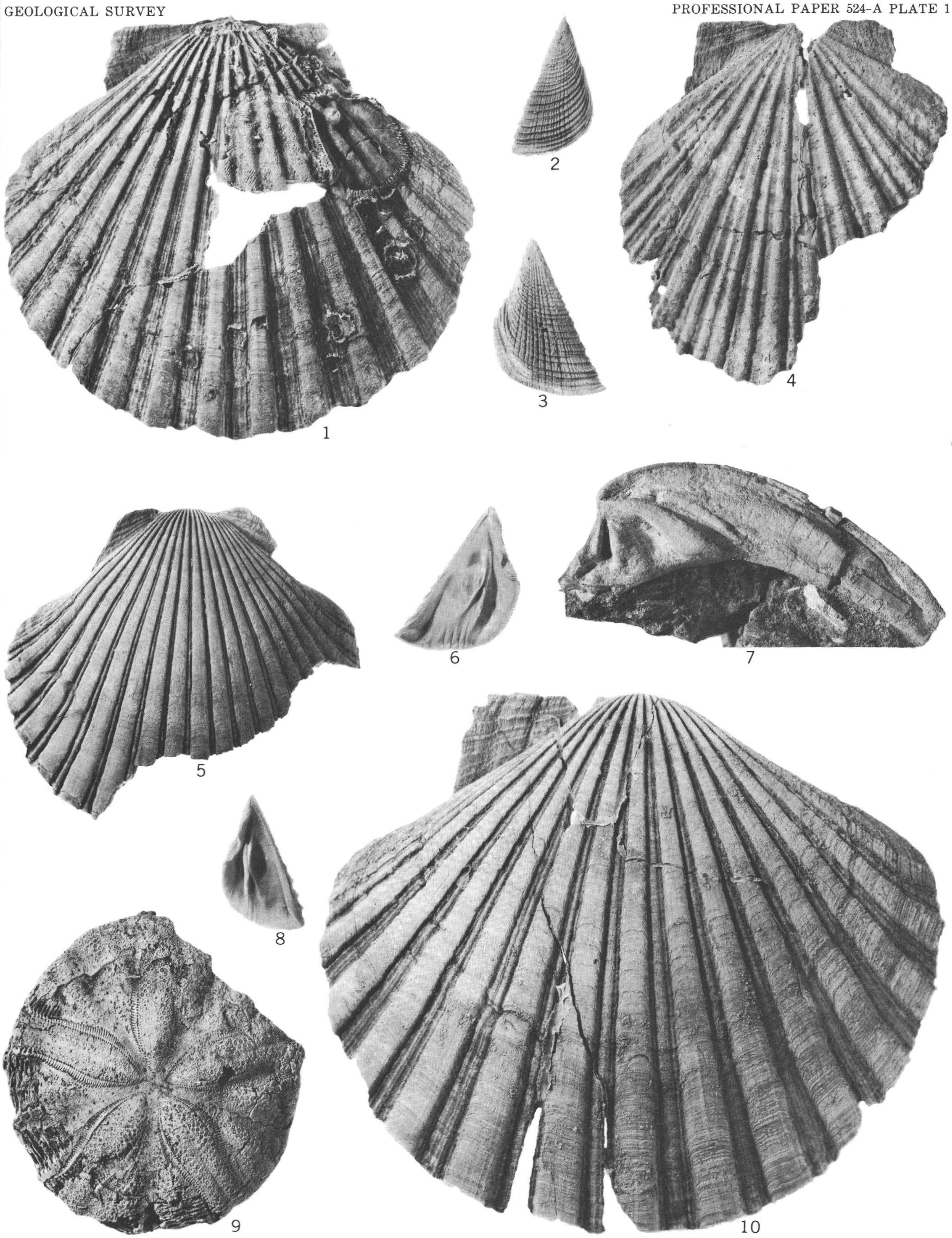
Right valve. Length 69 mm, height 60 mm. USNM 649085. USGS Cenozoic loc. M2050, 6 miles southwest of San Miguel.

7. *Dosinia* cf. *D. ponderosa* (Gray).

Length 70 mm. USNM 649086. USGS Cenozoic loc. M2047, 7 miles southwest of San Miguel.

9. *Astrodapsis arnoldi* Pack.

Length 70 mm, width 66 mm, height 14 mm. USNM 649087. USGS Cenozoic loc. M1929, lower part of Pancho Rico Creek.



MOLLUSKS, BARNACLE, AND ECHINOID OF THE PANCHO RICO FORMATION

PLATE 2

FIGURES 1, 10. *Lyropecten terminus* (Arnold).

1. Right valve. Length 105 mm, height 96 mm. USNM 649088. USGS Cenozoic loc. M1676, about 2½ miles south of San Ardo.

10. Left valve. Length 124 mm, height 115 mm. USNM 649089. USGS Cenozoic loc. M1939, lower part of Pancho Rico Creek.

2. *Anadara (Anadara) trilineata* (Conrad).
Length 25.4 mm. USNM 649090, a rubber cast. USGS Cenozoic loc. M996, Pine Valley.

3, 5. *Terebratalia arnoldi* Hertlein and Grant.
USNM 649091. USGS Cenozoic loc. M902, Reliz Canyon.

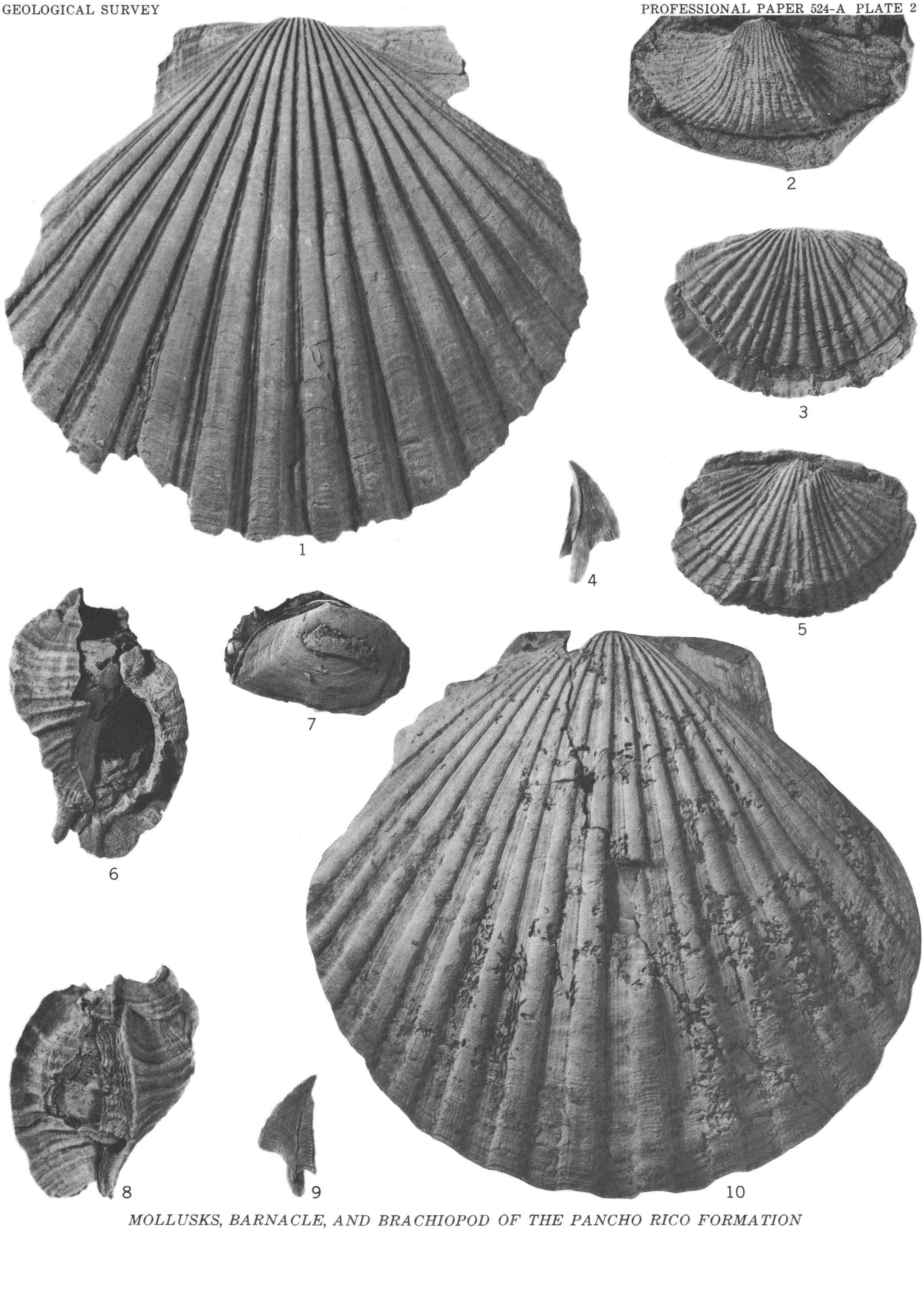
3. Brachial valve. Length 30.5 mm.

4. Pedicle valve. Length 33 mm, height (ventral margin crushed) 22 mm.

4, 9. *Balanus* sp.
Tergum. Length 16.2 mm, width 8 mm. USNM 649173. USGS Cenozoic loc. M1933, Indian Valley.

6, 8. *Ceratostoma foliatum* (Gmelin).
Height 53 mm, width 34 mm. SUPTC 9754. Sec. 27, T. 20 S., R. 9 E., Long Valley.

7. *Macoma affinis* Nomland.
Length 32.3 mm, height 23 mm. USNM 649092, a rubber cast. USGS Cenozoic loc. M979, lower part of Pancho Rico Creek.



MOLLUSKS, BARNACLE, AND BRACHIOPOD OF THE PANCHO RICO FORMATION

PLATE 3

FIGURE 1. *Patinopecten lohri* (Hertlein).
Left valve. Length 107 mm, height 97 mm. UCMP 36467. UCMP loc. A3161, between Bitterwater Road and Becker Valley.

2. *Mya arenaria* Linné.
Length (nearly complete) 63 mm, height 44.5 mm. USNM 649093. USGS Cenozoic loc. M1934, Railroad cut north of Sarah Canyon.

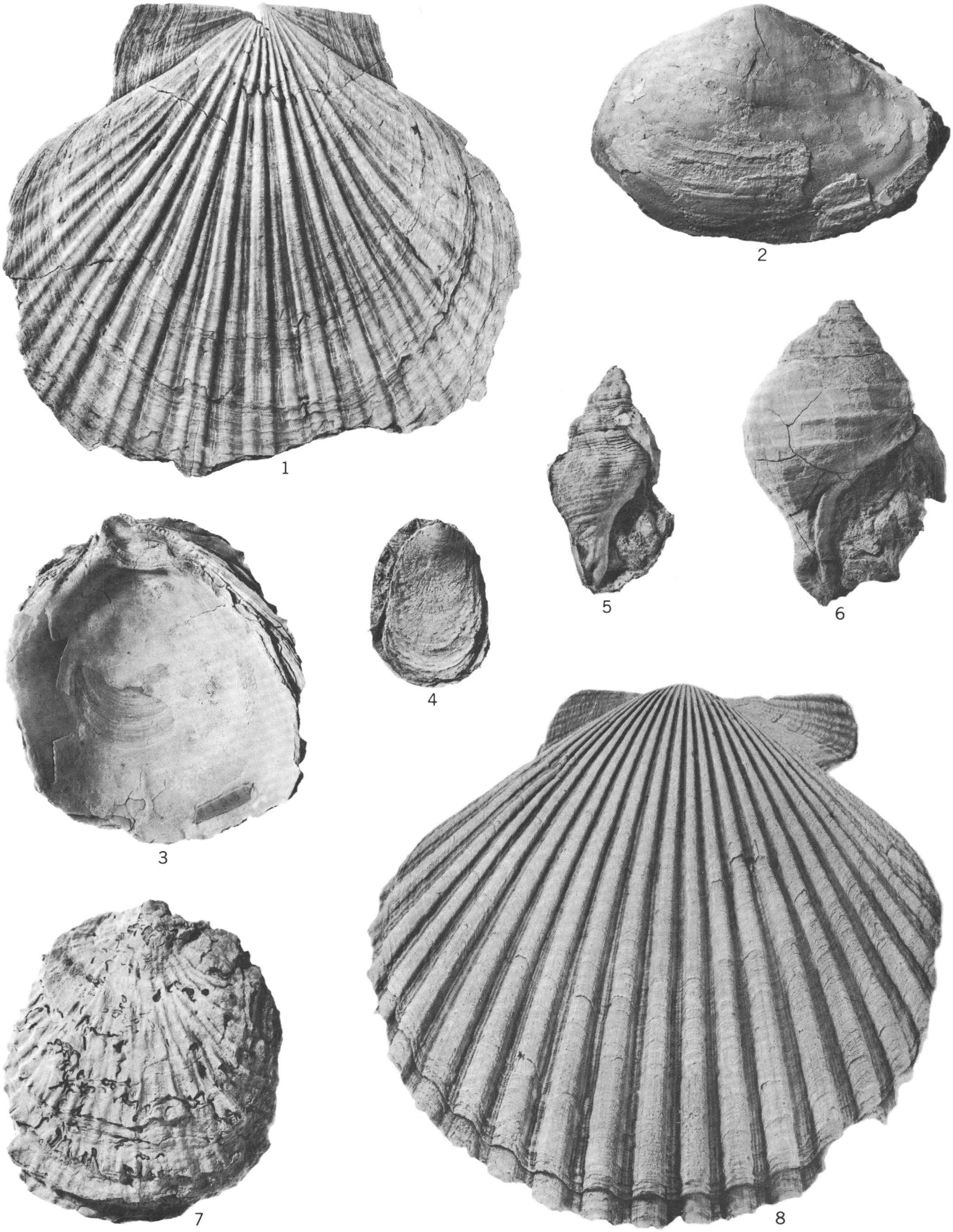
3, 7. *Ostrea atwoodi* Gabb.
Length 54 mm, height 59 mm. USNM 649094, USGS Cenozoic loc. M1939, lower part of Pancho Rico Creek.

4. *Crepidula nummaria* Gould.
Height 30 mm, width 19 mm. USNM 649095, a rubber cast. USGS Cenozoic loc. M1929, lower part of Pancho Rico Creek.

5. *Kelletia* cf. *K. kelleti* (Forbes).
Height 40.5 mm, width 22.5 mm. USNM 649096, a rubber cast. USGS Cenozoic loc. M1934, railroad cut north of Sarah Canyon.

6. *Thais etchegoinensis* Arnold.
Ribbed form. Height 59 mm, width 39.5 mm. SUPTC 9755. SU loc. C1001, 3 miles east of San Lucas.

8. *Lyropecten cerrosensis* (Gabb).
Right valve. Length 123 mm, height 112 mm. UCMP 36469. UCMP loc. A911, about 3 miles southeast of San Lucas.



MOLLUSKS OF THE PANCHO RICO FORMATION

PLATE 4

FIGURE 1. *Patinopecten lohri* (Hertlein).
Right valve. Length 113 mm, height 102 mm. UCMP 36468. UCMP loc. A3161, between Bitterwater Road and Becker Valley.

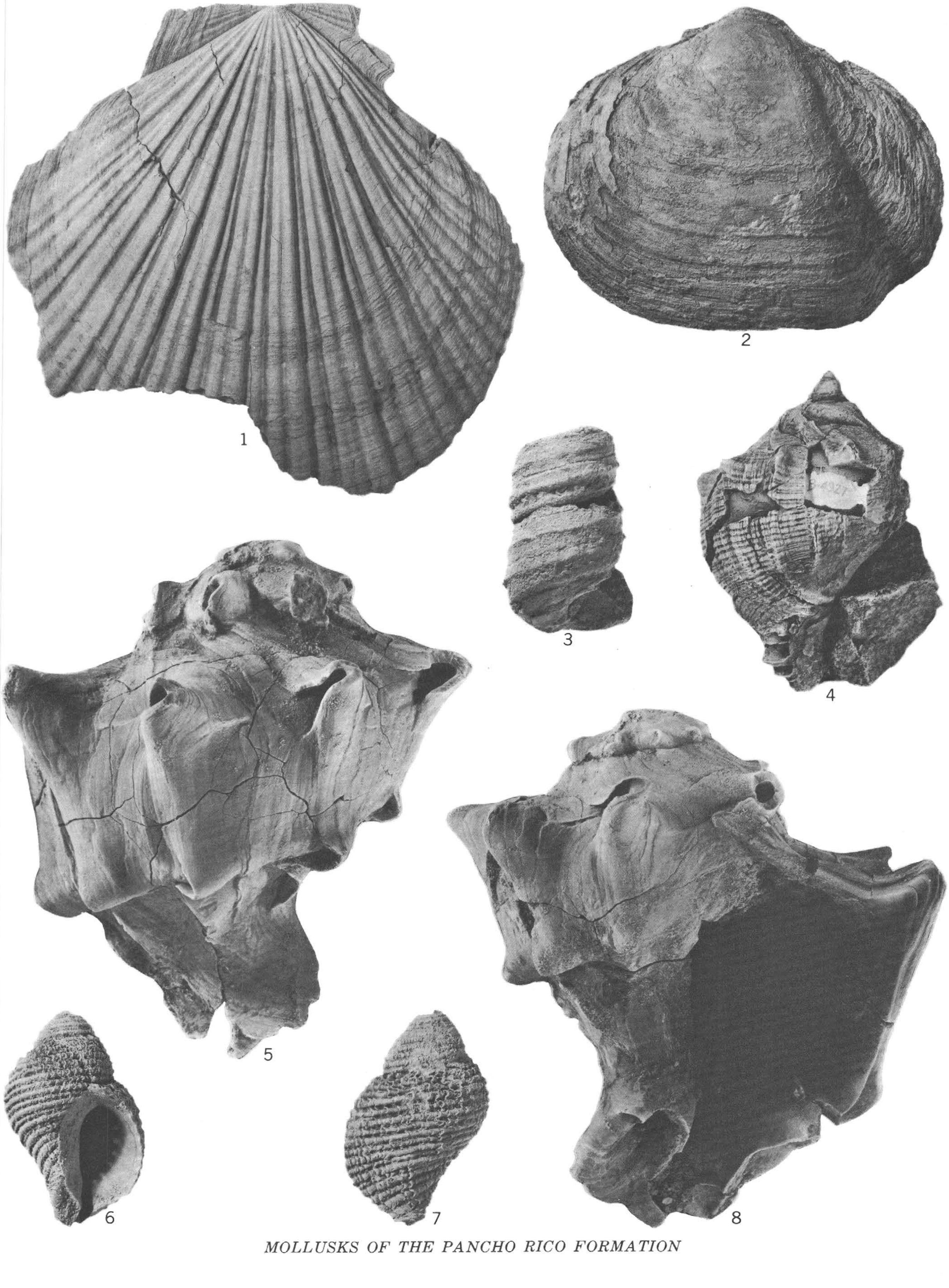
2. *Florimetis biangulata* (Carpenter).
Length 77 mm, height 62.5 mm, width 34.4 mm. USNM 649097. USGS Cenozoic loc. M1929, lower part of Pancho Rico Creek.

3. *Turritella cooperi* forma *nova* Nomland.
Height 18.5 mm, width 12.4 mm. USNM 649098. USGS Cenozoic loc. M1676, about 2½ miles south of San Ardo.

4. *Cancellaria tritonidea* Gabb.
Height 63.5 mm, width 48 mm. UCMP 36470. UCMP loc. B4926, about 1½ miles northeast of San Antonio Mission.

5, 8. *Forreria belcheri* (Hinds).
Height 101 mm, width 96 mm. UCMP 15177. UCMP loc. A4945, north side of Wildhorse Canyon.

6, 7. *Thais collomi* Carson.
Juvenile specimen. Height 27.9 mm, width 17.5 mm. UCMP 36471. UCMP loc. A4946, Long Valley.



MOLLUSKS OF THE PANCHO RICO FORMATION

PLATE 5

FIGURE 1. *Anadara (Anadara) trilineata* forma *canalis* (Conrad).
Length 23 mm, height 20 mm. USNM 649099, a rubber cast. USGS Cenozoic loc. M982. Reliz Canyon.

2, 4. *Calicantharus kettlemanensis* (Arnold).
USGS Cenozoic loc. M1929, lower part of Pancho Rico Creek.
2. Height 39.5 mm, width 39 mm. USNM 649100, a rubber cast.
4. Weakly noded form. Height 43 mm, width 32.5 mm. USNM 649101, a rubber cast.

3. *Calicantharus* cf. *C. fortis angulata* (Arnold).
Fragment of body whorl and spire. Width 17 mm. USNM 649102, a rubber cast. USGS Cenozoic loc. M980, lower part of Pancho Rico Creek.

5. *Diodora* n. sp.? aff. *D. inaequalis* (Sowerby).
Incomplete rubber cast. Height 17 mm. USNM 649103. USGS Cenozoic loc. M977, lower part of Pancho Rico Creek.

6, 7. *Calliostoma coalingense* Arnold.
6. Height 12.4 mm, width 13.5 mm. USNM 649104, a rubber cast. USGS Cenozoic loc. M1930, Indian Valley.
7. Height 13.5 mm, width 15 mm. USNM 649105, a rubber cast. USGS Cenozoic loc. M979, lower part of Pancho Rico Creek.

8. *Calicantharus* cf. *C. fortis* (Carpenter).
Body whorl slightly crushed. Height 36.5 mm, width 23 mm. USNM 649106, a rubber cast. USGS Cenozoic loc. M1939, lower part of Pancho Rico Creek.

9. *Turritella cooperi* Carpenter.
Body whorl slightly crushed. Height 37.5 mm, with 9.8 mm. USMN 649107, a rubber cast. USGS Cenozoic loc. M1929, lower part of Pancho Rico Creek.

10, 15. *Bittium casmaliense* (Bartsch).
10. Incomplete rubber cast. Width of last complete whorl 7.5 mm. USNM 649108. USGS Cenozoic loc. M1929, lower part of Pancho Rico Creek.
15. Strongly sculptured form. Height 19.3 mm, width 8.5 mm. USNM 649109, a rubber cast. USGS Cenozoic loc. M1967, Powell Canyon.

11, 14. *Turritella vanvlecki* Arnold.
11. Incomplete rubber cast. Width of last complete whorl 15.5 mm. USNM 649110. USGS Cenozoic loc. M1935, Walker Canyon.
14. Height 26.8 mm, width 11.5 mm. USNM 649111. USGS Cenozoic loc. M1934, railroad cut north of Sarah Canyon.

12. *Nassarius* aff. *N. californianus* (Conrad).
Height 8.8 mm, width 5.4 mm. USNM 649112, a rubber cast. USGS Cenozoic loc. M1676, about 2½ miles south of San Ardo.

13. *Forreria* cf. *F. coalingensis* (Arnold).
Height 27 mm, width 18.2 mm. UCMP 36472. UCMP loc. A906, north side of Wildhorse Canyon.

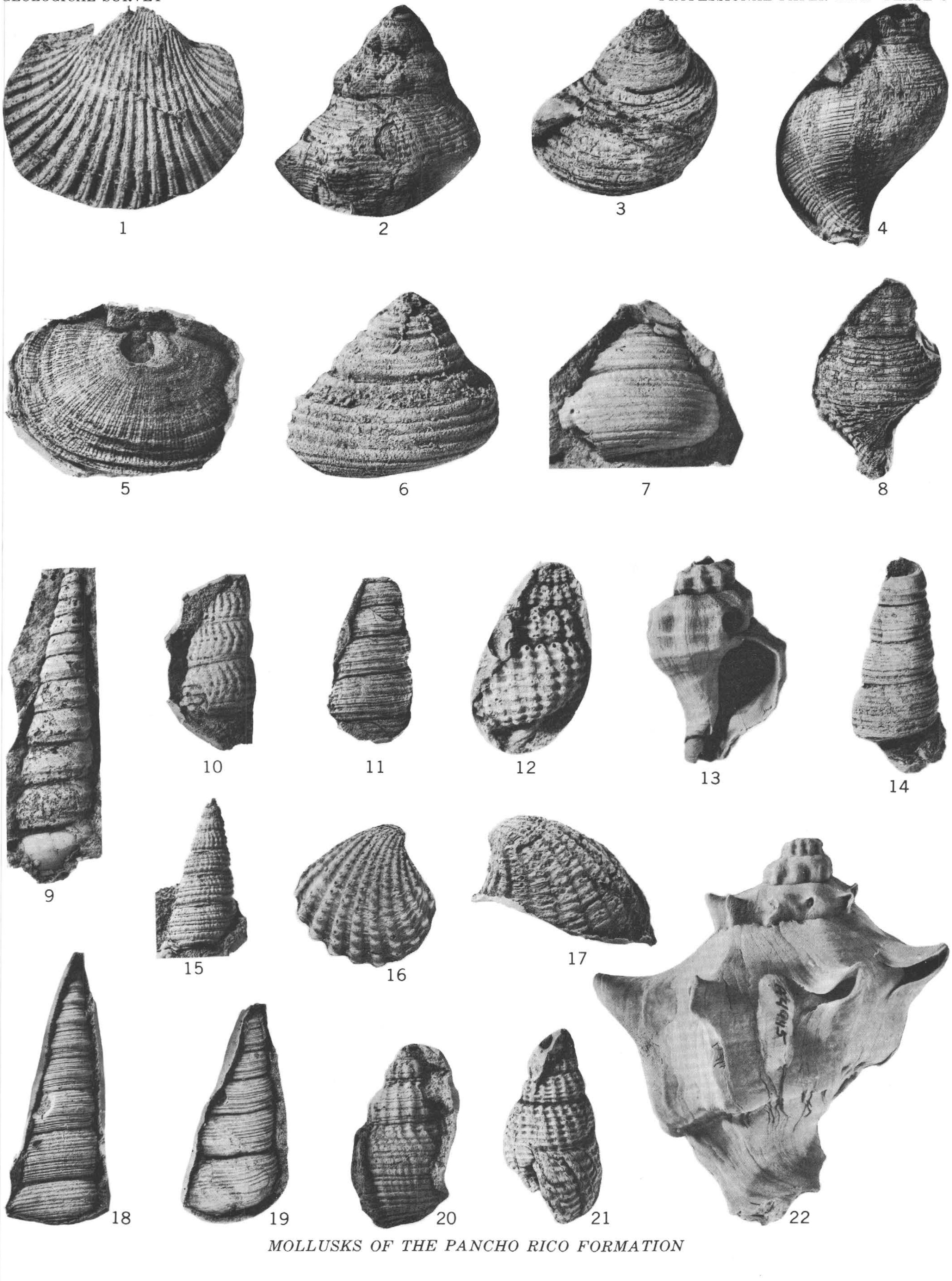
16, 17. *Cyclocardia californica* (Dall).
16. Immature specimen. Length 9.6 mm, width 9.2 mm. USNM 649113, a rubber cast. USGS Cenozoic loc. M982, highway cut 3 miles northwest of Bradley.
17. Length 22.7 mm, USNM 649114, a rubber cast, USGS Cenozoic loc. M1935, Walker Canyon.

18, 19. *Turritella gonostoma hemphilli* Applin *in* Merriam.
USGS Cenozoic loc. M982, highway cut 3 miles northwest of Bradley.
18. Height 33 mm, width 11.5 mm. USNM 649115, a rubber cast.
19. Height 38.5 mm, width 15.4 mm. USNM 649116, a rubber cast.

20. *Nassarius salinasensis* Addicott.
Height 17.8 mm, width 8.9 mm. USNM 648598, a rubber cast. USGS Cenozoic loc. M977, lower part of Pancho Rico Creek.

21. *Nassarius (Caesia) coalingensis* (Arnold).
Height 23.4 mm, width 12.3 mm. USNM 649117, a rubber cast. USGS Cenozoic loc. M979, lower part of Pancho Rico Creek.

22. *Forreria belcheri* (Hinds).
Height about 74 mm, width about 64 mm. UCMP 15178. UCMP loc. A4945, Wildhorse Canyon.



MOLLUSKS OF THE PANCHO RICO FORMATION