Geology and Paleontology of the Santa Maria District California

By W. P. WOODRING *and* M. N. BRAMLETTE

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Including a summary of the geologic features of producing and potential oil fields

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GEOLOGY AND PALEONTOLOGY OF THE SANTA MARIA DISTRICT, CALIFORNIA

By W. P. Woodring and M. N. Bramlette

ABSTRACT

Stratigraphy, paleontology, and geologic history.—A basement' consisting of igneous rocks of the Jurassic(?) Franciscan formation and sediments of the Upper Jurassic Knoxville formation, and formations of Tertiary and Quaternary age are exposed in the Santa Maria district. The outcrop section, exclusive of the Franciscan, has a maximum thickness of about 10,000 feet, the subsurface section about 27,000 feet. At no locality, however, is either outcrop or subsurface section as thick as the total maxima for the formations.

The outcrop Franciscan is made up of altered basalt, gabbro (generally greatly altered), and minor areas of peridotite and serpentine.

The marine Knoxville formation, consisting of shale, thin-bedded calcareous sandstone, and conglomerate, was deposited on the igneous rocks of the Franciscan. It has an outcrop thickness of about 500 feet and a known subsurface thickness of at least 1,250 feet. *Aucella* cf. *A. piochii*, which occurs in both outcrop and subsurface sections, suggests late Jurassic age.

The Franciscan and Knoxville were probably uplifted during Taliaferro's Diablan orogeny at the close of the Jurassic and formed a land area that presumably endured during early Cretaceous and perhaps during much of late Cretaceous time. If sediments were laid down while 10,000 feet of Upper Cretaceous were deposited in the adjoining San Rafael Mountains, they were eroded following uplift at the close of the Cretaceous, when Reed and Hollister's San Rafael uplift was formed. The district is inferred to have been part of a Franciscan and Knoxville land area at the south border of the San Rafael uplift during all of early Tertiary time.

The known history of the district as part of a Tertiary basin began in the early Miocene(?), possibly a little earlier or possibly a little later, when the nonmarine sediments of the early Miocene(?) Lospe formation were deposited. The Lospe formation has a maximum thickness of 2,700 feet, and is made up of coarse-grained reddish sandstone and conglomerate, and greenish sandstone, gypsiferous siltstone, and mudstone. White tuff is a minor but conspicuous constituent. The Lospe formation overlies the Knoxville, or overlaps it and rests on the Franciscan.

The first known Tertiary invasion of the sea took place immediately thereafter in early middle Miocene time, and from then on until approximately the end of the Pliocene the sea occupied continuously at least most of the region. The extent of the Miocene basin is not certainly known, but it was part of an extensive basin that has been designated the Santa Barbara embayment.

The early middle Miocene Point Sal formation is the earliest marine Tertiary formation. It has an outcrop thickness of as much as 1,500 feet and a maximum subsurface thickness of 3,600 feet, and consists of siltstone, mudstone, and thin beds of sandstone. The Point Sal formation overlies the Lospe formation without marked discontinuity, or overlaps it and rests on Knoxville or Franciscan. It contains a large foraminiferal fauna representing the *Siphogenerina hughesi* zone, or the lower part of Kleinpell's Relizian stage.

The Monterey shale overlies the Point Sal formation without noticeable discontinuity, or overlaps all the older sedimentary formations and rests on the Franciscan. It has a maximum outcrop thickness of 2,100 feet, but is as much as 5,000 feet thick in some subsurface sections. The Monterey is divided into three mapped members. The lower member is characterized by phosphatic shale and somewhat porcelaneous shale; the middle member by chert and cherty shale; and the upper member by porcelaneous shale, or by both porcelaneous shale and diatomaceous strata. The lower member contains Foraminifera representing the upper part of Kleinpell's Relizian stage and all of his Luisian stage, the middle member a few species indicating the lower part of his Mohnian stage, and the upper member a fauna representing the upper part of the *Bolivina hughesi* zone, at the top of the Mohnian, and in part a younger unnamed faunal division; that is, the Monterey is of late middle and late Miocene age.

The diverse stratigraphic relations of the Lospe and Point Sal formations and Monterey shale along the borders of the Franciscan rocks forming Point Sal Ridge are inferred to be the result of repeated movements during Miocene time in the area of basement rocks west of the district, presumably extending westward beyond the present coast.

Toward the close of the Miocene, low ridges appeared on the floor of the sea, ridges that grew during Pliocene time and were destined to become anticlines. At the same time deformation took place in the northeastern part of the district, and elsewhere on some anticlines, or on other structural highs bounded by faults. In those areas the Sisquoc formation overlies the Monterey shale with marked discordance; elsewhere there is no discordance.

Two facies of the Sisquoc formation are mapped: a marginal sandstone facies, designated the Tinaquaic sandstone member, and a basin facies. The Tinaquaic sandstone member is 1,400 feet thick and contains megafossils of middle Pliocene age (also early Pliocene just east of the mapped area). It is unconformable on the Monterey. The basin facies, at least 3,000 feet thick in outcrop sections and 5,000 in some subsurface sections, consists of diatomaceous mudstone, other types of diatomaceous strata, somewhat porcelaneous mudstone, and porcelaneous shale—deposits that are ordinarily characteristic of the Monterey shale. Even in areas where the two formations are lithologically indistinguishable and conformable, a field basis for differentiating them has been established. The basin facies of the Sisquoc conformably overlies the Monterey in outcrop sections, but in some subsurface sections the formations are unconformable, and on the north limb of the Santa Maria Valley syncline the basin facies of the Sisquoc overlaps the Monterey onto the basement, thus forming the overlap trap for the oil in the Monterey in the Santa Maria Valley field. The lower and middle parts of the basin facies contain Foraminifera of the *Bolivina obliqua* zone. Kleinpell assigned that zone to the lower part of his late upper Miocene Delmontian stage. Assignment to the upper Delmontian, however, appears to be preferable. The upper few hundred feet of the basin facies contain Foraminifera similar to those in the overlying Foxen mudstone and megafossils of middle Pliocene affinities. The basin facies is therefore considered late upper Miocene to middle Pliocene.

The submarine ridges were growing during Pilocene time. The Foxen mudstone is missing on them and in the northeastern

part of the district. On the north limb of the Santa Maria Valley syncline, the Foxen overlaps the Sisquoc formation and rests on the basement. In the basins between the submarine ridges, the mudstone, siltstone, and fine-grained sandstone of the Foxen (800 feet thick in outcrop sections and as much as 2,750 in subsurface sections) overlie conformably the Sisquoc formation. In some of the areas where the Foxen is missing as a lithologic unit, it appears to be represented by condensed deposits of phosphatic pellets, mapped with the underlying or overlying Formation, depending on the matrix, or by a condensed section of fine-grained sand, mapped with lithologically indistinguishable sand in the basal part of the overlying formation. Though foraminifera are abundant in the Foxen mudstone, relatively few species are represented. Those from the lower part of the formation may be of middle Pliocene age. Megafossils from the upper part of the Foxen are considered late Pliocene. The formation is therefore assigned to the middle(?) and upper Pliocene.

Movements during Pliocene time in the basement area west of Point Sal Ridge are indicated by the occurrence in the western Casmalia Hills of coarse detritus from the Monterey in the upper part of the Sisquoc formation and in the Foxen mudstone.

During late Pliocene time, when the Careaga sandstone was deposited, the Pliocene sea had its greatest extent. The region then flooded may be referred to as the Santa Maria basin. Throughout most of the district two mapped members of the Careaga sandstone are differentiated: the Cebada fine-grained member, which has a maximum outcrop thickness of 1,000 feet, and the Graciosa coarse-grained member, 50 to 425 feet thick. Mild deformation continued during the late Pliocene. The Cebada fine-grained member is missing on the embryonic anticlines, where it is overlapped by the Graciosa coarse-grained member. Both members of the Careaga sandstone contain a large megafauna.

The nonmarine Paso Robles formation conformably overlies the Careaga sandstone. The Paso Robles consists chiefly of sand and gravel, but clay, marl, and limestone are the most characteristic constituents. The maximum outcrop thickness is 2,000 feet, the estimated maximum subsurface thickness 4,500 feet. The Paso Robles fresh-water fauna is meager, consisting of a few species similar to living forms. The formation is currently assigned to the interval including late Pliocene and early Pleistocene(?). The age assignment late Pliocene(?) and early Pleistocene, however, may be preferable for the Santa Maria district.

Then followed the only period of strong general deformation in the known Tertiary and Pleistocene history of the district. The present structural features of the district were formed at that time, and the submarine ridges appeared as fully formed anticlines. Dating of the deformation is uncertain, because of uncertainty concerning the age of the Paso Robles formation. It is, however, without much doubt of the same age as the well-dated strong middle Pleistocene deformation in the Ventura basin.

Terrace deposits, laid down on both wave-cut and stream-cut platforms, are rather arbitrarily assigned to the late Pleistocene. The oldest and most extensive terrace deposits, not more than 100 feet thick, are designated the Orcutt sand. The Orcutt sand itself is tilted as much as 12° on the limbs of anticlines and is faulted on the north limb of the Graciosa anticline, indicating renewed growth of the anticlines, presumably in late Pleistocene time. Terrace deposits apparently younger than the Orcutt sand are arched in a low anticline west of lower Foxen Canyon.

Structure.—Santa Maria Valley is the boundary between two structural provinces. To the north, valleys and hills are either synclines or anticlines. To the south, on the contrary, major valleys coincide generally with major synclines, and the hills are anticlinal. Santa Maria Valley itself is a syncline. Unlike valleys farther south in the district, however, it lies athwart an older uplift. Also unlike most of the valleys farther south, the axis of the syncline is not in the middle of the valley, but is far to the south near the bordering hills. Indeed, in the western Casmalia Hills, the anticline in the bordering hills is overturned and overrides the axis of the syncline.

The major structural features of the district have a general west-northwestward trend parallel to the trend of the basin. Minor westward-trending and northward-trending folds and faults, however, extend across the trend of the major features. The district includes areas of wide, open folds and also areas of narrow, closely spaced, and steeply tilted folds, as well as some major overturned anticlines, most of the latter overturned northward. The closely spaced folds coincide almost invariably with outcrops of the Monterey shale and Point Sal formation.

Physiography.—The surface on which the terrace deposits, designated the Orcutt sand, were deposited is extensive but is locally deformed, and only remnants are preserved. Toward the coast it changes from a stream-cut surface to a wave-cut surface.

In the coastal area three main marine terraces are recognized: the high terrace (altitude about 800 feet), the intermediate terrace (altitude about 600 feet), and the low terrace (altitude 50 to 125 feet).

An indurated layer is present at or near the surface at many localities scattered throughout the district. It is suggested that the indurated layer is an ancient hardpan, the incomplete skeleton of a former soil profile developed on a former surface of less relief than the present surface.

Sand dunes extend inland from the coast at the north and south borders of the mapped area. They are classified under three age groups: old, intermediate, and modern. The old dunes, which have a protective cover of natural vegetation and are now inactive, are far more extensive than those of the other two groups. They cover many square miles on a terrace bordering Santa Maria Valley, and extend 20 miles inland. It has not been determined whether their inactivity is due to a cutting off of the supply of sand, or to a climatic change.

Occurrence of oil.—Oil has been produced in the Santa Maria district since 1901, the total production to the end of 1947 being 269,657,000 barrels. Throughout the district most of the oil is heavy. Seven producing fields are located in the mapped area.[1] In order of discovery from oldest to youngest the fields are as follows: Orcutt, Lompoc, West Cat Canyon, East Cat Canyon, Casmalia, Gato Ridge, and Santa Maria Valley. The Santa Maria Valley field is the largest in both area and productive capacity. It is the largest overlap field in coastal California, and one of the last major fields found in the State up to 1947. The Las Flores (Monterey) pool is transforming the West Cat Canyon field into one of the major fields of the district.

The Monterey shale is the chief oil-bearing formation, and the principal reservoir in the Monterey consists of fractured chert and cherty shale. Sand in the Sisquoc formation is the sole reservoir in the minor East Cat Canyon field and in the Pliocene pool of the West Cat Canyon field. The Point Sal formation yields some oil in the southeastern part of the Santa Maria Valley field (the only part of that field where the formation is present) and a recent well in the Casmalia field is producing a small amount of relatively light oil from the Point Sal. The Lospe formation is also productive in a recent well in the Casmalia field. The Knoxville formation is productive in three areas in the northern part of the Santa Maria Valley field.

The Point Sal formation offers the greatest promise for deeper-zone production. The Lospe and Knoxville formations can no longer be ignored in areas where younger marine formations overlap against them.

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[1] At the end of 1947 the mapped area included 12 named fields. (See pp. 135–136.)

Oil possibilities in undeveloped areas.—Two matters weigh heavily in prospecting in the Santa Maria district: the degree of fracturing of chert and cherty shale in the Monterey shale, and the gravity of the oil. Other things being equal, the productivity of the Monterey varies directly with the amount of fracturing. Very heavy oil, too heavy to produce commercially under present conditions, has been found in the Monterey in the northeastern part of the district, where five discoveries (one east of the mapped area) have been made in recent years.

Among areas of possible interest, three appear to be favorable for prospecting on the basis of surface geology: an area east of Foxen Canyon, where oil may be trapped in the basal part of the Tinaquaic sandstone member of the Sisquoc formation by westward overlap of successively higher Tinaquaic strata onto the Monterey shale; an area south of the Lions Head fault, where oil may be trapped by the fault; and the offshore extension of the north border of Point Sal Ridge, where oil may possibly be trapped in the Monterey by overlap of the Sisquoc formation.

INTRODUCTION

PURPOSE AND SCOPE OF REPORT

This report is one of a series of publications on the geology and paleontology of actual or potential oil-producing districts in California. Oil has been produced in the Santa Maria district since the early part of the century, and the area covered by this report now (1947) includes seven producing fields and four areas that have been proven potentially productive but are not now producing the very heavy oil that was found.

The geology of the Santa Maria district was studied by Ralph Arnold and Robert Anderson under the auspices of the U. S. Geological Survey soon after oil was discovered there and the results of that work were published as Bulletin 322, issued in 1907.[2] That report represents a considerable achievement. Not only was a large area covered by reconnaissance mapping in one field season, but the report and also a separate publication on the paleontology, as well as other publications resulting from the field work, were prepared and published during the following year. Interest in the Santa Maria district was greatly stimulated by the discovery in 1934–36 of the Santa Maria Valley field, one of the largest overlap fields in California and also one of the last major fields discovered in that State up to 1947. Without any reasonable doubt undiscovered oil remains hidden in the district. It therefore appeared to be appropriate to re-map the area in greater detail than was possible or necessary at the time of Arnold and Anderson's reconnaissance.

The outcrop geology and paleontology are described in the present report. Details of the subsurface geology and paleontology are available only to geologists and micropaleontologists who are on the ground at the time when wells are drilled and the subsurface material is available. The subsurface geology and paleontology, however, are briefly summarized in the discussion of the oil fields. The paleontology of the outcrop formations is emphasized throughout the report, for the district is of unusual importance to micropaleontologists interested in the relations of late Miocene and early Pliocene Foraminifera and to megapaleontologists interested in the relations of Pliocene megafaunas in regions farther north and farther south. It was planned to include in the report a summary of the rich Miocene and Pliocene diatom floras, which are being studied by K. E. Lohman, of the Geological Survey, but his work was not completed when this report was prepared.

The discussion of the occurrence of oil and the plotting of wells on the geologic map (pl. 1) is based on development to January 15, 1947. Later development is summarized under the heading "Development in 1947–48."

FIELD WORK AND PRELIMINARY PUBLICATIONS

The field work on which this report is based was carried on at intervals from the summer of 1938 to the fall of 1940. R. P. Bryson served as field assistant in 1939 and K. E. Lohman in 1940. The areas covered by the geologists responsible for the mapping are shown in an index map on plate 1. At the time when the field work was undertaken, the 1:125,000 maps of the Guadalupe and Lompoc quadrangles, which were used by Arnold and Anderson in their 1906 reconnaissance, were the only topographic maps available. The geology therefore was mapped on 1:24,000 airplane photographs, prepared by Fairchild Aerial Surveys and made available to the Geological Survey through the liberal cooperation of the Board of Supervisors of Santa Barbara County. By the time the geologic map was being prepared for engraving, the Geological Survey was distributing Army Map Service 1:24,000 topographic maps covering the Santa Maria district. These maps, however, do not meet the standards for maps of that scale and are unsuitable as a base for the geologic map. The 10-minute quadrangle sheets, serving as a base for the geologic map (pl. 1), are airplane photograph mosaics compiled by Fairchild Aerial Surveys on a scale of 1:24,000.

Preparation of this report, which was started in 1940, was interrupted before the end of that year by the Geological Survey's strategic minerals program and later by its war program. Compilation of the geologic map, however, had been completed and in the fall of 1943 a copy of the map was placed in open file at the Geological Survey's Conservation Branch office in Los Angeles. Because of the importance of the Santa Maria district as a source of heavy oil during the war, there was a demand for reproduction of the map. In order to make it available to the general public, it was issued early in 1945 as an uncolored map—Preliminary Map 14 of the Oil and Gas Investigations series. In the meantime a preliminary account summarizing the stratigraphy and paleontology was published in the

[2] Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Santa Maria oil district, Santa Barbara County, Calif.; U. S. Geol. Survey Bull. 322, 161 pp., 26 pls., 1907.

Bulletin of the American Association of Petroleum Geologists in 1943. (See bibliography.)

The final geologic map, reproduced as plate 1 of the present report, has only minor alterations and additions affecting the geology, as compared with the preliminary map. The final map, however, has numerous other additions: land net, land grant boundaries, and lease boundaries in the oil fields; and the oil-well data have been brought up to date to the time when the report was completed (January 15, 1947).

ACKNOWLEDGMENTS

The Board of Supervisors of Santa Barbara County generously granted release of the airplane photographs, and Fairchild Aerial Surveys generously permitted publication of its airplane-photograph mosaic quadrangles.

Geologists and engineers on the staff of oil companies operating in the Santa Maria district and consulting geologists and engineers furnished much subsurface information. Special acknowledgment is due to C. R. Canfield, F. E. Dreyer, A. W. Hughes, M. L. Krueger, and C. F. Manlove, of the Union Oil Co. of California. R. K. Cross and T. W. Dibblee, Jr., of the Richfield Oil Corp., and H. W. Hoots, formerly Chief Geologist of the Richfield Oil Corp.; Karl Arleth and W. S. W. Kew, of the Standard Oil Co. of California; the late E. W. Galliher and R. T. White, both Chief Geologists of the Barnsdall Oil Co.; C. M. Wagner, Chief Geologist of the General Petroleum Corp.; and W. R. Cabeen and H. H. Sullwold, Jr., consulting geologists. S. G. Dolman, Deputy Supervisor of the State Division of Oil and Gas, frequently furnished information on the location, status, and productive zones of wells, and reviewed the discussion of the history of oil development.

Professor A. O. Woodford, of Pomona College and the U. S. Geological Survey, prepared descriptive notes on some of the sedimentary and igneous rocks, and also read and criticized the entire report. The few remains of marine mammals were identified by Remington Kellogg, and the few remains of land mammals by C. L. Gazin, both of the United States National Museum. Professor Chester Stock, of the California Institute of Technology, assigned a collector to search the Lospe formation for vertebrate fossils; that search, however, proved unproductive. In addition to assisting in the mapping, K. E. Lohman, of the Geological Survey, made a preliminary examination of the late Miocene and Pliocene diatom floras, the results of which were used in the preliminary account and also in the present report pending completion of his work. Many of the wildcat wells were located by S. N. Daviess, formerly of the Geological Survey.

ANNOTATED BIBLIOGRAPHY

The following briefly annotated bibliography comprises publications on the geology, paleontology, and oil fields of the Santa Maria district. Aside from a few important exceptions, it does not include trade-journal reports of oil fields and oil-field development.

1888. [Goodyear, W. A.], Santa Barbara County: California Min. Bur., Eighth Rept. State Mineralogist, pp. 536–540.

Includes brief description of gypsum mines near Point Sal (p. 538).

1894. Crawford, J. J., Asphaltum and bituminous rock: Calif. Min. Bur., Twelfth Rept. State Mineralogist, pp. 26–33.

Includes description of asphalt mining operations in Purisima Hills and on Graciosa Ridge.

1894. Fairbanks, H. W., Geology of northern Ventura, Santa Barbara, San Luis Obispo, Monterey, and San Benito Counties: Idem, pp. 493–526, 17 figs.

Includes brief description of geology of Point Sal and nearby areas (p. 506).

1896. Fairbanks, H. W., The geology of Point Sal: California Univ., Dept. Geology, Bull., vol. 2, pp. 1–92, pls. 1–2, 7 figs.

Description of geology of Point Sal Ridge, with special emphasis on petrology and chemical composition of igneous rocks. Geologic map was used in compilation of geologic map accompanying U. S. Geological Survey Bulletin 322, issued in 1907.

1901. Eldridge, G. H., The asphalt and bituminous rock deposits of the United States: U. S. Geol. Survey 22d Ann. Rept., pt. 1, pp. 209–452, pls. 25–58, 52 figs.

Asphalt deposits of Santa Maria district are described (pp. 424–439).

1903. Dall, W. H., Contributions to the Tertiary fauna of Florida: Wagner Free Inst. Sci. Philadelphia Trans., vol. 3, pt. 6, pp. 1,219–1,654, pls. 48–60.

The last part (pt. 6) of this monumental work includes description of *Venericardia* (*Cyclocardia*) *californica* (p. 1,431), collected by Eldridge "5 miles southwest [southeast] of Guadalupe". According to the preservation and matrix, the Waldorf asphalt mine, presumably the mine dump, is the type locality. (See p. 85 of present report for comments on this species.)

1903. Eldridge, G. H., The Petroleum fields of California: U. S. Geol. Survey Bull. 213, pp. 306–321.

Includes brief description of geology of "La Graciosa district" [Orcutt field], where development had just begun (p. 313). Unconformity between Monterey shale [Sisquoc formation] and overlying Pliocene sand and conglomerate (Graciosa coarse-grained member of Careaga sandstone] is recognized.

1904. Fairbanks, H. W., Gypsum deposits of California: U. S. Geol. Survey Bull, 223, pp. 119–123.

Includes brief description of gypsum deposits near Point Sal (p. 122).

1907. Arnold, Ralph, New and characteristic species of fossil mollusks from the oil-bearing Tertiary formations of Santa Barbara County, Calif.: Smithsonian Misc. Coll., vol. 50, pt. 4, No. 1,781, pp. 419–447, pls. 50–58.

Includes descriptions and illustrations of fossils from Santa Maria district. The plates illustrating Santa Maria fossils were reproduced in U. S. Geological Survey Bulletin 322, issued in the same year.

1907. Arnold, Ralph, and Anderson, Robert, Diatomaceous deposits of northern Santa Barbara County, Calif.: U. S. Geol. Survey Bull. 315, pp. 438–447.

Includes description and chemical analysis of diatomaceous rocks of Santa Maria district.

1907. Arnold, Ralph, and Anderson, Robert, Preliminary report on the Santa Maria oil district, Santa Barbara County, Calif.: U. S. Geol. Survey Bull. 317, 69 pp., 2 pls., 1 fig.

Preliminary report on area covered by U. S. Geological Survey Bulletin 322, issued in the same year.

1907. Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Santa Maria oil district, Santa Barbara County, Calif.: U. S. Geol. Survey Bull. 322, 161 pp., 26 pls.

The standard work on geology of Santa Maria and adjoining districts. Arnold and Anderson's Vaqueros formation of the Mount Lospe area is now differentiated as the Lospe and Point Sal formations, much of their Monterey shale is assigned to the Sisquoc formation, and their Fernando formation is subdivided into Foxen mudstone, Careaga sandstone, and Paso Robles formation.

1910. Hess, F. L., A reconnaissance of the gypsum deposits of California: U. S. Geol. Survey Bull. 413, 36 pp., 4 pls., 2 figs.

The Point Sal deposits are mentioned (pp. 28–29).

1911. Bartsch, Paul, The Recent and fossil mollusks of the genus *Bittium* from the west coast of America: U. S. Nat. Museum Proc., vol. 40, pp. 383–414, pls. 51–58.

Includes description of *Bittium casmaliense*, from the railroad cut a mile north of Shuman, and *B. arnoldi*, from the Waldorf asphalt mine. (See p. 70 of present report for comments on these two forms.)

1912. Louderback, G. D., Pseudostratification in Santa Barbara County, Calif.: California Univ., Dept. Geology, Bull., vol. 7, pp. 21–38, pls. 3–6.

Description of pseudostrata, attributed to deposition of siliceous cement by downward percolating water, in area between Los Alamos Valley and Sisquoc River. In the present report it is suggested they are hardpan of "fossil soil"

1914. McLaughlin, R. P., and Waring, C. A., Petroleum industry of Californis: California Min. Bur. Bull. 69, 519 pp., 78 figs., map folio of 18 pls.

Brief description of Santa Maria [Orcutt], Lompoc, and Cat Canyon [West Cat Canyon] fields on pages 396–416; list of wildcat wells on p. 407. Plate 15 of map folio is a map of Santa Maria district showing location of wells.

1915. Prutzman, P. W., Notes on the Santa Maria oilfields: Western Engineering, vol. 6, pp. 256–257.

Brief description of Cat Canyon [West Cat Canyon], Orcutt, Casmalia, and Lompoc fields.

1915. Rademacher, Rudolf, Der Santa-Maria-Öldistrikt in Kalifornien, als Beispiel einer primären Erdöllagerstätte: Zeitsch. Prak. Geol., vol. 23, pp. 150–161, 1 fig.

Summary of stratigraphy, structure, and occurrence and origin of oil in Santa Maria district, based on Arnold and Anderson's 1907 report.

1917. Collom, R. E., Report covering the oil fields of the Santa Maria district: California Min. Bur. Bull. 73 (First Rept. State Oil and Gas Supervisor), pp. 192–211, 3 pls.

Principally a discussion of water conditions, but includes structure sections of Santa Maria [Orcutt] and Cat Canyon [West Cat Canyon] fields and a list of abandoned wells.

1918. Collom, R. E., Santa Barbara, San Luis Obispo, Monterey, and Santa Clara Counties: California Min. Bur. Bull. 82 (Second Rept. State Oil and Gas Supervisor), pp. 198–230.

Includes discussion of water conditions in Cat Canyon [West Cat Canyon and East Cat Canyon]. Santa Maria [Orcutt], Casmalia, and Lompoc fields; brief description of subsurface geology of Casmalia field; and discussion of surface and subsurface geology of Cat Canyon [West Cat Canyon and East Cat Canyon] field, leading to conclusion that productive sands are in Monterey formation [Sisquoc formation of present terminology].

1918. Bell, H. W., Santa Barbara, San Luis Obispo, Monterey, and Santa Clara Counties: California Min. Bur. Bull. 84 (Third Rept. State Oil and Gas Supervisor), pp. 359–409.

Includes discussion of developments in Casmalia, Cat Canyon [West Cat Canyon and East Cat Canyon], Lompoc, and Santa Maria [Orcutt] fields, and a structure contour map of the Casmalia field.

1918. Collom, R. E., Report on Soladino-Arrellanes group of wells, Doheny-Pacific Petroleum Co., Associated Oil Co., Casmalia field: Idem, pp. 372–385.

Principally discussion of water conditions in part of Casmalia field.

1919. Jordan, D. S., and Gilbert, J. Z., Fossil fishes of the Miocene (Monterey) formations, in Fossil fishes of southern California: Leland Stanford Junior Univ. Pub., Univ. ser., pp. 13–60, pls. 7–28.

Includes description of *Forfex hypuralis* n. sp., n. gen., from "soft clay shales of Monterey [Sisquoc] age, obtained in Pine Canyon, Santa Maria oil fields" (pp. 36–37). The locality designation "Santa Maria oil field," visible on the photograph of the fossil fish, indicates that "Pine Canyon" is the short canyon on the north slope of Graciosa Ridge, so labeled on the topographic map of the Lompoc quadrangle, not the "Pine Canyon" west of the Lompoc oil field, shown on the same map.

1920. Bell, H. W., Casmalia oil field: California Oil Fields (California Div. Oil and Gas), vol. 5, no. 10, pp. 10–42, 2 pls. (including structure contour map).

Discussion of subsurface geology and water conditions. Includes valuable annotated list of wildcat wells drilled nearby.

1920. Kew, W. S. W., Cretaceous and Cenozoic Echinoidea of the Pacific coast of North America: California Univ., Dept. Geol., Bull., vol. 12, pp. 23–236, pls. 3–42, 5 figs.

Includes description of *Dendraster ashleyi*, based on specimens from Santa Maria district (p. 115).

1921. Vander Leck, Lawrence, Petroleum resources of California with special reference to unproved areas: California Min. Bur. Bull. 89, 186 pp., 6 pls., 12 figs.

Oil fields of Santa Maria district are described on pages 102–106.

1921. Watson, E. B., and Smith, Alfred, Soil survey of the Santa Maria area, Calif.: U. S. Dept. Agr., Bur. Soils, Field Operations, 1916 (18th Rept.), pp. 2,531–2,574, pls. 72–75, fig. 64, map 61. (Issued separately 1919.)

Soil survey of Santa Maria Valley and adjoining areas.

1922. Gore, F. D., Report on water conditions in northwesterly part of Cat Canyon oil field: California Oil Fields (California Div. Oil and Gas), vol. 7, No. 9, pp. 12–17, 2 pls.

Discussion of occurrence of water in West Cat Canyon field.

1923. Gore, F. D., Oil shale in Santa Barbara County, Calif.: California Min. Bur., Mining in California, vol. 19, no. 4, pp. 211–224, 5 figs., 2 pls. (Republished in slightly altered form under same title in Am. Assoc. Petroleum Geologists Bull., vol. 8, No. 4, pp. 459–472, 5 figs., 1924.)

Technology of treatment of "oil shale" at Day experimental plant near Shuman siding and at NTU mine farther west in Casmalia Hills. The oil-impregnated strata are in Sisquoc formation of present terminology.

1925. Carson, C. M., Some new species from the Pliocene of southern California, with a few changes in nomenclature: Southern California Acad. Sci. Bull., vol. 24, pp. 30–35, 7 figs.

Includes record of *Searlesia portolaensis* from Fugler Point.

1926. Carson, C. M., New molluscan species from the California Pliocene: Idem, vol. 25, pp. 49–62, 4 pls.

Includes description of new species from Santa Maria district.

1928. Collom, R. E., Geology of the Santa Maria district: Oil Bulletin, vol. 14, No. 4, pp. 368–369, map, structure section.

Brief description of oil fields of Santa Maria district.

1929. Collom, R. E., Oil accumulation and structure of the Santa Maria district, Santa Barbara County, Calif., in Structure of typical American oil fields, vol. 2, pp. 18–22, 2 figs., Tulsa, Am. Assoc. Petroleum Geologists.

Brief discussion of structure, reservoirs, and origin of oil in fields of Santa Maria district.

1929. Stirton, R. A., and Weddle, H. W., The California tapir, *Tapirus haysii californicus* Merriam, from Santa Barbara County, Calif.: California Univ., Dept. Geol. Sciences, Bull., vol. 18, pp. 225–226, 1 fig.

Description of tapir molar from unconsolidated sand [presumably Orcutt sand] along Corralillos Canyon.

1931. Grant, U. S., IV, and Gale, H. R., Catalogue of the marine Pliocene and Pleistocene Mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, 1,036 pp., 32 pls., 15 figs.

Includes records of Pliocene species from Santa Maria district.

1932. Hodges, F. C., and Johnson, A. M., Subsurface storage of oil and gas in the Brea-Olinda and Lompoc fields: California Oil Fields (California Div. Oil and Gas), vol. 17, no. 4, pp. 5–12, 1 pl.

Includes description of reservoir storage operations in Lompoc field.

1932. Dolman, S. G., Lompoc oil field, Santa Barbara County, Calif.: Idem. pp. 13–19, 3 pls.

Subsurface geology and structure of Lompoc field.

1932. Porter, W. W., II, Lower Pliocene in Santa Maria district, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 16, no. 2, pp. 135–143, 2 figs.

Description of Sisquoc formation and discussion of its age and correlation.

1933. Porter, W. W., II, Influence of speed of migration of oil on water encroachment at Casmalia, Calif.: Idem. vol. 17, no. 9, pp. 1,133–1,136, 1 fig.

Discussion of unusual oil-water relations resulting from high specific gravity of oil in Casmalia field.

1933. Reed, R. D., Geology of California, 355 pp., 60 figs., Tulsa, Am. Assoc. Petroleum Geologists.

Includes table, prepared by L. M. Clark, of Pliocene formations of Santa Maria district (p. 232).

1935. Hoots, H. W., and Herold, S. C., Natural gas resources of California, in Geology of Natural Gas, pp. 113–220, 36 figs., Tulsa, Am. Assoc. Petroleum Geologists.

Includes description of subsurface geology and occurrence of oil and gas in Santa Maria [Orcutt] and Lompoc fields. Table of "Formations in Santa Maria district" (p. 156) lists Orcutt formation, which is Orcutt sand of present report.

1936. Reed, R. D., and Hollister, J. S., Structural evolution of southern California: Am. Assoc. Petroleum Geologists Bull., vol. 20, No. 12, pp. 1,529–1,704, 9 pls., 57 figs. (Also issued as separate publication, 157 pp., 9 pls., 57 figs., Tulsa, Am. Assoc. Petroleum Geologists.)

Contains scattered information on geologic history of Santa Maria district, especially in chapter 6.

1937. Porter, W. W., II, Santa Maria Valley, another great field: Petroleum World, Los Angeles, vol. 34, No. 7, pp. 24–30, 6 figs.

Description of newly discovered Santa Maria Valley field.

1937. Reinhart, P. W., Three new species of the pelecypod family Arcidae from the Pliocene of California: Jour. Paleontology, vol. 11, pp. 181–185, pl. 28.

Description of three species from Fugler Point: *Arca sisquocensis*, *A. santamariensis*, and *Barbatia pseudoillota*.

1938. Grant, U. S., IV, and Hertlein, L. G., The west American Cenozoic Echinoidea: California Univ. Los Angeles, Pub. Math. Phys. Sci., vol. 2, 225 pp., 30 pls., 17 figs.

Includes description of *Dendraster ashleyi* and records of that species from Santa Maria district.

1938. Kleinpell, R. M., Miocene stratigraphy of California, 450 pp., 22 pls., 14 figs., Tulsa, Am. Assoc. Petroleum Geologists.

The Santa Maria district is mentioned incidentally. The Santa Maria basin column in the correlation chart (fig. 14) is based on localities outside the district proper.

1938. Rogers, A. F., Fossil termite pellets in opalized wood from Santa Maria, Calif.: Am. Jour. Sci., 5th ser., vol. 36, no. 215, pp. 389–392, 1 fig.

Description of termite pellets from Arnold and Anderson's Fernando formation at undesignated locality in Santa Maria district.

1939. Canfield, C. R., Subsurface stratigraphy of Santa Maria Valley oil field and adjacent parts of Santa Maria Valley, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 23, no. 1, pp. 45–81, 8 figs.

Description of subsurface stratigraphy, foraminiferal zones, structure, and oil production of Santa Maria Valley field. Subsurface formations and zones described are for most part still used by subsurface geologists and micropaleontologists.

1940. Natland, M. L., New genus of foraminifera from the later Tertiary of California: Jour. Paleontology, vol. 14, pp. 568–571, pl. 69, 2 figs.

Includes description of new late Miocene species, *Cassidulinella renulinaformis*, the type of which is from Union Oil Company Newlove No. 51 well, Orcutt field, at depth of 2,165 feet.

1941. Frame, R. G., Santa Maria Valley oil field: California Oil Fields (California Div. Oil and Gas), vol. 24, no. 2, pp. 27–47, 9 pls., 1938 (1941).

Description of subsurface geology, development and production of oil in Santa Maria Valley field.

1941. Wissler, S. G., and Dryer, F. E., Correlation of the oil fields of the Santa Maria district: California Div. Mines Bull. 118, pt. 2, preprint, pp. 235–238, fig. 95.

Subsurface stratigraphy and foraminiferal zones of oil fields in Santa Maria district.

1941. Hoots, H. W., Origin, migration, and accumulation of oil in California: Idem, pp. 253–275, pl. 6, figs. 102–113.

Includes discussion of origin and accumulation of oil in fields of Santa Maria district, and of age of producing zones.

1942. Moyer, F. T., Lightweight aggregates for concrete: U. S. Bur. Mines Information Circ. 7,195, 26 pp.

Includes brief description of method used at Airox plant, near Shuman, for processing oil-impregnated diatomaceous mudstone into light-weigh aggretgate (p. 19).

1943. Dibblee, T. W., Jr., Lompoc oil field: California Div. Mines Bull. 118, pt. 3, pp. 427–429, fig. 177.
Geology and oil production of Lompoc field.

1943. Porter, W. W., II, Casmalia oil field: Idem, p. 430.
Geology and oil production of Casmalia field.

1943. Dryer, F. E., Santa Maria (Orcutt) oil field: Idem, p. 431.
Geology and oil production of Orcutt field.

1943. Manlove, Charles, West Cat Canyon area of the Cat Canyon oil field: Idem, pp. 432–434, fig. 178.
Geology and oil production of West Cat Canyon field.

1943. Cross, R. K., East Cat Canyon area of the Cat Canyon oil field: Idem, pp. 435–437, figs. 179–180.
Geology and oil production of East Cat Canyon field.

1943. Cross, R. K., Gato Ridge area of the Cat Canyon oil field: Idem, pp. 438–439, fig. 181.
Geology and oil production of Gato Ridge field.

1943. Canfield, C. R., Santa Maria Valley oil field: Idem, pp. 440–442, figs. 182–183.
Geology and oil production of Santa Maria Valley field.

1943. Reinhart, P. W., Mesozoic and Cenozoic Arcidae from the Pacific slope of North Americas: Geol. Soc. America Special Paper 47, 117 pp., 15 pls., 3 figs.
Includes description of the three species from Fugler Point described in 1937.

1943. Woodring, W. P., Bramlette, M. N., and Lohman, K. E., Stratigraphy and paleontology of Santa Maria district, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 27, No. 10, pp. 1,335–1,360, 4 figs.
Summary of stratigraphy and paleontology of Santa Maria district. The stratigraphic nomenclature is the same as in present report.

1944. Dolman, S. G., Airox concrete aggregate: California Jour. Mines and Mining, vol. 40, pp. 131–133, 1 fig.
Description of Airox mine and plant near Shuman. Oil-impregnated mudstone of Sisquoc formation is calcined to form light-weight aggregate.

1944. Hertlein, L. G., and Grant, U. S., IV, The Cenozoic Brachiopoda of western North America: California Univ. Los Angeles, Pub. Math. Phys. Sci., vol. 3, 236 pp., 21 pls., 34 figs.
Includes records of *Terebratalia arnoldi* and *T. occidentalis* from Santa Maria district.

1945. Woodring, W. P., Bramlette, M. N., Lohman, K. E., and Bryson, R. P., Geologic map of Santa Maria district, Santa Barbara County, Calif.: U. S. Geol. Survey, Oil and Gas Invest., Prel. Map 14, 6 sheets, scale 1:24,000.
With exception of a few minor alterations and additions, geology is the same as that on map sheets accompanying present report (pl. 1).

1945. Woodring, W. P., Loofbourow, J. S., Jr., and Bramlette, M. N., Geology of Santa Rosa Hills-eastern Purisima Hills district, Santa Barbara County, Calif.: Idem, Prel. Map 26, 1 sheet, scale 1:48,000.
Includes eastern Purisima Hills.

1945. Williams, M. D., and Holmes, C. N., Oil-impregnated diatomaceous rock near Casmalia, Santa Barbara County, Calif.: Idem, Prel. Map 34, 1 sheet, scale 1:3,600.
Description and map of small area at NTU mine in western Casmalia Hills.

1946. Cabeen, W. R., and Sullwold, H. H., Jr., California basement production possibilities: Oil Weekly, vol. 122, No. 8, pp. 17–25, 5 figs.
Includes history of Knoxville production in Santa Maria Valley field, and discussion of accumulation of oil and reservoir conditions.

LOCATION AND GEOGRAPHIC FEATURES

The term "Santa Maria district" is used rather arbitrarily for the area of about 400 square miles covered by the present report. Actually the district proper includes in addition to the mapped area the 10-minute quadrangle at the southwest border of the mapped area, a part of the Purisima Hills east of the mapped area, and an indefinite region farther east stretching toward the foot of the San Rafael Mountains. The region shown on plate 1 includes (with the exception of the Zaca Creek heavy-oil field) all the oil fields of the Santa Maria district, which is at the present time the northernmost major oil-producing district in coastal California.

As shown on figure 1, and on the 1:125,000 topographic maps of the Lompoc and Guadalupe quadrangles (and also on the 1:62,500 Army Engineer maps of the Point Sal, Santa Maria, Tepesquet Peak, Lompoc, Los Olivos, and San Rafael Mountain quadrangles), the Santa Maria district is part of an elongate triangular region of valleys and hills lying between the westward-trending Santa Ynez Mountains and the northwestward-trending San Rafael Mountains, the apex of the region pointing southeast toward the converging ranges. U. S. Highway 101, the coastal highway between Los Angeles and San Francisco, almost obliquely bisects the district. The Coast Line of the Southern Pacific Railroad crosses the Casmalia Hills in a pass at Shuman (spelled "Schuman" and "Schumann" in former publications). The Santa Maria Valley Railroad connects Santa Maria, the only city in the district, with the Southern Pacific at Guadalupe. A narrow-gauge railroad, the Pacific Coast Railway, formerly extended up the Santa Maria Valley from Santa Maria to the West Cat Canyon oil field and southward from Santa Maria through Orcutt and Los Alamos to Los Olivos, east of the mapped area. It was abandoned piecemeal and the tracks are now completely torn up.

The alluvium-floored Santa Maria Valley, the flood plain of the Santa Maria River and its tributary, the Sisquoc River, lies at the north border of the district. The valley is a rich agricultural region, irrigated by ground water from the valley itself. The principal crops are truck produce, sugar beets, which are processed in a refinery at Betteravia, flowers grown for seed, and dairy feeds. The valley is bordered on the south by rolling hills, designated the Casmalia Hills west of the pass followed by State Highway 1 between Orcutt and and Harris, and the Solomon Hills east of the pass. Eastward beyond the east border of the mapped area, the Solomon Hills merge into a gently sloping dissected upland stretching to the foot of the San Rafael Mountains. Farther south is the narrow Los Alamos Valley and its westward continuation, the San Antonio Valley. Still farther south are the Purisima Hills, named for one of the colonial missions, La Purisima, now the site of a State Park. The Purisima Hills are higher and more rugged than the Solomon Hills and somewhat

FIGURE 1.—Relief map of California showing location of the Santa Maria district.

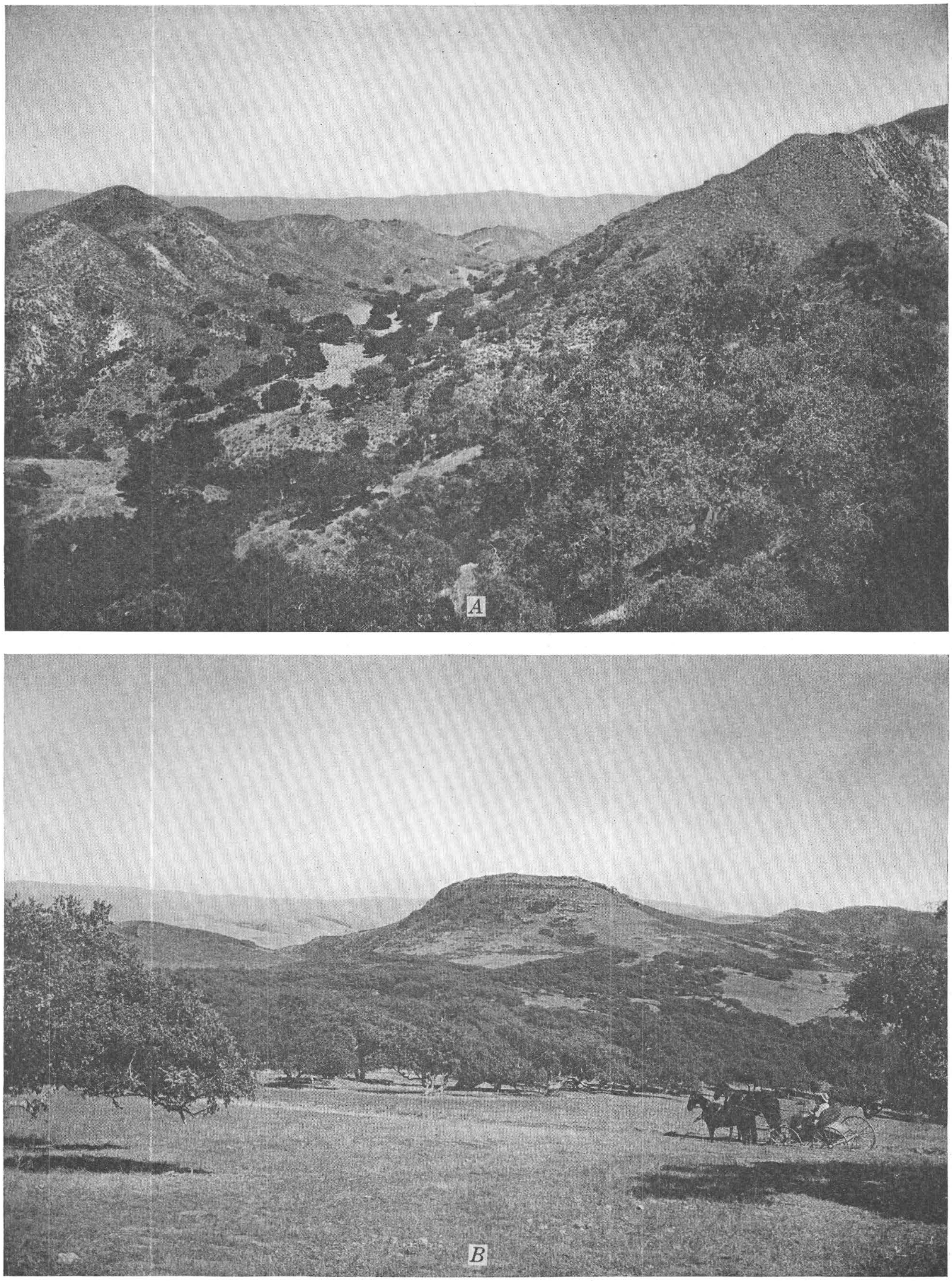


FIGURE 2.—Views in Purisima Hills and Solomon Hills. *A*, View looking eastward on north slope of Purisima Hills between Canada Laguna Seca and Canada de Santa Ynez; *B*, Mount Solomon as viewed from northwest.

higher than the Casmalia Hills. The mapped area includes the extreme north border of the western Santa Ynez Valley along the Santa Ynez River. Like the Santa Maria Valley, the western Santa Ynez Valley is a rich agricultural valley, the center of the flower-seed industry in California.

Mount Lospe (1,624 feet) in the Casmalia Hills, Mount Solomon (1,338 feet) in the Solomon Hills, and Redrock Mountain (1,968 feet) in the Purisima Hills are the highest peaks. They are dwarfed by the peaks in the San Rafael Mountains, which reach altitudes of almost 5,000 feet not more than 10 miles beyond the east border of the mapped area.

Lima beans and barley are grown on arable lands outside the irrigated valleys. These nonirrigated crops grow and mature during the summer when no rain falls. Aside from water naturally stored in the ground during the winter rainy season, the only moisture available to them is from the fogs that sweep in from the ocean almost every night during the summer and disappear a few hours after the sun rises. The rough hilly land that is not plowed is used for cattle grazing.

Some of the hills are grass-covered, or are covered with grass and orchardlike open stands of live oak (fig. 2 *B*). For the most part, however, the hills, especially the Purisima Hills, have denser stands of live oak interspersed with thickets of black sage and other shrubs (fig. 2 *A*), including, particularly in ravines and canyons, masses of poison oak—the shrub that is likely to be of greatest annoyance to geologists. Locally, as on the crest of the western Purisima Hills and on the crest of Graciosa Ridge in the Solomon Hills, there are groves of pine and practically impenetrable chaparral thickets of dwarf live oak, chamise, and manzanita.

The term "Santa Maria basin" is used in the present report for the late Pliocene depositional basin, not for a physiographic basin, for there is no well defined physiographic basin.

STRATIGRAPHY

OUTLINE OF GEOLOGIC HISTORY

The formations of the Santa Maria district, their general character and important fossils, and maximum outcrop and subsurface thickness are shown in the accompanying table, and a generalized graphic stratigraphic section is shown on plate 3.

The district is notable for the great thickness of Monterey-like rocks younger than the Monterey proper, and for the varying stratigraphic relations of formations within relatively small areas.

Formations of Santa Maria district

Age	Formation	Member	Maximum outcrop thickness (feet)	Maximum subsurface thickness (feet)	Lithology	Important fossils
Recent (more or less contemporaneous with dune sand).	Alluvium.		20	230	Sand, gravel, silt.	None found.
Recent.	Dune sand.		100	100(?)	Well-sorted strongly cross-bedded sand.	None found.
Late Pleistocene.	Terrace deposits younger than Orcutt sand.		100	1,000±	Marine sand and gravel, a foot to 6 feet thick, locally on platform of marine terraces. Reddish-brown sand, gravel, and rubble forming nonmarine cover on marine terraces. Sand and gravel on stream terraces.	Mostly tide-pool and rock-cliff mollusks and barnacles in marine deposits. None found in other deposits.
	Orcutt sand.		100		Reddish-brown sand, gravel.	Fresh-water mollusks and ostracodes.
Late Pliocene and early Pleistocene(?).	Paso Robles formation.		2,000	4,500	Sand, gravel, clay, limestone.	Fresh-water mollusks, ostracodes, and diatoms.
Late Pliocene.	Careaga sandstone.	Graciosa coarse-grained member.	425	2,250	Coarse-grained sandstone, conglomerate.	Megafossils: *Dendraster ashleyi*, *"Nassa" moraniana*, *"Drillia" graciosana*, *Patinopecten healeyi*, *Lyropecten cerrosensis*, *Macoma nasuta kelseyi*, *Pseudocardium densatum* var. cf. *gabbii*, *Pachydesma crassatelloides*, *Protothaca staleyi*.
		Cebada fine-grained member.	1,000		Fine-grained sandstone.	Megafossils: *Terebratalia occidentalis*, *Turritella gonostoma hemphilli*, *"Cancellaria" arnoldi*, *"C." hemphilli*, *Chlamys parmeleei*, *Patinopecten healeyi*, *Lyropecten cerrosensis*.
Middle(?) and late Pliocene.	Foxen mudstone.		800	2,750	Mudstone, siltstone, fine-grained sandstone.	Foraminifera (lower part): *Bolivina* aff. *B. obliqua*, *Bolivina foxenensis*, *Uvigerina foxenensis*, *Virgulina californiensis* var. *purisima*. Megafossils (upper part): *Merriamaster* cf. *M. perrini*, *"Nassa" waldorfensis*, *Chlamys parmeleei etchegoini*, *Patinopecten healeyi*, *P. dilleri*. Diatoms: *Podosira montagnei*, *Stephanopyxis turris* var. *cylindrus*, *Coscinodiscus asteromphalus*, *C. cirrus*, *Xanthiopyxis ovalis*.

Formations of Santa Maria district—Continued

Age	Formation	Member	Maximum outcrop thickness (feet)	Maximum subsurface thickness (feet)	Lithology	Important fossils
Late Miocene to middle Pliocene.	Sisquoc formation.	Tinaquaic sandstone member (marginal facies).	1,450	3,000(?)	Sandstone, conglomerate, siltstone.	Foraminifera: *Elphidiella* aff. *E. hannai, Nonion belridgensis.* Megafossils: *Dendraster* cf. *D. coalingaensis, "Nassa"* sp., *Patinopecten lohri, Pseudocardium densatum?, Cryptomya* cf. *C. californica, Siliqua* cf. *S. media.* Diatoms: *Coscinodiscus* cf. *C. excentricus, C. obscurus, Lithodesmium minusculum, Raphoenis angularis, Fragilaria ischaboensis.*
		Diatomaceous strata and equivalent somewhat porcelaneous mudstone, including Todos Santos claystone member (basin facies).	3,000+	5,000	Diatomaceous mudstone, clayey less diatomaceous mudstone, laminated diatomite, somewhat porcelaneous mudstone, somewhat porcelaneous claystone, porcelaneous shale.	Foraminifera (lower and middle parts): *Bolivina obliqua, B. rankini, B. ticensis, Nonion belridgensis, Nonionella miocenica* var., *Virgulina californiensis.* Megafossils (upper part): *Yoldia gala, Anadara trilineata, Patinopecten* cf. *P. lohri, P. dilleri* var., *Ostrea erici, Tellina* cf. *T. aragonia, T.* cf. *T. lutea.* Diatoms: *Melosira recedens, Endictya tubiformis, Coscinodiscus aeginensis, C. intersectus, Lithodesmium cornigerum.*
Middle and late Miocene.	Monterey shale.	Upper member.	1,000	5,000	Porcelaneous shale, laminated diatomite.	Foraminifera: *Cassidulinella renulinaformis, "Ellipsoglandulina" fragilis, Hopkinsina magnifica.* Diatoms: *Coscinodiscus gigas, C. oculisiridis* var. *borealis, Asterolampra marylandica, Lithodesmium californicum, Goniothecium rogersii.*
		Middle member.	250		Chert, cherty shale, porcelaneous shale.	Foraminifera: *Bolivina* aff. *B. hughesi, Eponides rosaformis, Robulus mohnensis.*
		Lower member.	900		Phosphatic shale, silty shale, somewhat porcelaneous shale.	Foraminifera: *Anomalina salinasensis, Pullenia miocenica, Siphogenerina collomi, S.* cf. *S. reedi, S. branneri.*
Middle Miocene.	Point Sal formation.		1,500	3,600	Mudstone, siltstone, thin beds of sandstone.	Foraminifera: *Siphogenerina hughesi* var., *Uvigerinella obesa, Valvulineria* cf. *V. miocenica* var. *depressa, V.* cf. *V. ornata, V. williami.*
Early Miocene(?).	Lospe formation.	Upper member.	2,100	2,000±	Greenish sandstone, siltstone, and gypsiferous mudstone.	None found.
		Lower member.	600		Reddish sandstone, conglomerate, and rubble.	
Late Jurassic.	Knoxville formation.		500±	1,250	Shale, thin-bedded sandstone, conglomerate.	*Aucella* cf. *A. piochii.*
Jurassic(?).	Igneous rocks of Franciscan formation.				Basalt, gabbro, peridotite, serpentine.	

The pre-Mesozoic history of the Santa Maria district is unknown, and most of the Mesozoic and early Tertiary history is obscure. During the later part of Jurassic time, the district was part of an extensive area of Franciscan rocks that doubtless reached westward far beyond the present coast. In the outcrop area the Franciscan formation includes only igneous rocks. The Knoxville sea covered at least part of the extensive Franciscan area toward the close of Jurassic time. In that sea were deposited the sediments now forming the dark-colored shale, sandstone, and conglomerate of the Knoxville formation.

The district may have shared in the deformation at the end of the Jurassic recognized elsewhere in the Coast Ranges, and it may have shared also in periods of Cretaceous deformation. There is, however, no direct local evidence. Nor is there any direct sign that Cretaceous and early Tertiary sediments were ever deposited in the district, which presumably was part of a long-enduring Franciscan-Knoxville land area. The great thickness of 8,000 to 10,000 feet of Upper Cretaceous deposits in the adjoining San Rafael Mountains suggests, however, that at least a veneer of Upper Cretaceous strata may have been deposited and then eroded.

The known history of the district as part of a Tertiary basin began in the early Miocene(?), possibly a little earlier or possibly a little later, when the nonmarine sediments of the Lospe formation were deposited. The first known Tertiary invasion of the sea took place immediately thereafter in early middle Miocene time, and from then until approximately the end of the Pliocene the sea occupied continuously at least most of the region. The extent of the Miocene basin is not certainly known, but it was part of an extensive basin that included what has been designated the Santa Barbara embayment.[3] The fine-grained clastic sediments of the Point Sal formation of early middle Miocene age, followed by the fine-grained siliceous sediments of the

[3] Reed, R. D., and Hollister, J. S., Structural evolution of southern California, fig. 6 (p. 14), Tulsa, Am. Assoc. Petroleum Geologists, 1936.

Monterey shale of late middle and late Miocene age, were laid down. In the meantime minor deformation apparently took place repeatedly along Point Sal Ridge, part of the Franciscan-Knoxville area, for each of the Tertiary formations so far mentioned overlaps, or appears to overlap, the next older formation or still older formations. Indirect evidence points also to minor Pliocene deformation in the same area.

Toward the close of the Miocene, low ridges evidently appeared on the floor of the sea, ridges that grew during Pliocene time and were destined to become anticlines. Also toward the end of the Miocene the northeastern part of the district was deformed. The sediments of the Sisquoc sea were deposited on the submarine ridges and in the intervening basins. The Sisquoc sediments in those areas are fine-grained and resemble typical Monterey deposits. Even in areas where the two formations are lithologically indistinguishable and are conformable, a field basis for differentiating them has been established. The facies of the Sisquoc formation just mentioned, the basin facies, is considered of late Miocene to middle Pliocene age. At the north border of the district the basin facies overlaps the Monterey shale and rests on Knoxville or Franciscan. A marginal sandstone facies in the northeastern part of the district rests unconformably on the Monterey shale, and is of early and middle Pliocene age.

In the basins between the growing ridges the fine-grained sediments of the middle(?) and late Pliocene Foxen mudstone overlie conformably the Sisquoc formation. The Foxen mudstone is missing on the submarine ridges and in the marginal northeastern part of the district. In some of the areas where it is missing as a lithologic unit, it appears to be represented by condensed deposits of phosphatic pellets, mapped with the underlying or overlying formation, depending on the matrix, or by a condensed section of fine-grained sand, mapped with indistinguishable sand in the basal part of the overlying formation. During Foxen time the basin was smaller than it had been previously.

During the succeeding late Pliocene Careaga time, the sea again advanced farther inland. The region then submerged, lying between the San Rafael Mountains and the Santa Ynez Mountains, may be referred to as the Santa Maria basin. The basin, however, was larger than the Santa Maria district. It extended northwestward along the border of the San Rafael Mountains, a narrow tongue reached far up Santa Ynez Valley, and the west end of the Santa Ynez Mountains may also have been submerged, as shown on Reed and Hollister's paleogeographic map.[4] The fine-grained sand of the lower member of the Careaga sandstone, like the Foxen mudstone, is missing on some of the embryonic anticlines, where it is overlapped by the coarse-grained sand and gravel of the upper member. It is also generally missing in the northeastern part of the district.

At the end of Careaga time, the rate of deposition outran the rate of subsidence, and the succeeding deposits, constituting the Paso Robles formation, are nonmarine. The age of the Paso Robles formation is not certainly known. Following current usage for other districts, it is designated late Pliocene and early Pleistocene(?), but a late Pliocene(?) and early Pleistocene assignment may be better for the Santa Maria district.

Strong deformation took place after Paso Robles time; the first, and last, period of widespread strong deformation in the known post-Mesozoic history of the district. Later terrace deposits extend unconformably across all the older formations, the oldest and most extensive terrace deposits constituting the Orcutt sand. The Orcutt is of Pleistocene age and is somewhat arbitrarily assigned to the late Pleistocene, as are later terrace deposits, both marine and fluvial.

UPPER JURASSIC SERIES

KNOXVILLE FORMATION

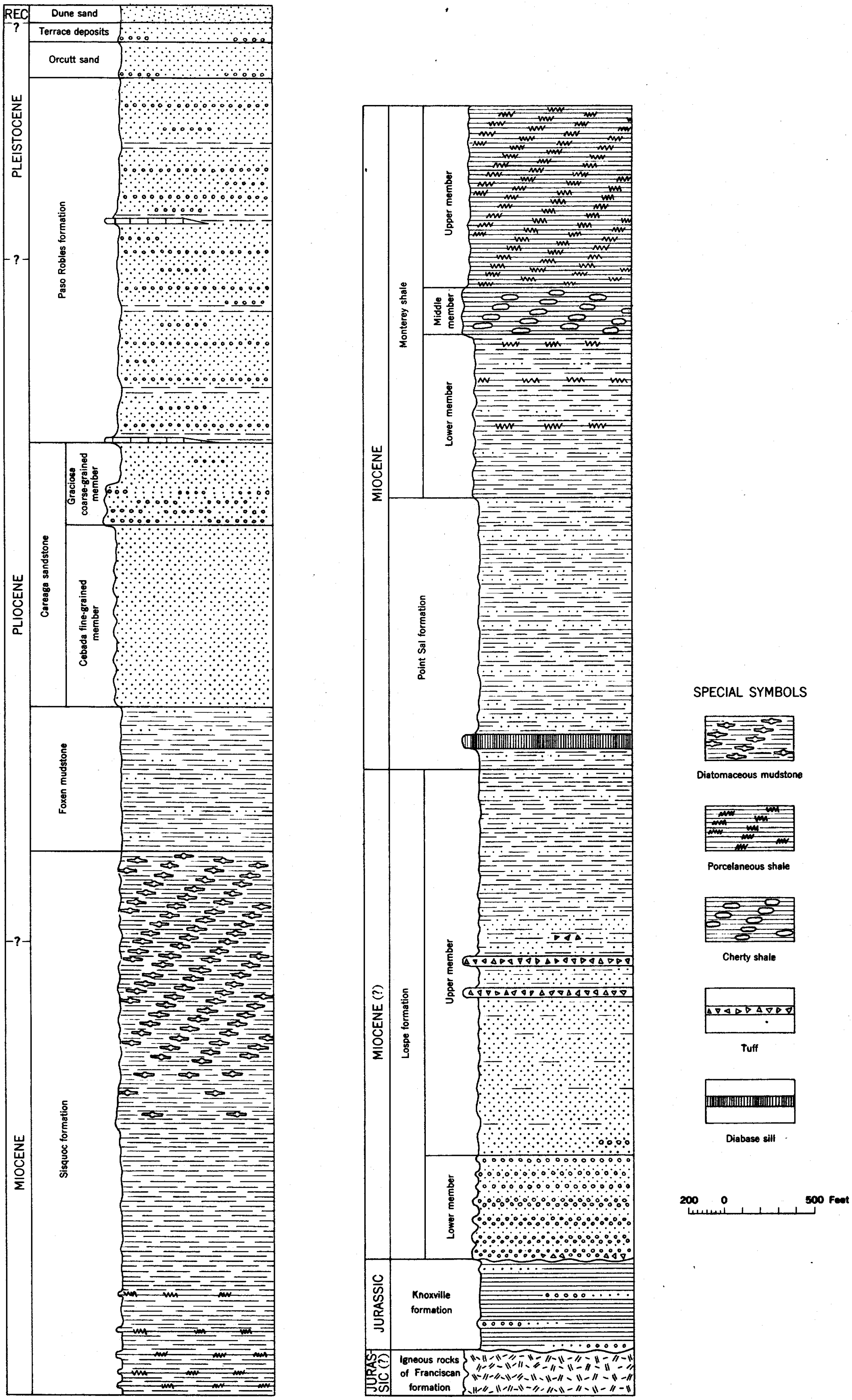
The Knoxville formation crops out in the Point Sal Ridge area, where it rests on the igneous rocks of the Franciscan formation. The actual relations, however, are uncertain owing to inadequate exposures. On the south slope of Point Sal Ridge, the Knoxville is overlapped by the Lospe formation or the Point Sal formation. In the Lions Head area of Franciscan rocks, the Knoxville is likewise overlapped by the Lospe formation. Owing to minor folds, the outcrop thickness of the Knoxville is difficult to determine. It is probably not more than 500 feet. Subsurface data a few miles east of the outcrop area indicate a thickness of 1,250 feet (structure section *A–A′* of plate 2). The formation thins rapidly westward toward Point Sal Ridge.

STRATIGRAPHY AND LITHOLOGY

The Knoxville formation consists of olive-gray to dark-gray shale, thin beds of rusty-brown or olive-brown, fine-grained to moderately coarse-grained calcareous sandstone, and thicker beds of conglomerate made up principally of small, smooth, well-rounded black chert pebbles. These rocks are not likely to be confused with more or less similar younger rocks of the Santa Maria district. The shale is harder and more fissile than younger mudstones, the sandstone contains more mica than younger sandstones, and the conglomerate contains a larger proportion of well-rounded black chert pebbles than conglomerates of younger formations.

The shale generally includes thin limy concretionary layers. At some localities it is greatly sheared and slickensided. Such material was erroneously reported

[4] Op. cit., fig. 22 (p. 45.)


REC
Dune sand
Terrace deposits
Orcutt sand
PLEISTOCENE
Paso Robles formation
PLIOCENE
Careaga sandstone
Graciosa coarse-grained member
Cebada fine-grained member
Foxen mudstone
MIOCENE
Sisquoc formation
Monterey shale
Upper member
Middle member
Lower member
Point Sal formation
MIOCENE (?)
Lospe formation
Upper member
Lower member
JURASSIC
Knoxville formation
JURASSIC (?)
Igneous rocks of Franciscan formation
SPECIAL SYMBOLS
Diatomaceous mudstone
Porcelaneous shale
Cherty shale
Tuff
Diabase sill
200 0 500 Feet

as "lustrous phyllite" in a preliminary paper.[5] In a small area north of Mount Lospe, the shale is very hard and platy owing to alteration by intrusive augite andesite.

The sandstone occurs in beds a few inches to half a foot thick. A sample from Corralillos Canyon was examined by A. O. Woodford, who reports that it is very fine-grained and very calcareous. Traverses across a thin section indicate the following approximate composition:

Mineral composition of sandstone from Knoxville formation

	Approximate percentage by volume
Quartz	24.1
Rock grains, including chert and diabase	14.7
Feldspar (plagioclase 10 grains, orthoclase 2 grains)	1.8
Mica and chlorite (muscovite 11 grains, biotite and chlorite 17 grains)	2.9
Opaques	4.3
Calcite cement	52.1

Many of the chert grains are brownish and may have been derived from the Franciscan formation. The diabase also may have been derived from the Franciscan.

The large proportion of smooth, well-rounded, black or blackish chert pebbles, presumably pre-Franciscan, is a characteristic feature of the conglomerates. Most of the pebbles are about half an inch in diameter, but the size range is from that of buckshot to three inches. Conglomerate forms the conspicuous knobs and ledges on the east side of Corralillos Canyon 0.4 mile north of the locality where the Point Sal road crosses the canyon. In the largest knob, conglomerate rests on an irregular surface of sandstone, which grades downward into pebbly sandstone and more conglomerate. The beds of conglomerate appear to occur sporadically almost throughout the exposed part of the formation. They were not observed near the base, but exposures near the base are inadequate.

FOSSILS

A small slender *Aucella*, identified as *Aucella* cf. *A. piochii*, was found in sandstone at fossil localities 2 and 3.[6] A leached specimen was observed in weathered conglomerate, probably not in place, at locality 1. Some of the sandstone contains carbonaceous debris and fragmentary leaf imprints. Such material is associated with the marine genus *Aucella* at locality 3.

MIOCENE(?) SERIES

LOSPE FORMATION

The nonmarine, nonfossiliferous formation overlying the Knoxville formation, or overlapping it and resting on igneous rocks of the Franciscan formation, has been named the Lospe formation.[7] This nonmarine formation is presumably the equivalent of an undetermined part of the nonmarine Sespe formation of the Santa Ynez Mountains, in southern Santa Barbara County, and that name would be appropriate for it. The name Lospe formation, however, has been in local usage for some years, even before it was formally proposed, and is adopted in deference to local usage.

The type region is between Lions Head and Mount Lospe, where the formation is 2,700 feet thick. It unconformably overlies igneous rocks of the Franciscan formation, and is conformably overlain by the marine Point Sal formation. The Lospe formation crops out in three areas along or near the coast: an area near Lions Head, the Point Sal Ridge-Corralillos Canyon area, and a small area at the east end of the Pezzoni anticline. Though the total outcrop area is small, the thickness and stratigraphic relations of the formation are quite different from place to place. The Lospe rests on Franciscan or Knoxville, is overlain without marked discontinuity by the Point Sal formation or is apparently overlapped by it, and ranges in thickness from the vanishing point to 2,700 feet.

STRATIGRAPHY AND LITHOLOGY

In the type region and nearby parts of the Lions Head area, the Lospe formation is divided into two mapped members: a lower member made up chiefly of coarse-grained reddish sandstone and conglomerate, and an upper member consisting principally of greenish sandstone, gypsiferous siltstone, and gypsiferous mudstone. The members are not sharply differentiated on a basis of color or texture. A transition zone toward the base of the upper member includes reddish sandstone, conglomeratic sandstone, and sillstone. Both members and the formation as a whole show a general upward decrease in grain size. In other areas, members were not differentiated, though both reddish and greenish strata are represented.

In the Lions Head area the Lospe formation, resting on igneous rocks of the Franciscan formation, extends from the coast to a locality 4 miles inland along the strike. At both ends of this strip much of the formation is concealed by marine terrace deposits. The base of the formation is well exposed in the present sea cliff and in canyons east of Lions Head. The most complete exposures of the formation and the thickest section are found along canyons near Lions Head in the type region. A thickness of 2,700 feet was measured in the first canyon northwest of Lions Head and its middle upper tributary. The lower member, 500 to 600 feet thick, consists of reddish conglomerate and sandstone. Much of the conglomerate is unsorted and unstratified, or rudely stratified, rubble. The boulders and slabs have generally a length of a foot or somewhat

[5] Woodring, W. P., Bramlette, M. N., and Lohman, K. E., Stratigraphy and paleontology of Santa Maria district, Calif.: Am. Assoc. Petroleum Geoligists Bull., vol. 27, No. 10, p. 1,343, 1945.

[6] The fossil localities are described on pages 136-142 and are plotted on the geologic map, pl. 1.

[7] Wissler, S. G., and Dryer, F. E., Correlation of the oil fields of the Santa Maria district: California Div. Mines Bull. 118, pt. 2, p. 237, 1941.

less, but a length of several feet is not unusual. With few exceptions, they consist of local Franciscan rocks, mostly more or less altered gabbro and altered basalt. Rocks that are not known to occur in the local Franciscan outcrop area, such as red and black chert and sandstone, are relatively rare. The upper member, 2,100 to 2,200 feet thick, is made up in ascending order of greenish sandstone, interbedded with occasional thin layers of reddish sandstone and siltstone, and greenish gypsiferous siltstone and mudstone. Half a mile northwest of Lions Head a mass of reddish and purplish greatly altered gabbro that has an exposed length of 125 feet, a width of 75 feet, and a thickness of 45 feet, crops out immediately below the most persistent tuff bed in the upper member. This huge mass, and smaller blocks of the same rock and of less altered gabbro nearby at the same horizon, are evidently landslide or avalanche blocks that were dumped into the fine-grained sediments. At many places the gypsiferous fine-grained strata form bare mud-covered slopes, generally deeply eroded by badland gullies exposing fresh rock. The gypsum occurs in veins and as layers and tabular masses several feet long and several feet thick. It was mined in the 1880's.[8]

In the Lions Head area the formation includes beds of hard white tuff. They are in the form of lenses of varying length and thickness, all in the upper member, with the exception of short lenses at the very base of the formation. As described by Fairbanks[9] and as shown on figure 3, *B*, the tuff forms cliffs and is as much as 60 feet thick. The most persistent bed, shown in the view on figure 3 *B*, extends a distance of 1¾ miles along the strike and is 1,200 feet below the top of the formation. Samples from this bed, collected along the ranch road three-quarters of a mile northwest of Lions Head, were examined by A. O. Woodford, who prepared the following description. The commonest facies is moderately well consolidated. It is made up of closely packed pumice shards that show numerous curved surfaces and have a maximum length of 2 millimeters. The material is in part clear or slightly cloudy glass with an index of refraction of 1.485 ± 0.003, in part cryptocrystalline devitrified glass, the mean index of which is close to 1.540. A sample of harder tuff, collected a few feet below the top of the bed, was sectioned (fig. 3 *A*). The curved, pronged, and cuspate shards are transparent and lie in a dull brown cloudy base. The base is mostly isotropic and has a variable index of refraction ranging from 1.500 to 1.507. The shards have been transformed into double rows of feebly birefringent plates, standing normal to the shard boundaries. Most sections through these minute plates show parallel extinction and plus elongation ($\alpha = 1.480 \pm 0.001$, $\gamma = 1.484 \pm 0.001$). They are possibly some species of zeolite, but may be analcite. An analcite druse on a loose piece of tuff found at the same locality is made up of trapezohedral crystals 1 to 6 millimeters across, which in thin-section show isotropic or faintly birefringent sectors, the latter having the following indices of refraction: $\alpha = 1.482 \pm 0.001$, $\gamma = 1.484 \pm 0.001$. The tuff contains occasional big grains of plagioclase and quartz, probably battered crystals or crystal fragments. The plagioclase appears to range in composition from oligoclase to andesine. Strata overlying and underlying the tuff are locally silicified, the result of the addition of silica liberated by devitrification of the volcanic ash.[10]

The lenses of tuff at the base of the formation rest directly on igneous rocks of the Franciscan formation or are separated from them by a few inches to a foot of conglomerate and rubble. Though the basal tuff is overlain by a great thickness of conglomerate and rubble, the tuff itself contains only scattered small pebbles. In addition to the tuff just described, beds of altered bentonitic(?) tuff, a few inches thick, occur in the lower member.

The lower member of the Lospe formation disappears three-quarters of a mile southeast of Lions Head, where the upper member rests on the Franciscan basement. The relations suggest that the lower member represents local accumulation of coarse fan, landslide, and avalanche debris. Farther east the upper member (not more than 200 feet thick) is much thinner than in the type region. The abrupt thinning doubtless represents a difference in original thickness, due to overlap on an irregular basement surface.

Still farther southeast, where the bedrock formations are exposed in canyons eroded through extensive marine terrace deposits, the thickness of the Lospe formation increases to 600 or 700 feet. Greenish conglomerate and sandstone and interbedded reddish muddy sandstone, representing a thickness of 150 to 250 feet, are all assigned to the lower member, despite the prevailing greenish color. The upper member, which includes olive-brown sandstone, some of which is conglomeratic, as well as greenish sandstone and hard white tuff, again rests on the Franciscan, but is faulted against the Todos Santos claystone member of the Sisquoc formation, in the easternmost exposures.

South of the Lions Head fault the Lospe formation was recognized at only one locality a mile southeast of Lions Head. At that locality it is represented by greenish sandstone and siltstone of the upper member, exposed in a narrow fault slice adjoining the main fault.

In the Point Sal Ridge-Corralillos Canyon area, meager exposures indicate that a narrow strip of Lospe

[8] Goodyear, W. A., Santa Barbara County: California Min. Bur., Eighth Rept. State Mineralogist, p. 538, 1888. Fairbanks, H. W., The geology of Point Sal: California Univ., Dept. Geol., Bull., vol. 2, p. 16, 1896. Fairbanks, H. W., Gypsum deposits of California: U. S. Geol. Survey Bull. 223, p. 122, 1904. Hess, F. L., A reconnaissance of the gypsum deposits of California: U. S. Geol. Survey Bull. 413, pp. 28–29, 1910.

[9] Fairbanks, H. W., op. cit. (California Univ., Dept. Geol., Bull., vol. 2, pp. 16–17), 1896.

[10] Bramlette, M. N., The Monterey formation of California and the origin of its siliceous rocks: U. S. Geol. Survey Prof. Paper 212, pp. 44–45, 1946.

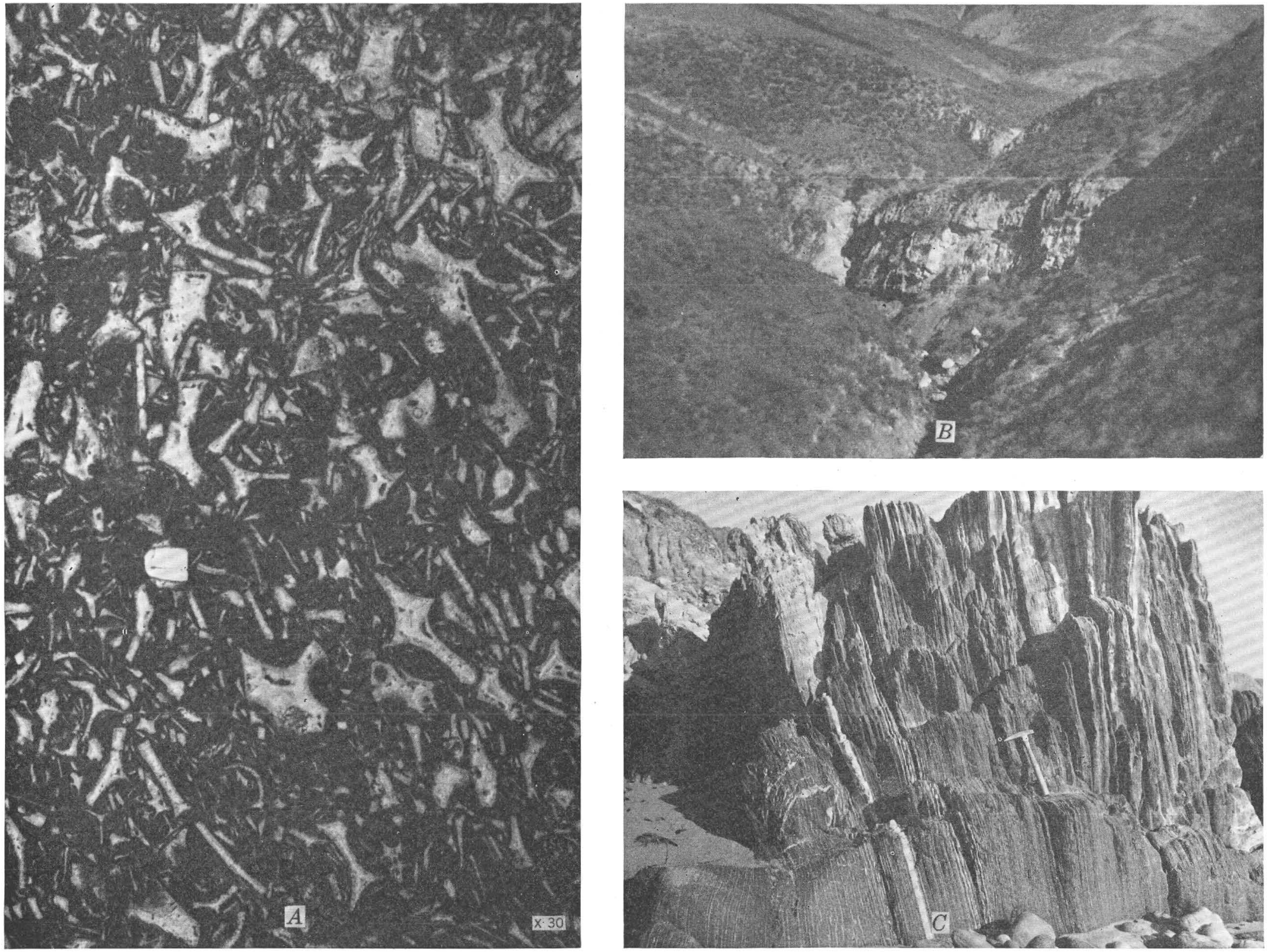


FIGURE 3.—Lospe formation and Monterey shale in Casmalia Hills. *A*, Tuff from Lospe formation. The shards are light-colored, somewhat cloudy. The clear rectangular grain is plagioclase. Ordinary light, × 30. *B*, Tuff in Lospe formation on south slope of Mount Lospe. Tuff forming cliff in middle view is 50 feet thick. *C*, Hard phosphatic shale in lower member of Monterey shale on coast near Lions Head.

sediments borders the Franciscan on the south slope of Point Sal Ridge. The exposed strata consist of greenish silty sandstone and siltstone, assigned to the upper member. Such material is involved in landslides extending to the coast, but appears to be in place in ravines adjoining the coast and in a cut on the road to Point Sal Landing, and is exposed along the main Point Sal road near the crest of the ridge. Vestiges of vitric shards are recognizable in greenish bentonitic(?) clay and siltstone in place, or at the foot of a slide, in the first canyon east of the main road. At the east end of Point Sal Ridge and on the adjoining north slope of Mount Lospe, the Lospe formation is evidently absent, the relations being interpreted as indicating overlap by the Point Sal formation.

Along the north slope of Point Sal Ridge and along Corralillos Canyon, members of the Lospe formation were not differentiated. Greenish-gray sandstone and mudstone cropping out in the sea cliff between Point Sal and Mussel Rock are assigned to the Lospe. There appears to be no marked discordance with the underlying strata, identified as the Knoxville formation, but the contact between the formations is not well exposed.

Along Corralillos Canyon and its tributaries, the Lospe formation overlies the Knoxville formation. Though the stratigraphic relations are uncertain, no well-defined discordance is apparent. Reddish conglomerate and coarse-grained sandstone are the most conspicuous constituents of the Lospe. They are well exposed in road cuts and in a road-metal quarry west of the canyon. The formation includes also greenish sandstone and siltstone, and olive-brown sandstone with conglomeratic layers. Conglomeratic limestone debris on a ridge east of the canyon is derived presumably from the Lospe formation, but was not observed in place. Hard white tuff, like that in the type region, was found on a tributary of lower Corralillos Canyon and at the east end of the Corralillos Canyon area, at the localities shown on the geologic map (pl. 1). In much of this area the Lospe formation is thin.

At the east end of the Pezzoni anticline, the Lospe formation is exposed in two small areas partly covered with landslide debris. The strata consist chiefly of brownish sandstone and conglomerate, but include greenish-gray sandstone and siltstone, and in the eastern area reddish conglomerate. Slide material at the west end of the western area contains hard white tuff debris, derived presumably from the Lospe formation.

MIOCENE SERIES

POINT SAL FORMATION

The marine Point Sal formation overlies the Lospe formation without marked discontinuity, or appears to overlap it and to rest on the Knoxville or Franciscan. The formation name was proposed provisionally by Canfield,[11] who suggested the south slope of Point Sal Ridge as the type region. The south slope of Mount Lospe, a mile or two farther east, is a more satisfactory type region. In that area the Point Sal formation, about 1,500 feet thick, overlies conformably the Lospe formation and is overlain, presumably conformably, by the Monterey shale.

Some geologists have designated the Point Sal formation as the Temblor formation or Temblor mudstone, names used at one time for the Rincon mudstone, which in the Santa Ynez Mountains overlies the lower Miocene Vaqueros sandstone and underlies the Monterey shale. Though the Point Sal formation and the Rincon mudstone consist chiefly, or almost entirely, of fine-grained rocks and though both underlie the Monterey shale, they are not similar lithologically. The Rincon is made up of hard brittle conchoidally fracturing mudstone, whereas siltstone is as prevalent as mudstone in the Point Sal formation, and the mudstone is, with minor local exceptions, softer and not brittle. The two formations are of different age, the Point Sal formation being somewhat younger.

Siltstone, mudstone, and thin beds of sandstone are the chief constituents of the Point Sal formation. In the type region and westward to the coast, it is intruded by diabase sills. The fine-grained rocks making up most of the formation contain Foraminifera, which are locally abundant and well preserved. A thick mantle of brownish soil is characteristic of the formation, and at many places, especially on the steep north slope of the Casmalia Hills east of Corralillos Canyon, this mantle forms extensive landslides. Minor folds are also characteristic of the formation, or are inferred to be present in areas of isolated exposures where the local structure does not agree with the regional structure. The thickness of the formation was not determined in many areas, but appears to range from 150 feet to 1,500 feet.

STRATIGRAPHY AND LITHOLOGY

The lower 800 feet of the Point Sal formation is well exposed in canyons on the south slope of Mount Lospe, particularly in the middle upper tributary of the first canyon northwest of Lions Head. An estimated additional thickness of 700 feet is concealed by deposits on the high-level marine terrace and by the soil mantle covering the uppermost part of the formation and the basal part of the overlying Monterey shale. The change from the greenish-gray nonfossiliferous siltstone and mudstone of the Lospe formation to the dark-gray, brown-weathering siltstone and mudstone of the Point Sal formation, some of which contains Foraminifera, is not abrupt. Thin beds of medium-grained brownish sandstone, a few inches to a foot thick, are interbedded with the fine-grained rocks. In the canyon mentioned the stratigraphically lowest observed Foraminifera are in siltstone 135 feet below the base of an 85-foot diabase

[11] Canfield, C. R., Subsurface stratigraphy of Santa Maria Valley oil field and adjacent parts of Santa Maria Valley, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 23, pp. 66–67 (footnote), 1939.

sill which was mapped for a distance of 1½ miles along the strike. A sandstone, 10 feet thick and 20 feet lower stratigraphically, was selected as the base of the Point Sal formation. Toward the top of the exposed section, beds of sandstone are more numerous and somewhat thicker. Some of the sandstones are calcareous, and a few thin beds of sandy limestone and concretionary layers of limestone are present. The well-exposed part of the formation includes a zone of minor folds, 500 to 750 feet wide across the strike. Some beds of mudstone in the zone of minor folds are somewhat hard and fissile. Mudstone immediately above and below the diabase sill, and included in sediments in the sill itself, is black, hard, and fissile.

Two miles southeast of Mount Lospe the Point Sal formation rests on Lospe sediments that are much thinner than farther west. The Point Sal formation itself is thinner than in the type region. In the canyon at the west border of the extensive area of terrace deposits, 2½ miles southeast of Mount Lospe, incomplete exposures indicate a thickness of 675 feet.

The most accessible exposures of the Point Sal formation are along the Point Sal road on the south slope of Point Sal Ridge, but many cuts along the road fail to penetrate the thick soil mantle. Foraminifera are abundant in siltstone 7½ to 8 feet above the top of a 27-foot diabase sill exposed along the road (locality 5). Above the sill, many thin beds of sandstone are interbedded with siltstone and mudstone. Strata that are inferred to be well above the base of the formation appear to rest on the narrow strip of Lospe sediments adjoining the igneous rocks of the Franciscan formation near the top of the ridge.

Much of the area between the Point Sal road and the coast is covered with landslide debris. Cliffs at the landward edge of the slide area expose sediments of the Point Sal formation, diabase sills, and irregular cross-cutting bodies of diabase. Two sandstone dikes are exceptional features. The base of the formation is exposed in the sea cliff south of the diabase headland near Point Sal Landing. The change from the greenish-gray sandstone and silty sandstone of the Lospe formation to the dark-gray siltstone, mudstone, and thin layers of sandstone of the Point Sal formation is more abrupt than on the south slope of Mount Lospe.

On the coast between Point Sal and Mussel Rock, the Point Sal formation is in fault contact with the Lospe formation. The Point Sal formation in that area consists of thin-bedded mudstone, sandstone, and calcareous sandstone in beds half a foot to 3 feet thick, and concretionary layers of limestone. Much of the mudstone contains Foraminifera, generally poorly preserved.

The Point Sal formation is not well exposed on the north slope of Mount Lospe. The observed relations are interpreted as indicating that the formation is not more than 200 feet thick, that it completely overlaps the Lospe formation to rest on the Knoxville, and that farther west at the east end of Point Sal Ridge it is perhaps 150 feet thick and lies directly on the Franciscan. The observed relations with reference to the Franciscan may, however, with perhaps equal plausibility be interpreted as indicating a fault between the igneous rocks of the Franciscan formation and the Point Sal formation.

On the main ridge along the east side of Corralillos Canyon, the Point Sal formation evidently overlaps the Lospe formation and lies on the Knoxville formation. Exposures are meager, however, and in many isolated outcrops along ravines the structure in the Point Sal formation does not agree with the regional structure, suggesting the presence of minor folds. Soft white fine-grained chalk forms a 2-inch layer exposed near the fault between the Point Sal formation and the middle member of the Monterey shale immediately east of lower Corralillos Canyon. The chalk, mistaken in the field for tuff and shown on the preliminary edition of the geologic map as tuff, was found by A. O. Woodford to be very porous and made up of calcite grains 8 to 20 microns in diameter. It is probably a surface alteration product.

At localities near the Pezzoni fault, thin layers of soft brown sandstone interbedded with siltstone and mudstone are impregnated with oil. The oil-saturated sandstone, and also hard brown calcareous sandstone and buff concretionary limestone, are conspicuous in the landslide debris derived from the Point Sal formation of that area.

FOSSILS

The Point Sal formation has a large foraminiferal fauna representing the *Siphogenerina hughesi* zone, or the lower part of Kleinpell's Relizian stage. The Point Sal form of *Siphogenerina hughesi* is a variety characterized by numerous very fine costae. This variety is elsewhere associated with the typical noncostate form. The following species were identified in collections from the Point Sal formation.

Foraminifera from Point Sal formation

[Identifications by M. N. Bramlette. R, rare; F, few; C, common; A, abundant]

Species	Localities				
	5	6	7	7a	8
Baggina californica Cushman	----	----	R	----	----
Baggina cancriformis Kleinpell	F	----	----	F	----
Baggina robusta Kleinpell	F	----	----	----	----
Bolivina aff. *B. advena* Cushman	----	----	----	F	----
Bolivina aff. *B. advena* var. *ornata* Cushman	----	F	C	----	----
Bolivina advena var. *striatella* Cushman	F	----	----	----	F
Bolivina californica Cushman	F	----	R	R	C
Bolivina floridana Cushman var	F	----	C	C	C
Bolivina imbricata Cushman	----	R	R	----	F
Bolivina aff. *B. imbricata* Cushman	----	----	----	F	----
Bolivina marginata Cushman	----	----	F	----	F
Bolivina perrini Kleinpell	F	R	C	C	F

Foraminifera from Point Sal formation—Continued

[Identifications by M. N. Bramlette. R, rare; F, few; C, common; A, abundant]

Species	Localities				
	5	6	7	7*a*	8
Bolivina salinasensis Kleinpell	----	----	----	R	F
Bolivina tumida Cushman	C	----	F	F	C
Bulimina pseudoaffinis Kleinpell	F	----	----	F	----
Buliminella californica Cushman	----	----	C	----	----
Buliminella subfusiformis Cushman	R	C	C	F	C
Cancris sp	R	----	----	R	R
Cassidulina sp	----	----	F	R	R
Cibicides relizensis Kleinpell	F	----	----	----	----
Dentalina sp	----	----	----	R	----
Elphidium aff. *E. panamense* Cushman	----	----	----	----	F
Globigerina bulloides d'Orbigny	C	F	A	A	C
Globigerina cf. *G. cretacea* d'Orbigny	----	----	----	F	----
Hemicristellaria beali (Cushman)	R	----	R	----	F
Lagena sp	----	----	----	----	F
Nodogenerina advena Cushman and Laiming	F	----	----	F	R
Nodosaria longiscata d'Orbigny	R	----	----	----	----
Nonion costiferum (Cushman)	R	F	F	F	R
Nonion sp. of Kleinpell	----	----	----	----	F
Planulina cf. *P. appressa* Kleinpell	F	----	F	R	F
Planulina baggi Kleinpell	----	----	F	R	F
Plectofrondicularia cookei Cushman	----	----	R	R	F
Pullenia aff. *P. miocenica* Kleinpell	----	----	----	----	R
Pulvinulinella subperuviana Cushman	----	F	C	R	C
Robulus hughesi Kleinpell	----	----	----	----	R
Robulus reedi Kleinpell	----	----	----	----	R
Robulus cf. *R. warmani* Barat and von Estorff	----	----	R	----	----
Siphogenerina hughesi Cushman var	----	----	----	C	----
Siphogenerina kleinpelli Cushman	F	----	----	----	----
Uvigerinella californica var. *gracilis* Cushman and Kleinpell	----	F	C	R	F
Uvigerinella obesa Cushman	F	----	C	A	C
Valvulineria californica var. *obesa* Cushman	C	----	----	F	C
Valvulineria aff. *V. casitasensis* Cushman and Laiming	----	R	----	----	R
Valvulineria cf. *V. miocenica* var. *depressa* Cushman	----	----	C	C	----
Valvulineria cf. *ornata* Cushman	----	F	F	F	----
Valvulineria williami Kleinpell	----	----	R	----	----
Virgulina californiensis Cushman	C	----	F	C	F

MONTEREY SHALE

The Monterey shale consists chiefly of hard silica-cemented rocks and soft diatomaceous rocks, as in many other Coast Range districts. The terms that are used for the silica-cemented rocks (chert, cherty shale, porcelaneous shale, porcelaneous mudstone) and for the diatomaceous rocks (diatomite, diatomaceous shale, diatomaceous mudstone) of the Monterey, as well as of the overlying Sisquoc formation, are those defined in a recent discussion of the Monterey and the origin of its siliceous rocks.[12] The porcelaneous shale of the Santa Maria and other districts is more or less porous, has a low specific gravity, and contains molds of diatoms. Rock of that character has been designated diatomaceous shale or diatomite by some geologists. Restriction of the terms diatomaceous shale and diatomite to rocks containing preserved diatoms, not molds, is useful, though somewhat arbitrary. Preserved diatoms can be differentiated from molds in the field, the opal of preserved frustules showing interference colors. The carbonate layers of the Monterey are designated limestone, though they are doubtless more or less dolomitic, as in other districts.[13]

Three members of the Monterey shale were differentiated and mapped. The lower member is characterized by phosphatic shale and somewhat porcelaneous shale, the middle member by chert and cherty shale, and the upper member by porcelaneous shale, or by both porcelaneous shale and diatomaceous strata. In areas where the upper member includes hard porcelaneous shale and soft diatomaceous strata, the two rock types were mapped separately. The middle member is the most readily recognized part of the Monterey, as the chert crops out generally in conspicuous ledges, even in areas where overlying or underlying strata are poorly exposed (fig. 4 *B*). Fractured chert and cherty shale of the Monterey are the chief oil-bearing strata in the major oil fields of the Santa Maria district. They are identical lithologically with those in the middle member of the Monterey in the outcrop section. In some fields the chert zone is of the same age as the dated middle member in the eastern Purisima Hills, in others it is younger. The middle member is not notably petroliferous at the outcrop, but locally fractures contain tar.

The three members crop out in the western Casmalia Hills, the middle and upper members in the eastern Purisima Hills, and the upper member in the Foxen Canyon-Sisquoc River area. In the Casmalia Hills, 3 miles northwest of Casmalia, the thickness of the formation is 1,600 feet. Throughout most of the Casmalia Hills, it overlies conformably the Point Sal formation, but toward the east end of Point Sal Ridge it evidently overlaps part of the Point Sal formation and finally appears to overlap all the older sedimentary formations and to rest on the Franciscan basement.

LOWER MEMBER

STRATIGRAPHY AND LITHOLOGY

The lower member of the Monterey shale, about 200 to 900 feet thick, is made up of phosphatic shale, silty shale, more or less porcelaneous shale, and limestone. The layers of limestone are generally the only well-exposed strata, except in sea-cliff exposures. Foraminifera are abundant locally and include the stratigraphically highest species of *Siphogenerina*, a genus readily recognized in the field.

The most accessible and most extensive outcrops of the lower member are in the sea cliff and in low-tide reefs along the coast southeast of Lions Head. The lower member, dipping steeply southwestward, or slightly overturned, is faulted against the Franciscan along the Lions Head fault. The lithologic types are shown in the following section, the total thickness of

[12] Bramlette, M. N., op. cit. (U. S. Geol. Survey Prof. Paper 212), pp. 2–3, 1946.

[13] Idem, p. 20.

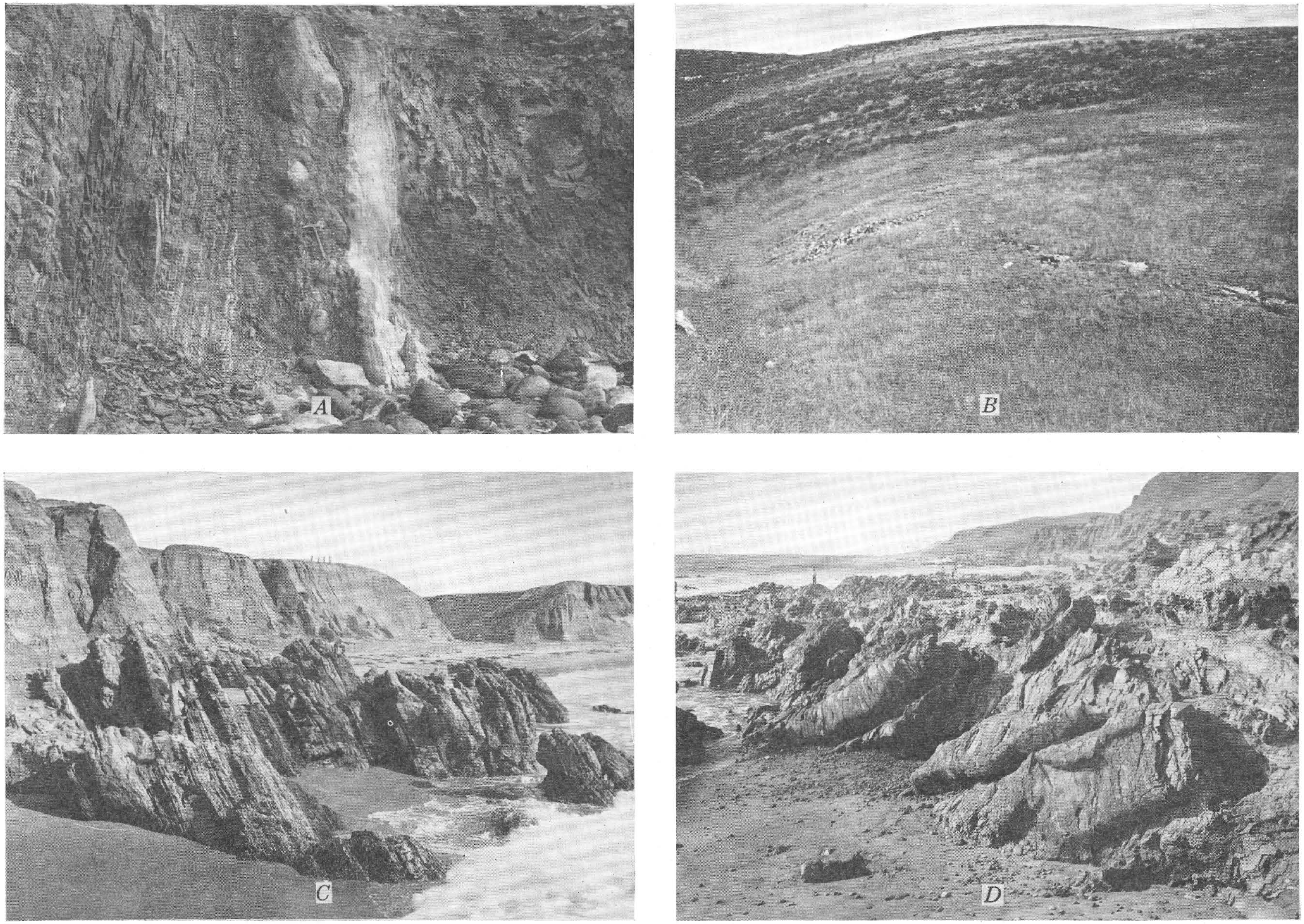


FIGURE 4.—Monterey shale in Casmalia Hills. *A*, Slightly overturned shale, sandstone (light-colored), and conglomerate and breccia (at hammer) in lower member of Monterey shale on coast near Lions Head. *B*, Monterey shale on south slope of Casmalia Hills. Lower member in foreground, ledge-forming middle member in mid-background, upper member in far background. *C*, Cherty shale and chert in middle member of Monterey shale on coast near Lions Head. *D*, Contorted chert in middle member of Monterey shale on coast near Lions Head.

which is uncertain, owing to possible displacement along sheared zones:

Section of lower member of Monterey shale on coast southeast of Lions Head

	Feet
Hard to moderately soft dark-gray shale containing thin layers and occasional nodules of light-colored phosphatic material, thin zones of harder somewhat porcelaneous shale, and numerous layers and concretions of limestone. Preserved Foraminifera in some of the relatively soft shale. Top of section evidently near top of lower member, chert of middle member being exposed on south side of cove 200 feet south of end of section	500±
Sheared shale, stained with jarosite, presumably marking fault	5
Dark-gray massive mudstone, 3-foot layer of concretionary limestone near top	21
Coarse-grained gray sandstone including grit layers 1½ to 3 inches thick in lower 2 feet, grading upward into sandstone of finer grain, which grades into the overlying mudstone. *Aequipecten* fragments at base	3½
Breccia and conglomerate consisting of small angular pieces and pebbles of chert, greenish igneous rock, and gray sandstone, and rounded elongate boulders of gray sandy, pebbly limestone as much as 4 feet long, in matrix made up mostly of brecciated foraminiferal shale. Few fragments of *Aequipecten* and other megafossils in matrix	2½–3
Thin-bedded, moderately hard dark-gray foraminiferal shale containing thin streaks of light-colored phosphatic material, scattered thin zones of harder, somewhat porcelaneous shale, and limestone concretions. Includes a band of closely spaced minor folds 18 feet wide and a zone 60 feet wide of sheared, jarosite-stained shale. The sheared shale adjoins fault breccia 50 feet wide marking Lions Head fault	200±

The phosphatic shale and thin zones of somewhat porcelaneous shale, which stand out in relief, in the upper part of the preceding section are shown on figure 3 *C*. The breccia and conglomerate, described in the preceding section and shown on figure 4 *A*, are considered an intraformational unit, but are probably not far above the base of the Monterey. Mudstone (like that overlying the conglomerate, breccia, and sandstone) is more prevalent in the Point Sal formation than in the lower member of the Monterey shale. *Siphogenerina* and other Foraminifera are abundant in many layers of the dark-colored shale underlying the conglomerate and breccia, but are not readily extracted.

The lower member was identified inland in several small areas adjoining the Lions Head fault. On the east side of the canyon 1.8 miles southeast of Lions Head and along the second tributary ravine to the west, conglomerate and breccia, consisting of Franciscan and limestone debris, mostly rounded, in a matrix of sandy limestone, is exposed within a few feet of the Lions Head fault.

Only a small fraction of the lower member is well exposed in the Mount Lospe and adjoining areas. Limestone is the most conspicuous, and in extensive areas the only exposed, constituent. Owing to the poor exposures, the contact with the Point Sal formation is generally uncertain. The lower member of the Monterey, however, yields a dark-colored, almost black, soil, which supports a growth of sage and sage-brush on most northward-facing slopes and dense stands of mustard on most southward-facing slopes, whereas the Point Sal formation yields a brownish soil, which is, for the most part, grass-covered. The member is about 900 feet thick immediately southeast of Mount Lospe, and 675 feet thick 2½ miles southeast of Mount Lospe. If the Point Sal formation is correctly identified on a minor anticline 1¾ miles east of Mount Lospe, the member is not more than 200 or 250 feet thick in that area.

The limestone is typically thin-bedded and dense, and forms ledges a fraction of a foot to several feet thick. It is found throughout the member, but the beds are thickest and most abundant in the lower part. The shale is thinly bedded or laminated. Thin layers and nodules of phosphatic material characteristic of beach exposures are not apparent. Nodule-shaped spaces filled with clayey material and silicified nodules and stringers suggest that phosphatic material has been leached and replaced, but evidence for leaching and replacement is much less common than would be expected from the relative abundance of phosphatic material in beach exposure. Toward the base of the member much of the shale is silty. Somewhat porcelaneous shale is common upward in the section, and locally the upper part of the member includes hard porcelaneous shale. Laminated buff shale, which has a low specific gravity and resembles diatomaceous shale but contains no diatoms, is exposed near the base of the member along the unnamed canyon 1.2 miles east-northeast of Mount Lospe. Molds of Foraminifera are common in soft shale and limestone. Preserved tests, however, are rare and were found only in soft shale near the base of the member (localities 10*c*, 10*d*).

In a section measured 2½ miles southeast of Mount Lospe, the base of the Monterey shale is drawn at the base of limy sandstone that contains scattered dark chert pebbles several inches in diameter, or smaller chert pebbles concentrated in a 6-inch layer.

Occasional outcrops in the western part of the Corralillos Canyon-Pezzoni fault area show limestone, soft buff shale, and somewhat porcelaneous shale. Well-preserved Foraminifera were found at locality 11 near the Pezzoni fault. Near Corralillos Canyon the member appears to be not more than 200 feet thick.

Laminated diatomite exposed on the west side of the canyon 1½ miles west-northwest of Waldorf is assigned to the lower member of the Monterey shale. This is the only locality in the Santa Maria district where preserved diatoms were found in the lower member. The diatomite has an exposed thickness of 200 feet, and includes lentils of concretionary limestone and a 2-inch layer of vitric volcanic ash stained black by asphaltic material. Cherty shale and thin-bedded

Baggina-bearing limestone are exposed farther north and at a lower level on the steep canyon wall. K. E. Lohman orally reports that the large diatom flora from the diatomaceous strata includes *Raphidodiscus*, an extinct genus that occurs in the "indicator bed" on Anticline Ridge near Coalinga on the west border of the San Joaquin Valley, in the diatomite at Sharktooth Hill near Bakersfield on the east border of the San Joaquin Valley, in the middle Miocene Calvert formation of Maryland, and in Miocene deposits in Hungary. The diatomite at Sharktooth Hill is considered of early Relizian age, the "indicator bed" probably late Relizian. Despite long-continued collecting, *Raphidodiscus* has not been found in California in deposits of late Miocene age. The strata just described were doubtfully referred to the upper member of the Monterey shale on the preliminary geologic map. As they probably overlie the Point Sal formation in normal succession, the tentatively mapped fault shown on the preliminary geologic map is deleted on the geologic map accompanying the present report (pl. 1).

On the coast near Mussel Rock, the lowest exposed strata in the lower member, estimated to be close to the middle of the member, consist of soft shale, which contains a few small phosphatic nodules, and thin limy and sandy layers. The well-exposed uppermost part is made up of soft shale, including many light-colored phosphatic layers, a few zones of hard somewhat porcelaneous shale, and limestone. Upward in the section porcelaneous shale containing cherty stringers is progressively more common, forming a transition zone to the highly siliceous middle member cropping out at Mussel Rock.

FOSSILS

The large foraminiferal fauna of the lower member of the Monterey shale represents the upper part of Kleinpell's Relizian stage and all of his Luisian stage. *Siphogenerina* is a conspicuous genus in the fauna, *S. branneri* being common in the lower part of the member and *S. collomi* in the upper part. The fauna is listed in the accompanying table.

The conglomerate and breccia shown on figure 4 *A*, and included in the section on page 20, contains fragments of *Aequipecten*, *Amusium*, *Ostrea*, and *Balanus*.

Foraminifera from lower member of Monterey shale

[Identifications by M. N. Bramlette. R, rare; F, few; C, common; A, abundant]

Species	Localities						
	9	10	10*a*	10*b*	10*c*	10*d*	11
Anomalina salinasensis Kleinpell		F	F	C	C		C
Baggina californica Cushman			F	F	R	R	R
Baggina robusta Kleinpell		F	R	R	F	R	
Bolivina advena Cushman				F			F
Bolivina advena var. *ornata* Cushman				F		F	
Bolivina californica Cushman	F	R			R		F
Bolivina cf. *B. conica* Cushman		C	F				
Bolivina cuneiformis Kleinpell							C
Bolivina imbricata Cushman	C	R	R	R	C		
Bolivina imbricata var. *inflata* Kleinpell			F	C			
Bolivina aff. *B. imbricata* Cushman						F	
Bolivina parva Cushman and Galliher	C						
Bolivina perrini Kleinpell		F	F	R	C		
Bolivina salinasensis Kleinpell	F				F	C	F
Bolivina tumida Cushman					F	A	
Bulimina pseudoaffinis Kleinpell	R	C					
Bulimina pseudotorta Cushman		R		F	F		
Buliminella henryana Cushman and Kleinpell						C	
Buliminella subfusiformis Cushman	C		R		F	F	
Cancris baggi Cushman and Kleinpell		R					
Cancris aff. *C. baggi* Cushman and Kleinpell					F		
Cassidulina crassa d'Orbigny of Kleinpell				C			
Cassidulina panzana Kleinpell							F
Cassidulina sp			F				
Chilostomella cf. *C. ovoidea* Reuss							F
Cibicides cf. *C. altamiraensis* Kleinpell	C						
Cibicides relizensis Kleinpell	F						
Cibicides? sp					F		
Dentalina barnesi Rankin							R
Dentalina obliqua Linné of Kleinpell			F	F	R		R
Dentalina cf. *D. pauperata* d'Orbigny							R
Elphidium sp					F		
Entosolenia sp	F						
Eponides rosaformis Cushman and Kleinpell							C
Globigerina bulloides d'Orbigny	A	R	C	F	A	A	
Globobulimina aff. *G. pacifica* Cushman							R
Lagena acuticosta Reuss of Kleinpell	C						
Lagena sp	R						
Marginulina sp					R		
Nodogenerina advena Cushman and Laiming		R	C	C	F	F	
Nonion costiferum Cushman					R		
Nonion cf. *N. pizarrensis* W. Berry					R		

Foraminifera from lower member of Monterey shale—Continued

[Identifications by M. N. Bramlette. R, rare; F, few; C, common; A, abundant]

Species	Localities						
	9	10	10*a*	10*b*	10*c*	10*d*	11
Planularia dubia Kleinpell	-----	-----	-----	R	-----	-----	-----
Planulina baggi Kleinpell	-----	R	R	-----	R	-----	-----
Planulina aff. *P. ornata* (d'Orbigny)	-----	-----	-----	-----	-----	-----	F
Pullenia miocenica Kleinpell	-----	F	F	C	-----	C	C
Pulvinulinella subperuviana Cushman	F	-----	F	-----	R	F	F
Robulus hughesi Kleinpell	-----	-----	F	R	R	-----	-----
Robulus miocenicus (Chapman)	-----	-----	-----	F	-----	-----	-----
Robulus reedi Kleinpell	-----	-----	R	-----	-----	-----	-----
Robulus smileyi Kleinpell	-----	-----	-----	-----	-----	-----	R
Siphogenerina branneri Cushman	F	F	F	F	-----	C	-----
Siphogenerina collomi Cushman	-----	-----	-----	F	-----	-----	C
Siphogenerina cf. *S. kleinpelli* Cushman	-----	F	-----	-----	R	-----	R
Siphogenerina cf. *S. nuciformis* Kleinpell	-----	-----	-----	-----	-----	-----	F
Siphogenerina cf. *S. reedi* Cushman	-----	-----	-----	F	R	F	-----
Sphaeroidina bulloides d'Orbigny	-----	-----	-----	-----	-----	-----	R
Uvigerinella californica Cushman	F	-----	R	-----	F	F	-----
Uvigerinella californica var. *ornata* Cushman	-----	R	-----	R	R	-----	-----
Valvulineria californica var. *obesa* Cushman	R	F	F	C	A	C	R
Valvulineria californica var. *appressa* Cushman	-----	R	-----	-----	F	-----	-----
Virgulina californiensis Cushman	-----	-----	-----	-----	-----	F	-----

MIDDLE MEMBER

STRATIGRAPHY AND LITHOLOGY

The middle member of the Monterey shale is characterized by chert and cherty shale, but includes also porcelaneous shale and limestone. In the western Casmalia Hills the thickness averages 200 feet and is quite uniform, not varying more than 25 feet from the average. It is not known whether the base and top of the highly siliceous strata differentiated as the middle member are at approximately the same horizon in the western Casmalia Hills and the eastern Purisima Hills. They evidently are at essentially the same horizon at various places in the western Casmalia Hills.

Chert is the most conspicuous constituent of the middle member and forms ledges a foot to 10 feet thick. Both chert and cherty shale are thinly bedded or laminated, and include dark and light layers, light-brown to dark-brown colors being most prevalent in the chert. At many places the chert is contorted; in fact, contortion is a characteristic feature. The contortions may affect only certain layers in a bed of chert, a considerable part of the member, or the entire member. Minor folds on a larger scale also are common. They extend generally into the upper member with decreasing intensity and less commonly extend into the lower member, also with decreasing intensity. At a few localities the chert includes breccia consisting of angular chert fragments in a matrix of chert and finely ground particles.

Sea cliff and low-tide reef exposures of the middle member are readily accessible on the coast southeast of Lions Head. The middle member, dipping steeply southward, overlies the lower member presumably in normal sequence, but a sand-filled cove in which there are no outcrops separates the two members. The thickness of the middle member north of the minor folds toward the south end of the exposures is about 200 feet. Figure 4 *D* shows the characteristically contorted chert. In addition to chert and cherty shale, the middle member includes thin zones of somewhat less hard, porcelaneous shale, represented by recesses in the view on figure 4 *C*. Limestone ledges occur in the lower part of the member, but are less abundant upward.

In the Corralillos Canyon area and farther southeast near the Pezonni fault, chert ledges are thin or absent, the exposed strata consisting chiefly of cherty and porcelaneous shale.

The middle member is exposed in a small area in the southeastern Purisima Hills. Thin-bedded chert and cherty shale are the most characteristic rocks, but interbedded porcelaneous shale is common.

FOSSILS

The middle member of the Monterey shale contains a few poorly preserved Foraminifera in the western Casmalia Hills. A collection from the eastern Purisima Hills at locality 12 indicates that the middle member in that area represents the lower part of Kleinpell's Mohnian stage. The species collected in the eastern Purisima Hills are as follows.

Foraminifera from middle member of Monterey shale at locality 12

[Identifications by M. N. Bramlette. R, rare; F, few; C, common; A, abundant]

Bolivina aff. *B. bramlettei* Kleinpell	R
Bolivina aff. *B. hughesi* Cushman (characteristic middle Mohnian sp.)	C
Bolivina pseudospissa Kleinpell	C
Bolivina salinasensis Kleinpell	C
Bolivina sinuata Galloway and Wissler var.	F
Bolivina tumida Cushman	C
Bolivina aff. *B. woodringi* Kleinpell	C
Bulimina delreyensis Cushman and Galliher	R
Buliminella subfusiformis Cushman	F
"*Ellipsoglandulina*" *fragilis* Bramlette, n. sp.? (mashed)	A

Foraminifera from middle member of Monterey shale at locality 12—Continued

[Identification by M. N. Bramlette, R, rare; F, few; C, common; A, abundant]

Eponides rosaformis Cushman and Kleinpell	R
Globigerina bulloides d'Orbigny	C
Gyroidina multicameratus (Kleinpell)	F
Nodogenerina aff. *N. advena* Cushman and Laiming	F
Pulvinulinella sp. (minute)	F
Robulus mohnensis Kleinpell	R
Suggrunda kleinpelli Bramlette, n. sp	F
Suggrunda kleinpelli Bramlette var. (globular chambers)	R
Uvigerina angelina Kleinpell	F
Uvigerina modeloensis Cushman and Kleinpell	F
Uvigerina aff. *U. subperegrina* Cushman and Kleinpell (large)	C

UPPER MEMBER

STRATIGRAPHY AND LITHOLOGY

Platy porcelaneous shale is the principal constituent of the upper member of the Monterey shale, but in some areas the member also includes diatomite and diatomaceous shale. Wherever the stratigraphic relations are well defined in those areas, the diatomite and diatomaceous shale are at the top of the section and grade laterally into hard porcelaneous shale. The thickness of the upper member is 600 to 1,000 feet. Crushed arenaceous Foraminifera are common in the porcelaneous shale and molds of Foraminifera occur in diatomaceous strata. The best-preserved specimens are calcite-filled molds that stand out in relief on weathered surfaces of thin-bedded concretionary limestone.

Casmalia Hills.—In the western Casmalia Hills east of Mount Lospe, the upper member is 600 to 725 feet thick. The lower third consists of porcelaneous shale that contains scattered limestone concretions. Toward the base thin layers of cherty shale are interbedded with the porcelaneous shale. The middle third shows a monotonous succession of platy porcelaneous shale like that in the view on figure 5 *A*. The upper third includes thin beds of siltstone and moderately hard somewhat porcelaneous shale as well as hard porcelaneous shale. Near the top of the member thin beds of claystone form a transition zone to the Todos Santos claystone member of the Sisquoc formation. The lithology of a section of the upper third of the member, measured at the locality shown on figure 5 *B*, is as follows:

Section of upper third of upper member of Monterey shale 1¾ miles northwest of Casmalia

	Feet
Platy porcelaneous shale. (Overlain by thick claystone unit mapped as base of Todos Santos claystone member of Sisquoc formation)	1½
Claystone	4⅕
Platy porcelaneous shale	1
Claystone	12⅗
Platy porcelaneous shale	12⅗
Claystone	6
Platy porcelaneous shale	46
Claystone	4
Platy porcelaneous shale	16
Hard massive siltstone	1
Platy porcelaneous shale	16
Hard massive siltstone	⅖
Silty conchoidally fracturing shale	1
Platy porcelaneous shale	9
Conchoidally fracturing porcelaneous shale	2⅖
Platy porcelaneous shale	3
Conchoidally fracturing porcelaneous shale	3
Hard massive siltstone	⅓
Conchoidally fracturing porcelaneous shale	⅓
Hard massive siltstone	⅓
Conchoidally fracturing porcelaneous shale	½
Hard massive to poorly bedded siltstone	1
Platy porcelaneous shale	4
Massive somewhat sandy siltstone	⅓
Platy porcelaneous shale	20
Hard massive somewhat sandy siltstone	⅕
Platy porcelaneous shale	15
Platy porcelaneous shale with thin silty layers	2
Hard fine-grained silty sandstone	½
Platy porcelaneous shale	16
Moderately hard, somewhat porcelaneous shale	12
Platy porcelaneous shale	5
Moderately hard, somewhat porcelaneous shale	2
Massive sandy siltstone	1½
Partly platy to conchoidally fracturing porcelaneous shale	18
Massive sandy siltstone	⅖
Platy, somewhat conchoidally fracturing, porcelaneous shale	5½
Hard sandy siltstone	⅕
Finely laminated, platy, porcelaneous shale	1½
Moderately hard, somewhat platy, conchoidally fracturing, porcelaneous shale	22
Massive or poorly bedded siltstone containing phosphatic nodules and pellets, and angular fragments of platy porcelaneous shale. Borings extending downward from upper surface are filled with shale like that in overlying bed. (Underlying strata through thickness of more than 100 feet consist dominantly of platy porcelaneous shale)	⅓
Total thickness of section	268⅔

Thin beds of siltstone like those in the preceding section are found in the overlying Todos Santos claystone member of the Sisquoc formation, and the claystone near the top of the section represents the lithologic type characteristic of the Todos Santos. The siltstone at the base of the preceding section indicates a discontinuity and may be an appropriate horizon for the base of the Sisquoc formation. The porcelaneous shale above the siltstone at the base of the section is possibly the equivalent of laminated diatomite and diatomaceous shale at the base of the Sisquoc in the southeastern Purisima Hills. The lowest thick claystone unit, however, was chosen as the base of the Sisquoc, as it marks the most pronounced lithologic change and could be mapped with reasonable assurance.

Siltstone containing phosphatic nodules crops out along and near the abandoned ranch road leading westward toward Mount Lospe 1.9 miles northwest of the

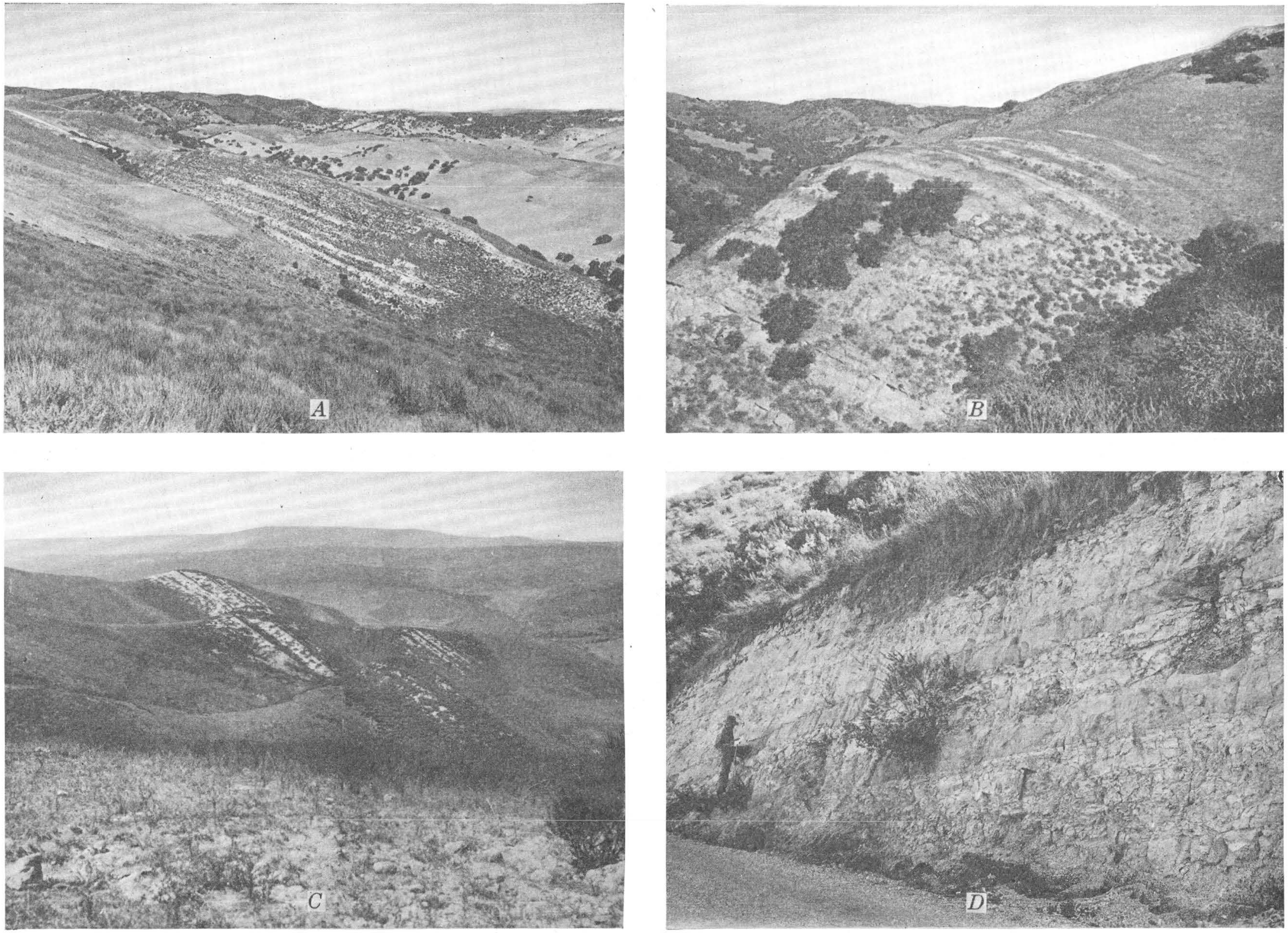


FIGURE 5.—Monterey shale and Sisquoc formation. *A*, Upper member of Monterey shale in Casmalia Hills. Upper member forms strike ridge in middle of view and the Sisquoc formation forms the hills at the right. *B*, Upper member of Monterey shale and Sisquoc formation in Casmalia Hills. Transition zone between the formations is on spur in middle of the view above the lower group of trees. *C*, Diatomaceous mudstone and underlying less diatomaceous clayey mudstone of Sisquoc formation on north slope of western Purisima Hills. The diatomaceous mudstone forms white outcrops. *D*, Siltstone and sandstone in transition zone between Sisquoc formation and Careaga sandstone on north slope of Gato Ridge. The siltstone (under hammer) is lighter colored than the sandstone.

preceding locality, and is in approximately the same part of the upper member of the Monterey as that just described. At localities near the ranch road two bed of sandy siltstone, a foot thick and three feet apart, are 50 feet below the phosphatic siltstone.

Porcelaneous shale is the prevailing lithologic type in the upper member of the Monterey shale in the Corralillos Canyon and adjoining areas, as in other parts of the western Casmalia Hills.

In a synclinal cove a quarter of a mile north of Mussel Rock, isolated exposures of porcelaneous shale and soft laminated shale represent the basal part of the upper member. Soft mudstone, laminated porcelaneous shale, laminated diatomite, and diatomaceous mudstone exposed at intervals in upward sequence for a distance of about a quarter of a mile north of the fault north of Mussel Rock are assigned doubtfully to the Sisquoc formation. Though no fossils were observed, these strata are reported to contain Sisquoc species of Foraminifera.

Purisima Hills. In the eastern Purisima Hills the upper member has a computed maximum thickness of about 1,000 feet. It is made up of porcelaneous shale including layers of thin-bedded concretionary limestone, or of porcelaneous shale overlain by laminated diatomite and diatomaceous shale. Some layers of concretionary limestone contain calcite casts of Foraminifera that stand out in relief on weathered surfaces. The soft diatomaceous strata occur only near the southeast corner of the mapped area, disappearing northwestward. By means of tracing thin beds and zones, it is apparent that the disappearance of the soft diatomaceous strata is due to lateral change into hard porcelaneous shale containing molds of diatoms, not to depositional thinning or to overlap by the Sisquoc formation. The change from soft to hard strata takes place at successively higher horizons northwestward.

Foxen Canyon-Sisquoc River area.—The upper member of the Monterey in most of the Foxen Canyon-Sisquoc River area is made up of porcelaneous shale, overlain by laminated diatomite and diatomaceous shale. The computed outcrop thickness of the member is about 750 feet, but the base is not exposed. Two miles east-northeast of the Fremont-Foxen Monument in Foxen Canyon, the diatomaceous strata disappear westward. Both unconformable overlap by the Sisquoc formation and lateral gradation into porcelaneous shale are probably involved. At that locality, however, the discordance between the Monterey and Sisquoc is not pronounced; it is, in fact, very slight.

Light-colored fine-grained soft sandstone, tar sand, and somewhat porcelaneous hard brownish mudstone are exposed on a steeply folded anticline on Sisquoc River at the northeast border of the mapped area. These strata are unlike those included in the upper member of the Monterey shale elsewhere in the mapped area. They are very similar to those in the Pismo formation of the San Luis Obispo district,[14] but are for convenience included in the upper member of the Monterey. On the south limb of the anticline the sandstone and mudstone are faulted against the Sisquoc formation; on the north limb, just beyond the mapped area, they are overlain with apparent conformity by the Sisquoc formation.

Fossils

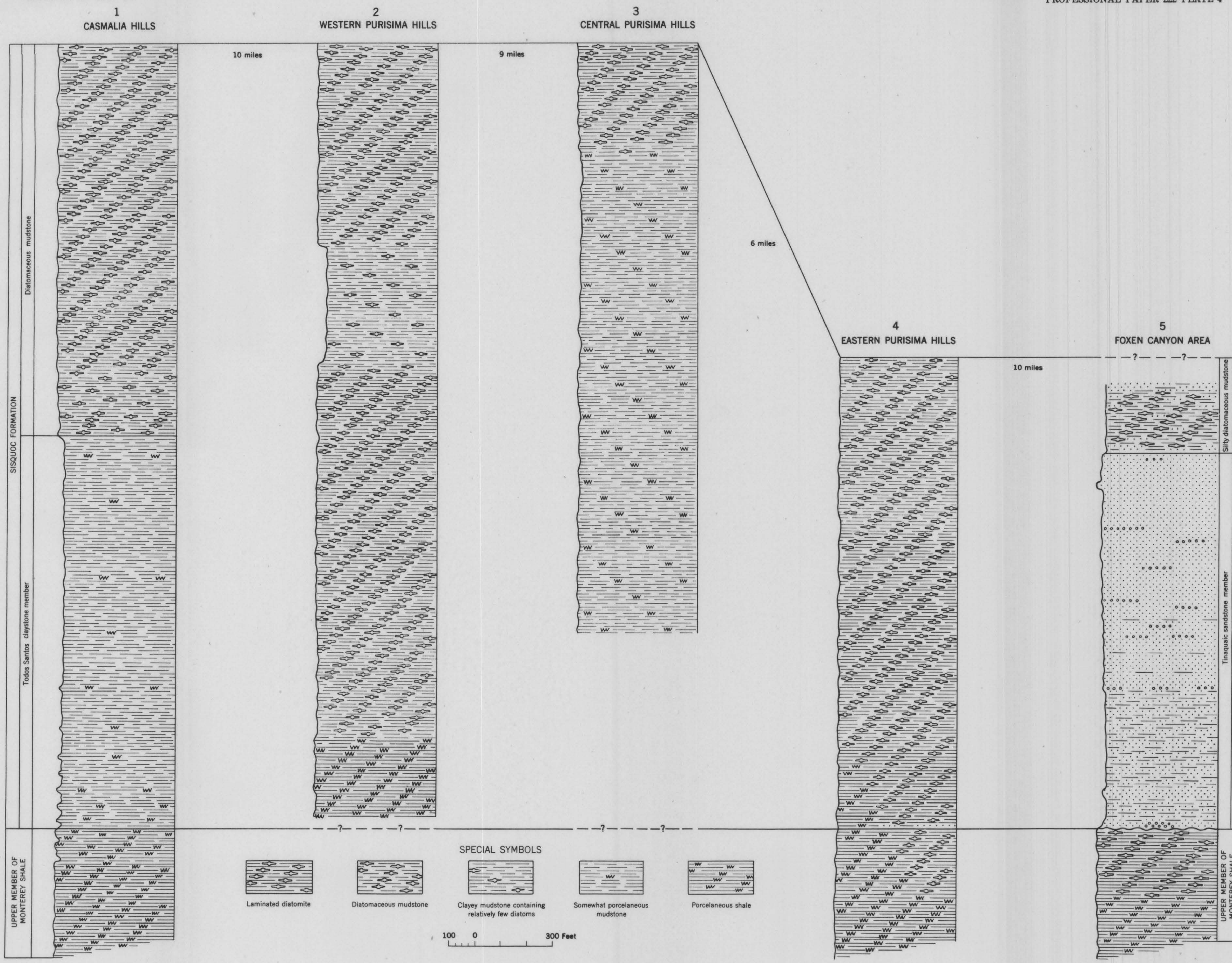
The upper member of the Monterey shale is almost barren of Foraminifera in the Casmalia Hills, but contains a moderately large fauna in the eastern Purisima Hills. The fauna includes *"Ellipsoglandulina" fragilis* (pl. 22, figs. 4, 8–10), *Hopkinsina magnifica* (pl. 22, figs. 1–3, 5), and *Pulvinulinella purisima* (pl. 23, figs. 10–15). These species are large and distinctive. They are useful in field identification of upper Monterey strata in the eastern Purisima Hills. The upper Monterey fauna belongs in the upper part of the *Bolivina hughesi* zone, at the top of Kleinpell's Mohnian stage, and in part to an unnamed faunal division. (See p. 100.) The species from the Purisima Hills are listed in the following table.

[14] Fairbanks, H. W., U. S. Geol. Survey Geol. Atlas, San Luis folio (no. 101), p. 4, 1904.

Foraminifera from upper member of Monterey shale

[Identifications by M. N. Bramlette. R, rare; F, few; C, common; A, abundant]

Species	Localities						
	14	15	16	17	18	19	20
Baggina aff. *B. californica* Cushman (large)	C	C	C				
Bolivina subadvena var. *spissa* Cushman of Kleinpell			F				
Bolivina parva Cushman and Galliher			R		R	R	
Bolivina sp.	R						
Bulimina cf. *B. galliheri* Kleinpell	R				R		
Bulimina ovula d'Orbigny						F	
Bulimina sp. (large)							R
Buliminella subfusiformis Cushman			F		F		
Cassidulina cf. *C. williami* Kleinpell						R	
Cassidulina sp. (large)							R
Cassidulinella renulinaformis Natland				C			
Cassidulinoides californiensis Bramlette, n. sp.			R	R	R		R
Chilostomella ovoidea Reuss?				F			R
Discorbinella valmonteensis Kleinpell			R		R		



SECTIONS, SHOWING LITHOLOGY AND STRATIGRAPHIC RELATIONS OF SISQUOC FORMATION

Foraminifera from upper member of Monterey shale—Continued

[Identifications by M. N. Bramlette. R, rare; F, few; C, common; A, abundant]

Species	Localities						
	14	15	16	17	18	19	20
"*Ellipsoglandulina*" *fragilis* Bramlette, n. sp.		R	C			F	C
Globigerina bulloides d'Orbigny							R
Globobulimina sp.			R				
Gyroidina multicameratus (Kleinpell)					R		
Hopkinsina magnifica Bramlette, n. sp. (pl. 22, fig. 3)	F	F	C	F		F	R
Nonionella miocenica Cushman							C
Nonionella aff. *N. miocenica* Cushman			C				
Pullenia sp.			R			R	
Pulvinulinella purisima Bramlette, n. sp.			F			R	
Suggrunda californica Kleinpell							R
Suggrunda kleinpelli Bramlette, n. sp.						R	R
Virgulina californiensis Cushman		F	A	F	F	C	A
Virgulina (*Virgulinella*) *pertusa* Reuss			R				

MIOCENE AND PLIOCENE SERIES

SISQUOC FORMATION, INCLUDING TINAQUAIC SANDSTONE MEMBER AND TODOS SANTOS CLAYSTONE MEMBER

STRATIGRAPHIC NOMENCLATURE

As shown on plate 4 and in the structure sections on plate 2, the Sisquoc formation does not have uniform lithology or uniform stratigraphic relations to the underlying Monterey shale. Two principal lithologic facies are represented in the Sisquoc: a fine-grained basin facies and a marginal sandstone facies. The fine-grained basin facies consists chiefly of diatomaceous mudstone and somewhat porcelaneous mudstone, and in the Casmalia Hills includes the Todos Santos claystone member. The marginal sandstone facies, represented by the Tinaquaic sandstone member, is present only in the northeastern part of the area covered by the present report. In outcrop sections in the Purisima Hills (pl. 4, column 4) the basin facies of the Sisquoc overlies the Monterey without discordance. In the Casmalia Hills (pl. 4, column 1) not only is there no discordance, the Sisquoc and Monterey are completely gradational. On some anticlines, however, the subsurface basin facies of the Sisquoc formation overlies discordantly the Monterey (pl. 2, structure sections *E–E′*, *F–F′*). In the Foxen Canyon area the marginal sandstone facies (Tinaquaic sandstone member) underlies a thin section of diatomaceous strata and rests on the Monterey with marked discordance, or locally with slight discordance (pl. 2, structure sections *E–E′*, *F–F′*; pl. 4, column 5).

When the Sisquoc formation was named by Porter,[15] the marginal sandstone facies in the Foxen Canyon-Sisquoc River area was described. That area, indeed, was evidently intended as the type region. Porter[16] realized, however, that the diatomaceous strata in the Purisima Hills, which previously had generally been referred to the Monterey shale, include the equivalent of the marginal sandstone facies, and he assigned at least the upper part of the diatomaceous strata to the Sisquoc formation. Stratigraphic names for one or both facies are advantageous, and assignment of member rank to the sandstone is also advantageous. Adoption of a new name for the basin facies is objectionable, because, according to current usage, the term Sisquoc when unqualified means that facies, which is more extensive in outcrop and subsurface sections and is economically important. Therefore it appears to be preferable to consider the basin facies as the typical facies and to propose a new name, Tinaquaic sandstone member of the Sisquoc formation, for the marginal facies. A name for the thick somewhat porcelaneous claystone of the basin facies in the Casmalia Hills is also considered desirable. It is designated the Todos Santos claystone member of the Sisquoc formation. The names just mentioned were proposed and defined in a preliminary paper.[17] This system of nomenclature has the disadvantage of cumbersome terms for the basin facies; such as, "typical facies of the Sisquoc formation" or "diatomaceous strata of the Sisquoc formation." Nevertheless the advantages are thought to outweight the disadvantages. The relations of the two facies of the Sisquoc formation to one another and to the Monterey shale are shown on plate 4 and in the structure sections on plate 2.

The western Purisima Hills may be regarded as the type region of the basin facies of the Sisquoc formation. In that area it has an exposed maximum thickness of about 3,000 feet, but the base is not exposed and subsurface data indicate a total thickness of as much as 5,000 feet (pl. 2, structure sections *C–C′* to *F–F′*). In the eastern Purisima Hills the basin facies overlies without discordance the Monterey shale, and is overlain conformably by the Foxen mudstone or is partly overlapped by the Careaga sandstone. The name "Tinaquaic" for the sandstone member of the marginal facies of the Sisquoc formation is derived from the name of a land grant in the type region in the Foxen Canyon-Sisquoc River area. In the type region, the Tinaquaic

[15] Porter, W. W., II, Lower Pliocene in Santa Maria district, Calif.: Am. Assoc. Petroleum Geologists Bull,. vol. 16, pp. 139-140, 1932.

[16] Idem, pp. 140-141.

[17] Woodring, W. P., Bramlette, M. N., and Lohman, K. E., op. cit. (Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 10). pp. 1,347-1 349 1943

member has an outcrop thickness of 1,450 feet. It overlies unconformably the Monterey shale and is overlain gradationally by diatomaceous strata of the Sisquoc. The Todos Santos claystone member in the basin facies of the Sisquoc is named for the Todos Santos y San Antonio land grant near the type region in the western Casmalia Hills, where the member has a maximum thickness of about 1,500 feet, overlies gradationally the Monterey shale, and grades upward into diatomaceous strata of the Sisquoc.

The basin facies of the Sisquoc formation represents essentially a Monterey-like facies, but massive diatomaceous mudstone is more prevalent than in typical sections of the Monterey. Nevertheless the Sisquoc includes both soft diatomaceous and hard porcelaneous strata indistinguishable lithologically from those in the Monterey. In their reconnaissance of the Santa Maria district, Arnold and Anderson [18] quite naturally assigned the basin facies to the Monterey, aside from the two following exceptions: the diatomaceous mudstone in the Foxen Canyon-Sisquoc River area was referred to their Fernando formation, because it overlies sandstone containing Pliocene fossils (Tinaquaic sandstone member of Sisquoc formation); somewhat porcelaneous mudstone near Redrock Mountain in the Purisima Hills (locality 113 of present report) was also referred to their Fernando formation, inasmuch as it contains a few fossils, which they considered Pliocene. In the Purisima Hills and Casmalia Hills, where a Monterey-like facies of the Sisquoc overlies the Monterey without discordance, it would be appropriate to consider the Sisquoc as a part of the Monterey. In areas where they are unconformable, as in the Gato Ridge subsurface section, or unconformable and separated by a unit of different lithology, as in the Foxen Canyon-Sisquoc River area, assignment of the Sisquoc to member or formation rank under the Monterey would be inappropriate. In view of the varying stratigraphic and lithologic relations and in view of current usage, it would be confusing to consider the Sisquoc as part of the Monterey, despite the occurrence in the Sisquoc of lithologic types characteristic of the Monterey.

STRATIGRAPHY AND LITHOLOGY

The diatomaceous strata of the Sisquoc formation include gradations from virtually white impure laminated diatomite through massive diatomaceous mudstone of the same color to buff clayey mudstone containing few diatoms. In outcrop sections of the upper part of the formation diatomaceous mudstone is the prevailing type. At many places the mudstone is so massive that bedding is not discernible, at other places it is indistinctly or distinctly bedded. A clue to bedding in massive strata may be given by flaking and by the orientation of relatively large discoidal diatoms, which lie parallel to the bedding. In most areas highly diatomaceous mudstone alternates with more clayey mudstone in which diatoms are less abundant, both types occurring in units varying in thickness from a few feet to several hundred feet. Diatomite and diatomaceous mudstone form scattered or almost continuous bare outcrops, whereas the more clayey mudstone is generally grass covered (fig. 5 *C*). Thin lenses of dark chert occur in the lower part of the diatomaceous strata, but are generally rare. Laminated diatomite at some places grades laterally into porcelaneous shale containing molds of diatoms. Zones of porcelaneous shale, decreasing in abundance upward in the section, are characteristic of the Todos Santos claystone member, and laminated porcelaneous shale is likewise common in the lower part of the formation in the Purisima Hills. The diatomaceous mudstone is locally cemented with silica forming somewhat porcelaneous mudstone, in which diatoms are represented by molds. Limestone concretions are found throughout the diatomaceous facies, but at most places are not abundant. Layers containing small phosphatic pellets ("sporbo" of local usage) are common, especially near the top of the formation. Tuffaceous material is not abundant, but is represented in most areas by occasional layers of vitric volcanic ash a fraction of an inch to several inches thick.

The diatomaceous mudstone is locally impregnated with oil, or with asphaltic residual products of oil; the oil-impregnated rock is light brown to almost black in color. At some places the mudstone contains veins of impure asphaltic material. Reddish burnt shale, described in considerable detail by Arnold and Anderson,[19] varies from virtually unaltered mudstone to fused slaglike rock, and is found generally adjoining oil-impregnated mudstone. The largest areas of burnt shale are shown on the geologic map (pl. 1).

Foraminifera are represented for the most part by molds; preserved tests occur in some layers or may be extracted from the soft weathered rind of limestone concretions. Mollusks occur as molds except at a few localities where shell material is preserved in strata impregnated with oil.

Purisima Hills.—In the western Purisima Hills along and near the Harris-Lompoc highway, the Sisquoc formation is about 3,000 feet thick, but the base is not exposed. Porcelaneous shale exposed at the base of the section on the crest of the Purisima anticline is assigned to the Sisquoc. With the exception of this hard porcelaneous shale, about 300 feet thick, the entire formation consists of soft diatomaceous strata subdivided into three mapped units (pl. 4, column 2).

[18] Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Santa Maria oil district, Santa Barbara County, Calif.: U. S. Geol. Survey Bull. 322, pp. 36–38, 54–55, 1907.

[19] Op. cit., pp. 48–52.

Section of Sisquoc formation in western Purisima Hills

	Feet
Light-colored diatomaceous mudstone. Forms bare outcrops, between which are stands of brush	775
Clayey diatomaceous mudstone containing relatively few diatoms. Supports growth of grass and annuals	450
Light-colored diatomaceous mudstone. Forms bare outcrops, between which are stands of pine and brush. Includes laminated diatomite cropping out at crest of hills	1, 425
Porcelaneous shale with thin cherty layers. Thickness uncertain, owing to crumpling and faulting near crest of anticline	300±
Approximate exposed thickness of Sisquoc formation	2,950±

The contrast in outcrop and vegetation afforded by the highly diatomaceous mudstone and the less diatomaceous clayey mudstone is shown on figure 5 *C*.

A sample from the lower diatomaceous mudstone unit of the preceding section was examined by A. O. Woodford and found to contain many diatom fragments and sponge spicules, and a few grains of quartz and feldspar, probably alkalic plagioclase, 50 to 120 microns in diameter. A considerable amount of calcite is present in fine grains, though molluscan fossils are molds. The bulk of the rock is composed of silt and clay particles that appear to be essentially isotropic.

In the central part of the Purisima Hills, eastward from Canada Laguna Seca (pl. 4, column 3), the Sisquoc formation is made up almost entirely of fairly hard brownish somewhat porcelaneous mudstone. A conspicuous white "marker bed," which has an average thickness of 100 feet and is 400 to 500 feet below the top of the formation, shows the lateral graduation from hard to soft strata. On the sharply plunging nose of the anticline east of Canada Laguna Seca the "marker bed" consists of porcelaneous shale including cherty layers. Toward the south in the adjoining syncline this hard shale changes to soft diatomaceous shale. The "marker bed" is underlain by soft clayey mudstone and appears to be the equivalent of the lower part of the uppermost unit of the section in the western Purisima Hills.

In the eastern Purisima Hills soft light-colored diatomaceous mudstone is again the prevailing type in the Sisquoc formation. In the southeastern part of the mapped area laminated diatomite underlies the diatomaceous mudstone and is at the base of the formation (pl. 4, column 4). At the east border of the mapped area the laminated diatomite changes gradually northwestward to laminated porcelaneous shale, the change taking place at progressively higher horizons upward from the base. That is, the relations between diatomite and porcelaneous shale are the same as in the underlying Monterey shale in that area. In part of the eastern Purisima Hills the diatomite at the base of the Sisquoc overlies lithologically indistinguishable diatomite at the top of the Monterey, or hard porcelaneous shale in the Sisquoc overlies shale of the same type in the Monterey. The two formations can be recognized by means of characteristic Foraminifera even in the field, as the Foraminifera of the Monterey are larger than those of the Sisquoc. A bed of silty strata, suggesting discontinuity, is present locally at the base of the Sisquoc. At some places it includes scattered Franciscan and Monterey pebbles and a few phosphatic nodules; at other places it contains much vitric volcanic ash. It is impregnated with tar, forming a "tar sand," and thickens and thins irregularly, possibly owing in part to plastic deformation during folding. Where the so-called tar sand is lacking, the strata at the Sisquoc-Monterey contact are commonly more or less impregnated with tarry material.

At locality 113*b* near the burnt shale forming Redrock Mountain, fragments of *Crepidula* cf. *C. princeps* and *Anadara* cf. *A. trilineata* weather out of oil-impregnated mudstone, the only locality in the Purisima Hills where preserved shells were found in the Sisquoc formation. Sandy asphaltic material occurring in veins south of Redrock Mountain and the so-called tar sand at the base of the Sisquoc were mined before the rise of the California oil industry.[20]

Foxen Canyon-Sisquoc River area.—In the Foxen Canyon-Sisquoc River area the Sisquoc formation consists chiefly of sandstone constituting the Tinaquaic sandstone member, which is 1,450 feet thick and is unconformable on the Monterey shale (pl. 4, column 5). Diatomaceous siltstone overlying the Tinaquaic sandstone crops out in a syncline near the Sisquoc River. It is about 225 feet thick, but the top of the formation is not represented in that area. The following generalized section was measured on a ridge 2¼ to 2½ miles northeast of the Fremont-Foxen Monument in Foxen Canyon.

Section of Sisquoc formation on ridge 2¼ to 2½ miles northeast of Fremont-Foxen Monument in Foxen Canyon

	Feet
Diatomaceous strata: Diatomaceous siltstone including a fine-grained yellowish-brown soft sandstone in upper part. The diatomaceous siltstone is sandy toward base, grading into underlying sandstone. Locality 92 represents the soft sandstone in upper part; locality 92a represents diatomaceous strata 25 feet lower	230±
Tinaquaic sandstone member:	
Medium-grained to coarse-grained sandstone with grit bed at base. Locality 46 is 10 feet above base; locality 45 is 15 feet above base	35
Medium-grained to coarse-grained sandstone with hard calcareous bed containing *Dendraster* cf. *D. coalingaensis* at base. Locality 43 is at base; locality 44 is 55 feet above base	100
Medium-grained buff sandstone, coarse-grained toward top. Locality 42 is 15 feet above base	125
Fine-grained to medium-grained, light-gray to buff sandstone including few thin layers of chert pebbles. Locality 41 is 150 feet above base	285

[20] Eldridge, G. H., The asphalt and bituminous rock deposits of the United States: U. S. Geol. Survey 22d Ann. Rept., pt. 1, pp. 438–439, 1901.

Section of Sisquoc formation on ridge 2¼ to 2½ miles northeast of Fremont-Foxen Monument in Foxen Canyon—Continued

Tinaquaic sandstone member—Continued	*Feet*
Fine-grained to medium-grained sandstone and clayey siltstone, the sandstone, including some thin layers of chert pebbles	150
Fine-grained sandstone and siltstone containing disseminated volcanic ash. Thin layers of chert pebbles at top and base. Locality 40 is 300 feet eastward along strike at horizon 30 feet below top	205
Clayey light-gray siltstone and thin beds of fine-grained sandstone	375
Fine-grained light-gray sandstone	30
Poorly exposed clayey light-gray siltstone, probably sandy toward base. Overlies diatomaceous shale at top of Monterey shale	135
Approximate thickness of Sisquoc formation	1, 670

Half a mile west of the measured section, lenses of tar sand and conglomerate, as much as 35 feet thick, are at the base of the formation. Megafossils are abundant in the upper half of the Tinaquaic sandstone member, but were not observed at horizons below that at locality 40, which is 715 feet above the base of the member. Coarse-grained calcareous sandstone containing *Dendraster* cf. *D. coalingaensis* is 135 feet below the top of the Tinaquaic on the south limb of the syncline at locality 43, and is at about the same horizon on the north limb at locality 51. The diatomaceous strata at the top of the section include detrital material of somewhat coarser grain than at the nearest basinward outcrops 3 miles to the southwest.

Gato Ridge-Foxen Canyon area.—On the southwest side of Foxen Canyon the Tinaquaic sandstone member has a maximum thickness of only 350 feet and overlies the Monterey with marked unconformity, the discordance being as much as 40° (pl. 2, structure section *E–E'*). Megafossils are abundant in the sandstone, and many of the fossils are in the form of phosphatic molds. Coarse-grained sandstone containing *Dendraster* cf. *D. coalingaensis*, 15 to 25 feet below the top of the Tinaquaic at localities 32, 33, 37, and 39, is presumably to be correlated with similar sandstone 135 feet below the top in the Foxen Canyon-Sisquoc River area. The Tinaquaic sandstone grades upward into diatomaceous mudstone through a transition zone of fine-grained sandstone and siltstone. The diatomaceous mudstone and clayey mudstone adjoining Foxen Canyon are not more than 300 feet thick and grade upward into the sandstone of the Cebada fine-grained member of the Careaga sandstone. At nearby localities to the north the Cebada overlaps the Sisquoc formation and rests unconformably on the Monterey. Phosphatic paired molds of *Anadara* cf. *A. trilineata* and *Cryptomya* cf. *C. californica*, like those in the Tinaquaic sandstone, are found in sandy or silty beds near the base of the diatomaceous strata, as at locality 91, and also near the top.

Farther west on Gato Ridge the outcrop thickness of diatomaceous mudstone and clayey mudstone is about 400 feet. Phosphatic material is less abundant than in the area adjoining Foxen Canyon, aside from occasional layers of phosphatic pellets. At the site of Barnsdall-Richfield Pezzoni No. 1 well, at the southeast end of Gato Ridge, a limy layer, half a foot to a foot thick, contains phosphatic pellets and nodules, bone fragments and phosphatized paired molds of *Anadara* cf. *A. trilineata*. Dikes and sills of massive soft medium-grained sandstone are common on Gato Ridge, sandstone dikes being well exposed in the high cut at Barnsdall Tognazzini No. 5 well. The Sisquoc formation grades upward into the Cebada fine-grained member of the Careaga sandstone through a transition zone of varying thickness. The lithology of the transition zone is shown in the following section measured on the north slope of Gato Ridge along the highway leading to Cat Canyon.

Section of transition zone between Sisquoc formation and Careaga sandstone on north slope of Gato Ridge

	Feet
Siltstone, including near base a half-foot sandstone dike. (Top of siltstone not exposed. Top of section about 25 feet below base of Cebada fine-grained member of Careaga sandstone)	10+
Fine-grained to medium-grained soft gray sandstone, bedding partings well defined. Lower surface sharply defined	3
Siltstone	6
Massive medium-grained soft sandstone. Lower surface sharply defined	1
Siltstone	1½
Massive medium-grained soft sandstone containing scattered pebbles, boulders, and slabs of chert and siliceous shale as much as 1½ feet long, the largest of which extend far up into overlying bed. Lower surface sharply defined	⅙–½
Sandy siltstone	4
Massive medium-grained soft sandstone. Lower surface sharply defined and irregular, the irregularity being due to deformation	1½
Silty mudstone and siltstone	3
Massive medium-grained soft sandstone. Lower surface sharply defined and irregular, the irregularity being due to deformation	1⅔
Siltstone	5
Massive medium-grained soft sandstone. Upper and lower surfaces, especially lower surface, irregular due to deformation	3–6
Siltstone, thickness variable owing to deformation	¼–2
Massive medium-grained soft sandstone. Lower surface sharply defined	2½
Siltstone	½
Massive medium-grained soft sandstone. Lower surface sharply defined	2
Silty mudstone containing few diatoms, grading downward into mudstone containing more abundant diatoms. (Bases not exposed. Underlain in next exposure to south by highly diatomaceous mudstone.)	10+
Approximate thickness of transition zone	60

The upper part of the preceding section is shown on figure 5 *D*. Some of the massive sandstone may represent sills, and some of the irregular contacts are due to intrusion of sandstone. The sandstone that has well-defined partings and the massive sandstone containing pebbles, boulders, and slabs of chert and siliceous shale are quite certainly depositional features. The siltstone superficially resembles diatomaceous mudstone, but has a gritty feel and contains no diatoms, whereas the diatomaceous mudstone at the base of the section is smooth. The transition zone may be the equivalent of the Foxen mudstone, which, as in the area adjoining Foxen Canyon, is not represented as a lithologic unit on Gato Ridge. That the transition zone is to be assigned to the Sisquoc formation is indicated by the occurrence of *Yoldia gala* at locality 79 in a limestone concretion in siltstone between the top of the preceding section and the base of the Careaga sandstone. This species was found in the upper part of diatomaceous strata of the Sisquoc formation throughout the Santa Maria district, but is not known to occur in younger formations.

Graciosa Ridge.—The exposed thickness of the Sisquoc formation on Graciosa Ridge is estimated to be 500 feet. The actual thickness, however, is uncertain, for at many places the dip of massive, greatly jointed, diatomaceous mudstone was not determined, distinctly bedded diatomaceous strata being relatively rare. On the crest of the Graciosa anticline and for a varying distance on the upper flanks, the Sisquoc formation is overlain with local discordance by the Graciosa coarse-grained member of the Careaga sandstone. Lower on the flanks, the Foxen mudstone or the Cebada fine-grained member of the Careaga sandstone rests on the Sisquoc.

The Sisquoc formation includes diatomaceous mudstone and less diatomaceous clayey mudstone or claystone in poorly defined units. At a few localities medium-grained soft sandstone, generally impregnated with oil, in beds a few inches to 5 feet thick, is interbedded with diatomaceous strata.

Burnt shale is found in small areas on the north slope of the ridge and on the south slope adjoining the fault on the west side of the graben in the Newlove lease, as well as in the area on the north slope shown on the geologic map (pl. 1). Oil-impregnated mudstone and asphaltic material are widespread, particularly along the west side of the graben just mentioned and on the north slope of the ridge near the east end. The asphaltic material occurs as veins consisting of asphalt, clastic debris, and inclusions of mudstone of the Sisquoc formation that at places are so numerous as to make the rock appear like breccia. Such material was formerly mined.[21] Asphaltic casts of Foraminifera can be found at localities where the Sisquoc formation contains molds of Foraminifera and is oil-impregnated.

[21] Eldridge, G. H., op. cit., pp. 426-429.

Casmalia Hills.—In the Casmalia Hills the Sisquoc formation has a maximum thickness of about 3,000 feet, but the total thickness in any one area does not exceed 2,500 feet. The lower part of the formation, 750 to 1,750 feet thick, is differentiated as the Todos Santos claystone member.

The claystone or clayey mudstone of the Todos Santos member forms low, smoothly rounded hills and a thin clayey soil covered with grass or groves of live oak (fig. 5 *A*). It is typically light gray and is massive or well-bedded. Much of it is somewhat porcelaneous, and some zones are distinctly porcelaneous. Some of the bedded more porcelaneous claystone weathers into narrow splinterlike fragments. Zones of platy shale, varying from slightly porcelaneous shale to porcelaneous shale like that in the upper member of the Monterey and varying in thickness from a few feet to 15 feet, exceptionally 30 feet, occur throughout the member, but are most numerous in the lower part. The Todos Santos claystone grades downward into the upper member of the Monterey shale through a transition zone of alternating claystone and porcelaneous shale, the base of the member being mapped at the base of the lowest thick claystone unit. The transition zone is well exposed at the locality 1¾ miles northwest of Casmalia shown on figure 5 *B*, in the type region of the Todos Santos claystone member. (See section, p. 23.)

Layers of siltstone or fine-grained silty sandstone, a few inches to a foot thick, occur in the Todos Santos claystone. They were found at scattered horizons almost throughout the member, but are most abundant in the lower part. Layers containing phosphatic pellets and limestone concretions containing such material are also present at scattered horizons almost throughout the member. Diatom molds are not common, except in porcelaneous shale, and appear to be absent in much of the claystone. Molds of Foraminifera are common, and preserved tests were found in slightly calcareous or limonitic layers and in the weathered rind of limestone concretions.

The diatomaceous mudstone strata of the Sisquoc formation, overlying the Todos Santos claystone member, has a thickness of 700 to 1,500 feet, the thickness being greater on the south flank of the eastern Casmalia anticline than on the north flank. The marked difference in thickness of both units is due to lateral gradation of diatomaceous strata into harder nondiatomaceous strata and to the varying thickness of the transition zone between the units, in which the boundary is more or less arbitrarily placed. During the course of detailed mapping on a scale of 300 feet to the inch at and near the NTU mine,[22] it was found that the boundary is in a complexly interfingering zone and that, in the area immediately southeast of the NTU mine, the boundary

[22] Williams, M. D., and Holmes, C. N., Oil-impregnated diatomaceous rock near Casmalia, Santa Barbara County, Calif.: U. S. Geol. Survey, Oil and Gas Invest. Prelim. Map 34, 1945.

was placed too high stratigraphically on the preliminary edition of the geologic map of the Santa Maria district issued in 1945 as Preliminary Map 14 of the Geological Survey's Oil and Gas Investigations series. At some localities farther southeast the transition zone between the units is marked by lenses and concretions of dark chert a few inches thick. Along the Southern Pacific Railroad, where the diatomaceous strata have a thickness of 1,500 feet, a 200-foot transition zone at the base, consisting of brownish somewhat porcelaneous mudstone containing diatom molds, was for convenience mapped with the diatomaceous strata.

Diatomaceous mudstone, less diatomaceous clayey mudstone, and impure diatomite, the last like that shown on figure 6 *A*, are included in the diatomaceous mudstone, but for the most part form ill-defined units. Southwest of Waldorf a conspicuous band of white diatomaceous mudstone, 50 feet thick, similar to the "marker bed" of the Purisima Hills, lies 100 to 150 feet below the top of the formation. Immediately southeast of Corralillos Canyon adjoining the Pezzoni fault, impure laminated diatomite is estimated to be 400 feet below the top of the formation. On the first ridge southeast of Corralillos Canyon, the diatomite is 45 feet thick. A prospect pit at that locality shows scattered leached phosphatic nodules and pebbles of diatomite, porcelaneous shale, and chert in the lowermost 1½ feet of the overlying sparingly diatomaceous mudstone.

A zone of breccia and conglomerate and interbedded mudstone that has a maximum thickness of 200 feet extends southeastward from Corralillos Canyon for a distance of a mile along the strike. On the second ridge southeast of Corralillos Canyon the base of the zone is 50 feet above the diatomite just described; on the first ridge southeast of the canyon it is 200 feet above the diatomite, owing evidently to lensing. The lenticular beds of breccia and conglomerate are 10 to 60 feet thick. They are made up of unsorted angular slabs and chips of chert, cherty shale, and porcelaneous shale, a fraction of an inch to a foot long, from the Monterey shale. Mixed with the angular debris are a few rounded pebbles of the same rock types, many of which are perforated by mollusk borings, and rare phosphatic nodules. The coarse debris is generally so closely packed that there is little matrix; at some places a considerable proportion of medium-grained somewhat muddy sandstone forms the matrix. Toward the southeast the zone of breccia and conglomerate includes beds of oil-impregnated sandstone containing brown limestone concretions that are packed with diatoms. The mudstone with which the breccia and congolomerate are interbedded contains few diatoms, is somewhat silty, and more or less transitional to the overlying Foxen mudstone, which in the area adjoining Corralillos Canyon is poorly exposed or is overlapped by the Orcutt sand. Thin layers of breccia and conglomerate, consisting of small pieces of Monterey rocks, were observed in the diatomaceous strata of the Sisquoc formation at localities as much as 3 miles southeast of Corralillos Canyon. The white diatomaceous unit southwest of Waldorf, already mentioned, contains opal-cemented layers of such conglomerate and grit a few inches to a foot thick. Asphaltic sandstone is fairly common in the western Casmalia Hills northwest of the NTU mine, and a few thin lenses are exposed in the railroad cut north of the highway underpass near Shuman.

The most extensive areas of oil-impregnated mudstone and burnt shale adjoin the NTU mine and the highway underpass near Shuman. At both localities plants were formerly operated to extract oil by distillation.[23] Bedding is not discernible at either locality. Though preserved fossil shells are abundant at the NTU mine, they are not arranged in layers, suggesting that the oil-impregnated mudstone yielded plastically to deformation. During recent years a plant was constructed at the highway underpass near Shuman to calcine the oil-impregnated mudstone for the production of light-weight aggregate. If this product is successfully marketed, the possibility of utilizing the naturally calcined mudstone in the adjoining area of burnt shale and in the much larger area near the NTU mine would be worth investigation.

FOSSILS

MARGINAL SANDSTONE FACIES (TINAQUAIC SANDSTONE MEMBER)

Mollusks and other megafossils from the Tinaquaic sandstone member of the Sisquoc formation are listed in the accompanying table. They are common in the upper half of the thick section east of Foxen Canyon and in the entire thin section west of Foxen Canyon, but none was found in the lower half of the thick section. Most of the mollusks are indefinitely identified molds. Of the seven most widespread species—"*Nassa*" sp. (pl. 7, figs, 3, 4), *Anadara trilineata* (or comparable molds), *Volsella* cf. *V. capax*, *Macoma* cf. *M. nasuta*, *Schizothaerus* cf. *S. nuttallii*, *Cryptomya* cf. *C. californica* (pl. 7, fig. 2), and *Siliqua* cf. *S. media* (pl. 7, figs. 1, 5)—all except one, the "*Nassa*", occur in younger formations in the Santa Maria district. The "*Nassa*," represented by molds, may be a form of "*Nassa*" *moraniana*, a common species in the younger formations. The *Cryptomya* and the *Siliqua*, however, are more abundant and more widespread than in the younger formations. The sand dollar *Dendraster* cf. *D. coalingaensis* (pl. 7, figs. 6, 8), the unidentified "*Nassa*" (pl. 7, figs, 3, 4), *Patinopecten lohri* (pl. 7, figs. 7, 9), and an unidentified *Macoma*-like *Spisula?* are not known to occur in the younger formations and are therefore the most dependable stratigraphic guides. The moderately eccentric

[23] Gore, F. D., Oil shale in Santa Barbara County, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 8, pp. 459–472, 5 figs., 1924. (Oil shale is a misnomer for the oil-impregnated mudstone, as the oil fills minute pores in the rock.)
Williams, M. D., and Holmes, C. N., op. cit.

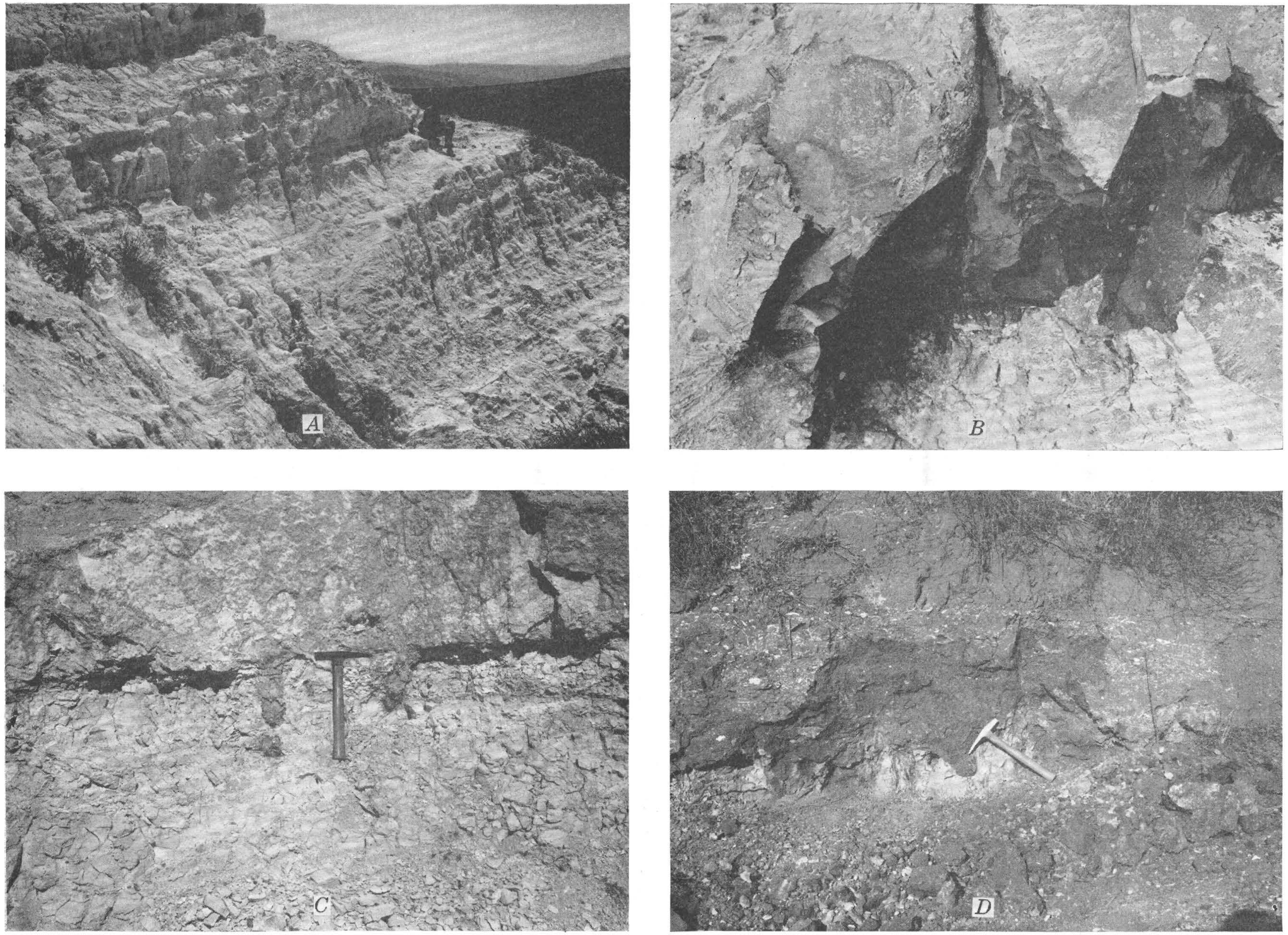


FIGURE 6.—Sisquoc formation and Careaga sandstone. *A*, Thin-bedded impure diatomite in Sisquoc formation of Casmalia Hills; *B*, Intrusive tar in Cebada fine-grained member of Careaga sandstone at fossil locality 177, near Union Oil Co. Newlove No. 42 well, Orcutt field; *C*, Burrows extending from base of Cebada fine-grained member of Careaga sandstone into Sisquoc formation, near Union Oil Co. Squires No. 18 well, Orcutt field; *D*, Burrows extending from tar sand at base of Graciosa coarse-grained member of Careaga sandstone into Sisquoc formation, near Union Oil Co. Folsom No. 3 well, Orcutt field.

Fossils from Tinaquaic sandstone member of Sisquoc formation

[Identifications by W. P. Woodring unless otherwise stated. P, Observed in field but not collected. For explanation of other symbols see p. 67]

Species	Localities																													Total localities (29)
	West of Foxen Canyon															East of Foxen Canyon														
	32	32*a*	32*b*	32*c*	33	34	35	36	36*a*	37	38	39	39*a*	39*b*	39*c*	40	41	42	43	44	45	46	47	48	49	50	51	52	53	
Echinoid: *Dendraster* cf. *D. coalingaensis* Twitchell (pl. 7, figs. 6, 8)	X				?sp.					P		P							X								X			6
Gastropods:																														
Crepidula cf. *C. princeps* Conrad					X			X	X				X							X										5
Calyptraea sp.				X					X																					2
"*Nassa*" sp. (pl. 7, figs. 3, 4)		X	X		X			X	X		X		X	X	X	X	X	X		X				X		X			X	16
Calicantharus cf. *C. portolaensis* (Arnold)					X															X		X		X		X		X		6
Pelecypods:																														
Anadara trilineata (Conrad) of Arnold			cf.	cf.			cf.	cf.					cf.	cf.		cf.				cf.	cf.	cf.				cf.		cf.	X	13
Anadara trilineata (Conrad) of Arnold, var. cf. *canalis* (Conrad)									cf.																	cf.				2
Volsella cf. *V. capax* (Conrad)				X			X	?	X		X		X	X						sp.	X	X								10
Patinopecten lohri (Hertlein) (pl. 7, figs. 7, 9)			?sp.				X															X	X					X	X	6
Lucinoma cf. *L. annulata* (Reeve)								X	sp.																					2
Macoma cf. *M. nasuta* (Conrad)				X				X	X		X		X	X	X					X		X				X				10
Macoma cf. *M. indentata* Carpenter							X														sp.									2
Spisula cf. *S. hemphilli* (Dall)									X						X															2
Spisula? sp.					X			X	X													X			X					5
Pseudocardium densatum (Conrad) of Arnold, var. cf. *gabbii* Rémond?					X																									1
Schizothaerus cf. *S. nuttallii* (Conrad)							X	X					X	X				X		X		X		X	X	X				10
Compsomyax cf. *C. subdiaphana* (Carpenter)								X	X							X	?sp.									X				5
Protothaca staleyi (Gabb)					X		?cf.	cf.	cf.		cf.		cf.	cf.																7
Protothaca cf. *P. tenerrima* (Carpenter)			X				X	X												X		X						X		6
Cerastoderma sp.					X																									1
Cryptomya cf. *C. californica* (Conrad) (pl. 7, fig. 2)		X		X	X		X	X	X		X		X	X	X	X	X	X		X	X	X		X	X	X				19
Solen perrini Clark													X		X	sp.														3
Siliqua cf. *S. media* (Sowerby) (pl. 7, figs. 1, 5)					X		X	X	X		X			X	X	X	X	X		X	X			X	X	X				15
Panope cf. *P. generosa* Gould																						X								1
Barnacle: *Balanus* sp.					X																									1
Marine mammal (identification by Remington Kellogg): Dolphin (periotic)						X																								1
Total forms 26	1	2	4	5	11	1	9	13	13	1	6	1	9	8	6	6	4	4	1	10	5	10	1	5	4	9	1	4	3	

Fossils from basin facies of Sisquoc formation, exclusive of Todos Santos claystone member

[Identifications by W. P. Woodring unless otherwise stated. For explanation of symbols see p. 67]

Species	Localities																																																								Total localities [2](55)
	Casmalia Hills								Graciosa Ridge											Eastern Solomon Hills																			Near Sisquoc River		Purisima Hills																	
	54	55	56	58	59	61	63	64	65	67	68	69	70	71	72	73	73a	[1]4472	74	75	75a	75b	76	76a	77	78	79	80	81	82	83	84	85	86	87	89	90	91	92	92a	94	95	97	98	100	101	113	113a	113b	117	118	122	123	125	129	130	132	
Gastropods:																																																										
Calliostoma sp			X																																																							1
Bittium casmaliense Bartsch																		X																																								1
Bittium casmaliense arnoldi Bartsch			X													X	X		X																																							[2]3
Aletes squamigerus Carpenter?, smooth var.?																	X																																									1
Turritella cooperi Carpenter																cf.	X	cf.	cf.													X																										[2]3
Crepidula princeps Conrad (pl. 8, figs. 3, 4, 9)			X																																												X		X		cf.			cf.	cf.	cf.	?sp.	8
Calyptraea cf. *C. fastigiata* (Gould)										X																																								X	X			X	X	X	X	7
Barbarofusus cf. *B. arnoldi* (Cossmann)																		X																																								1
"*Nassa*" *moraniana* Martin																		cf.		?sp.	sp.	?sp.					X		cf.			X	X																									8
"*Nassa*" *waldorfensis* Arnold (pl. 8, fig. 14)		?sp.	X															cf.									cf.	?sp.	cf.			cf.	cf.			cf.							?sp.				?sp.			cf.								12
Calicantharus? sp			X																																																							1
Boreotrophon cf. *B. stuarti* (Smith)																	X																																									1
"*Cancellaria*" cf. "*C.*" *arnoldi* Dall																		X				?																																				2
Mitrella gausapata (Gould)			X														?												cf.			cf.	cf.																									5
Psephaea oregonensis (Dall)																		X																																								1
Pelecypods:																																																									
Saccella cellulita (Dall)?			X																																																							1
Saccella orcutti (Arnold) (pl. 8, figs. 5, 7, 8, 13)																X	X	X	X	X	X				X			X	X				X								X		X	X				X										[2]12
Yoldia gala Woodring, n. sp. (pl. 8, figs. 1, 2; pl. 9, figs. 9, 10)			X		X			?sp.	X		X				X					X	X	X		X	X		X	X	X		X	X	X		X	X	X				X		X	X		X	?sp.			X								26
Anadara trilineata (Conrad) of Arnold (pl. 9, figs. 2, 5)	sp.	X	X									X		X		X	X	X	X			cf.						sp.				sp.	cf.	cf.			cf.	sp.	sp.	X					cf.		cf.		cf.			X	cf.	cf.	cf.		sp.	[2]24
Anadara trilineata (Conrad) of Arnold, var. cf. *canalis* (Conrad)																																								X																		1
Pecten cf. *P. hemphilli* Dall			X																																																							1
Chlamys hastatus (Sowerby)?																		X																																								1
Patinopecten cf. *P. lohri* (Hertlein)			X																																												X											2
Patinopecten dilleri (Dall), var. (pl. 9, figs. 6–8)			X																																																							1
Ostrea erici Hertlein (pl. 8, figs. 17, 18; pl. 9, figs. 1, 3, 4)																	X	X	X																																							[2]2
Cyclocardia californica (Dall.) (pl. 8, fig. 16)			X													X	X	X			cf.																																					[2]3
Lucinisca nuttallii antecedens (Arnold)																		X																																								1
Lucinoma sp	X																	X																																								2
Tellina cf. *T. aragonia* Dall																							X																																			1
Tellina cf. *T. lutea* Wood (pl. 8, fig. 15)		X								X		X														X	?sp.	?sp.	?sp.	X		?sp.																										9
Macoma n. sp.? (pl. 8, figs. 10, 11)																																							X																			1
Macoma? cf. *M. brota* Dall			X																																					sp.							?sp.											3
Macoma sp. (small)																																										X												?sp.				2
Semele? cf. *S. rubropicta* Dall			X																																																							1
Spisula? sp																																								X																		1
Compsomyax cf. *C. subdiaphana* (Carpenter)							X			X			X					X																							X												X				X	7
Transennella cf. *T. tantilla* (Gould)			X	?sp.	X	X			?sp.							X			X	X					X			X			X										X		X	X														14
Cryptomya cf. *C. californica* (Conrad)																																		X				X	X																	X		4
Siliqua cf. *S. media* (Sowerby)																																					X																					1
Pholadidea penita (Conrad) (pl. 8, fig. 6)																		X																													X											2
Zirfaea cf. *Z. pilsbryi* Lowe																		X																																								1
Pandora cf. *P. filosa* (Carpenter) (pl. 8, fig. 12)																																X	X																									2
Marine mammal (identification by Remington Kellogg):																																																									
Cetothere (tympanic bulla)																																																	X									1
Total forms 43	2	3	16	1	2	1	1	1	2	3	1	2	1	1	1	6	9	17	6	4	4	4	1	1	3	1	4	6	6	1	2	8	7	2	1	2	3	2	3	4	4	1	4	3	1	1	7	1	3	3	2	1	2	4	3	3	4	

[1] U. S. Geol. Survey locality 4472, [dump of] Pennsylvania asphalt mine, 3½ miles southeast of Orcutt, Ralph Arnold collector, 1906.
[2] The total number of localities is one or two less than the total number of occurences, localities 73, 73a, and 4472 being the same, or essentially the same.

sand dollar *Dendraster* cf. *D. coalingaensis* was found in clean coarse-grained sandstone, containing no other fossils, near the top of the member on both limbs of the syncline near Sisquoc River and in the same part of the section west of Foxen Canyon. It is not likely to be confused with the very eccentric *Dendraster ashleyi* of the Careaga sandstone. Nor is *Patinopecten lohri* likely to be confused with the younger *Patinopecten healeyi.*

The Tinaquaic sandstone contains a very meager foraminiferal fauna of shallow-water aspect. The following species, collected at locality 52, are representative of that fauna.

Foraminifera from Tinaquaic sandstone member of Sisquoc formation at locality 52

[Identifications by M. N. Bramlette. R, rare; F, few]

Buliminella elegantissima (d'Orbigny)	R
Elphidiella aff. *E. hannai* (Cushman and Grant)	F
Elphidium aff. *E. hughesi* Cushman and Grant	F
Eponides cf. *E. peruvianus* (d'Orbigny)	R
Nonion belridgensis Barbat and Johnson	F

According to a preliminary examination by K. E. Lohman, the diatom flora of the Tinaquaic is predominantly neritic and is characterized by *Coscinodiscus* aff. *C. excentricus*, *C. obscurus*, *Actinocyclus octonarius*, *Aulacodiscus sturti*, *Lithodesmium minusculum*, *Raphoneis angularis*, and *Fragilaria ischaboensis*.

BASIN FACIES, INCLUDING TODOS SANTOS CLAYSTONE MEMBER

Foraminifera from the lower and middle parts of the basin facies of the Sisquoc formation, exclusive of the Todos Santos claystone member, consist of small forms. *Bolivina obliqua* (pl. 23, fig. 22), *Buliminella curta*, *B. elegantissima*, *Nonionella miocenica*, a small variety of that species, and *Virgulina californiensis* are common. Less common species include *Bolivina rankini*, *B. ticensis*, *Cassidulinoides californiensis* (pl. 22, fig. 7), *Elphidium* aff. *E. hughesi*, *Eponides* cf. *E. patagonicus* (pl. 23, figs. 6–8), *Nonion belridgensis*, *Suggrunda kleinpelli* (pl. 23, fig. 5), *Virgulina* aff. *V. subplana* and *V.* (*Virgulinella*) *pertusa* (pl. 22, fig. 6). This fauna represents the *Bolivina obliqua* zone.

Foraminifera from the upper few hundred feet of the basin facies are similar to those in the basal part of the overlying Foxen mudstone. They include a variety of *Bolivina obliqua* (pl. 23, figs. 18, 23), relatively few specimens representing nearly the typical form of that species, *B. rankini*, *Buliminella curta*, *Virgulina californiensis* var. *purisima* (pl. 23, figs. 20, 25), and less numerous forms, such as *Buliminella elegantissima* and *Uvigerina foxenensis* (pl. 23, fig. 16).

Species from the basin facies, exclusive of the Todos Santos claystone member, are listed in the accompanying table.

Mollusks are widespread in the basin facies, except in the Todos Santos claystone member. As shown by the table facing page 34, however, the number of species at any locality is small, half of the localities yielding not more than one or two species. Only two unusual localities, the NTU mine in the Casmalia Hills (locality 56) and the dump of the old Pennsylvania asphalt mine in the Orcutt field (localities 73, 73*a*, 4472) yielded more than 10 species. The mollusks occur generally as molds in the mudstone or in limestone concretions, fossiliferous concretions being common in the Gato Ridge area in the eastern Solomon Hills. Preserved shells were found in oil-impregnated mudstone at the NTU mine, the dump of the Pennsylvania asphalt mine, locality 74 near Union Newlove No. 37 well in the Orcutt field, and at locality 113*b* near Redrock Mountain in the Purisima Hills. Shell material is also preserved in sand interbedded with silty diatomaceous mudstone in the syncline near Sisquoc River (localities 92, 92*a*).

Yoldia gala (pl. 8, figs. 1, 2; pl. 9, figs. 9, 10) and *Anadara trilineata* (pl. 9, figs. 2, 5) are the only really widespread species. *Turritella cooperi*, or exfoliated specimens probably representing that species, *Crepidula princeps* (pl. 8, figs. 3, 4, 9), *"Nassa" waldorfensis* (pl. 8, fig. 14), and *Saccella orcutti* (pl. 8, figs. 5, 7, 8, 13) are locally abundant at unusual localities. Not only is *Yoldia gala* widespread, it also was not found in other formations or in the Tinaquaic sandstone member of the Sisquoc; in fact, the genus in the restricted sense was not found in other formations or members, suggesting facies control. However that may be, *Yoldia gala* is a useful guide fossil. It occurs practically throughout the upper half of the basin facies of the Sisquoc formation, but is most abundant in the upper few hundred feet. Though it is rare in the Casmalia Hills, it is present in every area where the basin facies crops out, except in the syncline near Sisquoc River, where the sediments are not typical. It is particularly common on Gato Ridge and nearby.

Boreotrophon cf. *B. stuarti*, a variety of *Patinopecten dilleri* characterized by secondary ribs (pl. 9, figs. 6–8), *Tellina* cf. *T. aragonia*, *Macoma* n. sp.? (pl. 8, figs. 10, 11), and a small unidentified *Macoma* also were not found in other formations or members, but those species occur at only one locality, the small *Macoma* doubtfully at a second locality. Forms of *Patinopecten lohri* are present in the Tinaquaic sandstone member of the Sisquoc formation and at two localities in the basin facies, but not in other formations. A distinctive oyster, *Ostrea erici* (pl. 8, figs. 17, 18; pl. 9, figs. 1, 3, 4), was collected at the dump of the Pennsylvania asphalt mine and at an unusual locality in the Cebada fine-grained member of the Careaga sandstone. A large tellinid, *Tellina* cf. *T. lutea* (pl. 8, fig. 15), is fairly common in the diatomaceous strata and occurs in the overlying Foxen mudstone. *Pandora* cf. *P. filosa* (pl. 8, fig. 12) is present at two localities in the Gato Ridge area and at an unusual Foxen mudstone locality.

Foraminifera from basin facies of Sisquoc formation, exclusive of Todos Santos claystone member

[Identifications by M. N. Bramlette. R, rare; F, few; C, common; A, abundant]

Species	Localities																																				
	57	57*a*	57*b*	60	62	65	66	74	76	77	83	84	88	93	96	99	99*a*	102	103	104	105	106	107	108	109	111	112	114	115	116	119	120	126	127	128	131	133
Angulogerina cf. *A. angulosa* (Williamson)														F																							
Bolivina foxenensis Bramlette, n. sp	R					F																															
Bolivina obliqua Barbat and Johnson (pl. 23, fig. 22)	C	R	R												F		F		F								R	C	F		F		F	R		F	A
Bolivina obliqua Barbat and Johnson var. (pl. 23, figs. 18, 23)						C		C	C						C	C	C																				
Bolivina rankini Kleinpell								F	C						C	R	F																				F
Bolivina aff. *B. spissa* Cushman var. (serrate)						F		R																													
Bolivina ticensis Kleinpell																		F														R	R				
Bolivina aff. *B. tumida* Cushman									F																						R			C			
Buliminella curta Cushman	F					F		R	R				R		C	F	F																				
Buliminella dubia Barbat and Johnson				R																								F						F			
Buliminella elegantissima (d'Orbigny)				F	F	F		R	R						F	F	C	C				C	R	C	F		C					A	C			F	
Buliminella subfusiformis Cushman	F					F										R	F						R					C	A	F	C	R					C
Cassidulina sp														F																							
Cassidulinoides californiensis Bramlette, n. sp	R	R																												C				R			
Cibicides aff. *C. altamiraensis* Kleinpell														C																							
Cibicides concentricus (Cushman)								C																													
Cibicides sp														F																							
Discorbis sp														F																							
Elphidium aff. *E. hughesi* Cushman and Grant				F	F									C			R																				
Eponides cf. *E. patagonicus* (d'Orbigny) (pl. 23, figs. 6–8)			R	F	F													F				R		R								C	R				
Eponides cf. *E. peruvianus* (d'Orbigny) (pl. 23, figs. 1–3)														C	R																						
Globigerina bulloides d'Orbigny	R								R							R		R										R			R			R			
Nonion belridgensis Barbat and Johnson						?R									R		R																				
Nonion cf. *N. pizarrensis* W. Berry																				C					C								C				
Nonionella miocenica Cushman				C	C		C			C		F	C					C		A	C	C	C	A			A		R			A	A				F
Nonionella miocenica Cushman var. (small)	C	F	F								F				C	C	F		A						A	C		C			C			C	C	C	
Pulvinulinella purisima Bramlette, n. sp																														C							
Pulvinulinella sp	R																																				
Suggrunda kleinpelli Bramlette, n. sp. (pl. 23, fig. 5)	F																																	R			
Uvigerina foxenensis Bramlette, n. sp						A		A	R																												
Virgulina californiensis Cushman	C	C	C	C	C		C			C	C	C	C			R	F	C	C	A	C	F	F	C	F	F	C	C	R	C	F	R	C	C	A	C	F
Virgulina californiensis var. *grandis* Cushman and Kleinpell				F	F																																
Virgulina californiensis var. *purisima* Bramlette, n. var						A		C	F				C		C																						
Virgulina aff. *V. subplana* Barbat and Johnson																		F				F	F			R											
Virgulina (*Virgulinella*) *pertusa* Reuss (pl. 22, fig. 6)	F	R	R	R														R	F	R		R	R	R			R	F	F	F	F		R	F	F	F	R

Diatoms are abundant in much of the basin facies of the Sisquoc formation. A flora of 228 species and varieties has been identified by K. E. Lohman in samples from the Orcutt-Lompoc highway. The dominant and characteristic species are as follows: *Melosira clavigera, M. recedens, Stephanopyxis turris* var. *cylindrus, Endictya robusta, E. tubiformis, Coscinodiscus aeginensis, C. asteromphalus, C.* aff. *C. excentricus, C. intersectus, C. obscurus, C. stellaris, C. vetustissimus, Actinocyclus octonarius, Actinoptychus marmoreus, A. perisetosus, Lithodesmium cornigerum, Xanthiopysis ovalis, Thalassionema nitzschioides*, and several undescribed forms. *Lithodesmium cornigerum* [24] is the most distinctive species. This three-pronged diatom is much like a three-bladed airplane propeller in outline and is not likely to be confused with any other species. It is common in the lower three-quarters of the sampled basin facies of the Sisquoc, occurs in silty diatomaceous strata in the syncline near Sisquoc River, is recorded from the Sisquoc of Graciosa Ridge [25] and the NTU mine, but was not found in the underlying Monterey shale, or in the overlying Foxen mudstone.

[24] Arnold, Ralph, and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull. 322), pl. 20, fig. 1, 1907.

Molds of Foraminifera are common in the Todos Santos claystone member. Preserved tests found at localities 22 to 30 represent the *Bolivina obliqua* zone, like those from the overlying diatomaceous strata in the Casmalia Hills and from the lower and middle parts of the formation in the Purisima Hills. At locality 21, however, strata mapped as the Todos Santos claystone contain the fauna characteristic of the uppermost Monterey in the eastern Purisima Hills. The fauna from locality 21 includes *Cassidulinoides californiensis* (pl. 22, fig. 7), "*Ellipsoglandulina*" *fragilis* (pl. 22, fig. 10), and *Pulvinulinella purisima* (pl. 23, figs. 10–12). These and other species from the Todos Santos claystone member are listed in the accompanying table. One mollusk, *Yoldia gala*, was found at locality 31 in the transition zone between the Todos Santos and diatomaceous strata.

[25] Hanna, G. D., Observations on *Lithodesmium cornigerum* Brun: Jour. Paleontology, vol. 4, p. 190, 1930.

Foraminifera from Todos Santos claystone member of Sisquoc formation

[Identifications by M. N. Bramlette. R, rare; F, few; C, common; A, abundant]

Species	Localities									
	21	22	23	24	25	26	27	28	29	30
Bolivina obliqua Barbat and Johnson		R	F	C		C	R	C	R	
Bolivina rankini Kleinpell						R				
Bolivina aff. *B. seminuda* var. *foraminata* Stewart	F									
Bolivina ticensis Kleinpell		R								
Buliminella curta Cushman					R					
Buliminella dubia Barbat and Johnson		F			R					
Buliminella elegantissima (d'Orbigny)		R								
Buliminella subfusiformis Cushman	C		A							
Cassidulinoides californiensis Bramlette, n. sp. (pl. 22, fig. 7)	F									
'*Ellipsoglandulina*' *fragilis* Bramlette, n. sp. (pl. 22, fig. 10)	A									
Globigerina bulloides d'Orbigny	R	R						R		
Nonion belridgensis Barbat and Johnson			R							
Nonionella miocenica Cushman var. (small)		C	F	F	C	C	C	C	C	C
Pulvinulinella purisima Bramlette, n. sp. (pl. 23, figs. 10–12)	C									
Pulvinulinella sp						R				
Suggrunda kleinpelli Bramlette, n. sp		F			F					
Virgulina californiensis Cushman		C	C	F	C	F	C	C	F	C
Virgulina subplana Barbat and Johnson			F						R	R
Virgulina (*Virgulinella*) *pertusa* Reuss	F		R						R	R

PLIOCENE SERIES]

FOXEN MUDSTONE

The name "Foxen formation" was proposed in an unpublished report on the geology of the Santa Maria district prepared for the Marland Oil Company by C. F. Tolman and B. F. Hake. The only published indication of what the proposers meant by the name is a brief stratigraphic table [26] that includes three undefined new formation names, including the name "Foxen formation." According to that table, Tolman and Hake used the name for 750 feet of fine-grained sandstone and diatomite, overlying massive diatomite assigned to the undefined Harris formation (Sisquoc formation of current usage) and underlying massive yellow sandstone of the lower Fernando formation (Careaga sandstone of current usage). The name "Foxen formation" has crept into widespread use. The usage, however, was variable until it was stand-

[26] Tolman, C. F., Biogenesis of hydrocarbons by diatoms: Econ. Geology, vol. 22, p. 459, 1927.

ardized in 1938 at a conference of geologists interested in the Santa Maria district. The standardized usage is followed in the present report, but the lithologically more distinctive designation "Foxen mudstone" is adopted. By mutual agreement of geologists familiar with the Santa Maria district, the type region of the Foxen mudstone is on the north slope of the western Purisima Hills, where it has a thickness of 800 feet. There it consists chiefly of mudstone and siltstone, conformably overlies the Sisquoc formation, and is overlain conformably by the Careaga sandstone. The lower part of the Foxen mudstone includes locally thin beds of diatomaceous shale. As thus defined, the formation is not represented along Foxen Canyon, which furnished the name and was presumably intended by the proposers as the type region. Diatomaceous strata along and near Foxen Canyon are now referred to the Monterey shale and the upper part of the Sisquoc formation. It is unfortunate that the Foxen mudstone is not represented in the presumed original type region. Nevertheless that objection is not sufficient for violation of current usage by urging suppression of the name, or by transferring it to the formation that now bears the name Sisquoc.

As shown in the structure sections on plate 2 and in the stratigraphic sections on plate 5, the Foxen mudstone is generally thick in synclines in the Santa Maria basin and is thin or absent on anticlines in the basin, and is absent at the eastern margin of the basin.

In some of the areas where it is absent as a lithologic unit, a thin section of fine-grained sandstone, mapped with the overlying Cebada fine-grained member of the Careaga sandstone appears to be a greatly condensed equivalent of the Foxen. These relations indicate that as a result of mild deformation during Pliocene time the present synclines were basins and the present anticlines were ridges on the floor of the Foxen sea. They indicate further that the finest sediments were winnowed out and swept into the basins, leaving condensed sandy deposits. on the ridges The relations therefore between submarine topography and the character and thickness of sediments are inferred to have been the same as at the present time off the coast of southern California [27] and at greater depths on the North Atlantic ridge and in the adjoining basins.[28]

STRATIGRAPHY AND LITHOLOGY

The Foxen mudstone consists principally of gray or buff mudstone and clayey siltstone, but includes fine-grained silty sandstone, and in some areas the basal part includes thin layers of diatomaceous shale. Limestone concretions are widespread. Phosphatic pellets are generally abundant in the lower part of the formation, particularly where it is thin. The formation forms thick, dark, clayey soil scarred by minor landslides and is covered in most areas with a rank growth of mustard.

In most sections where the Foxen is thick, typical diatomaceous strata of the Sisquoc formation are separated from typical Foxen strata by a transition zone as much as 100 feet thick. Various parts of the transition zone were mapped with either formation, depending on the type or lack of outcrops. Strata forming light-colored bare outcrops were mapped with the Sisquoc formation.

The lower part of the Foxen includes mudstone and siltstone characterized by great numbers of *Uvigerina foxenensis*, constituting a readily recognized datum plane. Diatoms occur in mudstone and clayey siltstone, but are much less abundant than in the Sisquoc formation.

Purisima Hills.—On the north slope of the western Purisima Hills the Foxen mudstone, consisting of mudstone, clayey siltstone, and thin beds of silty sandstone, is 800 feet thick (pl. 5, column 1). West of the Harris-Lompoc Highway the formation is progressively more sandy. Southward, toward the crest of the Purisima Hills anticline in that area, it contains more phosphatic pellets, and the mapped base of the Cebada fine-grained member of the Careaga sandstone continues southward up the spurs much farther than would be expected from the dip. Therefore it appears probable, but is difficult to establish definitely, that updip the lower part of the Cebada fine-grained member of the Careaga includes strata of late Foxen age. On the crest of the Purisima anticline, 1¾ miles east of the Harris-Lompoc Highway and on most of the adjoining south flank, the Foxen is absent.

Eastward, on both flanks of the Purisima Hills, the Foxen mudstone thins and gradually disappears (pl. 5, columns 2, 3). On the north flank, where exposures are better, as the formation thins beds made up chiefly of phosphatic pellets are more numerous both in the basal part of the Cebada fine-grained member of the Careaga sandstone and at the top of the Sisquoc formation. The uppermost part of the Sisquoc and at least the lower part of the Foxen of more complete sections to the west appear to be represented by a greatly condensed deposit composed largely of these pellets. That the upper part of the Foxen of more complete sections is represented by fine-grained sandstone, mapped with the Cebada fine-grained member of the Careaga sandstone, is indicated by the presence of fine-grained volcanic ash in the lower part of the exceptionally thick Cebada section three-quarters of a mile east of Canada Laguna Seca (pl. 5, column 2). This volcanic ash appears to be the same as ash in the upper part of the Foxen west of Canada Laguna Seca.

[27] Trask, P. D., Sedimentation in the Channel Islands region, Calif.: Econ. Geology, vol. 26, pp. 29-33, 1931. Origin and environment of source sediments of petroleum, pp. 88-90, 119-124, 237-238, Houston, The Gulf Publishing Co., 1932. Revelle, Roger, and Shepard, F. P., Sediments off the California coast, Recent marine sediments, pp. 249-258, Am. Assoc. Petroleum Geologists, Tulsa, 1939.

[28] Bramlette, M. N., and Bradley, W. H., Geology and biology of North Atlantic deep-sea cores between Newfoundland and Ireland; Pt. 1, Lithology and geologic interpretations: U. S. Geol. Survey Prof. Paper 196, pp. 14-15, 1940.

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Casmalia Hills.—In the Casmalia Hills the lithology of the Foxen mudstone is essentially similar to that in the Purisima Hills. Conglomerate and calcareous strata, however, are common minor constituents. Three miles northwest of the Southern Pacific Railroad the Foxen is 800 feet thick; two miles northwest of the railroad the thickness appears to be 900 feet. In the region of maximum thickness *Uvigerina*-bearing strata at locality 140 are 475 feet above the mapped base of the formation. Eastward the formation thins and as it thins *Uvigerina*-bearing strata are close to the base. On spurs northwest of the railroad there is a suggestion that the uppermost part of the formation grades southward updip into fine-grained sandstone mapped with the overlying Cebada fine-grained member of the Careaga sandstone. In the eastern Casmalia Hills the Foxen disappears on the plunging crest and adjoining flanks of the Casmalia anticline, but reappears in the syncline to the south.

Virtually the entire Foxen mudstone, 575 feet thick, is well exposed in a ravine 0.6 mile west of the railroad (locality 145). At the base, conglomerate, 6 to 8 inches thick, made up of chert pebbles and phosphatic nodules, fills cracks or borings extending down into the underlying diatomaceous mudstone assigned to the Sisquoc formation. The conglomerate grades upward into a foot of sand containing phosphatic pellets, and the sand is overlain by several feet of siltstone, also containing phosphatic pellets, at the top of which are molds of *Uvigerina* representing the base of strata characterized by abundance of that genus. Foraminifera occur in much of the mudstone and siltstone making up the bulk of the formation. A 4-foot silty fine-grained soft sandstone, the lowest thick sandstone, is 250 feet above the base of the formation and a 6-inch calcareous sand is 50 feet higher. As in other sections, sandstone is increasingly more abundant upward in the upper half of the formation.

Along the railroad the Foxen is 450 feet thick. The lower third of the formation is not exposed, but *Uvigerina* molds were found in siltstone about 50 feet above the base on the hillside west of the railroad. The lithology of the upper two-thirds, exposed in the railroad cut, is shown in the following section. The strata in the railroad cut have a prevailing buff or brownish color. Foraminifera are rare as compared with nearby localities.

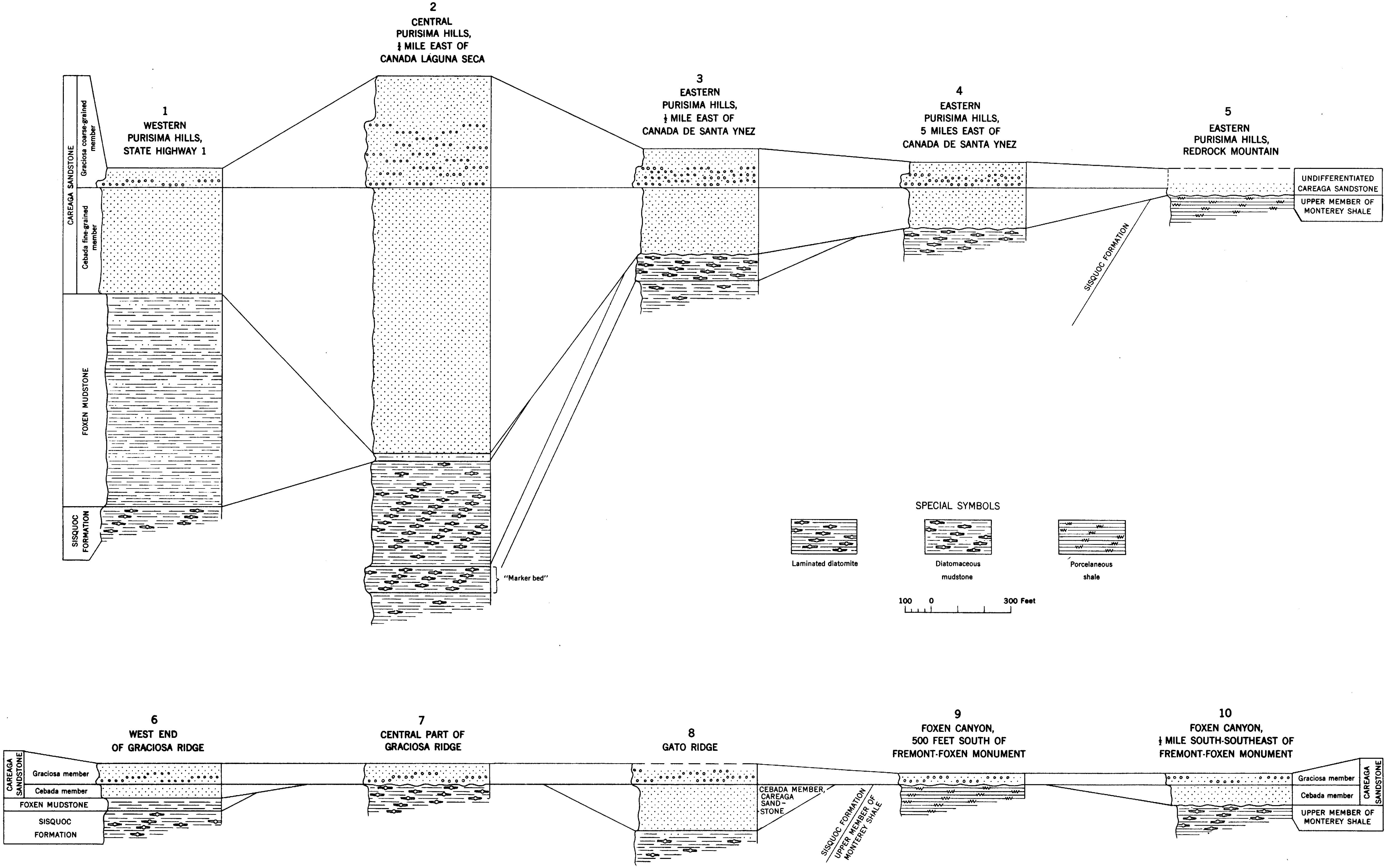
Section of upper two-thirds of Foxen mudstone in cut on Southern Pacific Railroad three-quarters of a mile northeast of Shuman

	Ft.	In.
Silty fine-grained soft sandstone. (Overlain by massive fine-grained soft sandstone assigned to Cebada fine-grained member of Careaga sandstone. For upward continuation of section see p. 44)		6
Siltstone	13	10
Silty fine-grained soft sandstone		1–2
Siltstone; *Crepidula princeps* and *Bittium casmaliense* in lower third	21	
Silty fine-grained soft sandstone		9

Section of upper two-thirds of Foxen mudstone in cut on Southern Pacific Railroad three-quarters of a mile northeast of Shuman—Con.

	Ft.	In.
Mudstone and thin layers of fine-grained softs andstone	6	3
Silty fine-grained soft sandstone		10
Mudstone	4	4
Silty fine-grained soft sandstone		2
Mudstone	5	10
Fine-grained soft sandstone	6	6
Mudstone	12	
Silty fine-grained soft sandstone		1
Silty mudstone	5	6
Mudstone containing *Crepidula princeps*, basal 10 inches sandy	6	6
Mudstone and siltstone in poorly graded units	12	
Concretionary limestone	1	3
Poorly sorted fine-grained and medium-grained soft sandstone	5	
Concretionary limestone	1	
Mudstone and siltstone	2	9
Fine-grained soft sandstone, silty toward top		4
Mudstone, thin seams of gypsum	14	6
Concretionary limestone	1	
Mudstone	7	9
Very coarse-grained calcareous sand containing scattered phosphatic pellets		1–6
Mudstone and thin beds of siltstone. Includes a zone of scattered limestone concretions and fossiliferous zones containing *Crepidula princeps* and an occasional large *Tellina* cf. *T. lutea*	42	
Fine-grained soft sandstone		9
Siltstone and mudstone; *Patinopecten dilleri* near top	3	4
Fine-grained calcareous sand grading upward into overlying mudstone	2	
Mudstone. *Patinopecten dilleri* near top (locality 147)	12	
Limestone concretion		0–8
Coarse-grained calcareous sand		6
Mudstone and siltstone; *Crepidula princeps* in uppermost 2½ feet	22	6
Limestone concretion		0–6
Mudstone and siltstone	27	
Limestone concretion	0–1	
Fine-grained gray sandstone	1	
Mudstone	11	
Limestone concretion	1	
Impure volcanic ash		6
Mudstone; *Patinopecten dilleri* in basal part	20	6
Fine-grained soft sandstone		2
Mudstone. Base not exposed	8+	
Thickness of section	285	

Conglomerate of varying extent and thickness is found at various horizons in the western Casmalia Hills. The pebbles and scattered boulders consist of chert and porcelaneous shale of the Monterey, and at most localities some of the debris is angular. Numerous phosphatic nodules, many of which contain diatoms and some of which enclose fish remains, are mixed with the pebbles. Conglomerate, or pebbly sandstone including phosphatic nodules or pellets, occurs locally at the base of the Foxen mudstone, as at locality 145 already described. At localities 1½ to 1¾ miles northwest of Shuman, exposures of lenticular con-



SECTIONS, SHOWING STRATIGRAPHIC RELATIONS OF FOXEN MUDSTONE AND CAREAGA SANDSTONE glomerate at the mapped base of the formation show pebbles a few inches long, and loose boulders of contorted chert a foot to 4 feet long are presumably derived from it. The conglomerate, however, is possibly in the Sisquoc formation instead of at the base of the Foxen. Exposures are poor through an estimated thickness of several hundred feet of strata overlying the conglomerate and the outcrops of leached mudstone suggest transitional lithology. Nevertheless, conglomerate is not known to occur in the Sisquoc formation so far southeastward, and conglomerate in the Sisquoc of the Casmalia Hills is not known to contain such a large proportion of rounded pebbles and phosphatic nodules. If the base of the Foxen is correctly identified and if there are no structural complications, the burnt shale southeast of the NTU mine includes Foxen strata. Tar sand and conglomerate, mapped as the base of the Foxen, are exposed in a pit in the second ravine southeast of the NTU mine adjoining the burnt shale.

The most conspicuous conglomerate is in the upper part of the Foxen mudstone on the high ridge 1.4 miles northwest of Shuman. Boulders of contorted chert a foot to 3 feet long are mixed with pebbles and phosphatic nodules in a matrix of sandstone containing shell fragments and molds of *Anadara* and *Lucinoma*. Huge chert boulders as much as 6 feet long strewn along the strike are evidently residual products of the conglomerate.

The calcareous strata also are of varying extent and thickness, and are at various horizons. The thickest beds are shown on the geologic map (pl. 1). In composition they range from coarse-grained sand containing little calcareous material to calcareous sand, or more generally hard limestone, made up chiefly of calcareous material. Echinoid spines, Foraminifera, barnacle and mollusk fragments are the principal identifiable constituents among the calcareous particles. The thickest and most extensive limestone is in the area southeast of Waldorf at a horizon about 100 feet below the top of the formation. Incomplete exposures indicate that it has a thickness of between 50 and 100 feet. Locally it includes layers of pebbles from the Monterey and phosphatic nodules. At locality 149 east of the railroad and nearby to the northwest the base of the Foxen mudstone is marked by coarse-grained sandy and pebbly fossiliferous limestone 15 to 40 feet thick. Higher in the section at locality 149 are exposures of conglomerate, 60 feet thick, made up of closely packed Monterey pebbles and including 1-foot to 2-foot beds of sandy siltstone.

Graciosa Ridge.—*Uvigerina* molds in mudstone representing float and debris from rodent burrows at locality 150*a* and nearby indicate that a thin section of Foxen strata, forming soil-covered slopes, is present at the plunging west end of the Graciosa anticline (pl. 5, column 6). Updip in that area and elsewhere on the lower flanks of the anticline the Foxen is absent as a lithologic unit (pl. 5, column 7), though at some localities on the flanks strata that may represent a condensed Foxen section were mapped as the basal part of the Cebada fine-grained member of the Careaga sandstone. A foot of conglomerate and about 10 feet of siltstone overlying the conglomerate, exposed in the main canyon a quarter of a mile southeast of locality 150*a*, are, for example, probably of Foxen age. The conglomerate includes phosphatic nodules and the siltstone contains sponge spicules and diatoms. At other localities a few feet of silty sandstone characterized by numerous sponge spicules may be the equivalent of the Foxen mudstone.

Inclusions of *Uvigerina*-bearing mudstone in asphalt that intrudes the Cebada fine-grained member of the Careaga sandstone at locality 177 and farther north on the east side of the fault marking the west border of the graben in the Newlove lease indicate that the Foxen mudstone is represented in the subsurface section on the south flank of the eastern Graciosa anticline. (See p. 45.) At locality 74 nearby to the east, however, where the Sisquoc formation crops out, the Foxen was not recognized.

FOSSILS

Foraminifera are abundant in the Foxen mudstone, but in general include few species at any locality, as is shown by the following table. The similarity of the faunas from the uppermost part of the Sisquoc and the basal part of the Foxen has already been mentioned. A variety of *Bolivina obliqua* (pl. 23, figs. 18, 23) and *Virgulina californiensis* var. *purisima* (pl. 23, figs. 20, 25) occur in both. A few specimens identified as the typical form of *Bolivina obliqua* (pl. 23, figs. 17, 21) are in a sample from the basal Foxen at locality 156*b*. The variety of *B. obliqua* just mentioned, however, is much more abundant at that locality. The basal part of the formation also contains *Bolivina foxenensis* (pl. 23, figs. 19, 24). Somewhat higher strata in the lower Foxen are characterized by a great abundance of *Uvigerina foxenensis* (pl. 23, fig. 16) and the progressively more common occurrence of forms of *Bulimina*. Increasingly sandy strata in the upper part of the Foxen contain genera of shallow-water facies, namely, *Cibicides*, *Elphidium*, and *Nonion*.

Foraminifera from Foxen mudstone

[Identifications by M. N. Bramlette. R, Rare; F, few; C, common; A, abundant]

Species	Localities																		
	137	140	145	145*a*	145*b*	145*c*	151	152	153	154	155	156	156*a*	156*b*	157	158	159	160	161
Angulogerina cf. *A. baggi* (Galloway and Wissler)					F	F													
Angulogerina sp				R															
Bolivina foxenensis Bramlette, n. sp. (pl. 23, figs. 19, 24)												A	A	A					
Bolivina obliqua Barbat and Johnson (pl. 23, figs. 17, 21)														F					
Bolivina obliqua Barbat and Johnson var	C										R	A	C	C					
Bolivina aff. *B. rankini* Kleinpell													C	C					
Bolivina sp	R																		
Bulimina pagoda var. *deformata* Cushman and Parker				R	R														
Bulimina marginata d'Orbigny		F	F	R			F												
Buliminella curta Cushman												R							
Buliminella elegantissima (d'Orbigny)	R																		
Buliminella cf. *B. subfusiformis* Cushman	R																		
Cassidulina limbata Cushman and Hughes					C	C													
Cassidulina sp					F														
Cibicides aff. *C. cushmani* Nuttall						F													
Cibicides lobatulus (Walker and Jacob)					F	F													
Cibicides cf. *C. refulgens* Montfort						F													
Cibicides sp				R		C													
Discorbis aff. *D. rosaceous* (d'Orbigny)					F	F													
Elphidium crispum (Linné)					F	C													
Elphidium hughesi Cushman and Grant					C	C													
Entosolenia catenulata Williamson					F														
Eponides cf. *E. peruvianus* (d'Orbigny)				F	C	F													
Globigerina bulloides d'Orbigny	R			F	C	C							R	R					
Globorotalia sp						R													
Lagena pliocenica Cushman and Gray					F														
Lagena sulcata (Walker and Jacob)					R														
Nonion cf. *N. scaphum* (Fichtel and Moll)		R		C															
Nonionella aff. *N. cushmani* Stewart	F																		
Nonionella miocenica Cushman				C		F													
Nonionella miocenica var. *stella* Cushman and Moyer					R	R													
Orbulina universa d'Orbigny				R	R														
Planulina cf. *P. ariminensis* d'Orbigny						F													
Rotalia sp						C													
Uvigerina foxenensis Bramlette, n. sp. (pl. 23, fig. 16)		C	A				A	A	A	A	A	R	F						
Uvigerina foxenensis Bramlette, n. sp. (molds)															A	A	A	A	A
Virgulina californiensis var. *purisima* Bramlette, n. var. (pl. 23, figs. 20, 25)	C										R	C	F	F					
Virgulina sp. (minute)				C															

Mollusks and other megafossils, listed in the accompanying table, are locally abundant in the Foxen mudstone of the Casmalia Hills, but are very rare in the Purisima Hills. Arnold's 1906 collection from the dump of the Waldorf asphalt mine, which contains 60 named forms and unidentified decapod crustacean remains, and a later collection from the same locality (locality 139) are included in the list of Foxen fossils. According to an oral communication from Dr. Arnold, his fossils were collected from the mine dump. The entrance to the mine, plotted on the geologic map (sheet 1 of pl. 1), is now caved and almost unrecognizable, but is located in the upper part of the Cebada fine-grained member of the Careaga sandstone, overlying the Foxen mudstone. The dump, overgrown with vegetation and doubtless modified by erosion, is about 200 feet down the canyon, and is still recognizable as an unnatural feature. The drift is said to have extended a distance of 1,500 feet.[29] Though its azimuth is not recorded, it presumably penetrated the Foxen, as the matrix of the fossils is mudstone or silty mudstone like that of the Foxen and contains Foraminifera characteristics of horizons above the lower part of the formation. There is no reasonable doubt that the dump fossils are Foxen fossils, presumably from the upper part of the formation. The dump is an important locality, not only because of the large number of well-preserved fossils, the exceptional preservation of which is due principally to impregnation with asphalt, but also because it is the type locality of five forms: *Nassa waldorfensis*, *Ocinebra micheli* var. *waldorfensis*, *Drillia waldorfensis*, *Leda orcutti*, and *Venericardia californica*. More than three-quarters of the known Foxen fauna is recorded only from this locality.

Most of the fossil localities are in the upper half of the formation, but localities 142 and 149 are in the basal part. *Bittium casmaliense* (pl. 11, figs. 7, 8), *Crepidula princeps* (pl. 10, fig. 4; pl. 11, fig. 5), "*Nassa*" *waldorfensis* (pl. 10, fig. 9), *Mitrella gausapata*, and *Patinopecten dilleri* (pl. 11, figs. 1, 9) are the most common species in the upper part of the formation, and *Patinopecten dilleri* is the most distinctive of these species. It was found at one locality in the overlying Cebada fine-grained member of the Careaga sandstone, and a well-defined variety occurs at one locality in diatomaceous strata of the upper part of the Sisquoc formation. The thick-margined sand dollar *Merriamaster* cf. *M. perrini* (pl. 10, figs. 11–14) occurs in the Foxen mudstone at two localities, at both in an unusual lithologic facies of coarse-grained calcareous sediments made up principally of echinoid spines, Foraminifera, mollusks, and barnacle fragments. The genus *Merria-*

[29] Gore, F. D., Oil shale in Santa Barbara County, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 8, p. 465, 1924.

Fossils from Foxen mudstone

[Identifications by W. P. Woodring. P, Observed in field but not collected. For explanation of other symbols, see p. 67.]

Species	Localities																Total locali-ties (15)[2]
	Casmalia Hills															Puri-sima Hills	
	134	135	136	138	139	4473[1]	141	142	143	144	146	147	148	149	150	162	
Coral: *Dendrophyllia* sp						X											1
Echinoid: *Merriamaster* cf. *M. perrini* (Weaver) (pl. 10, figs. 11–14)		P					X										2
Gastropods:																	
Puncturella cucullata (Gould) (pl. 10, figs. 5, 6)						X											1
Puncturella cooperi aphales Woodring, n. var					X												1
Turcica imperialis brevis Stewart?						X											1
Bittium casmaliense Bartsch (pl. 11, figs, 7, 8)					X	X				X	X		X			cf.	[2] 5
Bittium casmaliense arnoldi Bartsch						X											1
Aletes squamigerus Carpenter?, smooth var.?						X											1
Turritella cooperi Carpenter					X	X											[2] 1
Crepidula princeps Conrad (pl. 10, fig. 4; pl. 11, fig. 5)					X	X				X	X		X		X		[2] 5
Trochita radians (Lamarck), small var					sp.	X											[2] 1
Cryptonatica aleutica Dall, small var. (pl. 10, fig. 1)					X	X											[2] 1
Neverita reclusiana (Deshayes)						X											1
Lunatia cf. *L. lewisii* (Gould)						X											1
"*Gyrineum*" *mediocre lewisii* Carson						X											1
"*Gyrineum*" cf. "*G.*" *elsmerense* English						X											1
Fusitriton cf. *F. oregonensis* (Redfield)						X											1
Opalia varicostata Stearns (pl. 10, fig. 2)					X												1
Odostomia cf. *O. pratoma* Dall and Bartsch					X	X											[2] 1
Barbarofusus cf. *B. arnoldi* (Cossmann)						X											1
"*Nassa*" *waldorfensis* Arnold (pl. 10, fig. 9)					X	X				X	X		X				[2] 4
Neptunea cf. *N. stantoni* (Arnold)						X											1
Neptunea? sp						X											1
Calicantharus? sp						X											1
Jaton cf. *J. carpenteri* (Dall)?						X											1
Nucella lamellosa shumanensis (Carson)?														X			1
Nucella lamellosa collomi (Carson)						X											1
"*Cancellaria*" *arnoldi* Dall (pl. 10, fig. 10)						X											1
Mitrella gausapata (Gould)						X				X	X		X				4
Amphissa sp						X											1
Psephaea oregonensis (Dall)						X											1
Olivella cf. *O. baetica* Carpenter					sp.	X											[2] 1
Megasurcula carpenteriana tyroniana (Gabb), strongly shouldered form (pl. 11, fig. 6)						X											1
Elaeocyma cf. *E. empyrosia* (Dall)						X											1
Propebela sp						X											1
Scaphopod: *Cadulus fusiformis* Pilsbry and Sharp					cf.	X											[2] 1
Pelecypods:																	
Saccella cellulita (Dall)						X											1
Saccella orcutti (Arnold) (pl. 10, fig. 3)					X	X											[2] 1
Pododesmus macroschisma (Deshayes)?									X								1
Arca sisquocensis Reinhart						X											1
Anadara trilineata (Conrad) of Arnold (pl. 11, fig. 4)					sp.	X				sp.							[2] 2
Glycymeris sp						X											1
Mytilus cf. *M. coalingensis* Arnold									X								1
Volsella cf. *V. capax* (Conrad)						X											1
Pecten stearnsii Dall?						X											1
Chlamys hastatus (Sowerby)						X							cf				2
Chlamys parmeleei etchegoini (Anderson)						X			X								2
Patinopecten healeyi (Arnold)			?						?					X			3
Patinopecten dilleri (Dall) (pl. 11, figs. 1, 9)	?										X	X			X		4
Ostrea cf. *O. vespertina* Conrad					sp.	X							X	X			[2] 3
Cyclocardia californica (Dall) (pl. 10, figs. 7, 8; pl. 11, figs. 2, 3)					X	X											[2] 1
Miodontiscus cf. *M. prolongatus* (Carpenter)					X												1
Thyasira cf. *T. gouldii* (Philippi)						X											1
Axinopsis viridis Dall					X												1
Lucinisca nuttallii antecedens (Arnold)						X											1
Lucinoma cf. *L. annulata* (Reeve)				X		X											2
Parvilucina cf. *P. tenuisculpta* (Carpenter)						X											1
Kellia laperousii (Deshayes)						X											1
Tellina cf. *T. lutea* Wood						X		X									2
Macoma cf. *M. brota* Dall						X											1
Macoma sp						X											1
Semele cf. *S. rubropicta* Dall						X											1
Semele? sp						X											1
Schizothaerus cf. *S. nuttallii* (Conrad)														X			1
Protothaca cf. *P. tenerrima* (Carpenter)?								X									1
Transennella cf. *T. tantilla* (Gould)					?sp.	X											[2] 1
Mya sp						X											1
Sphenia cf. *S. globula* Dall						X											1
Panope cf *P. generosa* Gould						X								?			2
Pholadidea penita (Conrad)					X	X											[2] 1
Pandora cf. *P. filosa* (Carpenter)						X											1
Barnacles:																	
Balanus cf. *B. aquila* Pilsbry					X												1
Balanus hesperius proinus Woodring, n. var						X							X				2
Total forms 73	1	1	1	1	20	60	1	2	4	5	5	1	7	5	2	1	

[1] U. S. Geol. survey locality 4473, [dump of] Waldorf asphalt mine, 3 miles east-southeast of Guadalupe, Ralph Arnold collector, 1906.
[2] The total number of localities is one less than the total number of occurrences, localities 139 and 4473 being the same.

master was not found at other horizons in the Santa Maria district. Eight forms of mollusks, including "*Gyrineum*" cf. "*G*". *elsmerense*, *Neptunea* cf. *N. stantoni*, and *Chlamys parmeleei etchegoini* also were not found at other horizons. All except the *Chlamys*, however, were collected only at the unusual locality at the Waldorf mine.

According to a preliminary examination by K. E. Lohman, the Foxen mudstone along the Orcutt-Lompoc highway in the Purisima Hills has a diatom flora of 242 species and varieties. Abundant and characteristic species are as follows: *Melosira sulcata*, *Podosira montagnei*, *Stephanopyxis turris* and variety *cylindrus*, *Endictya robusta*, *Coscinodiscus asteromphalus*, *C. cirrus*, *C. excentricus*, *Xanthiopyxis ovalis*, *Thalassiothrix longissima*, and *Navicula pennata*.

CAREAGA SANDSTONE, INCLUDING CEBADA FINE-GRAINED MEMBER AND GRACIOSA COARSE-GRAINED MEMBER

The sandstone overlying the Foxen mudstone was designated the Careaga formation in 1938 at a conference of geologists interested in the Santa Maria district. The designation "Careaga sandstone" is adopted in the present report. "Careaga sand" would be a better name for many areas, for the lower member consists almost invariably of uncemented sand, and there is every gradation between loose sand and hard cemented sandstone in the upper member.

The type region is on the north slope of the Purisima Hills south of Careaga station of the Pacific Coast Railway, now abandoned. In the type region the formation has a thickness of 725 feet, overlies conformably the Foxen mudstone, and is overlain conformably by the Paso Robles formation. The Careaga sandstone is divided into two mapped members: a lower fine-grained sandstone designated the Cebada fine-grained member, and an upper coarse-grained sandstone and conglomerate—the Graciosa coarse-grained member.[29a] The Cebada member is named for Cebada Canyon in the Purisima Hills, the Graciosa member for Graciosa Ridge. The type region of both members is the same as the type region of the formation.

The thickness of the Careaga sandstone ranges from 50 to 1,425 feet. The greatest variation is in the Cebada fine-grained member, which is absent at some localities and has a maximum thickness of 1,000 feet. The thickness of the Graciosa coarse-grained member is 25 to 425 feet. The marked range in thickness is closely correlated with structural features, as shown in the stratigraphic sections on plate 5 and in the structure sections on plate 2. The thickest sections are in synclines and on the flanks of anticlines in the basin, the most abbreviated sections are on the crest of anticlines in the basin and at localities near the eastern margin of the basin. The relations between thickness and structural features, like the similar relations shown by the Foxen mudstone, indicate that the present synclines and anticlines were basins and ridges, respectively, during Careaga time.

[29a] Woodring, W. P., Bramlette, M. N., and Lohman, K. E., op. cit. (Am. Assoc. Petroleum Geologists Bull., vol. 27, No. 10), p. 1, 356, 1943.

The Careaga sandstone has varying stratigraphic relations to underlying formations, and these relations, like the varying thickness, show a close correlation with structural features. In complete sections, as in the western Purisima Hills (pl. 5, column 1), the Foxen mudstone grades upward into the Careaga sandstone. In the area extending from Gato Ridge (pl. 5, column 8) to Foxen Canyon the Sisquoc formation grades upward into the Careaga, the transition zone or the basal part of the Careaga including beds evidently equivalent to the Foxen. Eastward, in the eastern Purisima Hills, where the Foxen is thin or absent, the Careaga overlies transitional silty Sisquoc strata, and farther east overlaps discordantly the upper part of the Sisquoc (pl. 5, columns 3, 4). In the interior of the southeastern Purisima Hills the Careaga overlies unconformably the lower part of the Sisquoc or the upper member of the Monterey (pl. 5, column 5). On Graciosa Ridge the Graciosa coarse-grained member of the Careaga overlaps the Cebada find-grained member and rests with at least local discordance on the Sisquoc formation (pl. 5, column 7). Along Foxen Canyon near the eastern margin of the basin either the Cebada or Graciosa member rests with marked discordance on the Monterey shale (pl. 5, columns 9, 10).

STRATIGRAPHY AND LITHOLOGY

The Cebada fine-grained member of the Careaga sandstone consists chiefly or entirely of fine-grained, or very fine-grained, generally massive sand. The lower part is typically very fine-grained and light gray, almost white, but most of the sand is light yellowish brown. Medium-grained sand, including stringers of grit and small porcelaneous shale pebbles, forming a transition zone to the Graciosa member, is at some places mapped with the Cebada. Fossils are abundant locally, but are represented for the most part by molds except in tar sand and asphalt.

The Graciosa coarse-grained member is made up of two parts: a lower part consisting of coarse-grained gray and brownish sandstone and conglomerate (or sand and gravel), and including locally medium-grained sandstone; and an upper part consisting of coarse-grained gray sand or sandstone that at a few places has thin stringers of gravel or conglomerate. Cross bedding is common, especially in the upper part. Porcelaneous shale is virtually the only constituent among the pebbles and cobbles in most of the conglomerates in the lower part of the Graciosa member. In some conglomerates, however, generally in the upper third of the lower part, porcelaneous shale is a minor constituent, reddish and gray quartzite and rhyolite porphyry being the chief constituents. Where the Careaga is typically developed the upper part of the Graciosa member forms a conspicuous belt of deep sandy soil between conglomerate in the lower part of the member and clay at the base of the Paso Robles formation. The upper part of the Graciosa locally includes ledges of hard sandstone. Sandstone and conglomerate in the lower part of the Graciosa are fossiliferous. Sand dollars of the genus *Dendraster* are widespread and at many places abundant in the fossiliferous strata. Though sand dollars are not present everywhere, the *Dendraster*-bearing strata constitute a useful datum plane recognized at least locally throughout the district. These fossiliferous strata are typically "reefs" of hard calcareous sandstone in which most of the fossils other than *Dendraster* are molds. The coarse-grained sandstone, constituting the upper part of the Graciosa member is in general nonfossiliferous. In the Casmalia Hills it contains marine fossils, and locally in the Purisima Hills and in the Solomon Hills east of U. S. Highway 101 it contains fresh-water fossils or remains of land mammals. Except in the western part of the basin this sandstone is probably for the most part nonmarine and should perhaps be grouped with the Paso Robles formation.

The two members of the Careaga sandstone and the twofold division of the Graciosa coarse-grained member are quite uniform over the greater part of the Santa Maria district. In some areas, however, the members are not well defined and in those areas the Careaga is undifferentiated.

Every gradation from loose sand and gravel to hard sandstone and conglomerate is found in the formation, especially in the Graciosa member. The prevailing types are rocks that are indurated enough to form cliffs, even though they are virtually uncemented. The Cebada member is typically covered with grass or scattered brush. A dense growth of brush, mostly black sage, is characteristic of the Graciosa member, particularly the lower part.

Purisima Hills.—In the Purisima Hills the thickness of the Careaga sandstone ranges from 125 to 1,425 feet, the Cebada fine-grained member being 75 to 1,000 feet thick and the Graciosa coarse-grained member 65 to 425 feet.

On the north slope at the west end of the hills conglomerate is virtually absent and the formation is not differentiated into members. The sand dollars that are abundant in medium-grained sandstone at locality 246 on the San Antonio Valley road are in the stratigraphic position of strata characterized by abundance of *Dendraster* elsewhere. The following section is typical of the formation on the north slope of the hills in the area adjoining the Harris-Lompoc Highway:

Section of Careaga sandstone on first ridge east of Harris-Lompoc Highway on north slope of Purisima Hills (locality 225)

	Feet
Graciosa coarse-grained member:	
Coarse-grained gray sand	45
Coarse-grained conglomeratic sandstone. A few *Dendraster ashleyi* at base and hard fossiliferous "reef" (locality 225) at top	20
Cebada fine-grained member:	
Medium-grained sand	120
Fine-grained yellowish-brown and light-gray sand	275
Total thickness of Careaga sandstone	460

Eastward the formation thickens as shown by a section in the type region:

Section of Careaga sandstone in type region on ridge on north slope of Purisima Hills, 1.8 miles south-southwest of Careaga station (first ridge east of locality 230)

	Feet
Graciosa coarse-grained member:	
Coarse-grained gray sand	230
Medium-grained to coarse-grained sandstone, including conglomerate beds and hard fossiliferous "reefs" in lower part	50
Medium-grained sandstone, including a few conglomerate beds	100
Cebada fine-grained member:	
Fine-grained yellowish-brown sand	300
Fine-grained silty light-gray sand. A few phosphatic pellets in basal part	50
Thickness of Careaga sandstone	730

The thickest section in the Purisima Hills is in the area half a mile to 1½ miles east of Canada Laguna Seca where the strata are practically vertical (pl. 5, column 2). The exceptionally thick Cebada member in that area, shown in the following section, doubtless includes the equivalent of at least the upper part of the Foxen mudstone, which is very thin or virtually absent.

Section of Careaga sandstone in canyon on north slope of Purisima Hills three-quarters of a mile east of Canada Laguna Seca

	Feet
Graciosa coarse-grained member:	
Coarse-grained gray sand	185
Medium-grained to coarse-grained sandstone, including conglomerate beds	240
Cebada fine-grained member:	
Fine-grained yellowish-brown sand	940
Fine-grained silty gray hard sandstone. Many phosphatic pellets	60
Total thickness of Careaga sandstone	1, 425

Farther east overlap of the Careaga sandstone and discordance with the Sisquoc formation are shown by the relations of the Careaga to the "marker bed," 400 to 500 feet below the top of the Sisquoc, and to Sisquoc strata above and below the "marker bed" (pl. 5, columns 3, 4). Tar sand occurs locally at and near the base of the Careaga where it is discordant on the Sisquoc formation. Toward the southeast border of the mapped area the Careaga lies on strata far below the "marker bed" and the thickness of the formation is reduced to about 200 feet. At locality 247 in the interior of the Purisima Hills near Redrock Mountain, fossiliferous tar sand in undifferentiated Careaga, sandstone unconformably overlies strata near the base of the Sisquoc formation and a mile to the east the sandstone rests on the Monterey shale (pl. 5, column 5). This overlapping sandstone is fine-grained to medium-grained and has scattered pebbles, but no layers of conglomerate. Sand and gravel resting unconformably on Monterey shale near the southeast border of the mapped area were shown on the preliminary geologic map as Orcutt sand, but are now thought to represent the Careaga sandstone.

Along the north slope of the central Purisima Hills yellowish-green sand, 10 to 15 feet thick, is characteristic of the basal part of the upper division of the Graciosa member. Fresh-water diatoms occur in silty strata 25 feet below the top of the Careaga sandstone three-quarters of a mile west of Canada Laguna Seca (locality 231). Fragmentary remains of marine and land mammals were found on the outcrop of the upper part of the Graciosa member in the same region, and remains of land mammals were later found in place 10 feet below the top of the Careaga sandstone at locality 231*a*. At localities between Canada de Santa Ynez and the next main canyon to the east, ostracodes and fresh-water gastropods occur in a 2-foot chert bed 100 to 150 feet below the top of the formation.

On the south slope of the western Purisima Hills the Careaga sandstone is 225 to 600 feet thick. The Graciosa member is impregnated with tar where it is in fault contact with the Sisquoc formation along and near the Harris-Lompoc Highway. About 1¼ miles east-southeast of the highway a thick zone of tar sands extends from the Cebada member into the Graciosa member.

On the north slope of the hills marine fossils, including sand dollars at one or more horizons, occur in the lower part of the Graciosa coarse-grained member in the type region and westward from the type region. Fossils were not found between the type region and locality 232 near the east border of the mapped area, where they again appear and are found southeastward for a distance of 1¼ miles. Likewise on the south slope of the hills fossils are common westward from Cebada Canyon, but were not found farther east. Between the branches of Cebada Canyon sand dollars disappear as the fossils become fewer, and the thick-shelled clam *Pachydesma crassatelloides* is the most abundant form.

Casmalia Hills.—In the Casmalia Hills the Careaga sandstone is 150 to 500 feet thick. Northwest of the Southern Pacific Railroad the Graciosa coarse-grained member, 75 to 250 feet thick, is in general well defined, but fossils are not abundant and sand dollars were found at only two localities (195, 196*b*). Marine fossils, mostly poorly preserved molds, occur in the upper part of the Graciosa immediately west of the railroad. Farther west fossiliferous limy sandstone is found in the Cebada fine-grained member apparently at different horizons. Pectens and oysters are abundant in the limy sandstone, which contains a few phosphatic nodules and scattered pebbles. Along the railroad the formation is 400 feet thick and the lower two-thirds is well exposed. As shown in the following section measured at that locality, the Graciosa member is not sharply defined:

Section of Careaga sandstone in cut on Southern Pacific Railroad three-quarters of a mile northeast of Shuman

	Feet
Graciosa coarse-grained member:	
Medium-grained gray sand; stringers of grit and porcelaneous shale pebbles. Top not exposed. (Exposed top about 100 feet below top of formation.)	85
Gray sandstone	3–4
Grayish-brown sandstone	10
Medium-grained grayish-brown fossiliferous sand; *Lucinoma* cf. *L. annulata* relatively abundant (locality 196c)	2–2½
Massive fine-grained to medium-grained grayish-brown sand	10
Medium-grained to coarse-grained grayish-brown fossiliferous sand; fossils include *Glycymeris* cf. *G. grewingki* and few specimens of *Dendraster ashleyi* (locality 196b)	3–4
Gray sandstone and sand containing scattered pebbles; lower third well bedded	30
Coarse-grained sand and gravel, locally cemented. A 6-inch lens at base on west side of cut (locality 196) and a 1-foot lens near base on east side of cut (locality 196*a*) contain fossils, mostly fragments	10
Cebada fine-grained member:	
Medium-grained massive yellowish-brown sand	13
Medium-grained to coarse-grained fossiliferous gray sand, locally cemented; *Anadara trilineata* and *Cyclocardia californica* abundant (locality 170)	7–10
Coarse-grained brown sand containing phosphatic pellets and small phosphatic nodules. Contact at base irregular	1
Massive fine-grained yellowish-brown sand, silty and clayey toward base	110
Total thickness of section	290

Southeast of the railroad the two members of the Careaga sandstone were not differentiated, conglomerate being a minor constituent in the upper part of the formation. Sand dollars occur in fossiliferous sandstone cropping out near the Orcutt-Harris highway. This fossiliferous sandstone is correlated with strata characterized by abundance of *Dendraster* elsewhere, and may be regarded as marking approximately the base of beds equivalent to the Graciosa member. Southward toward the plunging crest of the Casmalia anticline the formation thins to about 150 feet and sand dollars are found about 50 feet above the base, indicating a marked reduction in the thickness of beds equivalent to the Cebada member. Phosphatic nodules and at some places phosphatized bone fragments occur in conglomerate at the base of the Careaga, which in this area rests on the Sisquoc formation. The intervening Foxen mudstone reappears in the syncline south of the Casmalia anticline, and the Careaga thickens to several hundred feet. *Dendraster*-bearing strata, found at scattered localities, are well above the middle of the formation.

Graciosa Ridge and adjoining parts of Solomon Hills.—On the part of Graciosa Ridge corresponding to the structurally highest part of the Graciosa anticline, the Graciosa coarse-grained member of the Careaga lies on the Sisquoc formation (pl. 5, column 7). Meager evidence, not entirely satisfactory because at many places the dip of diatomaceous mudstone of the Sisquoc is uncertain, indicates at least local discordance. The Graciosa member is 50 to 100 feet thick. Coarse-grained sand containing scattered pebbles is at the base and is overlain by conglomerate, or conglomerate is at the base, as at the locality shown on figure 7*A*. Throughout almost the entire area where the Graciosa rests on the Sisquoc, the basal Graciosa through a thickness of a few feet to 85 feet is heavily impregnated with tar, forming a black or dark-brown tar sand. At numerous localities well-preserved fossil shells are abundant in the tar sand. The fossiliferous tar sand and its relations to the Sisquoc formation are well shown at locality 199 along the road leading to Union Oil Co. Folsom No. 3 well, where large clams of the genus *Platyodon*, oriented in life position, can be dug out of their burrows penetrating diatomaceous mudstone of the Sisquoc formation (fig. 6 *D*). At some places tar sand, pebbles, and angular pieces of diatomaceous mudstone fill cracks extending down from the base of the Graciosa. Practically vertical veins of asphaltic material, a foot or two wide, extend as much as 50 feet below the contact between the formations. The asphaltic material encloses pieces of diatomaceous mudstone and small pockets of sand and gravel, in some of which are fragments of fossils like those in the tar sand. These veins are inferred to represent fissures in the diatomaceous mudstone more or less filled with wall rock. Sand, pebbles, and shell fragments, transported on the sea floor, were trapped in the fissures, which served as paths for oil moving upward.

Down dip from the crest of the Graciosa anticline and along the crest at the plunging ends, sandstone of the Cebada fine-grained member appears as a wedge that thickens at varying rates. Some of the sandstone and conglomerate of the Graciosa coarse-grained member resting directly on the Sisquoc, of course, may be the equivalent of part of the Cebada member, but the discontinuity at the base of the Graciosa member represents probably at least the greater part of Cebada time. Though both members of the Careaga sandstone are present in the graben in the Newlove lease, it was not practicable to attempt to map them separately. Discontinuity is apparent at the base of the Cebada member at localities where it is thin. Figure 6 *C*, a view of a road-cut on the south slope of Graciosa Ridge 150 feet east of Union Oil Co. Squires No. 18 well, shows burrows extending from the base of the Cebada into diatomaceous mudstone of the Sisquoc formation. The Cebada at that locality is 35 feet thick. Poorly sorted coarse-grained sand and grit containing small phosphatic nodules make up the lower two feet and grade upward into moderately fine-grained, well-sorted, gray sand. Eastward toward the Mount Solomon anticline, the Cebada member thickens rapidly. At the north end of the anticline yellowish-brown sand and light-gray sand of the Cebada member are about 250 feet thick. The light-gray sand toward the base of the section is very fine-grained and interbedded with sandy siltstone, evidently part of a transition zone between the Cebada and the Sisquoc formation, or Foxen mudstone, but the base of the Cebada is not exposed.

Fossiliferous sandstone, including strata characterized by abundance of *Dendraster*, is generally present at the base of the Graciosa member of the Careaga on the slopes of Graciosa Ridge. Fossils were not found on the Mount Solomon anticline, with the exception of float containing a few *Dendraster*, nor in the outcrops a mile south of the Shell Oil Co. camp. In both those areas fossiliferous strata are a few feet below the top of the Cebada member.

Tar sand is present locally at the base of the Cebada member. Veins and irregular masses of asphaltic material are found in the Cebada, especially in the eastern part of Graciosa Ridge adjoining areas where similar material occurs in the Sisquoc formation. At locality 177 near the fault at the west border of the graben in the Newlove lease, an excavation shows an irregular mass of silty and sandy asphalt (fig. 6 *B*). The country rock represents undifferentiated Careaga sandstone of fine-grained facies. The asphalt contains inclusions of silty mudstone, in some of which are numerous specimens of the *Uvigerina* that is known to occur in such abundance only in the lower part of the Foxen mudstone. The asphalt evidently was emplaced like an igneous rock and plucked wall rock as it was intruded. The inclusions of Foxen material indicate that the Foxen mudstone is present in the subsurface section, though it was not recognized in the outcrop section a third of a mile east of this locality. *Uvigerina*-bearing mudstone was found as inclusions in asphalt also on the dump of a prospect pit immediately east of the fault on the west side of the graben just mentioned, half a mile north of locality 177. At other localities Foraminifera in mudstone inclusions in asphalt suggest the uppermost part of the Sisquoc formation.

Gato Ridge and adjoining parts of Solomon Hills.—In the Solomon Hills east of U. S. Highway 101, the Careaga sandstone has a thickness of approximately 300 to 700 feet. On the Gato Ridge anticline the Cebada fine-grained member is about 175 feet thick (pl. 5, column 8), whereas on the south flank of the

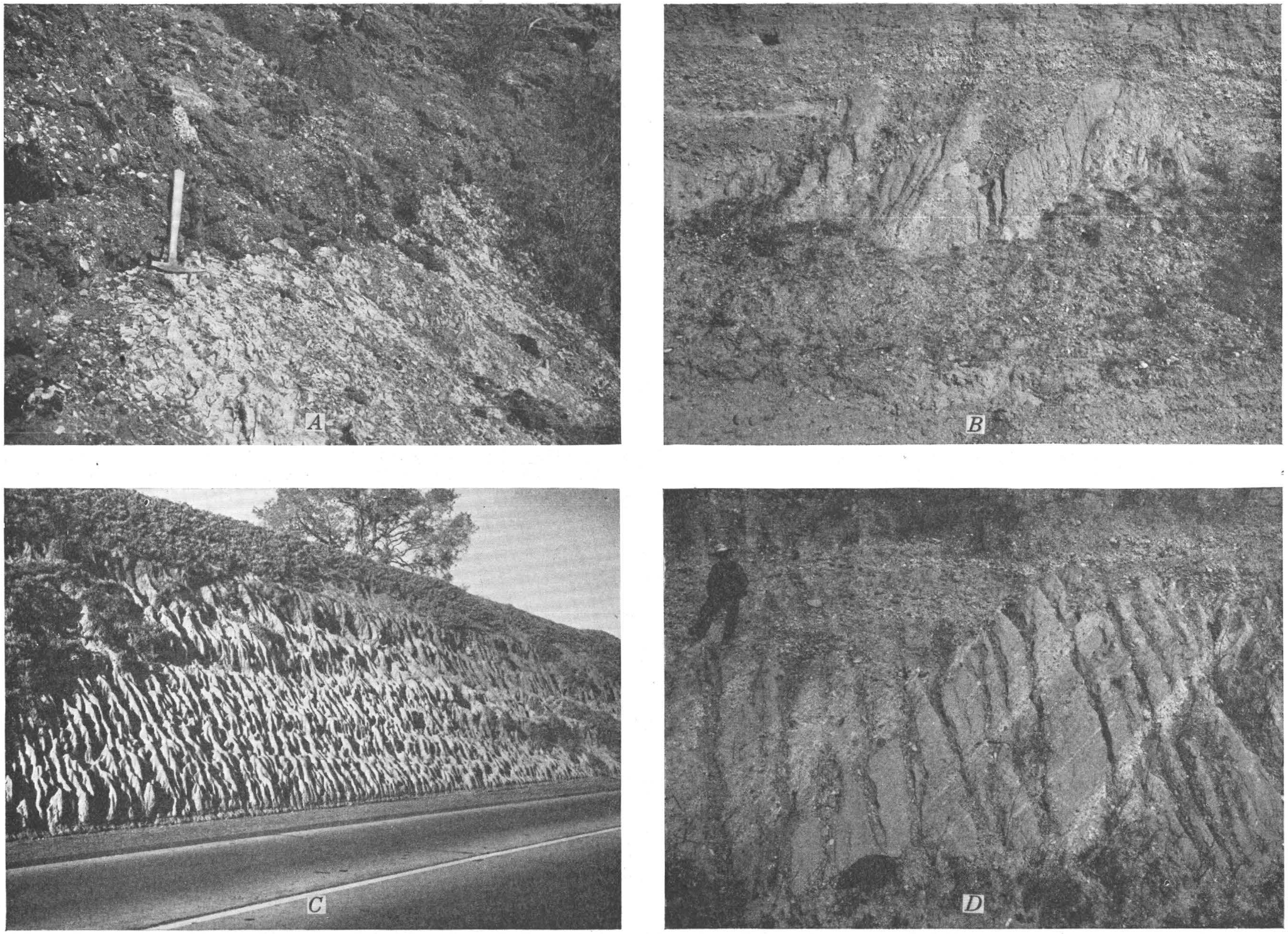


FIGURE 7.—Careaga sandstone, Paso Robles formation and Orcutt sand. *A*, Tar sand and gravel of Graciosa coarse-grained member of the Careaga sandstone and underlying diatomaceous mudstone of Sisquoc formation, Graciosa Ridge near Union Oil Co. Newlove No. 13 well, Orcutt field. *B*, Orcutt sand and Paso Robles formation, railroad cut near Shuman. Gravel and sand of Orcutt dip few degrees away from observer, Paso Robles formation dips 45° to left (full dip, 65°). *C*, Orcutt sand on U. S. Highway 101, 7½ miles southeast of Santa Maria. *D*, Orcutt sand and Paso Robles formation, railroad cut near Shuman. Closer view of unconformity shown in *B*.

anticline the thickness is as much as 500 feet. The entire formation thins eastward toward the east margin of the basin. Throughout the area from Gato Ridge to Foxen Canyon the Careaga sandstone overlies the Sisquoc formation. The transition zone between the formations, or the basal part of the Careaga, or both, evidently represents the Foxen mudstone. Phosphatic pellets occur in the transition zone on the south flank of the Gato Ridge anticline, but are rare or absent on the crest and north flank.

The base of the Graciosa coarse-grained member is marked by conglomerate or by medium-grained and coarse-grained pebbly sandstone. Fossiliferous strata are found at or near the base of the Graciosa at widely scattered localities, but sand dollars are not abundant. Identification of the Graciosa member on the north side of Cat Canyon is supported by the occurrence of sand dollars at localities 222 and 223. Molds of fresh-water gastropods occur in limestone in the upper part of the Graciosa at locality 211 on the south flank of the Las Flores anticline.

Fugler Point.—The Careaga sandstone crops out beneath terrace gravel in the bluff on the south side of Santa Maria River at Fugler Point, 1. 1 miles west-northwest of Garey. The strata dip toward the west-southwest at varying rates and directions, younger beds appearing northwestward along the bluff. Exposures are not continuous. The following section is based on the assumption that a 4-foot fossiliferous bed appearing at several places along the bluff is a reliable datum plane, and is the same as the bed along which an entry was driven to prospect for asphalt at the southeast end of the bluff. The asphalt occurs as irregular masses and contains well-preserved fossils.

Section of Careaga sandstone at Fugler Point

	Feet
Graciosa coarse-grained member: Conglomerate and coarse-grained sandstone. Few molds of fragments of fossils. Top not exposed	6+
Cebada fine-grained member:	
4. Moderately fine-grained and medium-grained, brownish and grayish sand and sandstone. A poorly preserved sand dollar (*Dendraster*), 8 feet above base. Irregular masses of asphalt	25
3. Fossiliferous, moderately fine-grained, yellowish-brown sand. Fossils concentrated in upper and lower foot, scattered through remainder. Irregular masses of asphalt. (Locality 178)	3½–4½
2. Closely packed brachiopods and other fossils in matrix of sand and asphalt. Appears to be a lens not represented at southeast end of bluff. (Locality 178*b*)	1–7
1. Moderately fine-grained, yellowish-brown sand. Scattered fossils and masses of asphalt. (Localities 178*a*, 178*c*.) Base not exposed	4+

The richly fossiliferous strata at Fugler Point are assigned to the Cebada member on lithologic grounds. The medium-grained sandstone in which a poorly preserved sand dollar was found represents lithology more or less transitional between that of the Cebada and Graciosa members.

Foxen Canyon-Sisquoc River area.—On the southwest side of Foxen Canyon near the Fremont-Foxen Monument the Cebada fine-grained member of the Careaga sandstone overlaps the Sisquoc formation and rests unconformably on the Monterey shale, the discordance being as great as 40° (pl. 5, column 10). In the same area the Graciosa coarse-grained member of the Careaga also overlaps the Cebada member, and overlies the Monterey with as great discordance (pl. 5, column 9). On the east side of the narrow valley a third of a mile southwest of the monument, the Cebada appears beneath the overlapping Graciosa and thickens rapidly southward to about 100 feet, most of the strata consisting of light-gray sand. The contact between the Cebada and the Monterey is exposed in a slit-like ravine at the edge of the terrace on the northeast side of Foxen Canyon 0. 2 mile west-northwest of the monument (locality 190). Fine-grained silty sandstone that contains sponge spicules, scattered pebbles of black chert, and angular pieces of cherty shale, rests on an irregular surface of steeply dipping diatomaceous shale of the Monterey. The thickness of the sandstone is variable, the maximum being 2½ feet. It is overlain by a lens, a few inches to 1½ feet thick, of medium-grained sandstone. Phosphatic material (paired molds of *Anadara*, nodules, and bone fragments) is abundant in the medium-grained sandstone; pebbles and angular pieces of cherty and porcelaneous shale are scattered through it. At the contact the Cebada dips almost as steeply as the Monterey but flattens within a few feet.

The Graciosa member appears to be not more than 25 or 35 feet thick on the west side of Foxen Canyon opposite locality 190. Loose blocks of fossiliferous coarse-grained pebbly sandstone along the Foxen Canyon road at locality 224 represent presumably the Graciosa, but the fossiliferous strata were not found in place. The faunal association is like that in the Graciosa on the north side of Cat Canyon.

Coarse-grained pebbly sandstone cropping out in the area between Foxen Canyon and Sisquoc River is assigned to the Graciosa member. At a few localities it contains imperfect molds of fossils, and in the canyon 0.8 mile southeast of the mouth of Foxen Canyon poorly preserved sand dollars were found in float sandstone of that character. The sandstone is better sorted than typical sandstone in the Tinaquaic member of the Sisquoc formation, on which it appears to rest, and the grains lack the light-gray coat characteristic of much of the sandstone in the Tinaquaic. Differentiation of the Graciosa and Tinaquaic, however, is not satisfactory.

FOSSILS

CEBADA FINE-GRAINED MEMBER

Megafossils from the Cebada fine-grained member of the Careaga sandstone are listed in the table opposite

Fossils from Cebada fine-grained member of Careaga sandstone

[Identifications by W. P. Woodring. P, Observed in field but not collected. For explanation of other symbols see p. 67]

Species	Localities																																					Total localities [1] (37)
	Casmalia Hills								Western Solomon Hills, including Graciosa Ridge							Fugler Point					Eastern Solomon Hills, including Gato Ridge												Foxen Canyon		Purisima Hills				
	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	178a	178b	178c	Other collections	179	180	180a	181	182	183	184	185	186	187	188	189	190	191	192	192a	193	194	
Coral: *Dendrophyllia* sp															X		?sp.	X																					3
Brachiopods:																																							
Glottidia cf. *G. albida* (Hinds)																											X												1
Discinisca cf. *D. cumingii* (Broderip)																		X																					1
Terebratalia occidentalis (Dall) (pl. 13, figs. 1–4, 8, 9, 25)															P		X	X																					3
Chiton: *Callistochiton* sp																	X																						1
Gastropods:																																							
Acmaea cf. *A. funiculata* (Carpenter)																				[2] X																			1
Megathura crenulata (Sowerby)?															X					[3] X																			2
Diodora aspera (Eschscholtz)																			X																				1
Puncturella cucullata (Gould)?															X			X																					2
Puncturella cooperi aphales Woodring, n. var. (pl. 12, figs. 2, 3)															X			X																					2
Tegula? sp																							X																1
Calliostoma coalingense catoteron Woodring, n. var. (pl. 13, figs. 5, 6, 10)															X																								1
Calliostoma virgineum (Dillwyn)															X																								1
Calliostoma cf. *C. virgineum* (Dillwyn)															X		sp.	X																					3
Calliostoma cf. *C. gemmulatum* Carpenter								X																						X									2
Calliostoma cf. *C. ligatum* (Gould)															X		sp.																						2
Calliostoma sp																		X																					1
Cidarina cidaris (A. Adams), n. var.? (pl. 12, fig. 11)																				[4] X																			1
Turcica imperialis brevis Stewart (pl. 12, figs. 9, 10, 12, 14)															?sp.			X																					2
Solariella n. sp.? (pl. 13, figs. 7, 11)															X																								1
Pupillaria cf. *P. optabilis* (Carpenter)								sp.							X																								2
Vitrinella stearnsi Bartsch, var. (pl. 12, figs. 6–8)															X					[2] X																			2
Pseudorotella cf. *P. supravallata* (Carpenter)								?																															1
Pachypoma cf. *P. gibberosum* (Dillwyn)																		X																					1
Homalopoma cf. *H. paucicostata* (Dall) (pl. 12, fig. 4)																		X																					1
Homalopoma cf. *H. carpenteri* (Pilsbry)															X																								1
Iselica fenestrata (Carpenter), var. (pl. 13, figs. 17, 18)																				[2] X																			1
Diala cf. *marmorea* Carpenter																		X																					1
Bittium casmaliense Bartsch							?sp.	X		X					X	X	X														X	X							8
Bittium casmaliense arnoldi Bartsch (pl. 13, fig. 16)															X																								1
Seila montereyensis Bartsch								X							X																								2
Aletes squamigerus Carpenter?, smooth var.?									X																														1
Micranellum crebricinctum (Carpenter)																		X																					1
Turritella cooperi Carpenter (pl. 13, figs. 12, 14, 15)									X	X					X	X	X				sp.																X	X	8
Turritella gonostoma hemphilli Applin (pl. 13, fig. 13)																		X																					1
Crepidula princeps Conrad								X		X						X																							3
Crepidula adunca Sowerby								X										X																					2
Crepidula cf. *C. excavata* (Broderip)																		X																					1
Crepidula aculeata (Gmelin)															X	X			X																				3
Crepidula nummaria Gould																	X	?	X																				3
Crepipatella cf. *C. lingulata* (Gould)																	X																						1
Calyptraea cf. *C. fastigiata* (Gould)								X										X																					2
Trochita radians (Lamarck), small var. (pl. 13, fig. 19)								X							X	X	X		X		X													X					7
Crucibulum cf. *C. imbricatum* (Sowerby)																	X																						1
Cryptonatica aleutica Dall, small var								sp.		X					X		X	X																					5
Neverita reclusiana (Deshayes)				sp.											X	X	X	X	X											sp.								sp.	8
Lunatia cf. *L. lewisii* (Gould) (pl. 12, fig. 1)																	X		X					?															3
Sinum scopulosum (Conrad) (pl. 12, fig. 5)																				[4] X																			1
Trivia cf. *T. sanguinea* (Gray) (pl. 13, figs. 21, 22)															X																								1
Erato cf. *E. scabriuscula* Gray (pl. 13, fig. 20)															X		X	X																					3
"*Gyrineum*" *mediocre lewisii* Carson (pl. 12, figs. 13, 15; pl. 13, figs. 23, 24, 26, 27)				X											X		X	X	X																				5
Fusitriton cf. *F. oregonensis* (Redfield)															X																								1
Architectonica sp																				[2] X																			1
Epitonium cf. *E. tinctum* (Carpenter)															X																								1
Opalia varicostata Stearns		X																																					1
Opalia varicostata anomala Stearns								[5] X																															1
Turbonilla cf. *T. arnoldi* Dall and Bartsch															X																								1
Turbonilla cf. *T. antestriata* Dall and Bartsch															X																								1
Odostomia cf. *O. farallonensis* Dall and Bartsch								sp.									X	?sp.																					3
Balcis cf. *B. micans* (Carpenter)															X																								1
Barbarofusus cf. *B. arnoldi* (Cossmann)															X	X	X	X	X																				5
"*Nassa*" *moraniana* Martin (pl. 14, figs. 13, 14)								X			X	X	X		X	X	X	X			X	X		X	X	cf.				X		X			X	X		X	18
"*Nassa*" cf. "*N.*" *fossata* (Gould)																X																							1
"*Nassa*" *waldorfensis* Arnold (pl. 15, fig. 4)								X					sp.								cf.																		3
"*Nassa*" *mendica* Gould, small var. (pl. 15, figs. 5, 6)															X	X	X	X	X																				5
"*Nassa*" *mendica cooperi* Forbes, small form															X	X	X	X	X																				5
Calicantharus fortis (Carpenter), var. cf. *angulata* (Arnold) (pl. 14, fig. 10; pl. 15, figs. 14, 15)																				[2, 4] X																			1
Calicantharus portolaensis (Arnold) (pl. 14, figs. 8, 9)																		X	X																				2
Jaton cf. *J. carpenteri* (Dall) (pl. 15, figs. 9, 11)																				[2] X																			1
Tritonalia lurida (Middendorff)								X							cf.																								2
Tritonalia cf. *T. barbarensis* (Gabb)															X																								1
Tritonalia cf. *T. clathrata* Dall								sp.							X		X	X																					4
Boreotrophon multicostatus (Eschscholtz), inflated var. (pl. 15, figs. 22, 24)																				[4] X																			1
Nucella sp							X				X																												2
Cancellaria lipara Woodring, n. sp. (pl. 16, figs. 13, 14)																				[4] X																			1
"*Cancellaria*" *rapa* Nomland?																				[3] X																			1
"*Cancellaria*" *rapa perrini* Carson															X	X								?						?									4
"*Cancellaria*" cf. "*C.*" *tritonidea* Gabb (pl. 16, fig. 5)																	X		sp.																				2
"*Cancellaria*" *arnoldi* Dall (pl. 15, figs. 18, 20)								?							X	X	X		X																				5
"*Cancellaria*" *hemphilli* Dall (pl. 15, figs. 16, 17)																				[4] X																			1
Crawfordina fugleri (Arnold) (pl. 16, fig. 7)																				[3, 4] X																			1
Admete gracilior (Carpenter) of Arnold (pl. 15, fig. 10)																				[4] X																			1
Mitrella gausapata (Gould) (pl. 15, fig. 7)								X				?sp.	?		X																								4
Mitrella tuberosa (Carpenter) var. (pl. 15, figs. 23, 25)															X		X	X																			?sp.		4
Amphissa cf. *A. versicolor* Dall																	X	X	X																				3
Psephaea oregonensis (Dall) (pl. 14, figs. 1, 2, 4, 5; pl. 15, figs. 19, 21)															X		X	X																					3
Olivella biplicata (Sowerby), slender var								X				X				X										sp.													4
Olivella cf. *O. baetica* Carpenter (pl. 15, fig. 8)															X																								1
Megasurcula carpenteriana (Gabb), inflated var																X	X		cf.						cf.													cf.	5
Megasurcula? cf. *M. carpenteriana tryoniana* (Gabb)															X																								1
Elaeocyma cf. *E. empyrosia* (Dall)															X					[2] X																			2
"*Drillia*" *graciosana* Arnold													X																										1
Mangelia variegata (Carpenter), angulated var. of Willett															X					[2] X																			2
Mangelia interlirata Stearns, inflated var															X					[2] X																			2
"*Mitromorpha*" *intermedia* Arnold, var															X			X																					2
Glyphostoma conradiana (Gabb)															X					[2] X																			2
Propebela sp															X																								1
Strioterebrum martini (English) (pl. 16, fig. 21)																										X													2
Acteon cf. *A. punctocaelatus* (Carpenter)															X					[2] sp.																			2
Acteocina cf. *A. culcitella* (Gould)															X		X																						2
Cylichna cf. *C. attonsa* Carpenter															X																								1
Scaphopods:																																							
Dentalium neohexagonum Pilsbry and Sharp															X																								1
Dentalium cf. *D. semipolitum* Broderip and Sowerby															?sp.			X																					2
Cadulus? sp																	X	X																					2
Pelecypods:																																							
Acila cf. *A. castrensis* (Hinds)																	X	X																					2
Saccella cellulita (Dall) (pl. 15, figs. 3, 26)															X			X																					2
Saccella taphria (Dall)											?		?		X	?	sp.				?	?		sp.		?	?	?		?	X	?					?	?	16
Saccella orcutti (Arnold)																		X								?													2
Saccella redondoensis (Burch) (pl. 16, fig. 18)															X		?																						2
Yoldia cf. *Y. supramontereyensis* Arnold																								X											X	X			3
Pododesmus macroschisma (Deshayes)								X								?						?																	3
Arca santamariensis Reinhart (pl. 14, figs. 6, 7)																		X																					1
Arca sisquocensis Reinhart															X	X		X																					3
Barbatia pseudoillota Reinhart (pl. 15, figs. 12, 13)															X		X	X																					3
Anadara trilineata (Conrad) of Arnold (pl. 16, fig. 19)							cf.	X	X	cf.			cf.		X	X	cf.	cf.	X		sp.				cf.	cf.		X		X			sp.	sp.	sp.				18
Glycymeris sp																		X																					1
Mytilus cf. *coalingensis* Arnold																				[3] X																			1
Volsella cf. *V. capax* (Conrad)						sp.		sp.												[3] X	sp.	X	X	X			sp.	X							sp.				10
Crenella cf. *C. decussata* (Montagu)								X																															1
Pecten stearnsii Dall?					X															[3] X																			2
Pecten hemphilli Dall (pl. 16, figs. 15, 16)	X	?	X	?	X	X									X				?								?												9
Aequipecten? cf. *A. circularis* (Sowerby)																				[3] X						X													2
Chlamys hastatus (Sowerby)			?	sp.	X			?							X		X	X	X																				8
Chlamys parmeleei (Dall) (pl. 16, fig. 20)															X			X																					2
Patinopecten healeyi (Arnold)	X	X	X	X	X	?	?	X														X	?		?														11
Patinopecten dilleri (Dall)										X																													1
Lyropecten cerrosensis (Gabb) (pl. 21, fig. 1)	cf.	X				cf.												cf.	X																				5
Lima cf. *L. hemphilli* Hertlein and Strong																				[3] X																			1
Ostrea erici Hertlein															X			sp.																					2
Ostrea vespertina Conrad		cf.	X	cf.	X		X	X				sp.	X		cf.					[3] cf.																			10
Glans subquadrata (Carpenter)															X			X																					2
Cyclocardia californica (Dall) (pl. 15, figs. 1, 2)				X			X	X	X	X					X	X	X	X	X																				10
Miodontiscus cf. *M. prolongatus* (Carpenter)				X																																			1
Lucinisca nuttallii antecedens (Arnold)																					sp.					sp.	sp.			cf.	X	X			cf.	cf.			8
Lucinoma cf. *L. annulata* (Reeve)							sp.			X		X	X	sp.	sp.					[3] X					X		sp.	sp.					?sp.					X	12
Parvilucina cf. *P. tenuisculpta* (Carpenter)				X											X		X																						3
Diplodonta sp																			X																				1
Kellia laperousii (Deshayes)															X																								1
Tellina cf. *T. idae* Dall																									X		X												2
Tellina cf. *T. buttoni* Dall													?		X							?													?				4
Tellina cf. *T. bodegensis* Hinds																																			X				1
Macoma cf. *M. nasuta kelseyi* Dall								X			X	X	X	X								sp.													X	X			8
Macoma cf. *M. brota* Dall															X		X																						2
Macoma cf. *M. yoldiformis* Carpenter																	X				X									X									3
Macoma cf. *M. indentata* Carpenter																					X						X				X								3
Semele cf. *S. rubropicta* Dall (pl. 14, fig. 12)															X			X	X																				3
Cumingia californica Conrad										cf.					X	X	X	X	X																				6
Spisula cf. *S. hemphilli* (Dall)								?sp.			X			X						[3] sp.					X										?sp.	X			7
Spisula cf. *S. catilliformis* Conrad																						X	X	X															3
Schizothaerus cf. *S. nuttallii* (Conrad)							X	sp.			X		?sp.			X						X		X															7
Dosinia ponderosa (Gray), var. (pl. 16, fig. 6)																X	cf.								cf.		cf.			X									5
Saxidomus cf. *S. nuttalli* Conrad									?sp.						X															?sp.									3
Compsomyax cf. *C. subdiaphana* (Carpenter)																			X				X				X		X										4
Protothaca cf. *P. staleyi* (Gabb)					X			?sp.							sp.						?sp.									?sp.			?sp.						6
Protothaca cf. *P. tenerrima* (Carpenter)								X			?	X	X	X	?sp.					[3] X	X		?	X															10
Irus? cf. *I. lamellifer* (Conrad)																		X																					1
Transennella cf. *T. tantilla* (Gould)								X				?			X		X	?sp.	X			?sp.																	7
Petricola cf. *P. carditoides* (Conrad)															?					[3] X																			2
Petricola cf. *P. buwaldi* Clark																				[3] X																			1
Cerastoderma cf. *C. meekianum* (Gabb)								sp.			X				sp.	X																				X			5
Trachycardium cf. *T. quadragenarium* (Conrad)															X	?sp.		?sp.																					3
Chama cf. *C. pellucida* Broderip															X				X																				2
Gari? cf. *G. californica* (Conrad)													X																										1
Mya sp							X																																1
Cryptomya cf. *C. californica* (Conrad)								X			X	X	X	?	?					[3] X	X												X		X				10
Sphenia? cf. *S. globula* Dall																										X									X				2
Solen perrini Clark								sp.			X	sp.	X		?sp.					[3] cf.		X				sp.			sp.	X						sp.	sp.		12
Siliqua cf. *S. media* (Sowerby)											X	X									X														X	X			5
Panope cf. *P. generosa* Gould				X		X							X					?			X	X		X	X	X		X											10
Panomya cf. *P. beringianus* Dall																				[3] X																			1
Pholadidea penita (Conrad) (pl. 14, fig. 3)															X	cf.	sp.																						3
Thracia cf. *T. trapezoides* Conrad																				[3] X																			1
Pandora cf. *P. punctata* Conrad																					X														X				2
Barnacles:																																							
Balanus cf. *B. aquila* Pilsbry								sp.							cf.			X																					3
Balanus hesperius proinus Woodring, n. var				sp.				X																															2
Total forms 175	3	5	4	11	6	5	9	37	5	9	11	11	16	5	87	27	44	57	26	------	16	12	6	10	9	11	9	6	2	12	4	4	4	2	13	8	4	6	

[1] The total number of localities is 1 less than the total number of locality columns, "other collections, Fugler Point" being a duplication.
[2] Calif. Inst. Tech. locality 869, Fugler Point, lower part of exposure at east end of bluff, W. P. Popenoe collector.
[3] U. S. Geol. Survey locality 4475, Fugler Point asphalt mine, a mile north of Garey, Ralph Arnold collector, 1906.
[4] Fugler Point collection of Mr. Alex Clark, Shell Oil Co., Los Angeles, Calif.
U. S. Geol. Survey locality 4474, railroad cut a mile north of Shuman, Ralph Arnold collector, 1906.

Fossils from Graciosa coarse-grained member of Careaga sandstone

[Identifications by W. P. Woodring unless otherwise stated. P, Observed in field but not collected. For explanation of other symbols see p. 67]

Species	Localities																																																		Total localities (52)
	Casmalia Hills					Western Solomon Hills, including Graciosa Ridge														Eastern Solomon Hills, including Gato Ridge														Cat Canyon		Foxen Canyon	Purisima Hills															
	195	196	196a	196b	196c	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	214a	215	215a	216	216a	217	218	219	220	221	222	223	224	225	226	227	227a	228	229	230	230a	231	232	233	234	234a	235	235a	
Echinoid: *Dendraster ashleyi* (Arnold) (pl. 17, figs. 11, 12; pl. 18, figs. 12–14; (pl. 19, fig. 6; pl. 20, figs. 5, 6)	?sp.			X		sp.					X	X	X					P					P				X	P		X	cf.	X	P	X	cf.	sp.		X	X	X			X				sp.		X		X	24
Gastropods:																																																				
Calliostoma virgineum (Dillwyn)			sp.																																																	1
Pupillaria cf. *P. optabilis* (Carpenter)								X																																												1
Littorina cf. *L. petricola* Dall (pl. 19, fig. 12)														X																																						1
Lacuna cf. *L. carinata* Gould										X		X																																								2
Amnicola? sp																				X																																1
Bittium casmaliense Bartsch				X	X																																				?sp.											3
Turritella cooperi Carpenter								X				cf.	X	X																																						4
Crepidula princeps Conrad															X															cf.			cf.																			3
Cryptonatica aleutica Dall				sp.			X	X				X	X	X	X	X																																				8
Neverita reclusiana (Deshayes) (pl. 20, fig. 4)				X			X	X	X	X		X	X	X	X	X	X																															X				12
Lunatia cf. *L. lewisii* (Gould)																X																																				1
Sinum sp								X																																												1
Opalia varicostata Stearns?					X																																															1
Odostomia cf. *O. phanea* Dall and Bartsch								sp.		X																																										2
"*Nassa*" *moraniana* Martin (pl. 17, figs. 7, 8; pl. 19, fig. 4)			X			X	X	X	X	X	X	X	X	X	X	X	X	X				X	X			X		X	X	X	cf.		X	X	X	cf.	X						X	X			X	X		cf.		31
"*Nassa*" *waldorfensis* Arnold (pl. 19, figs. 3, 5)			X	?			X	X	X	X		X	X	X	X	X																																				11
Calicantharus fortis (Carpenter) var. cf. *angulata* (Arnold)								X																																												1
Calicantharus? sp								X																																												1
Nucella lamellosa shumanensis (Carson)				?				X																														X														3
Nucella lamellosa collomi (Carson)					X																																															1
"*Cancellaria*" *rapa perrini* (Carson) (pl. 17, figs. 1, 2; pl. 18, figs. 2, 3, pl. 19, fig. 10)								X					X	?		X								?					cf.																							6
"*Cancellaria*" *arnoldi* Dall														X																																						1
Mitrella gausapata (Gould)							X	X	X	X		X	X	X	X	X	X													?sp.			?																			12
Olivella biplicata (Sowerby), slender var. (pl. 19, figs. 7, 11)			X	X			X	X	X	X		X	X	X	X	X	X											sp.	sp.	sp.	sp.		cf.		X	sp.								sp.						X		21
Megasurcula capenteriana (Gabb), inflated var. (pl. 17, fig. 9)								X	X				X	X																cf.																						5
Elaeocyma? sp				X																																																1
"*Drillia*" *graciosana* Arnold (pl. 17, figs. 3–6, 10)							X	X	X	X		X	X	X	X	X																					X															10
Strioterebrum martini (English)																														X																						1
Menetus? sp																				X																																1
Physa sp																				X																																1
Scaphopod: *Cadulus?* sp					X		X	X																																												3
Pelecypods:																																																				
Nuculana cf. *N. leonina* (Dall)				X	X																																															2
Saccella taphria (Dall) (pl. 21, fig. 7)					X		X	X									X												?	?			?														?					8
Yoldia cf. *Y. supramontereyensis* (Arnold)										X													X								X						X															4
Pododesmus macroschisma (Deshayes)				X				X																																												2
Anadara trilineata (Conrad) of Arnold			?sp.			?sp.		sp.								X													cf.	cf.			cf.		cf.												sp.					9
Glycymeris cf. *G. grewingki* Dall		sp.	sp.	X																																																3
Mytilus cf. *M. coalingensis* Arnold																																X																				1
Volsella cf. *V. capax* (Conrad)																														X			X																			2
Pecten hemphilli (Dall) (pl. 21, fig. 8)				X																																																1
Chlamys hastatus (Sowerby)?				X																										?sp.																	sp.					3
Patinopecten healeyi (Arnold) (pl. 19, fig. 9; pl. 21, fig. 9)				X									?																																							2
Lyropecten cerrosensis (Gabb)				X																																																1
Ostrea vespertina Conrad	cf.	X	X	X	cf.		sp.	cf.																														X														8
Cyclocardia californica (Dall) (pl. 21, fig. 5)		X		X	X																					sp.																										4
Lucinisca nuttallii antecedens (Arnold) (pl. 20, fig. 3; pl. 21, fig. 6)							X	X	X	sp.					X	X	X					X						cf.	cf.						cf.		cf.									sp.	cf.					14
Lucinoma cf. *L. annulata* (Reeve) (pl. 19, fig. 8)				sp.	X			sp.																																												3
Parvilucina cf. *P. tenuisculpta* (Carpenter)					X																																										X					2
Rochefortia tumida (Carpenter)				X																																																1
Corbicula? sp																																									X											1
Sphaerium? sp																																									X											1
Tellina cf. *T. buttoni* Dall				X																																											?sp.					2
Tellina cf. *T. bodegensis* Hinds																																					X															1
Macoma nasuta kelseyi Dall (pl. 20, figs. 2, 8)				cf.		cf.	X	X	X	X		sp.	X	sp.	X	X	X	cf.								cf.			cf.	cf.			cf.		cf.	cf.	cf.										sp.					21
Macoma cf. *M. indentata* Carpenter																										X																										1
Macoma cf. *M. secta* (Conrad)																																																		X		1
Cumingia? cf. *C. californica* (Conrad)																																	X																			1
Spisula cf. *S. hemphilli* (Dall)						X		sp.	sp.			sp.	sp.															cf.	?sp.							X																8
Spisula cf. *S. catilliformis* Conrad																							X										X		?	X																4
Pseudocardium densatum (Conrad) of Arnold, var. cf. *gabbii* Rémond (pl. 17, fig. 14; pl. 19, fig. 2)						?	X					X	sp.			X		?sp.												X			?sp.				X											X				10
Schizothaerus cf. *S. nuttallii* (Conrad)				sp.				sp.	sp.				?sp.	sp.							X	X	X	X	X	X			X	X	X																					14
Dosinia ponderosa (Gray) var. (pl. 19, fig. 1; pl. 20, fig. 7)								X					X	X			cf.							cf.					cf.	cf.														cf.								8
Pachydesma crassatelloides (Conrad) (pl. 18, fig. 1)		cf.	cf.																																							cf.						X		X		5
Saxidomus cf. *S. nuttalli* Conrad?				?sp.																																										X						2
Compsomyax cf. *C. subdiaphana* (Carpenter)					X	X																														?sp.																3
Lirophora cf. *L. mariae* (d'Orbigny)																																															X					1
Protothaca staleyi (Gabb) (pl. 21, figs. 2–4)		cf.		cf.		cf.	X	cf.	X	cf.		X	cf.	X	X	X	X	cf.												?							cf.										?sp.	X				18
Protothaca cf. *P. tenerrima* (Carpenter)							X	X								X	X	X						X				cf.	?				X		X																	10
Transennella cf. *T. tantilla* (Gould)				cf.	X		X	X		X		X	X			X		?																																		9
Petricola cf. *P. buwaldi* Clark																	X																																			1
Cerastoderma cf. *C. meekianum* (Gabb)		sp.	?sp.	?sp.	sp.	X				sp.			sp.																	X					X	X	X											sp.				12
Mya sp				X	X																																															2
Cryptomya cf. *C. californica* (Conrad)								X								X							X			?	X		X		X		X		X	?sp.											X					11
Platyodon cf. *P. colobus* Woodring								X																																												1
Solen perrini Clark						sp.	?sp.	X								sp.	X	sp.																	X												sp.			X		9
Siliqua cf. *S. media* (Sowerby)													X					X								X				sp.							X										X					6
Panope cf. *P. generosa* Gould				X				X					X											X									X																			5
Saxicava? cf. *S. pholadis* (Linné)																	X																																			1
Pholadidea penita (Conrad)																	X											X																								2
Zirfaea cf. *Z. pilsbryi* Lowe		X																																																		1
Pandora punctata Conrad (pl. 17, fig. 13)								X					X	X			X																cf.		cf.		cf.															7
Barnacles:																																																				
Balanus cf. *B. aquila* Pilsbry		sp.		X	X		X	X						X		X	sp.																															sp.				9
Balanus hesperius proinus Woodring, n. var				X				sp.	sp.	sp.																																	sp.									5
Reptile (identification by C. L. Gazin): Turtle (fragment of carapace)																																													X							1
Land mammals (identification by C. L. Gazin):																																																				
Mastodon (immature maxillary portion without teeth)																																													X							1
Mastodon? (incomplete centrum of large vertebra)																																													X							1
Marine mammals (identification by Remington Kellogg):																																																				
Sea lion (femur)																			X																																	1
Cetothere (occipital portion of young animal)																																													X							1
Total forms, 89	2	8	9	30	15	10	18	37	13	15	2	15	23	18	11	19	16	9	1	3	1	3	6	5	1	7	2	7	12	18	6	2	16	2	12	9	11	3	1	1	3	1	3	3	4	2	14	7	1	5	1	

page 48. The fauna, consisting of 175 forms, is exceptionally large. Almost three-quarters of the forms, however, were found at only one or two localities (counting the Fugler Point collections as one locality), and a little more than half were found only at two unusual localities: Fugler Point and the dump of an old asphalt mine on the south slope of Graciosa Ridge (locality 177). At both these localities the shells are preserved in tar sand or asphalt, whereas at most Cebada localities the fossils are molds. Fugler Point has yielded 123 listed forms and about 20 additional species are represented in the collection from that locality made by Mr. Alex Clark, of the Shell Oil Company.

All the most widespread species, namely, "*Nassa*" *moraniana* (pl. 14, figs. 13, 14), *Sacella taphria*, *Anadara trilineata* (pl. 16, fig. 19), *Volsella* cf. *V. capax*, *Patinopecten healeyi*, *Ostrea vespertina*, *Lucinoma* cf. *L. annulata*, *Protothaca* cf. *P. tenerrima*, *Cryptomya* cf. *C. californica*, *Solen perrini*, and *Panope* cf. *P. generosa*, occur also in the younger Graciosa coarse-grained member of the Careaga sandstone, and all except the *Saccella* occur in the older Foxen mudstone or in the still older upper Sisquoc formation, or in both. At the usual Cebada localities the Cebada fauna is closely allied to the fauna of the Graciosa member, but at the two unusual localities it is more closely allied to that of the Foxen.

As shown by the consolidated faunal list on pages 62–66, 20 forms, notably "*Cancellaria*" *rapa perrini*, "*Drillia*" *graciosana*, *Strioterebrum martini* (pl. 16, fig. 21), *Saccella taphria*, *Yoldia* cf. *Y. supramontereyensis*, *Lyropecten cerrosensis*, *Dosinia ponderosa* var. (pl. 16, fig. 6), and *Petricola* cf. *P. buwaldi*, were found in both members of the Careaga sandstone, or in undifferentiated Careaga strata, but not in older formations. All except three of the 20 species occur at localities other than the two unusual localities. In contrast, 17 species, notably *Puncturella cooperi aphales* (pl. 12, figs. 2, 3), *Turcica imperialis brevis* (pl. 12, figs. 9, 10, 12, 14), "*Gyrineum*" *mediocre lewisii* (pl. 12, figs. 13, 15; pl. 13, figs. 23, 24, 26, 27), *Arca sisquocensis*, and *Patinopecten dilleri* were found in the Cebada member of the Careaga and in the Foxen mudstone, but not in other formations or members. All except six of the 17 species occur only at one or both of the unusual localities. Seventy-eight forms, almost half of the Cebada fauna, are not known to occur in other formations or members. All except 16, however, are present only at the unusual localities and therefore are not useful stratigraphic guides. Notable species among the 78 forms are as follows: *Terebratalia occidentalis* (pl. 13, figs. 1–4, 8, 9, 25), *Turritella gonostoma hemphilli* (pl. 13, fig. 13), *Architectonica* sp., *Cancellaria lipara* (pl. 16, figs. 13, 14), "*Cancellaria*" cf. "*C.*" *tritonidea* (pl. 16, fig. 5), "*Cancellaria*" *hemphilli* (pl. 15, figs. 16, 17), *Crawfordina fugleri* (pl. 16, fig. 7), *Arca santamariensis* (pl. 14, figs. 6, 7), *Barbatia pseudoillota* (pl. 15, figs. 12, 13), and *Chlamys parmeleei* proper (pl. 15, figs. 12, 13).

A meager fauna of shallow-water Foraminifera is found locally in the Cebada member, the most common species being *Elphidiella hannai*.

GRACIOSA COARSE-GRAINED MEMBER

Megafossils, listed in the table (opposite page) are widespread and locally abundant in the Graciosa coarse-grained member of the Careaga sandstone. Though only molds of most of the mollusks are represented at many localities, well-preserved shells are present in tar sand on Graciosa Ridge (localities 198 to 201, 203 to 208). Shell material is preserved also at the railroad cut near Shuman (localities 196 to 196*c*), at locality 234 in the Purisima Hills, and at a few other places.

Dendraster ashleyi (pl. 17, figs. 11, 12; pl. 18, figs. 12–14; pl. 19, fig. 6; pl. 20, figs. 5, 6), "*Nassa*" *moraniana* (pl. 17, figs. 7, 8; pl. 19, fig. 4), a slender variety of *Olivella biplicata* (pl. 19, figs. 7, 11), *Lucinisca nuttallii antecedens* (pl. 20, fig. 3; pl. 21, fig. 6), *Macoma nasuta kelseyi* (pl. 20, figs. 2, 8), *Schizothaerus* cf. *S. nuttallii*, and *Protothaca staleyi* (pl. 21, figs. 2–4) are the most common species. The abundance of these species and, above all, the occurrence of the markedly eccentric sand dollar *Dendraster ashleyi* serve to distinguish the Graciosa fauna from that of the Cebada member. The widespread occurrence, restricted stratigraphic range, and well-defined characters of this sand dollar as compared with others in the Santa Maria district fill the requirements of a useful stratigraphic guide. A poorly preserved sand dollar, possibly *D. ashleyi*, was observed at Fugler Point in strata identified as the upper part of the Cebada fine-grained member (see table), but sand dollars were not found elsewhere in that member. Though *D. ashleyi* is widespread in the Graciosa member, it is not abundant in the Casmalia Hills or in the Solomon Hills, except at locality 202 on Graciosa Ridge. Twelve other species, including *Littorina* cf. *L. petricola* (pl. 19, fig. 12), *Nuculana* cf. *N. leonina*, *Pachydesma crassatelloides* (pl. 18, fig. 1), *Lirophora* cf. *L. mariae*, and *Platyodon* cf. *P. colobus*, were not found at other horizons. Except the *Pachydesma*, a Recent species, they are present, however, at only one or two localities.

Bittium casmaliense, *Turritella cooperi*, *Crepidula princeps*, "*Nassa*" *waldorfensis* (pl. 19, figs. 3, 5), "*Cancellaria*" *arnoldi*, *Anadara trilineata*, *Patinopecten healeyi* (pl. 19, fig. 9; pl. 21, fig. 9), *Lyropecten cerrosensis*, *Ostrea vesperina*, *Cyclocardia californica* (pl. 21, fig. 5), *Lucinoma* cf. *L. annulata* (pl. 19, fig. 8), and *Pholadidea penita* are less common than at lower horizons. *Saccella orcutti*, which is common at lower horizons, was not recognized. On the contrary, "*Cancellaria*" *rapa perrini* (pl. 17, figs. 1, 2; pl. 18, figs. 2, 3; pl. 19, fig. 10), "*Drillia*" *graciosana* (pl. 17, figs. 3–6, 10), and *Pandora punctata* (pl. 17, fig. 13) are more common than at lower horizons. *Pseudocardium densatum* var. cf. *gabbii* (pl. 17, fig. 14; pl. 19, fig. 2) is fairly widespread in the Graciosa, and probably occurs in the Tinaquaic sandstone member of the Sisquoc formation, but was not found in the intervening Cebada member of the Careaga.

Foraminifera are rare in the Graciosa. A few worn specimens of *Elphidium* were collected in the western Casmalia Hills. Unidentified fresh-water diatoms occur near the top of the Graciosa at locality 231 in the Purisima Hills.

UNDIFFERENTIATED CAREAGA SANDSTONE

Fossils from strata mapped as undifferentiated Careaga sandstone are listed in the accompanying table. Locality 236 represents calcareous sandstone and locality 243 silty fine-grained sandstone, both suggestive of the Cebada fine-grained member. The fossils from the other localities occur in coarse-grained sandstone or pebbly sandstone, corresponding presumably to the Graciosa coarse-grained member. *Ostrea vespertina* (pl. 16, figs. 4, 17) and the small barnacle *Balanus hesperius proinus* (pl. 14, figs. 11, 15; pl. 16, figs. 1–3, 8–12) are exceptionally abundant at locality 236.

Fossils from undifferentiated Careaga sandstone

[Identifications by W. P. Woodring. P, Observed in field but not collected. For explanation of other symbols, see p. 67]

Species	Localities													Total localitie (13)
	Casmalia Hills											Purisima Hills		
	236	237	238	239	240	241	241a	242	243	244	245	246	247	
Echinoid: *Dendraster ashleyi* (Arnold) (pl. 20, fig. 1)				X			X			X	P	X		5
Gastropods:														
Bittium casmaliense Bartsch									X					1
Turritella cooperi Carpenter									X					1
Turbonilla sp									X					1
"*Nassa*" *moraniana* Martin		X	X			X		X			X		X	6
"*Nassa*" cf. "*N.*" *mendica* Gould, small var									X					1
"*Cancellaria*" *arnoldi* Dall?									X					1
Mitrella gausapata (Gould)?									X					1
Olivella? sp									X					1
Pelecypods:														
Saccella taphria (Dall)?									X					1
Saccella orcutti (Arnold)									X					1
Yoldia cf. *Y. supramontereyensis* Arnold											X			1
Anadara cf. *A. trilineata* (Conrad) of Arnold									sp.				X	2
Mytilus cf. *M. coalingensis* Arnold													X	1
Pecten hemphilli Dall					X									1
Ostrea vespertina Conrad (pl. 16, figs. 4, 17)	X	cf.			X									3
Lucinisca sp													X	1
Tellina? sp., small									X					1
Tellina? cf. *T. bodegensis* Hinds								X	?sp.					2
Macoma cf. *M. nasuta kelseyi* Dall		X									X			2
Spisula cf. *S. hemphilli* (Dall)?													X	1
Spisula cf. *S. catilliformis* Conrad								X					X	2
Pseudocardium densatum (Conrad) of Arnold, var. cf. *gabbii* Rémond								X						1
Schizothaerus cf. *S. nuttallii* (Conrad)						X		X						2
Saxidomus cf. *S. nuttalli* Conrad?		X												1
Compsomyax cf. *C. subdiaphana* (Carpenter)									X					1
Protothaca staleyi (Gabb)		X	X		?sp.			X		cf.	cf.			6
Protothaca cf. *P. tenerrima* (Carpenter)						X							?	2
Transennella cf. *T. tantilla* (Gould)						X								1
Cerastoderma cf. *C. meekianum* (Gabb)						?sp.		X						2
Cryptomya cf. *C. californica* (Conrad)?						X			X					2
Siliqua cf. *S. media* (Sowerby)						X								1
Barnacle: *Balanus hesperius proinus* Woodring, n. var. (pl. 14, figs. 11, 15; pl. 16, figs. 1–3, 8–12)	X													1
Total forms 33	2	5	2	1	3	7	1	7	14	2	5	1	7	

PLIOCENE AND PLEISTOCENE(?) SERIES

PASO ROBLES FORMATION

The Careaga sandstone is the youngest marine formation in the Santa Maria district, aside from Pleistocene marine terrace deposits of limited extent along the coast. The uppermost part of the Careaga, which includes at least locally nonmarine deposits, might better be grouped with the Paso Robles formation, but the overlying clay is a more useful cartographic base for the Paso Robles. The name "Paso Robles formation" is used for the nonmarine formation that conformably overlies the Careaga sandstone. The type region of the Paso Robles formation [30] is in the Salinas Valley, in the Coast Ranges northwest of the Santa

[30] Fairbanks, H. W., Geology of a portion of the southern Coast Ranges: Jour. Geology, vol. 6, pp. 565–566, 1898.

Maria district. In the type region and adjoining regions it overlies marine deposits of Pliocene age or the Miocene Monterey shale. A nonmarine formation that has the same general stratigraphic position in the southern part of the San Luis Obispo quadrangle, immediately north of the Santa Maria Valley, has been designated the Paso Robles formation [31], and it appears appropriate to extend usage of that name into the Santa Maria district. Though the Paso Robles is essentially a nonmarine formation, the basal part includes thin tongues of marine sand, or sandstone, in the western Casmalia Hills. The Paso Robles formation has a maximum exposed thickness of about 2,000 feet in the Santa Maria district. In extensive areas much of it is overlapped by the Orcutt sand or other terrace deposits.

STRATIGRAPHY AND LITHOLOGY

Sand and gravel are the principal constituents of the Paso Robles formation. Clay and limestone are minor but the most characteristic constituents. Fresh-water fossils are common in the limestone. Most of the Paso Robles has a monotonous gray color, but silty clay and silty sand in the upper part of the formation are light brown.

Clay, at many places accompanied by limestone, was mapped as the base of the Paso Robles formation. Limestone at the base of the formation is discontinuous and at many places is absent. Clay is also discontinuous and locally absent, but individual beds are so thin that they are not readily traceable. The beds of clay used in mapping the base of the Paso Robles evidently represent a zone 50 to 100 feet thick recognized almost throughout the district. With few known exceptions, the base of the Paso Robles, as identified by the occurrence of clay and fresh-water limestone, represents an essentially uniform stratigraphic position with reference to identifiable strata in the Careaga sandstone. An apparent exception is a locality on the north slope of the Purisima Hills 1¼ miles southeast of the Orcutt-Lompoc Highway, where clay mapped as the base of the Paso Robles is only 45 feet above *Dendraster*-bearing conglomerate in the lower part of the Graciosa coarse-grained member of the Careaga sandstone. The upper part of the Graciosa, 100 to 150 feet thick at nearby localities, is very thin, or clay is present at a lower horizon than elsewhere. The presence of the Paso Robles formation, identified by clay and fresh-water limestone, on the crest of Graciosa Ridge indicates that the Graciosa member of the Careaga sandstone is condensed on the crest of the Graciosa anticline.

At localities where clay or limestone was not found at an expectable horizon above the upper part of the Careaga sandstone, conglomerate was chosen as the base of the Paso Robles formation. At those localities the base is not well controlled, as similar conglomerate occurs locally in the upper part of the Careaga. In a few areas where clay, limestone, or conspicuous conglomerate were not found, the base of the Paso Robles is doubtful and arbitrary. The western Solomon Hills in the angle between the Orcutt-Harris Highway and the road to the southern part of the Orcutt field, and the Solomon Hills south of the east end of the Orcutt field are examples of such areas.

Clay occurs at various horizons in the Paso Robles formation in beds a few inches to a few feet thick. It is gray to greenish gray and has a characteristic waxy appearance suggesting that it contains bentonitic material. Vegetation on clayey soil is different from that on sandy soil, the difference being most marked after the winter rains begin and annuals germinate. The Paso Robles formation includes also gray or brownish silty clay that is less conspicuous than the waxy clay.

The beds of limestone are of variable thickness from 1 to 30 feet, though generally from 1 to 5 feet. Beds of limestone of greater extent than a few isolated outcrops, other than those at the base of the formation, are shown on the geologic map (pl. 1). Many beds of clay include limy nodules, and limestone is commonly interbedded with clay, grading into it through soft limestone and marl. Most of the limestone is more or less sandy and at places grades into muddy sand. Limestone occurs almost throughout the district. No conspicuous beds were observed in the northern part of the district from Foxen Canyon westward to U. S. Highway 101 and in the eastern Casmalia Hills. The thickest beds are on the north slope of the Purisima Hills. At localities on the north slope of the Purisima Hills near the east border of the mapped area, limestone at the base of the Paso Robles has a thickness of 25 to 30 feet. It varies in thickness and in degree of induration within short distances. On the south limb of the syncline 1½ miles southwest of Careaga station, a limestone about 1,200 feet above the base of the Paso Robles is generally 1 to 10 feet thick, but has a maximum thickness of 20 feet. It is the most persistent limestone in the Purisima Hills. At some places on the crest of Graciosa Ridge and on Mount Solomon thin layers of limestone and marly clay are silicified.

The gravel is made up principally of porcelaneous shale pebbles from the Monterey, but includes a variety of porphyries and Cretaceous(?) sandstone. It closely resembles conglomerate in the Graciosa coarse-grained member of the Careaga sandstone that contains a large proportion of porcelaneous shale pebbles, and is practically indistinguishable from conglomera › : that character occurring locally in the upper part of the Graciosa member. Minor scour discontinuities at the base, and cross-bedding are perhaps more general in gravel of the Paso Robles than in gravel and conglomerate of the Careaga sandstone. Cobbles and boulders of brown micaceous sandstone, derived evi-

[31] Fairbanks, H. W., U. S. Geol. Survey Geol. Atlas, San Luis folio (no. 101), pp. 4-5, 1904.

dently from the wide-spread outcrops of Cretaceous strata in the San Rafael Mountains, occur in conglomerate of the Paso Robles formation in the northern part of the district and are in general more common than in older conglomerate. Chert and cherty shale pebbles are present in the upper part of the Paso Robles, but are rare or absent in the lower part except near the west end of the Casmalia Hills, indicating that extensive areas of the middle member of the Monterey shale were not uncovered until late Paso Robles time. Near local uplifts, however, such material is found even in the Sisquoc formation.

Much of the sand in the Paso Robles formation is cross-bedded, poorly sorted and silty, and includes stringers of grit and small pebbles. Better-sorted coarse-grained sand is indistinguishable from sand of the same character forming the upper part of the Graciosa member of the Careaga.

FOSSILS

Molds of a few species of fresh-water gastropods are fairly common in limestone and marl of the Paso Robles formation. Such material was not collected, as it is not determinable. Preserved shells were found at localities 253 and 255. Unidentified minute ostracodes occur in great numbers at localities 248 and 249. Unidentified fresh-water diatoms are associated with the mollusks and ostracodes at locality 255.

Fragmentary remains of marine fossils (molds of *Olivella*, *Macoma*, and *Balanus*, and small fragments of oyster shells) were observed in the basal part of the Paso Robles at localities 250, 251, and 252 in the western Casmalia Hills. An eared seal vertebra, collected at locality 254 in the Solomon Hills east of U. S. Highway 101 but not found in place, may have been derived from the Careaga sandstone. Fossils collected from the Paso Robles formation are as follows:

Fossils from Paso Robles formation

[Identifications by W. P. Woodring unless otherwise stated.

Species	Localities				
	248	249	253	254	255
Gastropods:					
Amnicola longinqua Gould, small var. (pl. 18, figs. 9, 10)					X
"Lymnaea" alamosensis Arnold (pl. 18, fig. 6)			X		X
Gyraulus cf. *G. vermicularis* (Gould) (pl. 18, figs. 5, 8)			X		
Helisoma sp.					X
Menetus cf. *M. cooperi* F. C. Baker (pl. 18, figs. 4, 7)			X		X
Physa sp.			X		
Unidentified ostracodes	X	X			X
Land mammal: Unidentified rodent molars					X
Marine mammal (identification by Remington Kellogg): Eared seal (atlas vertebra)				X	

PLEISTOCENE SERIES

ORCUTT SAND

Sand and gravel resting unconformably on the Paso Robles formation and older formations are designated the Orcutt sand.[32] The name "Orcutt formation" appeared in a stratigraphic table [33] in 1935, but was not defined. The type region of the Orcutt sand is the north slope of the Casmalia Hills, immediately west of Orcutt, where it overlaps formations down to and including the Sisquoc formation, and has a maximum thickness of about 50 feet. Throughout the Santa Maria district the maximum outcrop thickness is between 50 and 100 feet.

The Orcutt sand may be regarded as a terrace deposit, the oldest and most extensive terrace deposit in the Santa Maria district. Unlike younger terrace deposits throughout most of the district it is somewhat deformed, being tilted as much as 12° on the flanks of anticlines. The surface on which the Orcutt was deposited was very extensive. It probably extended over virtually the entire area described in the present report and evidently sloped gently from the foot of the mountains to the ocean. The largest areas of the Orcutt sand now remaining are on the south border of the Santa Maria Valley and on the slopes of the adjoining hills from the ocean eastward to Sisquoc, and at the west end of the Purisima Hills. On much of the wide terrace on the south border of Santa Maria Valley, the Orcutt is covered with old inactive dune sand. On the geologic map (pl. 1) Orcutt deposits are shown rather arbitrarily at the north edge of the terrace, bordering the Santa Maria Valley and along valleys cut into the terrace, for at scattered localities, such as the cut at the north edge of the terrace on U. S. Highway 101, even shallow cuts expose gravel and sand of the Orcutt under the dune sand. Westward from the Purisima Hills, beyond the area covered by the present report, the Orcutt sand is continuous with deposits on Burton Mesa, which is a marine terrace.[34] In other words, the surface on which the Orcutt sand was deposited evidently merges into a marine terrace platform and the Orcutt doubtless

[32] Woodring, W. P., Bramlette, M. N., and Lohman, K. E., op. cit. (Am. Assoc. Petroleum Geologists Bull., vol. 27, No. 10), p. 1,359, 1943.

[33] Hoots, H. W., and Herold, S. C., Natural gas resources of California, in Geology of Natural gas, p. 156, Am. Assoc. Petroleum Geologists, Tulsa, 1935.

[34] Arnold, Ralph, and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull. 322) pp. 23, 62, 1907.

includes marine deposits in that area. It is not known whether the bedrock platform on Burton Mesa represents one exceptionally wide terrace platform or more than one platform, the risers between which are concealed by nonmarine terrace deposits (the nonmarine terrace cover) that were spread seaward after emergence, forming a smoothly graded surface.[35] On the south border of the Santa Maria Valley near the ocean the surface on which the Orcutt sand was deposited may likewise merge into a marine terrace platform. So much of that area, however, is covered with dune sand that the relations of the Orcutt are uncertain.

Wherever the Paso Robles formation is strongly deformed the Orcutt sand is readily distinguished from the Paso Robles because of the marked unconformity between them. At localities where the Orcutt overlies gently dipping Paso Robles identification of the two formations may be uncertain. It may be difficult also to distinguish the Orcutt sand from younger terrace deposits. Between U. S. Highway 101 and the West Cat Canyon field, where both the Paso Robles and Orcutt dip gently, the Orcutt is well defined and is covered with a chaparral growth of chamise and scrub live oak, whereas the Paso Robles is covered with grass and scattered live oaks. Northeast of the West Cat Canyon field the distribution of the Paso Robles, Orcutt, and terrace deposits younger than the Orcutt was not satisfactorily determined.

STRATIGRAPHY AND LITHOLOGY

The Orcutt sand consists almost entirely of sand interbedded with gravel. Much of the sand is poorly sorted and has scattered pebbles and stringers of gravel. In areas of low relief that have not been deeply eroded, much of the sand in the Orcutt (as well as in younger terrace deposits) near the present land surface is reddish brown owing to a ferruginous coat on the sand grains resulting from oxidation of iron compounds. Outcrops of such sand on steep slopes, as shown on figure 7 *C*, are rilled and fluted. Elsewhere the sand is light-brown or gray.

Gravel of the Orcutt sand is in general poorly sorted and includes a variety of rocks. On the north slope of the Casmalia Hills and north of Graciosa Ridge pebbles of diatomaceous mudstone and burnt shale, both derived from the Sisquoc formation, occur in gravel of the Orcutt and are locally common. Such material was not observed in the Paso Robles formation. In a cut on the Southern Pacific Railroad, a mile northeast of Shuman, gravel of the Orcutt dipping gently northeastward overlies sand and gravel of the Paso Robles formation dipping 65° in the same direction. The gravel of the Orcutt fills gutters in the Paso Robles formation parallel to the bedding (fig. 7, *B*, *D*). It is remarkable that the gutters were preserved during deposition of the coarse gravel of the Orcutt, for the sand and gravel of the Paso Robles are quite unconsolidated and were presumably little, if at all, better consolidated during Orcutt time. Perhaps they were cut and filled during one exceptional storm. According to field identifications by A. O. Woodford at the locality just described, the cobbles and boulders of the Orcutt, which have a length of as much as a foot, include the following rocks: Cretaceous(?) micaceous sandstone, Cretaceous(?) feldspathic sandstone, porcelaneous shale of the Monterey, biotite granite, rotten augen-gneiss. Smaller cobbles and pebbles include gray and reddish quartzite, Monterey shale, red chert of the Franciscan formation, rhyolite(?) porphyry, brown vein(?) quartz, red silicified lava(?), and aplite. Though porcelaneous shale of the Monterey is the chief constituent among the pebbles and cobbles in the Paso Robles formation at the same locality, they include a variety of porphyries, probably mostly rhyolitic, Cretaceous(?) sandstone, aplite, and greenish rhyolitic(?) lava.

Silt, silty clay, and marl are minor local constituents of the Orcutt sand.

FOSSILS

A few fresh-water mollusks and ostracodes were found in clay and marl of the Orcutt sand at localities 256 and 257 in the western Purisima Hills. The meager fauna, which is essentially like that of the Paso Robles formation, is listed in the following table:

Fossils from Orcutt sand

[Identifications by W. P. Woodring. For explanation of symbol "?sp." see p. 67.]

Species	Localities	
	256	257
Gastropods:		
Amnicola longinqua Gould, small var	X	?sp.
"*Lymnaea*" sp	X	------
Gyraulus cf. *G. vermicularis* (Gould)	X	------
Physa sp	X	------
Pelecypod: *Pisidium* sp	X	------
Unidentified ostracodes	X	X

TERRACE DEPOSITS YOUNGER THAN ORCUTT SAND

DEPOSITS ON STREAM TERRACES

Gravel and sand representing stream-terrace deposits younger than the Orcutt sand were differentiated principally on a basis of physiographic development. For the most part they were not mapped carefully and at some places may include the equivalent of the Orcutt sand. South of Sisquoc River, terrace gravel younger than the Orcutt includes boulders as much as 3 feet

[35] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., Geology and paleontology of Palos Verdes Hills, Calif.: U. S. Geol. Survey Prof. Paper 207, pp. 113-114, 1946.

long, larger than those in the Paso Robles formation and Orcutt sand. Brown sandstone boulders, representing presumably Upper Cretaceous sandstone, are conspicuous in the terrace gravel of that area. Terrace deposits in the Casmalia Hills immediately east of Shuman, adjoining burnt shale in the Sisquoc formation, are made up of burnt-shale pebbles in a bricklike matrix of the same material. Where the terrace deposits are well exposed, as in cuts on U. S. Highway 101 northwest of Los Alamos, the sand and gravel are poorly sorted and much of the outcrop is rilled and fluted. Small remnants of terrace deposits resting on steeply dipping Paso Robles strata at the north edge of Los Alamos Valley east of Los Alamos were not mapped.

The stream terrace deposits are in general not more than 25 feet thick. Along Sisquoc River east of Foxen Canyon, however, the thickness is estimated to be as much as 75 feet.

DEPOSITS ON MARINE TERRACES

Marine terraces along the coast are described under the heading "Physiography". At scattered localities marine deposits, identified by the occurrence of marine fossils in cleanly washed sand and gravel, were found immediately above the terrace platform on three of the five terraces recognized. Some of the nonfossiliferous sand and gravel resting on terrace platforms is perhaps marine, but the presence of marine strata evidently is exceptional. The marine deposits are too thin and of too limited extent to be shown on the geologic map (pl. 1).

The thickest and most conspicuous marine deposits are on the highest terrace. At locality 258 on the south slope of Mount Lospe (same as locality 8), where the terrace platform is at an altitude of 830 feet above sea level, calcareous sand and grit, partly cemented to form hard limestone, is 6 feet thick. This material is made up principally of barnacle fragments. Slabs of similar limestone are strewn over the outcrop of the Lospe formation a mile to 1½ miles southeast of locality 258. The limestone was not found on the high terrace north of that area, indicating that lenticular marine deposits have been removed by erosion. Thin marine strata crop out on the highest terrace also at localities 259 and 260.

Finely ground fragments of marine fossils occur in cemented sandstone and grit at an altitude of 600 feet on the platform of an extensive intermediate terrace at locality 261. The sandstone and grit include cobbles and angular rubble, and are a foot to two feet thick.

At locality 263 marine fossils are abundant in gravel on the platform at the rear of the lowest terrace at an altitude of 115 feet. The gravel includes some sand and angular rubble. It is as much as 5 feet thick, but the thickness is variable owing to the very irregular surface of the terrace platform. A lens of cleanly washed fossiliferous sand and grit having a maximum thickness of 3 feet is located at an altitude of 40 feet close to the seaward edge of the lowest terrace at locality 262. Lenses of sand and gravel containing fragmentary remains of marine fossils were observed at a few other localities along the cliff at the seaward edge of the lowest terrace.

Nonmarine deposits, constituting the nonmarine terrace cover,[36] overlie the marine deposits just described or in their absence rest directly on the terrace platform. These deposits consist of sand, gravel, and rubble, for the most part poorly sorted and poorly stratified. They have a maximum thickness of about 100 feet. The sand is rilled and fluted, and much of it is reddish brown in color. Strongly rilled and fluted sand forming the nonmarine cover on the highest terrace is shown on figure 9 *C*, and the nonmarine cover on the lowest terrace is shown in the view on figure 8 *D*.

Along the coast from Point Sal northward beyond Mussel Rock, the terrace deposits are covered by a veneer of dune sand. Dune sand and terrace sand spill down over the cliff and it is impracticable to show the narrow cliff-face band of terrace deposits at the few localities where those deposits are exposed.

FOSSILS

Fossils from marine deposits on the marine terraces are listed in the following table. Localities 258, 259, and 260 represent the highest terrace at an altitude of about 800 feet above sea level; locality 261 represents an intermediate terrace at an altitude of about 600 feet; localities 262 and 263 are on the lowest terrace, the platform of which has an approximate altitude range of 50 to 125 feet.

Marine shells found at or near the surface of the nonmarine cover on marine terraces are kitchen-midden shells. They are common in dark-colored sand, containing much organic material, on an intermediate terrace three-quarters of a mile north-northwest of Lions Head close to springs issuing at the base of the terrace deposits. This is clearly a site occupied by aboriginal inhabitants. Species that are still used for food—mussel (*Mytilus californianus*), Pismo clam (*Pachydesma crassatelloides*) and rock clam (*Protothaca staminea*)—are most abundant at that locality.

[36] Woodring, W. P., Bramlette, N. M., and Kew, W. S. W., op. cit., pp. 106-107, 113-114.

Fossils from marine deposits on marine terraces

[Identifications by W. P. Woodring. P, Observed in field but not collected. For explanation of other symbols see p. 67.]

Species	Localities					
	258	259	260	261	262	263
Echinoid: *Strongylocentrotus* sp		X				
Chiton: *Stenoplax* cf. *S. heathiana* Berry					sp.	X
Gastropods:						
Acmaea mitra Eschscholtz						X
Acmaea limatula Carpenter						X
Acmaea pelta Eschscholtz						X
Acmaea scabra (Gould)	X	cf.	X			X
Acmaea insessa (Hinds)					X	
Haliotis cracherodii Leach						X
Megatebennus bimaculatus (Dall)					X	
Norrisia cf. *N. norrisi* (Sowerby)						X
Tegula funebralis (A. Adams)	X	cf.	X			X
Tegula cf. *T. montereyi* (Fischer)						X
Pupillaria pupilla (Gould)						X
Littorina scutulata Gould						X
Bittium eschrichtii (Middendorff)					X	
Seila montereyensis Bartsch						X
Aletes squamigerus Carpenter					X	X
Hipponix antiquatus (Linné)						X
Crepidula adunca Sowerby					X	X
Crepidula onyx Sowerby						X
Crepidula nummaria Gould					X	X
Neverita reclusiana (Deshayes)						X
Trivia californica (Gray)						X
Opalia chacei Strong						X
"*Nassa*" *fossata* (Gould)					X	X
"*Nassa*" *mendica cooperi* Forbes						X
Pterorytis foliatus (Gmelin)						X
Tritonalia lurida (Middendorff)	sp.				X	cf.
Nucella lamellosa (Gmelin)			X		X	X
Mitrella carinata gausapata (Gould)					X	sp.
Amphissa versicolor Dall					X	X
Olivella biplicata (Sowerby)						X
Olivella pedroana (Conrad)					X	X
Megasurcula cf. *M. carpenteriana* (Gabb)						X
Gadinia reticulata (Sowerby)					X	
Pelecypods:						
Mytilus cf. *M. californianus* (Conrad)	X				sp.	X
Chlamys sp					X	
Tellina bodegensis Hinds					X	X
Macoma sp					X	
Schizothaerus cf. *S. nuttallii* (Conrad)					X	X
Protothaca staminea (Conrad)				P	X	X
Petricola carditoides (Conrad)						X
Cerastoderma cf. *C. nuttallii* (Conrad)					X	
Cryptomya californica (Conrad)						X
Siliqua cf. *S. patula* (Dixon)					X	
Pholadidea penita (Conrad)					X	
Zirfaea pilsbryi Lowe						X
Barnacles:						
Balanus cf. *B. aquila* Pilsbry					X	
Balanus sp	X	X	X		X	X
Balanus cf. *B. glandula* Darwin					X	
Tetraclita sp	X		X		X	

RECENT SERIES

DUNE SAND

Dune sand is distributed widely along the south border of the Santa Maria Valley and extends inland from the coast on San Antonio terrace at the southwest border of the mapped area. Under the heading "Physiography" the dunes are classified as old, intermediate, and modern. All the dune sand is considered Recent, the youngest division consisting of sand that is now moving. The corresponding sets of dune sand are shown on the geologic map (pl. 1). The intermediate dunes are probably not much older than the modern dunes, and differentiation between these two sets is locally indefinite. The dune sand is probably nowhere more than 100 feet thick and much of the old dune sand, which has been considerably modified by erosion, is not more than 10 to 25 feet thick.

The dune sand is better sorted than typical sand in the Orcutt and other terrace deposits, and exposures of the dune sand are not strongly rilled and fluted. Well-sorted sand exposed at some places at the top of the Orcutt sand was probably more or less winnowed by the wind soon after deposition. Exposures showing the internal structure of the dunes are rare. Cuts on U. S. Highway 101, covered with road oil to insure stability, show strong cross-bedding in the old dune sand.

The sand that extends up the north flank of Point Sal Ridge, overlapping the Fransiscan basement and reaching an altitude of 1,200 feet above sea level on the crest of the ridge, is shown as Orcutt sand on the geologic map (pl. 1), but is perhaps old dune sand. The old dune sand, however, has a well-defined inland border 1¼ miles southeast of Mussel Rock, and the sand identified as Orcutt has a different topographic expression, like that of the Orcutt in other areas.

ALLUVIUM

The most extensive area of alluvium in the mapped region is in the Santa Maria Valley. The following brief description of alluvium in the valley is extracted from a report by G. F. Worts, Jr., prepared under the supervision of J. E. Upson for the Geological Survey's Division of Ground Water.[37]

According to logs of water wells and oil wells, the thickness of the alluvium ranges from 50 feet along Sisquoc River to 230 feet at the coast, the westward increase being fairly uniform. Two members are recognized: a lower coarse-grained member and an upper fine-grained member; both in general decrease in grain size westward. The lower member consists principally of coarse gravel, including boulders, and sand. Near the coast it includes minor lenses of clay. Throughout most of the Santa Maria Valley the upper member is made up of gravel and sand, grading westward into sand and silt with progressively less gravel. Near the coast it consists of clay and silt, with which some sand and fine gravel are interbedded. Along Sisquoc River the two members are indistinguishable, both consisting of coarse gravel and sand. They are also indistinguishable in the eastern part of the Santa Maria Valley, where they are made up chiefly of gravel and sand. The clay beds near the coast are probably marine; the other alluvial deposits are fluvial.

[37] Worts, G. F., Jr., Geology and ground-water resources of the Santa Maria Valley, Santa Barbara County, Calif.: U. S. Geol. Survey, Water Supply Paper 1000 (in preparation).

MINERALOGY OF SANDSTONE FROM PASO ROBLES FORMATION, CAREAGA SANDSTONE, FOXEN MUDSTONE, AND SISQUOC FORMATION

The mineralogy of 77 samples of sandstone from the Paso Robles formation, Careaga sandstone, Foxen mudstone, and Sisquoc formation was determined to test the possible value of such data as a check on stratigraphic relations, particularly on stratigraphic relations between outcropping strata and those penetrated by oil wells. The results were found to be unpromising and therefore this work was discontinued. The data, however, are presented in the accompanying table, for they may be of some value in other studies, such as possible sources of the sediments.

Quartz constitutes less than 50 percent of the total minerals, as in most Tertiary sandstones of California, and is commonly less than the total of alkalic feldspar and andesine. Chert grains are locally common and in two samples from the Foxen mudstone constitute half or more of the total. This chert is derived evidently from the Monterey shale and includes many silicified Foraminifera from that formation. Though thin beds of nearly pure volcanic ash are not uncommon in the Sisquoc formation and Foxen mudstone, only one sample of sandstone (a sample from the Tinaquaic sandstone member of the Sisquoc formation) contains much volcanic glass. The determination of some grains in the light-mineral fraction is difficult and their percentages are less accurately shown than those of the heavy minerals.

The heavy minerals, which have a specific gravity greater than that of bromoform (about 2.85), are generally less than one percent of the total. The percentages of heavy minerals are tabulated, however, on a basis of 100 percent for the total of this small heavy-mineral fraction. Titanite, epidote, zircon, and the opaque minerals are the most common, but variations in their relative abundance are large and show little apparent relation to stratigraphic occurrence.

Mineral composition of sandstone from Paso Robles formation, Careaga sandstone, Foxen mudstone, and Sisquoc formation

[R, less than 1 percent; F, few sponge spicules; C, common sponge spicules; S, some phosphatic pellets]

Sample locality and number	Percentage of light-mineral fraction							Percentage of heavy minerals	Percentage of heavy-mineral fraction																						Formation
	Quartz	Alkalic feldspar	Andesine	Chert	Aphanitic	Volcanic glass	Sponge spicules		Leucoxene	Black opaque	Chromite	Zircon	Garnet	Tourmaline	Rutile	Anatase	Brookite	Titanite	Hornblende	Actinolite	Pyroxene	Epidote	Andalusite	Glaucophane	Muscovite	Biotite (brown)	Biotite (green)	Chlorite	Glauconite	Phosphatic pellets	
Purisima Hills, 198a	30	25	15	20	10	----	----	1.3	4	10	2	16	5	R	R	R	----	25	----	----	----	37	----	----	----	----	----	----	----	----	Paso Robles formation.
Purisima Hills, 103	20	25	25	25	5	----	----	.7	5	10	2	12	5	4	R	R	----	20	3	----	----	30	----	R	1	R	----	----	----	----	
Purisima Hills, 21	35	20	20	20	5	?	----	.6	6	12	3	20	8	R	R	R	----	23	3	----	----	25	----	R	R	----	----	----	----	----	
Purisima Hills, 186	50	25	5	15	5	----	F	.7	3	14	4	23	8	2	1	2	----	24	----	----	----	18	R	R	R	----	----	R	----	----	Careaga sandstone.
Purisima Hills, 300	20	35	25	8	12	----	----	.3	12	10	1	20	6	3	R	4	----	20	----	----	----	20	R	R	1	----	----	----	----	----	
Purisima Hills, 301	25	35	20	7	13	----	F	.3	16	7	1	20	3	2	1	5	----	25	----	----	----	20	R	R	R	----	----	----	----	----	
Purisima Hills, 1	40	30	15	2	13	----	----	.9	7	8	1	26	6	1	R	1	R	27	----	----	----	22	R	----	R	----	----	----	----	----	
Purisima Hills, 2	40	30	15	6	9	----	----	.6	12	11	2	19	6	2	R	2	----	23	----	----	----	21	R	R	1	----	----	----	----	----	
Purisima Hills, 225	25	25	25	14	11	----	C	.4	12	13	R	23	4	2	1	2	R	27	----	----	----	14	R	----	1	----	----	----	----	----	
Purisima Hills, 173	30	30	15	10	15	----	F	1.0	8	12	1	22	5	2	2	1	----	25	----	----	----	21	R	----	R	----	----	----	----	----	
Purisima Hills, 54	25	25	20	20	10	----	----	.4	9	12	1	21	4	2	1	3	----	26	----	----	----	20	R	R	1	----	----	----	----	----	
Purisima Hills, 46	35	30	20	3	12	----	----	1.3	10	16	R	18	5	2	1	R	----	28	----	----	----	19	----	R	----	----	----	----	----	----	
Purisima Hills, 193	40	30	15	3	12	----	----	.4	8	9	1	17	6	2	R	R	----	33	R	R	----	23	R	R	1	----	----	----	----	----	
Purisima Hills, 193a	35	25	20	5	15	----	----	.4	5	10	R	20	6	2	1	R	----	28	----	R	----	28	R	----	----	----	----	----	----	----	
Purisima Hills, 46	40	25	15	5	15	----	----	2.0	7	12	R	18	5	1	1	1	----	30	R	R	----	25	R	----	----	----	----	----	----	----	
Purisima Hills, 37a, concretion	40	40	5	2	10	3	R	.2	6	15	R	13	4	1	1	3	R	33	R	----	----	22	----	----	1	----	1	----	----	----	
Purisima Hills, 37	40	40	5	3	9	3	R	.1	5	20	R	10	5	2	2	3	----	45	----	----	----	5	----	----	2	----	1	----	----	----	
Purisima Hills, 13	25	30	30	4	11	----	----	.6	8	9	2	20	6	3	R	1	----	28	----	----	----	22	R	R	R	----	----	----	----	----	
Purisima Hills, 130	40	30	15	2	13	----	C	.8	7	11	3	28	8	3	2	1	----	23	----	----	----	14	R	----	R	----	----	----	----	S	
Purisima Hills, 13a	45	35	6	4	10	----	----	1.4	4	20	4	10	10	R	R	R	R	25	----	----	----	26	R	----	----	----	----	----	----	----	
Purisima Hills, 331	40	25	20	5	10	----	F	.7	5	13	1	15	4	1	R	R	R	40	----	----	----	20	----	R	----	----	----	----	----	----	
Graciosa Ridge, near Union Oil Co. well Squires No. 4	40	35	15	5	5	----	----	.8	7	9	3	19	6	2	R	R	----	40	----	----	----	14	----	----	----	----	----	----	----	----	
Purisima Hills, 331a	40	25	20	4	11	----	----	.6	9	9	5	15	10	2	2	R	R	32	----	----	----	16	----	----	----	----	----	----	----	----	
Purisima Hills, 271	40	35	10	8	7	----	----	.2	4	14	2	15	4	1	R	----	----	45	----	----	----	15	R	R	----	----	----	----	----	S	
Purisima Hills, 316	30	25	15	25	5	?	C	.4	8	13	4	23	7	1	1	2	----	23	----	----	----	18	R	R	----	----	----	----	----	----	
Purisima Hills, 2a	40	35	15	5	5	?	----	.2	12	9	1	19	5	2	R	2	----	26	----	R	----	22	R	----	2	----	----	----	----	----	
Union Oil Co. well Rice No. 1, Santa Maria Valley field, depth 1,014 feet	35	35	10	3	17	----	F	1.0	?	15	1	20	6	2	1	R	----	30	----	----	----	25	----	----	----	----	----	----	----	----	
Fugler Point	40	40	10	5	5	----	R	.3	4	13	6	20	5	2	1	3	R	28	----	R	----	16	----	----	2	----	----	R	R	----	
Railroad cut near Shuman, 27	35	35	10	10	10	----	----	.1	?	27	?	6	3	R	R	1	----	35	----	----	----	26	----	----	2	R	----	----	----	----	
Railroad cut near Shuman, 26	40	30	10	12	8	----	----	.8	?	16	2	12	8	3	1	2	1	30	----	----	----	20	R	----	1	2	1	----	----	----	
Railroad cut near Shuman, 25	40	40	10	5	5	----	----	.8	?	18	?	18	4	2	1	3	R	25	----	R	----	25	R	----	1	1	1	----	----	----	
Railroad cut near Shuman, 24	40	25	15	5	15	----	----	.4	?	18	2	10	8	1	R	1	----	35	----	R	----	20	----	----	4	R	----	----	1	----	
Railroad cut near Shuman, 23	40	35	15	5	5	----	----	.5	?	19	3	11	7	4	R	----	----	32	R	R	----	18	R	----	3	R	3	----	----	----	Foxen mudstone.
Railroad cut near Shuman, 22	35	40	15	6	4	----	----	.7	?	15	1	10	8	4	R	R	----	36	?	----	----	26	----	----	R	R	----	----	R	S	
Railroad cut near Shuman, 20	35	35	10	15	5	----	F	.3	?	20	5	10	7	3	1	1	R	26	----	----	----	26	----	R	1	R	R	----	R	----	
Railroad cut near Shuman, 20a	35	30	10	15	10	----	F	.2	?	21	5	12	10	1	1	2	----	26	----	----	----	21	----	----	1	R	----	----	----	----	
Railroad cut near Shuman, 19	35	35	15	5	10	----	----	.5	12	10	3	20	5	2	2	1	----	35	----	----	----	10	----	----	----	----	----	----	----	----	
Railroad cut near Shuman, 18	40	30	10	15	5	----	F	.4	14	11	4	24	3	2	2	5	----	28	----	----	----	8	----	R	----	----	----	----	----	----	
Purisima Hills, 312	15	15	15	50	5	----	C	.3	10	15	11	21	5	2	1	R	----	24	----	----	----	9	R	R	1	----	----	----	----	----	
Purisima Hills, PH3	20	10	10	55	5	----	F	.4	6	28	13	20	10	R	R	----	----	21	----	----	----	2	----	R	----	----	----	----	R	----	
Purisima Hills, 311	35	20	10	30	5	----	F	.3	?	21	8	15	8	2	1	1	----	24	----	----	----	18	----	----	----	----	----	----	----	S	
Purisima Hills, 306	35	20	5	33	7	----	C	.6	3	25	6	15	10	3	R	1	----	20	----	----	----	15	R	R	----	----	----	----	----	S	
Union Oil Co. well Rice No. 1, Santa Maria Valley field, depth 1,226 to 1,249 feet	35	30	10	5	20	----	F	.5	3	21	5	28	9	2	1	4	----	24	----	----	----	3	R	R	----	----	----	----	----	----	
Union Oil Co. well Rice No. 1, Santa Maria Valley field, depth 1,453 feet	40	30	10	10	10	----	F	.6	3	12	3	15	7	3	R	R	----	30	----	R	----	26	----	R	----	----	----	----	----	----	
Union Oil Co. well Leroy No. 1, Santa Maria Valley field, depth 1,905 feet	30	25	15	15	15	----	R	.5	8	17	8	23	10	5	1	----	----	26	----	----	----	1	R	R	----	----	----	1	----	S	
Union Oil Co. well Leroy No. 1, Santa Maria Valley field, depth 2,900 feet	40	30	10	15	5	----	----	.6	10	17	8	20	8	3	1	1	----	25	----	----	----	4	R	R	2	----	----	----	----	----	
Union Oil Co. well Enos No. 1, Santa Maria Valley field, depth 2,716 feet	40	20	15	20	5	----	----	.4	6	15	8	27	8	4	R	R	----	30	----	R	----	1	----	R	R	----	----	----	----	----	
Standard Oil Co. well Las Flores No. 1, West Cat Canyon field, depth 1,410 feet	40	30	15	10	5	----	F	.5	10	11	5	30	11	3	1	1	----	23	----	----	----	----	----	R	5	----	----	----	----	----	
Standard Oil Co. well Las Flores No. 1, West Cat Canyon field, depth 1,505 feet	40	30	15	15	----	----	R	.3	10	14	4	30	10	3	1	2	----	20	----	----	----	----	R	----	5	----	----	----	----	----	

Sisquoc Ranch, 2	40	35	20	2	3	----	F	.6	3	14	5	18	5	2	R	1	----	36	R	----	----	16	----	R	----	----	----	----	----	----	Tinaquaic sandstone member of Sisquoc formation.
Sisquoc Ranch, 3	40	30	10	15	3	2	R	.8	4	10	5	9	6	R	R	R	----	30	6	----	----	30	----	R	----	----	----	----	----	----	
Sisquoc Ranch, 4	25	15	10	10	5	35	C	.7	8	12	3	8	2	R	R	R	----	40	8	4	----	13	----	R	2	----	----	----	----	----	
Sisquoc Ranch, 5	40	25	20	12	3	----	F	.8	10	11	4	9	3	1	R	R	----	35	5	----	----	17	----	R	2	----	----	----	----	----	
Sisquoc Ranch, 6	35	35	20	10	----	----	R	.9	5	11	4	5	3	1	R	----	----	40	R	R	----	30	R	R	1	----	----	----	----	----	
Sisquoc Ranch, 7	35	30	15	15	5	----	F	.8	6	11	4	15	4	1	R	2	----	23	12	3	----	20	----	R	R	R	----	----	----	----	
Sisquoc Ranch, 8	35	35	15	12	3	----	----	.4	8	22	3	8	9	R	R	----	----	36	R	----	----	14	----	----	----	----	----	----	----	----	
Sisquoc Ranch, 13	40	35	10	15	----	----	F	.8	?	16	8	9	4	1	R	R	----	32	4	2	----	24	----	R	----	----	----	----	----	----	
Sisquoc Ranch, 542	40	25	15	15	5	----	F	.9	6	18	3	3	4	R	----	----	----	28	1	1	----	36	----	----	R	----	----	R	----	----	
Sisquoc Ranch, 543	25	20	20	30	5	----	F	.4	3	23	6	20	5	3	R	R	----	25	R	----	----	15	R	R	R	R	----	----	----	----	
Gato Ridge	40	35	15	5	5	----	R	.6	8	16	8	21	8	2	R	2	----	19	R	----	----	15	----	R	----	----	----	----	----	----	Sisquoc formation.
Railroad cut near Shuman, 4, tar sand	40	40	10	3	----	2	F	.4	3	45	20	13	1	3	3	----	----	12	----	----	----	----	----	----	----	----	----	----	----	----	
Purisima Hills, 228	35	25	25	6	8	1	F	.3	14	14	6	20	3	3	1	2	----	18	R	----	----	15	R	1	3	----	----	----	----	----	
Purisima Hills, 32	25	25	15	25	10	----	F	.2	18	15	4	20	9	2	2	2	----	26	----	----	----	2	R	R	----	----	----	----	----	----	
Purisima Hills, 233*a*	35	25	20	8	12	----	F	1.0	5	10	2	25	7	1	R	----	----	30	----	----	----	20	R	R	----	----	----	----	----	----	
Purisima Hills, 290	40	30	15	4	10	1	C	.2	4	8	7	30	4	1	1	R	----	45	----	----	----	----	----	R	----	----	----	----	----	----	
Purisima Hills, 334	35	25	20	10	10	R	C	.5	10	10	3	12	3	1	1	R	----	31	----	1	----	26	----	2	----	----	----	----	----	----	
Standard Oil Co. well Las Flores No. 1, West Cat Canyon field, depth 2,422 feet	40	30	15	7	8	----	----	.3	5	32	17	22	16	5	R	1	----	1	----	----	----	----	----	----	----	----	----	----	----	----	
Standard Oil Co. well Las Flores No. 1, West Cat Canyon field, depth 3,705 feet	45	25	15	5	10	----	----	.2	12	15	8	30	20	3	2	1	----	----	----	----	----	----	----	----	----	4	4	----	----	----	
Standard Oil Co. well Las Flores No. 1, West Cat Canyon field, depth 4,013 feet	40	30	15	5	10	----	----	.3	14	16	8	26	14	8	2	R	R	R	----	R	2	----	----	R	2	5	5	----	----	----	
Standard Oil Co. well Las Flores No. 1, West Cat Canyon field, depth 4,238 feet	50	20	12	3	15	----	----	.2	10	14	6	32	20	7	1	----	----	2	----	----	----	R	----	R	2	4	2	----	----	----	
Standard Oil Co. well Las Flores No. 1, West Cat Canyon field, depth 4,398 feet	40	20	20	5	15	----	----	.2	10	13	12	30	15	7	3	2	----	2	----	----	----	----	----	R	2	3	1	----	----	----	
Barnsdall Oil Co. well Tognazzini No. 2, Gato Ridge field, depth 911 feet	30	25	20	15	10	----	F	.7	2	23	4	28	7	2	R	R	----	32	----	----	----	----	----	R	----	1	1	----	----	----	
Union Oil Co. well Enos No. 1, Santa Maria Valley field, depth 2,751 feet	35	20	20	12	13	----	F	.5	5	21	8	27	11	2	R	R	----	26	----	----	----	----	----	R	----	----	----	----	----	----	
Union Oil Co. well Leroy No. 1, Santa Maria Valley field, depth 3,064 feet	25	20	20	20	15	----	F	.3	11	14	4	22	10	3	1	1	----	24	----	----	----	----	----	1	3	3	3	----	----	----	
Union Oil Co. well Leroy No. 1, Santa Maria Valley field, depth 3,277 feet	30	20	20	10	15	----	F	.5	6	15	6	28	11	3	2	----	----	28	----	----	----	----	----	1	----	----	----	----	----	S	
Union Oil Co. well Rice No. 1, Santa Maria Valley field, depth 1,497 feet	35	20	10	20	13	2	C	.4	5	15	6	24	7	6	1	----	----	27	----	----	----	8	----	1	----	----	----	----	----	----	
Union Oil Co. well Newlove No. 51, Orcutt field, depth 1,860 feet	35	20	25	10	10	?	F	.2	8	10	9	40	21	3	4	4	R	----	----	----	----	----	----	----	1	----	----	----	----	----	

PALEONTOLOGY

FORAMINIFERA

The new species and varieties of Foraminifera mentioned and listed on preceding pages and a few other forms are described by M. N. Bramlette in the following paragraphs and are illustrated on plates 22 and 23. Dimensions of figured specimens, including types, and National Museum catalog numbers are inserted in the explanation of the plates. Footnote citations are omitted for species and varieties that may be found in the systematic catalog in Kleinpell's well-indexed book.[38] The new species and varieties are as follows:

Bolivina foxenensis Bramlette, n. sp. (p. 58).
Cassidulinoides californiensis Bramlette, n. sp. (p. 61).
"Ellipsoglandulina" fragilis Bramlette, n. sp. (p. 60).
Hopkinsina magnifica Bramlette, n. sp. (p. 59).
Pulvinulinella purisima Bramlette, n. sp. (p. 60).
Suggrunda kleinpelli Bramlette, n. sp. (p. 59).
Uvigerina foxenensis Bramlette, n. sp. (p. 59).
Virgulina californiensis var. *purisima* Bramlette, n. var. (p. 58).

Buliminidae.—The new variety *Virgulina californiensis* var. *purisima* (pl. 23, figs. 20, 25) is a large form, nearly as large as the variety *grandis*. It tends to show a more regular increase in size than *V. californiensis* and varieties of that species so far described. The sutures at the base of the chambers are in general more oblique than on the other forms. The aperture is rather prominent and almost protrudes into a neck, and is more terminal, or father separated from the suture of the adjacent chamber, than on most specimens of *V. californiensis*. An inconspicuous lip is present on the convex side of the comma-shaped aperture, but this lip is also present on other forms. The apical spine is shown only on exceptionally well preserved specimens. A longer and stouter spine is commonly shown on a variant that appears somewhat higher stratigraphically. The type locality of *V. californiensis* var. *purisima* is locality 156, a cut, exposing the lower part of the Foxen mudstone, on the Lompoc-Orcutt highway on the north slope of the Purisima Hills. This variety is found in the lower part of the Foxen mudstone and in the uppermost part of the Sisquoc formation. Although the range of variation in *V. californiensis* and its varieties makes differentiation difficult and of doubtful significance, at least very locally the different forms seem to have some stratigraphic value.

The *Virgulinella* from the upper member of the Monterey shale and the Sisquoc formation, identified as *Virgulina* (*Virgulinella*) *pertusa* (pl. 22, fig. 6), appears to be identical with topotypes of that species as figured by Cushman.[39] This California *Virgulinella* was listed by Kleinpell as *V. miocenica*. If any consistent distinction can be made in these similar species, the California form appears to be closer to *V. pertusa* in both shape and size of sutural processes. It is widespread in the California upper Miocene, but in general is not found in large numbers.

The new species *Bolivina foxenensis* (pl. 23, figs. 19, 24) has a small regularly tapering, relatively thick test. About 10 pairs of chambers are generally present. The walls are smooth, the perforations fine. The sutures are somewhat depressed between the later chambers, and are nearly straight and horizontal, except in the early stage, where they bend down near the periphery. The aperture is the usual narrow slit on the apertural face and is slightly curved. Locality 156*b*, a cut, exposing the lower part of the Foxen mudstone, on the Lompoc-Orcutt highway on the north slope of the Purisima Hills, is the type locality of this species. It occurs in the lower part of the Foxen mudstone and in the uppermost part of the Sisquoc formation, associated with variants of *Bolivina obliqua*, but does not range down into the Sisquoc formation as far as that species. *B. foxenensis* is another of the small rather nondescript Bolivinas that occur together in great abundance, are variable, and evidently closely related. It resembles *B. tumida* in size and in the nearly straight and horizontal sutures. It is, however, somewhat larger than the average *B. tumida*, and the chambers increase in size more regularly. Moreover, variants that have somewhat more oblique sutures, like those between the early chambers of the holotype of *B. foxenensis*, closely resemble some of the forms identified as a variety of *B. obliqua*. Despite the general similarity to *B. tumida*, the relationship to *B. obliqua* is evidently closer.

Bolivina obliqua (pl. 23, figs. 17, 21, 22) is locally abundant in the lower part of the Sisquoc formation. Though the Sisquoc specimen shown on plate 23, figure 22, shows somewhat more curvature of the oblique sutures than the average, it is considered the typical form. The specimen shown on plate 23, figures 17, 21, also seem to be indistinguishable from the typical form. It is from a much higher stratigraphic position in the lower part of the Foxen mudstone. The typical form is, however, rare in the lower part of the Foxen and is associated with the much more abundant variety described in the next paragraph. The exaggerated perforations of figures 17, 21, plate 23, are a matter of preservation. They are actually not larger than those of the other specimens of *Bolivina* illustrated.

The common *Bolivina* in the upper part of the Sisquoc formation and basal part of the Foxen mudstone is identified as *Bolivina obliqua* var. (pl. 23, figs. 18, 23), the figured specimen being from the upper part of the Sisquoc. This variety is more compressed and wider than the typical form, and the chambers, including the last pair, continue to increase in width. The sutures of the variety are more curved, approaching horizon-

[38] Kleinpell, R. M., Minocene stratigraphy of California, 450 pp., 22 pls., 14 figs., Tulsa, Am. Assoc. Petroleum Geologists, 1938.

[39] Cushman, J. A., A monograph of the subfamily Virgulininae of the foraminiferal family Buliminidae: Cushman Lab. Foram. Research Spec. Pub. 9, p. 31, pl. 5, figs. 6–9, 1937.

tality near the median line. Though this form appears to be sufficiently distinctive for a varietal designation, the abundant specimens in the lower part of the Foxen show complete gradation to the typical form of *B. obliqua*. Some variants in the lower part of the Foxen that show a narrow band of imperforate glassy wall not completely covered by the succeeding chamber appear to be indistinguishable from *B. rankini*.

A *Suggrunda* from the middle and upper members of the Monterey shale and the Sisquoc formation is named *Suggrunda kleinpelli* (pl. 23, figs. 4, 5, 9). The test is small, cuneiform, and thick through the median part. The chambers are biserial, 8 to 10 pairs generally present. The sutures are depressed and variable in the degree of down-curve between chambers. The later chambers overhang at the periphery and commonly terminate in backward projections, thus resembling *Bolivina pygmea* in front view. Perforations are perceptible only at magnifications of about 100. The aperture is an elongate slit parallel to the suture at the base of the inner margin of the apertural face. It is of variable length, ranging from the length of the septal line to a length less than that on the holotype. Short apertures are more arched, like that typical of *Gumbelina*. The holotype, which is better preserved than specimens from the Santa Maria district, is from the diatomaceous member of the Monterey shale exposed in a road cut on Laureles grade, near the west edge of the Salinas quadrangle, 0.4 mile south of the north line of the Corral de Tierra grant, Monterey County. *S. kleinpelli* is a very variable species, widely distributed in the upper, middle, and part of the lower Miocene of California, but in general is not abundant. Specimens that have smooth and nearly globular chambers would ordinarily be assigned to *Gumbelina*. Such specimens, however, intergrade with, and are associated with, those showing the characters of *S. kleinpelli*. The *Suggrunda* characterized by more quadrate chambers and downward projecting corners, named by Kleinpell *S. californica*, evidently developed from the form that has smooth and nearly globular chambers. *S. kleinpelli* resembles the Venezuelan *S. porosa*, the type of the genus, but the chambers of the California species enlarge more rapidly and its perforations are presumably much finer. It shows no evidence of an early planispiral stage and therefore affords no additional evidence concerning the relationship of the genus.

The new species *Uvigerina foxenensis* (pl. 23, fig. 16) is the costate *Uvigerina* that occurs in vast numbers as a "flood zone" in the lower part of the Foxen mudstone and is less common in the uppermost part of the Sisquoc formation. The test is of medium size for the genus and is rather elongate. The chambers are arranged triserially, except that the last four of mature specimens are twisted biserially. The chambers are inflated and show a tendency to overhang at their base. The costae are conspicuous, though variable, and are not as thick and heavy as the illustration may suggest. Later chambers have 12 to 15 costae, which are interrupted at the sutures, but are commonly in alignment with those of adjacent chambers. The apertural neck is rather short, has a phialine lip, and shows the tooth-like termination of the internal tube. As on many species, this so-called internal tube is actually a trough-like rod extending from one aperture to the next. The type locality is a cut on the Lompoc-Orcutt highway, on the north slope of the Purisima Hills, in the lower part of the Foxen mudstone (locality 155). This is the species listed under the nude name *Uvigerina foxeni* by Canfield.[40] Although many costate Uvigerinas have been named and are difficult to differentiate, *U. foxenensis* seems to be fairly well characterized. The twisted biserial arrangement of the last four chambers of mature specimens is the most distintive feature, more distinctive than is apparent in the illustration. This species might be assigned to *Hopkinsina*. So many species of *Uvigerina*, however, show a tendency toward a biserial arrangement of the last chambers that it may be preferable to designate as *Hopkinsina* only those in which the biserial stage is clearly dominant.

A large species found in the upper member of the Monterey shale is named *Hopkinsina magnifica* (pl. 22, figs. 1–3, 5). The test is unusually large for a *Uvigerina*-like form. The last four pairs of chambers, in twisted biserial arrangement, form about three-quarters of the length of mature specimens, the earlier triserial chambers being definitely subordinate. The chambers are distinct and inflated, but are more closely appressed than in most species of the genus. The wall is smooth and the perforations inconspicuous. The aperture is rather large, has a short neck and phialine lip, and shows the tooth-like termination of the internal tube. Microspheric forms are relatively common (pl. 22, fig. 1). The type locality is on the north side of a ravine at the north edge of Peck Park in San Pedro, Los Angeles County, in the Valmonte diatomite member of the Monterey shale (locality 20 of Professional Paper 207[41]). This fine big species is distinctive merely on account of its unusual size and robustness. It is assigned to *Hopkinsina* on account of the dominant twisted biserial stage. *Hopkinsina*, however, might better be classed as a subgenus of *Uvigerina*, as many species assigned to *Uvigerina* show varying degrees of biserial arrangement in the last chambers. *H. magnifica* is found in the middle and upper parts of the Mohnian stage of the upper Miocene, its acme being in the *Bolivina hughesi* zone of the upper Mohnian. Early representatives tend to be shorter and to show less development of the biserial arrangement. This species seems to have

[40] Canfield, C. R., Subsurface stratigraphy of Santa Maria Valley oil field and adjacent parts of Santa Maria Valley, Calif.: Am. Assoc. Petroleum Geologists Bull. vol. 23, no. 1, pp. 56, 57, 1939.

[41] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., Geology and paleontology of Palos Verdes Hills, Calif.: U. S. Geol. Survey Prof. Paper 207, p. 121, 1946.

developed from a middle Mohnian finely costate form that is otherwise similar.

Ellipsoidinidae.—The new species "*Ellipsoglandulina*" *fragilis* (pl. 22, figs. 4, 8–10) is another large species from the upper member of the Monterey shale. In association with other upper Monterey species it was found at locality 21 in strata mapped as the Todos Santos claystone member of the Sisquoc formation. Mashed specimens from the middle member of the Monterey are doubtfully referred to it. The test is unusually large, the length normally more than twice the diameter, and the apertural end tapers less than the apical end. The chambers are uniserial, 7 or 8 being the usual number. The chambers overlap strongly, the last one forming half or more of the length. The sutures are not depressed and are quite obscure in mashed specimens. The walls are smooth and thin, the perforations too fine to be observed under normal magnification. The aperture is terminal, crescentic or comma-shaped, and has a flange-like tooth along the convex side. The internal tube is terminated by the apertural tooth. Rare specimens, which are larger, more inflated, and have a smaller proloculus, doubtless represent the microspheric form (pl. 22, fig. 9). The types are from the weathered "rind" of a calcareous concretion in a road-cut exposure of the upper member of the Monterey formation (Modelo formation of some geologists), 0.32 mile S. 17° E. from the junction of Ventura Boulevard and Dixie Canyon Road (in the second canyon west of that followed by Coldwater Canyon Road), on the north slope of the Santa Monica Mountains, Los Angeles County. "*E.*" *fragilis* ranges from the upper Mohnian to the lower Delmontian of the upper Miocene of southern California, its acme being near the boundary of those two stages. This unusually large species has thin walls and is so fragile that it is especially susceptible to crushing in compacted sediments. Bedding planes of shale commonly show a great abundance of "pancaked" specimens. Undeformed specimens are found only in limestone concretions.

The species listed by Wissler[42] as "*Bulimina* sp. (large, crushed)", in his zones B and C of the Delmontian of the Los Angeles Basin, is "*E.*" *fragilis*. Assignment to the genus *Ellipsoglandulina* is tentative. No internal tube is indicated in an otherwise similar form designated *Daucina* by Bornemann.[43] The thin walls and apertural characters suggest a close relationship to *Bulimina*, particularly to the subgenus *Desinobulimina*. "*E.*" *fragilis* may prove to have developed from *Desinobulimina*, which tends toward a uniserial arrangement and terminal aperture in the last chamber. Occasional specimens of "*E.*" *fragilis* suggest an early triserial stage like that of *Bulimina*, and some forms from the lower Mohnian, similar in size and shape to "*E.*" *fragilis*, appear to have a more irregular chamber arrangement. Some of the early chambers of these lower Mohnian forms seem in thin section to be much like *Desinobulimina*, but preservation is not good enough for definite identification.

Rotaliidae.—The Sisquoc species identified as *Eponides* cf. *E. peruvianus* (pl. 23, figs. 1–3) appears to be rather different from the conventionalized original figure of d'Orbigny, but resembles the Recent form from the west coast of South America assigned to *E. peruvianus* by Cushman and Kellett.[44] In their synonymy it is listed as *Rosalina peruviana*, but according to the citation it is evident that they meant *Rotalina peruviana*, *Rosalina peruviana* being quite different. The Sisquoc form shows more curvature of the sutures on the ventral side and perhaps somewhat less inflation of the chambers on that side than is indicated for the Recent species. The sharpness of the angle at the periphery is rather variable. *E.* cf. *E. peruvianus* is common in the Sisquoc formation. A similar, but somewhat larger form, occurs in the Foxen mudstone.

Eponides cf. *E. patagonicus* (pl. 23, figs. 6–8) closely resembles the Recent *E. patagonicus* and probably is that species. It is common in the Sisquoc formation below the faunal zone characterizing the uppermost part of the formation and the basal part of the Foxen mudstone. Similar, or perhaps identical, forms are wide ranging elsewhere.

Cassidulinidae.—A species occurring in the uppermost part of the Monterey shale and at locality 21, in strata mapped as the Todos Santos claystone member of the Sisquoc formation, is named *Pulvinulinella purisima*[44a] (pl. 23, figs. 10–15). It is rather large for the genus. The chambers are arranged in a compressed low trochoid coil, 9 or 10 generally present in the last whorl. The sutures are somewhat depressed, and are almost radial near the center, but curve back on the outer half of both dorsal and ventral sides. The aperture is a somewhat curved slit extending out in the axis of coiling nearly to the periphery in the apertural face. This species resembles the lower Mohnian *P. capitanensis* and might be classed as a variety of that species. The relations of the two, however, are not clear and forms connecting them are not known. *P. capitanensis* is more nearly complanate and shows less curvature of the sutures. It also normally has fewer chambers in the last whorl and the sutures are not so depressed. *P. purisima* tends to develop variants that are thicker than the typical form, the ventral side being more convex and the dorsal side flat or even

[42] Wissler, S. G., Stratigraphic relations of the producing zones of the Los Angeles Basin oil fields: California Div. Mines Bull. 118, p. 210, 1941.

[43] See Ellis, B. F., and Messina, A. R., Catalogue of Foraminifera: Am. Mus. Nat. History Special Pub., vol. 6, 1940.

[44] Cushman, J. A., and Kellett, Betty, Recent Foraminifera from the west coast of South America: U. S. Nat. Mus. Proc., vol. 75, art. 25, p. 10, pl. 4, figs. 5a–c, 1929.

[44a] *Pseudoparrella* has recently been proposed for *Pulvinulinella*, which is a homonym. (Cushman, J. A., and ten Dam, A., *Pseudoparrella*, a new generic name, and a new species of *Parrella:* Cushman Lab. Foram. Research Contr., vol. 24, no. 3, p. 49, 1948.)

concave. The type material is from a calcareous concretion in the Monterey formation (Modelo formation of some geologists) on the east slope of the spur 0.35 mile, S. 30° E. from the intersection of Ventura Boulevard and Topanga Canyon Avenue, near Woodland Hills (formerly known as Girard) on the north slope of the Santa Monica Mountains, Los Angeles County. *P. purisima* is common in the type region through about 500 feet of the strata between the upper Miocene *Bolivina hughesi* zone and *Bolivina obliqua* zone. Kleinpell assigned these strata to his Delmontian stage and included them in his *Bolivina obliqua* zone. That action, however, was arbitrarily taken because of the lack of faunal evidence. These strata (Hoots' [45] unit 17 and also his units 16 and 15), which contain a distinctive fauna, lie between the *Bolivina hughesi* zone and the *Bolivina obliqua* zone and seem to be best assigned to the lower Delmontian. *P. purisima* and a similar faunal association occur in the same stratigraphic position in the southeastern Puente Hills. Elsewhere its range may prove to be less restricted.

The new species *Cassidulinoides californiensis* (pl. 22, fig. 7) is common in the uppermost part of the Monterey shale in the Purisima Hills and occurs also in the Sisquoc formation. The test is small, not compressed in the axis of coiling, and the periphery is rounded. The chambers, generally five pairs, are biserial. The later chambers increase rapidly in size and are partially uncoiled. The overlap of the chambers along the periphery, on the side opposite that shown on figure 7 of plate 22, is similar to the overlap shown by *C. cornuta* [46] and other species of the genus. The sutures are somewhat depressed. The wall is smooth, the perforations not perceptible under normal magnifications. The comma-shaped aperture extends out from the apertural face nearly at right angles to the septal suture, and apparently continues down about the same distance as a narrower slit along the septal suture. Some specimens, possibly microspheric, that have more chambers than the typical form, are more uncoiled, but not to the extent of *C. parkeriana* [47] or even of *C. erecta*.[48] The type locality of *C. californiensis* is locality 21, where it occurs in strata mapped as the Todos Santos claystone member of the Sisquoc formation. It is found in strata of lower Delmontian age in the Los Angeles region and also in the lower Mohnian of that region.

[45] Hoots, H. W., Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, Calif.: U. S. Geol. Survey Prof. Paper 165, p. 103, 1931.

[46] Cushman, J. A., op. cit., p. 28, pl. 4, figs. 20–21, 1937 (as *Virgulina*).

MEGAFOSSILS

The stratigraphic distribution of megafossils in formations of the Santa Maria district is shown in the table on pages 62–66. In order to correlate differences in nomenclature, the names used by Arnold in Bulletin 322 [49] are cited opposite the names used in the present report. A few of Arnold's indefinitely identified forms are not listed under his names, either because they are not represented in the collections studied or because it is uncertain what form was intended. Some of Arnold's names cannot be matched with specimens now in his collections. He did not identify a considerable number of species in some collections, particularly in his Waldorf asphalt mine collection.

[47] Brady, H. B., *Challenger* Rept., Zoology, vol. 9, p. 432, pl. 54, figs. 11–16, London, 1884.

[48] Cushman, J. A., and Renz, H. H., New Oligocene-Miocene Foraminifera from Venezuela: Cushman Lab. Foram. Research Contr., vol. 17, p. 25, pl. 4, figs. 6, 7, 1941.

[49] Arnold, Ralph, and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull., 322), pp. 58–60, pls. 21–26, 1907.

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Stratigraphic distribution of fossils in formations of Santa Maria district

Name used in present report	Formation and member: Sisquoc formation: Tinaquaic sandstone member	Sisquoc formation: Diatomaceous strata	Foxen mudstone	Careaga sandstone: Cebada fine-grained member	Careaga sandstone: Graciosa coarse-grained member	Careaga sandstone: Undifferentiated	Paso Robles formation	Orcutt sand	Name used by Arnold in Bulletin 322
Coral: *Dendrophyllia* sp			X	X					
Echinoids:									
Dendraster cf. *D. coalingaensis* Twitchell (pl. 7, figs. 6, 8).	X								
Dendraster ashleyi (Arnold) (pl. 17, figs. 11, 12; pl. 18, figs. 12–14; pl. 19, fig. 6; pl. 20, figs. 1, 5, 6).					X	X			*Echinarachinus ashleyi* Merriam. *Echinarachnius* cf. *excentricus* Eschscholtz var.
Merriamaster cf. *M. perrini* (Weaver) (pl. 10, figs. 11–14).			X						
Brachiopods:									
Glottidia cf. *G. albida* (Hinds)				X					
Discinisca cf. *D. cumingii* (Broderip)				X					
Terebratalia occidentalis (Dall) (pl. 13, figs. 1–4, 8, 9, 25).				X					*Terebratalia occidentalis* Dall.
Chiton: *Callistochitom* sp				X					
Gastropods:									
Acmaea cf. *A. funiculata* (Carpenter)				X					
Megathura crenulata (Sowerby)?				X					*Lucapino* cf. *crenulata* Sowerby.
Diodora aspera (Eschscholtz)				X					
Puncturella cucullata (Gould) (pl. 10, figs. 5, 6)			X	?					
Puncturella cooperi aphales Woodring, n. var. (pl. 12, figs. 2, 3).			X	X					
Tegula? sp				X					
Calliostoma coalingense catoteron Woodring, n. var. (pl. 13, figs. 5, 6, 10).		sp.		X					?*Calliostoma* sp. indet.
Calliostoma virgineum (Dillwyn)				X	sp.				
Calliostoma cf. *C. virgineum* (Dillwyn)				X					
Calliostoma cf. *C. gemmulatum* Carpenter				X					
Calliostoma cf. *C. ligatum* (Gould)				X					
Calliostoma sp				X					
Cidarina cidaris (A. Adams), n. var.? (pl. 12, fig. 11).				X					
Turcica imperialis brevis Stewart (pl. 12, figs. 9, 10, 12, 14).			?	X					*Thalotia caffea* Gabb.
Solariella n. sp.? (pl. 13, figs. 7, 11)				X					
Pupillaria cf. *P. optabilis* (Carpenter)				X	X				
Vitrinella stearnsi Bartsch, var. (pl. 12, figs. 6–8).				X					
Pseudorotella? cf. *P. supravallata* (Carpenter)				X					
Pachypoma cf. *P. gibberosum* (Dillwyn)				X					
Homalopoma cf. *H. paucicostata* (Dall) (pl. 12, fig. 4).				X					
Homalopoma cf. *H. carpenteri* (Pilsbry)				X					
Littorina cf. *L. petricola* Dall (pl. 19, fig. 12)					X				
Lacuna cf. *L. carinata* Gould					X				
Iselica fenestrata (Carpenter), var. (pl. 13, figs. 17, 18).				X					
Amnicola longinqua Gould, small var. (pl. 18, figs. 9, 10).					?sp.		X	X	
Diala cf. *D. marmorea* Carpenter				X					
Bittium casmaliense Bartsch (pl. 11, figs. 7, 8)		X	X	X	X	X			*Bittium casmaliaensis* Bartsch.
Bittium casmaliense arnoldi Bartsch (pl. 13, fig. 16).		X	X	X					*Bittium arnoldi* Bartsch.
Seila montereyensis Bartsch				X					
Aletes squamigerus Carpenter?, smooth var.?		X	X	X					
Micranellum crebricinctum (Carpenter)				X					
Turritella cooperi Carpenter (pl. 13, figs. 12, 14, 15).		X	X	X	X	X			*Turritella cooperi* Carpenter.
Turritella gonostoma hemphilli Applin (pl. 13, fig. 13).				X					
Crepidula princeps Conrad (pl. 8, 3, 4, 9; pl. 10, fig. 4; pl. 11, fig. 5).	cf.	X	X	X	X				*Crepidula princeps* Conrad.
Crepidula adunca Sowerby				X					
Crepidula cf. *C. excavata* (Broderip)				X					
Crepidula aculeata (Gmelin)				X					
Crepidula nummaria Gould				X					
Crepipatella cf. *lingulata* (Gould)				X					
Calyptraea cf. *fastigiata* (Gould)	sp.	X		X					*Galerus inornatus* Gabb.

Stratigraphic distribution of fossils in formations of Santa Maria district—Continued

Name used in present report	Formation and member: Sisquoc formation: Tinaquaic sandstone member	Sisquoc formation: Diatomaceous strata	Foxen mudstone	Careaga sandstone: Cebada fine-grained member	Careaga sandstone: Graciosa coarse-grained member	Careaga sandstone: Undifferentiated	Paso Robles formation	Orcutt sand	Name used by Arnold in Bulletin 322
Gastropods—Continued									
Trochita radians (Lamarck), small var. (pl. 13, fig. 19).			X	X					{*Trochita radians* Lamarck. {?*Crucibulum spinosum* Sowerby.
Crucibulum cf. *C. imbricatum* (Sowerby)				X					
Cryptonatica aleutica Dall, small var. (pl. 10, fig. 1).			X	X	X				*Natica clausa* Broderip and Sowerby.
Neverita reclusiana (Deshayes) (pl. 20, fig. 4)			X	X	X				*Neverita recluziana* Petit.
Lunatia cf. *L. lewisii* (Gould))pl. 12, fig. 1)			X	X	X				*Lunatia lewisii* Gould.
Sinum scopulosum (Conrad) (pl. 12, fig. 5)				X	sp.				*Sigaretus debilis* Gould.
Trivia cf. *T. sanguinea* (Gray) (pl. 13, figs. 21, 22).				X					
Erato cf. *E. scabriuscula* Gray (pl. 13, fig. 20)				X					{*Tritonium* sp. indet.
"*Gyrineum*" *mediocre lewisii* Carson (pl. 12, figs. 13, 15; pl. 13, figs. 23, 24, 26, 27).			X	X					{*Priene oregonensis* Redfield var. *angelensis* Arnold?
"*Gyrineum*" cf. "*G.*" *elsmerense* English			X						
Fusitriton cf. *F. oregonensis* (Redfield)			X	X					*Priene oregonensis* Redfield.
Architectonica sp				X					
Epitonium cf. *E. tinctum* (Carpenter)				X					
Opalia varicostata Stearns (pl. 10, fig. 2)			X	X	?				*Opalia varicostata* Stearns.
Opalia varicostata anomala Stearns				X					*Opalia anomala* Stearns.
Turbonilla cf. *T. arnoldi* Dall and Bartsch				X					
Turbonilla cf. *T. antestriata* Dall and Bartsch				X		sp.			
Odostomia cf. *O. pratoma* Dall and Bartsch			X						
Odostomia cf. *O. phanea* Dall and Bartsch					X				
Odostomia cf. *O. farallonensis* Dall and Bartsch				X					
Balcis cf. *B. micans* (Carpenter)				X					
Barbarofusus cf. *B. arnoldi* (Cossmann)		X	X	X					*Fusus* sp. a.
"*Nassa*" *moraniana* Martin (pl. 14, figs. 13, 14; pl. 17, figs. 7, 8; pl. 19, fig. 4).		X		X	X	X			*Nassa californiana* Conrad.
"*Nassa*" sp. (pl. 7, figs. 3, 4)	X								
"*Nassa*" cf. "*N.*" *fossata* (Gould)				X					
"*Nassa*" *waldorfensis* Arnold (pl. 8, fig. 14; pl. 10, fig. 9; pl. 15, fig. 4; pl. 19, figs. 3, 5).		X	X	X	X				*Nassa waldorfensis* Arnold.
"*Nassa*" *mendica* Gould, small var. (pl. 15, figs. 5, 6).				X		sp.			
"*Nassa*" *mendica cooperi* Forbes, small form				X					
Neptunea cf. *N. stantoni* (Arnold)			X						
Neptunea? sp			X						
Calicantharus fortis (Carpenter), var. cf. *angulata* (Arnold) (pl. 14, fig. 10; pl. 15, figs. 14, 15).			?sp.	X	X				
Calicantharus portolaensis (Arnold) (pl. 14, figs. 8, 9).	cf.	sp.		X	?sp.				
Jaton cf. *J. carpenteri* (Dall) (pl. 15, figs. 9, 11)			?	X					?*Ocinebra micheli* Ford var. *waldorfensis* Arnold.
Tritonalia lurida (Middendorff)				X					*Ocinebra lurida* Middendorf.
Tritonalia cf. *T. barbarensis* (Gabb)				X					
Tritonalia cf. *T. clathrata* Dall				X					
Boreotrophon cf. *B. stuarti* (Smith)		X							
Boreotrophon multicostatus (Eschscholtz), inflated var. (pl. 15, figs. 22, 24).				X					
Nucella lamellosa shumanensis (Carson)			?	sp.	X				*Purpura crispata* Chemnitz (part).
Nucella lamellosa collomi (Carson)			X		X				*Purpura crispata* Chemnitz (part).
Cancellaria lipara Woodring, n. sp. (pl. 16, figs. 13, 14).				X					
"*Cancellaria*" *rapa* Nomland?				X					
"*Cancellaria*" *rapa perrini* Carson (pl. 17, figs. 1, 2; pl. 18, figs. 2, 3; pl. 19, fig. 10).				X	X				
"*Cancellaria*" cf. "*C.*" *tritonidea* Gabb (pl. 16, fig. 5).				X					
"*Cancellaria*" *arnoldi* Dall (pl. 10, fig. 10; pl. 15, figs. 18, 20).		cf.	X	X	X	?			*Cancellaria* sp. a.
"*Cancellaria*" *hemphilli* Dall (pl. 15, figs. 16, 17)				X					
Crawfordina fugleri (Arnold) (pl. 16, fig. 7)				X					*Cancellaria crawfordiana* Dall var. *fugleri* Arnold.
Admete gracilior (Carpenter) of Arnold (pl. 15, fig. 10).				X					

Stratigraphic distribution of fossils in formations of Santa Maria district—Continued

Name used in present report	Formation and member: Sisquoc formation		Formation and member	Formation and member: Careaga sandstone			Formation and member		Name used by Arnold in Bulletin 322
	Tinaquaic sandstone member	Diatomaceous strata	Foxen mudstone	Cebada fine-grained member	Graciosa coarse-grained member	Undifferentiated	Paso Robles formation	Orcutt sand	
Gastropods—Continued									
Mitrella gausapata (Gould) (pl. 15, fig. 7)		X	X	X	X	?			*Astyris richthofeni* Gabb.
Mitrella tuberosa (Carpenter), var. (pl. 15, figs. 23, 25).				X					
Amphissa cf. *A. versicolor* Dall			sp.	X					?*Amphissa*? sp.
Psephaea oregonensis (Dall) (pl. 14, figs. 1, 2, 4, 5; pl. 15, figs. 19, 21).		X	X	X					*Miopleiona oregonensis* Dall.
Olivella biplicata (Sowerby), slender var. (pl. 19, figs. 7, 11).				X	X				*Olivella biplicata* Sowerby.
Olivella cf. *O. baetica* Carpenter (pl. 15, fig. 8)			X	X		?sp.			?*Olivella* cf. *intorta* Carpenter.
Megasurcula carpenteriana (Gabb), inflated var. (pl. 17, fig. 9).				X	X				*Bathytoma carpenteriana* Gabb var. *fernandoana* Arnold.
Megasurcula carpenteriana tryoniana (Gabb), strongly shouldered form (pl. 20, fig. 6).			X	?cf.					*Bathytoma* cf. *tryoniana* Gabb.
Elaeocyma cf. *E. empyrosia* (Dall)			X	X	?sp.				{*Drillia johnsoni* Arnold. {*Drillia waldorfensis* Arnold.
"*Drillia*" *graciosana* Arnold (pl. 17, figs. 3–6, 10)				X	X				*Drillia graciosana* Arnold.
Mangelia variegata Carpenter, angulated var. of Willett.				X					
Mangelia interlirata Stearns, inflated var				X					
"*Mitromorpha*" *intermedia* Arnold, var				X					
Glyphostoma conradiana (Gabb)				X					
Propebela sp			X	X					
Strioterebrum martini (English) (pl. 16, fig. 21)				X	X				
Acteon cf. *A. punctocaelatus* (Carpenter)				X					
Acteocina cf. *A. culcitella* (Gould)				X					
Cylichna cf. *attonsa* Carpenter				X					
"*Lymnaea*" *alamosensis* Arnold (pl. 18, fig. 6)							X	sp.	*Lymnaea alamosensis* Arnold.
Gyraulus cf. *G. vermicularis* (Gould) (pl. 18, figs. 5, 8).							X	X	
Helisoma sp							X		
Menetus cf. *M. cooperi* F. C. Baker (pl. 18, figs. 4, 7).					?sp.		X		
Physa sp. (pl. 18, fig. 11)					X		X	X	
Scaphopods:									
Dentalium neohexagonnm Pilsbry and Sharp				X					
Dentalium cf. *D. semipolitum* Broderip and Sowerby.				X					
Cadulus fusiformis Pilsbry and Sharp			X	?sp.	?sp.				*Cadulus fusiformis* Sharp and Pilsbry.
Pelecypods:									
Acila cf. *A. castrensis* (Hinds)				X					
Nuculana cf. *N. leonina* (Dall)					X				
Saccella cellulita (Dall) (pl. 15, figs. 3, 26)		?	X	X					*Leda taphria* Dall (part).
Saccella taphria (Dall) (pl. 21, fig. 7)				X	X	?			*Leda taphria* Dall (part).
Saccella orcutti (Arnold) (pl. 8, figs. 5, 7, 8, 13; pl. 10, fig. 3).		X	X	X		X			{*Leda orcutti* Arnold. {*Leda taphria* Dall (part).
Saccella redondoensis (Burch) (pl. 16, fig. 18)				X					
Yoldia gala Woodring, n. sp. (pl. 8, figs. 1, 2; pl. 9; figs. 9, 10).		X							
Yoldia cf. *Y. supramontereyensis* Arnold				X	X	X			
Pododesmus macroschisma (Deshayes)			?	X	X				*Monia macroschisma* Deshayes.
Arca santamariensis Reinhart (pl. 14, figs. 6, 7)				X					
Arca sisquocensis Reinhart			X	X					*Arca* sp. a.
Barbatia pseudoillota Reinhart (pl. 15, figs. 12, 13)				X					
Anadara trilineata (Conrad) of Arnold (pl. 9, figs. 2, 5; pl. 11, fig. 4; pl. 16, fig. 19).	X	X	X	X	X	cf.			*Arca trilineata* Conrad.
Anadara trilineata (Conrad) of Arnold, var. cf. *canalis* (Conrad).	X	X							
Glycymeris cf. *G. grewingki* Dall			sp.	sp.	X				*Glycymeris* cf. *barbarensis* Conrad.
Mytilus cf. *M. coalingensis* Arnold			X	X	X	X			
Volsella cf. *V. capax* (Conrad)	X		X	X	X				*Modiolus rectus* Conrad.
Crenella cf. *C. decussata* (Montagu)				X					
Pecten stearnsii Dall?			X	X					*Pecten* (*Pecten*) *stearnsii* Dall.
Pecten hemphilli Dall (pl. 16, figs. 15, 16; pl. 21, fig. 8).		cf.		X	X	X			*Pecten* (*Pecten*) *hemphilli* Dall.

Stratigraphic distribution of fossils in formations of Santa Maria district—Continued

Name used in present report	Formation and member: Sisquoc formation: Tinaquaic sandstone member	Sisquoc formation: Diatomaceous strata	Foxen mudstone	Careaga sandstone: Cebada fine-grained member	Careaga sandstone: Graciosa coarse-grained member	Careaga sandstone: Undifferentiated	Paso Robles formation	Orcutt sand	Name used by Arnold in Bulletin 322
Pelecypods—Continued									
Aequipecten? cf. *A. circularis* (Sowerby)				X					*Pecten* (*Plagioctenium*) near *cerrosensis* Gabb.
Chlamys hastatus (Sowerby)		?	X	X	?				*Pecten* (*Chlamys*) *lawsoni* Arnold.
Chlamys parmeleei (Dall) (pl. 16, fig. 20)				X					*Pecten* (*Chlamys*) *wattsi* Arnold.
Chlamys parmeleei etchegoini (Anderson)			X						
Patinopecten lohri (Hertlein) (pl. 7, figs. 7, 9)	X	cf.							*Pecten* (*Patinopecten*) *oweni* Arnold.
Patinopecten healeyi (Arnold) (pl. 19, fig. 9; pl. 21, fig. 9).			X	X	X				*Pecten* (*Patinopecten*) *healeyi* Arnold.
Patinopecten dilleri (Dall) (pl. 11, figs. 1, 9)			X	X					
Patinopecten dilleri (Dall), var. (pl. 9, figs. 6–8)		X							
Lyropecten cerrosensis (Gabb) (pl. 21, fig. 1)				X	X				
Lima cf. *L. hemphilli* Hertlein and Strong				X					
Ostrea erici Hertlein (pl. 8, figs. 17, 18; pl. 9, figs. 1, 3, 4).		X		X					*Ostrea*, possibly *veatchii* Gabb.
Ostrea vespertina Conrad (pl. 16, figs. 4, 17)			cf.	X	X	X			*Ostrea veatchii* Gabb.
Glans subquadrata (Carpenter)				X					
Cyclocardia californica (Dall) (pl. 8, fig. 16; pl. 10, figs. 7, 8; pl. 11, figs. 2, 3; pl. 15, figs. 1, 2; pl. 21, fig. 5).		X	X	X	X				*Venericardia californica* Dall.
Miodontiscus cf. *M. prolongatus* (Carpenter)			X	X					
Thyasira cf. *T. gouldii* (Philippi)			X						*Thyasira* aff. *gouldii* Philippi.
Axinopsis viridis Dall			X						
Lucinisca nuttallii antecedens (Arnold) (pl. 20, fig. 3; pl. 21, fig. 6).		X	X	X	X	sp.			*Phacoides nuttalli* Conrad var. *antecedens* Arnold.
Lucinoma cf. *L. annulata* (Reeve) (pl. 19, fig. 8)	X	sp.	X	X	X				*Phacoides annulatus* Reeve.
Parvilucina cf. *P. tenuisculpta* (Carpenter)			X	X	X				*Phacoides intensus* Dall.
Diplodonta sp				X					
Kellia laperousii (Deshayes)			X	X					
Rochefortia tumida (Carpenter)					X				
Corbicula? sp					X				
Sphaerium? sp					X				
Pisidium sp								X	
Tellina cf. *T. aragonia* Dall		X							
Tellina cf. *T. lutea* Wood (pl. 8, fig. 15)		X	X						? *Tellina* sp. (part).
Tellina cf. *T. idae* Dall				X					
Tellina cf. *T. buttoni* Dall				X	X	?sp.			
Tellina cf. *T. bodegensis* Hinds				X	X	?sp.			*Tellina* aff. *bodegensis* Hinds.
Macoma cf. *M. nasuta* (Conrad)	X								*Macoma nasuta* Conrad (part).
Macoma nasuta kelseyi Dall (pl. 20, figs. 2, 8)				cf.	X	cf.			*Macoma nasuta* Conrad (part).
Macoma n. sp.? (pl. 8, figs. 10, 11)		X							
Macoma cf. *M. brota* Dall		?	X	X					*Macoma nasuta* Conrad (part).
Macoma sp. (small)		X							
Macoma cf. *M. yoldiformis* Carpenter			sp.	X					
Macoma cf. *M. indentata* Carpenter	X			X	X				
Macoma cf. *M. secta* (Conrad)					X				? *Macoma* cf. *secta* Conrad.
Semele cf. *S. rubropicta* Dall (pl. 14, fig. 12)		?	X	X					
Semele? sp			X						
Cumingia californica Conrad				X	?				*Cumingia californica* Conrad.
Spisula cf. *S. hemphilli* (Dall)	X			X	X	?			*Spisula sisquocensis* Arnold.
Spisula cf. *S. catilliformis* Conrad				X	X	X			*Spisula catilliformis* var. *alcatrazensis* Arnold.
Spisula? sp	X	sp.							
Pseudocardium densatum (Conrad) of Arnold, var. cf. *gabbii* Rémond (pl. 17, fig. 14; pl. 19, fig. 2).	?				X	X			
Schizothaerus cf. *S. nuttallii* (Conrad)	X		X	X	X	X			*Tresus nuttallii* Conrad.
Dosinia ponderosa (Gray), var. (pl. 16, fig. 6; pl. 19, fig. 1; pl. 20, fig. 7).				X	X				*Dosinia ponderosa* Gray.
Pachydesma crassatelloides (Conrad) (pl. 18, fig. 1).					X				
Saxidomus cf. *S. nuttalli* Conrad				X	?	?			*Saxidomus gracilis* Gould.
Compsomyax cf. *C. subdiaphana* (Carpenter)	X	X		X	X	X			*Callista subdiaphana* Carpenter.
Lirophora cf. *L. mariae* (d'Orbigny)					X				
Protothaca staleyi (Gabb) (pl. 21, figs. 2–4)	X			cf.	X	X			{? *Tapes* cf. *lacineata* Carpenter. {*Tapes staleyi* Gabb.

Stratigraphic distribution of fossils in formations of Santa Maria district—Continued

Name used in present report	Formation and member: Sisquoc formation			Careaga sandstone					Name used by Arnold in Bulletin 322
	Tinaquaic sandstone member	Diatomaceous strata	Foxen mudstone	Cebada fine-grained member	Graciosa coarse-grained member	Undifferentiated	Paso Robles formation	Orcutt sand	
Pelecypods—Continued									
Protothaca cf. *P. tenerrima* (Carpenter)	X		?	X	X	X			*Tapes tenerrima* Carpenter.
Irus cf. *I. lamellifer* (Conrad)				X					
Transennella cf. *T. tantilla* (Gould)		X	X	X	X	X			
Petricola cf. *P. carditoides* (Conrad)				X					
Petricola cf. *P. buwaldi* Clark				X	X				
Cerastoderma cf. *C. meekianum* (Gabb)	sp.			X	X	X			*Cardium meekianum* Gabb.
Trachycardium cf. *T. quadragenarium* (Conrad)				X					
Chama cf. *C. pellucida* Broderip				X					
Gari? cf. *G. californica* (Conrad)				X					
Mya sp.			X	X	X				{*Mya truncata* Linné. {? *Platyodon cancellatus* Conrad var.
Cryptomya cf. *C. californica* (Conrad) (pl. 7, fig. 2)	X	X		X	X	?			*Cryptomya ovalis* Conrad.
Platyodon cf. *P. colobus* Woodring					X				
Sphenia cf. *S. globula* Dall			X	?					
Solen perrini Clark	X			X	X				*Solen* cf. *sicarius* Gould.
Siliqua cf. *S. media* (Sowerby) (pl. 7, figs. 1, 5)	X	X		X	X	X			
Panope cf. *P. generosa* Gould	X		X	X	X				*Panopea generosa* Gould.
Panomya cf. *P. beringianus* Dall				X					*Panomya* cf. *ampla* Dall.
Saxicava? cf. *S. pholadis* (Linné)					X				
Pholadidea penita (Conrad) (pl. 8, fig. 6; pl. 14, fig. 3).		X	X	X	X				*Pholadidea ovoidea* Conrad.
Zirfaea cf. *Z. pilsbryi* Lowe		X			X				
Thracia cf. *T. trapezoides* Conrad				X					*Thracia* cf. *trapezoides* Conrad.
Pandora cf. *P. filosa* (Carpenter) (pl. 8, fig. 12)		X	X						*Kennerlia?* sp.
Pandora punctata Conrad (pl. 17, fig. 13)				cf.	X				*Clidiophora punctata* Carpenter.
Unidentified ostracodes							X	X	
Barnacles:									
Balanus cf. *B. aquila* Pilsbry	sp.		X	X	X				*Balanus* cf. *concavus* Bronn.
Balanus hesperius proinus Woodring, n. var. (pl. 14, figs. 11, 15; pl. 16, figs. 1–3, 8–12).			X	X	X	X			
Reptile: Turtle (fragment of carapace)					X				
Land mammals:									
Unidentified rodent molars							X		
Mastodon (immature maxillary portion without teeth).					X				
Mastodon? (incomplete centrum of large vertebra).					X				
Marine mammals:									
Sea lion (femur)					X				
Eared seal (atlas vertebra)							X		
Dolphin (periotic)	X								
Cetothere (tympanic bulla)		X							
Cetothere (occipital portion of young animal)					X				
Total forms 231.	26	43	73	175	89	33	9	6	

The table does not include Foraminifera and diatoms, which are practically the only fossils in the Miocene formations. The formations included are those that contain Pliocene fossils or fossils of Pliocene affinities. The Todos Santos claystone member of the Sisquoc formation is omitted, as it yielded only one megafossil at one locality, *Yoldia gala*. The only megafossils from Miocene formations are the few fragmentary remains from the lower member of the Monterey shale mentioned on page 21. The table, however, includes the nonmarine fossils of the Paso Robles formation, of late Pliocene and early Pleistocene(?) age, and the nonmarine fossils of the Orcutt sand, considered of late Pleistocene age. The meager Orcutt fauna is included to show its close relations to the almost equally meager Paso Robles fauna. The table does not include fossils from marine deposits on the late Pleistocene marine terraces, listed on page 54.

Subgeneric names are not cited for the species, but are generally mentioned in the discussions on pages 67 to 92. Owing to imperfect preservation, to the inaccessibility of some characters, and to other incomplete data, about half of the species are indefinitely identified. A few question marks are used for specific names in the species list. For the most part, however, the noncommittal designation "cf." is used in the species list for varying degrees of affinity; that is, it is used instead of attempting to differentiate "cf.", "aff.", and question marks. Unidentified forms listed as "sp." in the species list presumably represent some other species than those under the same generic name. The designation "cf." in the formation columns indicates the presence of a comparable form that may or may not be the same as that listed opposite in the species column. Likewise the designation "sp." in the formation columns means the presence of an unidentified species that may or may not be the same as that in the species column. Therefore, a "cf." and an "sp." on the same horizontal line do not necessarily refer to the same form. The designations "?sp." and "?cf." in the formation columns indicate that the genus is questioned. The same symbols are used in the lists of fossils under the description of the formations, locality columns taking the place of formation columns.

The affinities and distribution of most of the species of echinoids, brachipods, mollusks, and barnacles are discussed under the systematic headings that follow. This discussion was prepared by W. P. Woodring. It is not burdened with footnote citations for species, citations for which may be found in the following well-known catalogs and monographs, all of which should be accessible to anyone interested in these fossils:

Catalogs and monographs containing citations for species discussed in present report

Echinoids:

Kew, W. S. W., Cretaceous and Cenozoic Echinoidea of the Pacific Coast of North America: California Univ., Dept. Geology, Bull., vol. 12, pp. 23–236, pls. 3–42, 5 figs., 1920.

Grant, U. S., IV, and Hertlein, L. G., The West American Cenozoic Echinoidea: California Univ. at Los Angeles, Pub. Math. Physical Sci., vol. 2, 225 pp., 30 pls., 17 figs., 1938.

Brachiopods:

Hertlein, L. G., and Grant, U. S., IV, The Cenozoic Brachiopoda of western North America: Idem, vol. 3, 235 pp., 21 pls., 34 figs., 1934.

Fossil mollusks:

Grant, U. S., IV, and Gale, H. R., Catalogue of the marine Pliocene and Pleistocene Mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, 1,036 pp., 32 pls., 15 figs., 1931.

Keen, A. M., and Bentson, Herdis, Check list of California Tertiary marine Mollusca: Geol. Soc. America Special Paper 56, 280 pp., 1944.

Recent Mollusks:

Dall, W. H., Summary of the marine shell-bearing mollusks of the northwest coast of America: U. S. Nat. Mus. Bull. 112, 217 pp., 22 pls., 1921.

Barnacles:

Pilsbry, H. A., The sessile barnacles (Cirripedia) contained in the collections of the U. S. National Museum, including a monograph of the American species: U. S. Nat. Mus. Bull. 93, 366 pp., 76 pls., 99 figs., 1916.

With the exception of some species for which suitable material is not available, the characteristic and abundant species of the different formations and members are shown on plates 7–21. These plates may be useful to field geologists working in the Santa Maria and nearby districts as well as to laboratory paleontologists. Arnold's 1906 collections from the Santa Maria district were used to supplement the collections made during the field work for the present report. Some well-preserved specimens, mostly from Fugler Point, originally in the collection of Mr. Alex Clark, of the Shell Oil Company, and other specimens from Fugler Point in the collections of the California Institute of Technology, were used to supplement the collections at the United States National Museum, thus making the record of the fauna at an unusual locality more complete. Mr. Clark has deposited in the United States National Museum the figured specimens from his collection. Dimensions of figured specimens, including types, and National Museum catalog numbers may be found in the explanation of the plates.

The following new names are proposed:

Gastropods:

Puncturella cooperi aphales Woodring, n. var. (p. 69).
Calliostoma coalingense catoteron Woodring, n. var. (p. 69).
Cancellaria lipara Woodring, n. sp. (p. 76).

Pelecypod:

Yoldia gala Woodring, n. sp. (p. 81).

Barnacle:

Balanus hesperius proinus Woodring, n. var. (p. 92).

ECHINOIDS

A thin moderately eccentric sand dollar from the Tinaquaic sandstone member of the Sisquoc formation is identified as *Dendraster* cf. *D. coalingaensis* (pl. 7, figs. 6, 8). Wherever the sand dollars were found they were at about the same horizon in the upper part of the member. Their preservation is poor. In degree of eccentricity the Tinaquaic sand dollar is similar to *D. coalingaensis*, a San Joaquin and upper Etchegoin species of the Coalinga district.[50] Moreover, the thin margin indicates relationship to that species. The opening at the end of the petals is wide on the few Tinaquaic specimens that clearly show the petals, a character suggesting *D. coalingaensis* proper. The degree of eccentricity and the widely open petals also indicate relationship to the Jacalitos species *D. jacalitosensis*, which was described as having a thin margin and evidently is an early member of the *D. coalingaensis* group. In fact, Kew's illustrations of the type of *D. jacalitosensis* suggest that it is indistinguishable from *D. coalingaensis* proper except for its larger size. The Tinaquaic sand dollar also is larger than *D. coalingaensis*. Difference in size alone, however, is an untrustworthy guide. A comparable thin moderately eccentric

[50] Stewart, Ralph, in Woodring, W. P., Stewart, Ralph, and Richards, R. W., Geology of the Kettleman Hills oil field, Calif.: U. S. Geol. Survey Prof. Paper 195, p. 81, pls. 39–41, 44, 45, 1940 (1941).

sand dollar occurs in Reed's Pancho Rico formation[51] in a tributary of Lynch Canyon on the east side of the Salinas Valley (U. S. Geol. Survey locality 9385). At least the lower part of this formation contains *Astrodapsis* and is considered of early Pliocene (Jacalitos) age.

Dendraster ashleyi (pl. 17, figs. 11, 12; pl. 18, figs. 12–14; pl. 19, fig. 6; pl. 20, figs. 1, 5, 6), a thin markedly eccentric sand dollar, is characteristic of the Graciosa coarse-grained member of the Careaga sandstone. In degree of eccentricity *D. ashleyi* is comparable to the Jacalitos, Etchegoin, and lower San Joaquin species *D. gibbsii*.[52] It is distinguished from *D. gibbsii* by the narrow opening at the end of the petals and by the thin margin. The width of the opening at the end of the petals of *D. ashleyi* is perhaps too variable for consistent differentiation; the opening of the petals on the type, for example, is relatively wide. The thin margin, however, is an invariable character of about 250 available specimens of *D. ashleyi*. As shown by the illustrations, the outline of *D. ashleyi* is variable. The typical form, and the usual form, is wide. An occasional specimen is narrow (pl. 20, fig. 6), like the usual form of *D. gibbsii*. Though the degree of eccentricity of *D. ashleyi* is fairly uniform, one specimen is only moderately eccentric (pl. 20, fig. 1). It approaches a form named *D. ashleyi* variety *ynezensis* by Kew. The type locality of the variety *ynezensis* is in the upper Santa Ynez Valley in strata presumably of Careaga age. Kew's illustration of the type shows that the opening at the end of the petals is narrow, indicating that this form is not allied to the Tinaquaic *D.* cf. *D. coalingaensis*, which has a similar degree of eccentricity. The type of *D. ashleyi* was collected from the Graciosa member of the Careaga on Graciosa Ridge. Arnold figured as "*Echinarachnius*" cf. "*E.*" *excentricus* variety, a small specimen of *D. ashleyi* from the railroad cut near Shuman.

Arnold's figured "*Echinarachnius*" *gibbsii* variety *ashleyi* from the Coalinga district has the thick margin and widely open petals of *D. gibbsii*, but is wider than the usual form. Though Arnold's illustration appeared on a plate of Etchegoin fossils, the locality for the sand dollar he assigned to *ashleyi* is a Jacalitos formation locality (U. S. Geol. Survey locality 4767). Numerous sand dollars in the collection from that locality have the characters of *D. gibbsii*.

Merriamaster cf. *M. perrini* (pl. 10, figs. 11–14) was found in the upper part of the Foxen mudstone at two localities in the western Casmalia Hills. Though these Foxen sand dollars are not well preserved, they appear to be closely comparable to the upper San Joaquin *M. perrini*,[53] aside from their larger size and slightly less inflated margin. *Merriamaster* has recently been aptly suggested to be an *Astrodapsis*-like *Dendraster* and treated as a subgenus of *Dendraster*.[54] Some specimens of the small upper San Joaquin form *M. arnoldi* (specimens that have poorly defined *Merriamaster* characters) were found by Stewart to be practically indistinguishable from small specimens of *Dendraster coalingaensis*, with which they are associated. Nevertheless, the slight eccentricity, inflated test, and large spine bases characteristic of large mature specimens of *Merriamaster* differentiate it from *Dendraster* and appear to warrant generic rank. *M. perrini* is the type of the genus.

BRACHIOPODS

Brachiopods are rare except in the brachiopod layer of the Cebada fine-grained member of the Careaga sandstone at Fugler Point, where the genus *Terebratalia* is represented by many specimens. They are considered forms of a variable species identified as *Terebratalia occidentalis* (pl. 13, figs. 1–4, 8, 9, 25). The different forms, some of which are shown on plate 13, intergrade in the collection of almost 100 specimens from Fugler Point. Recent specimens of *T. occidentalis*, including the variety *obsoleta*, also are variable. None of the Santa Maria fossils, however, completely lacks ribs, and no recent specimen available is as wide as the wide fossil form shown on plate 13, figures 3, 4. The wide form superficially resembles *T. transversa caurina*, but has a median concave fold on the pedicle valve like the other forms of *T. occidentalis*, whereas *T. transversa* and its allies have a median convex fold on the pedicle valve. *T. arnoldi* has been recorded from Fugler Point. The great range of variation shown by the Fugler Point brachiopods casts some doubt on the validity of that species.

MOLLUSKS

GASTROPODS

Fissurellidae.—The genus *Puncturella* occurs in the Foxen mudstone and the Cebada fine-grained member of the Careaga sandstone. *Puncturella cucullata* (pl. 10, figs. 5, 6) was collected by Arnold from the Foxen mudstone at the Waldorf asphalt mine, and fragments from the Cebada are probably that species. *P. cucullata* is characterized by strong primary ribs, the median anterior rib being double. Recent specimens examined have 13 to 19 primary ribs, generally 15 or 16; the Foxen fossil has 13. In the Recent fauna *P. cucullata* is essentially a northern species, but ranges southward to San Diego in gradually deeper water (34 to 110 fathoms off the California coast). California specimens are smaller than those from Alaska and Puget Sound, the largest California shell in the collection of the National Museum, dredged off Point Loma at a depth of 71 to 75 fathoms, having a length of 16 millimeters. The Foxen fossil is as large as the largest Alaskan specimen examined.

[51] Reed, R. D., The post-Monterey disturbance in the Salinas Valley, Calif.: Jour. Geology, vol. 33, pp. 591, 606, 1925. (Reed used the name "Poncho Rico", which is the spelling on some maps, but on current maps the name of the creek is "Pancho Rico.")

[52] Stewart, Ralph, op. cit., pp. 79–81, pls. 20, 21, 40, 42–44, 1940 (1941).

[53] Stewart, Ralph, op. cit., p. 81, pl. 46, 1940 (1941).

[54] Stewart, Ralph, op. cit., p. 83.

A small *Puncturella*, represented by a specimen from the Foxen mudstone, collected at the dump of the Waldorf asphalt mine, and by nine specimens from the Cebada member of the Careaga sandstone, is identified as a strongly sculptured new variety of *Puncturella cooperi*—*P. cooperi aphales* (pl. 12, figs. 2, 3). It is sculptured with 22 to 26 strong primary ribs, the interspaces bearing a weak secondary rib or none. Concentric threads roughen the primary ribs and are of varying strength in the interspaces. The specimen from the dump of the Waldorf mine has a length of 6. 7 millimeters and is somewhat larger than the type. This variety is of the same size and shape as the Recent *P. cooperi*, but has stronger primary ribs, weaker secondary ribs, and stronger concentric sculpture. *P. cooperi* or closely related forms have not heretofore been recognized in California Pliocene faunas. The sculpture of *P. cooperi aphales* suggests that of the large Recent northern *P. multistriata*, which, however, has strong secondary ribs.

Trochidae.—Six species of the genus *Calliostoma* are recognized in collections from the Cebada fine-grained member of the Careaga sandstone; a fragment was found in the Graciosa coarse-grained member of the Careaga, and a poorly preserved specimen in diatomaceous mudstone of the Sisquoc formation. A new variety of *Calliostoma coalingense*, *C. coalingense catoteron* (pl. 13, figs. 5, 6, 10), is represented by a specimen in Arnold's collection from the railroad cut near Shuman (presumably from the Cebada member of the Careaga), and by a small specimen from the Cebada at locality 177. It has a lower spire than *C. coalingense* proper and the base is almost smooth except in the columellar and peripheral areas. The small specimen shows that the sutural spiral is a fine smooth thread on the early whorls and that it is beaded as it widens. On the body whorl of the type the spiral adjoining the sutural spiral and the intervening secondary spiral also are beaded. In outline the Santa Maria specimens are most similar to a low-spired form of *C. coalingense* from the *Acila* zone of the San Joaquin formation in the Kettleman Hills,[55] but that form has the strongly sculptured base of *C. coalingense* proper.[56] There does not appear to be any closely related species living along the California coast.

Small incomplete specimens may represent two undescribed forms of *Calliostoma*. *Calliostoma* cf. *C. virgineum* has the flat whorls and angulated periphery of the Recent *C. virgineum* ["*annulatum*"], but the beads on the spirals of the fossils are more compressed axially and the spirals on the base are stronger. *Calliostoma* sp. has inflated whorls, four smooth primary spirals, and three or four closely spaced narrow smooth secondary spirals in the sutural area. The spirals on the base are very narrow and closely spaced except in the columellar area. No close relative of this species has been recognized. The other species of *Calliostoma* are Recent California species or are similar to Recent California species, the material being insufficient for certain identification.

Mr. Alex Clark's collection from the Cebada member of the Careaga sandstone at Fugler Point includes a specimen of *Cidarina* that probably represents a new variety of the Recent *Cidarina cidaris* (pl. 12, fig. 11). A narrow band adjoining the suture is weakly sculptured, forming a sutural channel, whereas the corresponding band on Recent specimens is strongly noded. *C. cidaris* has not been recorded heretofore from California Pliocene formations.

Turcica imperialis brevis (pl. 12, figs. 9, 10, 12, 14) was found in the Cebada member of the Careaga sandstone and is represented probably by a poorly preserved specimen from the Foxen mudstone at the Waldorf asphalt mine. The figured specimens, more complete than any collected during the field work for the present report, are in a California Institute of Technology collection from Fugler point and in Mr. Alex Clark's collection from the same locality. One of these specimens (pl. 12, figs. 9, 10), however, is somewhat worn and the sculpture above the peripheral spiral is subdued. This *Turcica*, which was based on fossils from the *Acila* and *Pecten* zones of the late Pliocene San Joaquin formation in the Kettleman Hills,[57] has a strong peripheral spiral. It appears to be closely related to the Recent Japanese *T. imperialis*, but has stronger sculpture, the basal sculpture especially being stronger, and the later whorls are more tightly coiled. A Recent form dredged off Cabo San Lucas (Cape San Lucas), Lower California, at a depth of 66 fathoms, also is evidently closely related to *T. imperialis*. It is strongly sculptured like the fossils, but has the loosely coiled later whorls of *T. imperialis*. Because of the strong peripheral spiral, the relationship of the fossils to *T. imperialis* is considered closer than the relationship to the Recent California *T. caffea*. When the Kettleman Hills fossils were named as a variety of *T. caffea* the Lower California form was accepted as typical of *T. caffea*. *T. caffea* occurs in the lower Pleistocene Timms Point silt at San Pedro.[58] *T. imperialis brevis* occurs in the San Diego formation at Pacific Beach (locality 2567).

A thick-shelled worn or corroded specimen from the Cebada member of the Careaga sandstone represents apparently a new species of *Solariella* (pl. 13, figs. 7, 11). The spire is turreted and the sculpture consists of heavy spirals, two on the spire and six on the body whorl. Traces of axial swellings on the spirals and of axial

[55] Stewart, Ralph, in Woodring, W. P., Stewart, Ralph, and Richards, R. W., Geology of the Kettleman Hills oil field, Calif.: U. S. Geol. Survey Prof. Paper 195, p. 83, pl. 11, figs. 2, 3, 1940 (1941).

[56] Idem, p. 83, pl. 15, figs. 15, 16.

[57] Op. cit., p. 84, p. 11, figs. 1, 6.

[58] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., Geology and paleontology of the Palos Verdes Hills, Calif.: U. S. Geol. Survey Prof. Paper 207, p. 62, pl. 32, figs. 1, 2, 1946.

sculpture between the spirals are visible. This species has fewer and heavier spirals, more turreted spire, and thicker shell than the Recent *S. peramabilis*.

Vitrinellidae.—A variety of the Recent *Vitrinella stearnsi* (pl. 12, figs. 6–8) occurs in the Cebada member of the Careaga sandstone. The fossils closely resemble the typical form, but the umbilical wall is not sculptured with heavy wrinkles. The early whorls of the fossils, like those of *V. stearnsi* proper, are sculptured with fine axial ribs that disappear gradually. Though the fossils evidently represent a form of *V. stearnsi*, the type of the subgenus *Docomphala*, they lack the wrinkles on the umbilical wall cited as the distinguishing character of that subgenus.[59]

Turbinidae.—*Homalopoma* cf. *H. paucicostata* (pl. 12, fig. 4), from the Cebada member of the Careaga sandstone, is probably a new species. The characters are uncertain, however, on the basis of the three available specimens, two of which are in a California Institute of Technology collection from Fugler Point. This *Homalopoma* is larger than the Recent *H. paucicostata* and has heavier spirals. The figured specimen is sculptured with three peripheral spirals that are slightly swollen at irregular intervals, a weaker somewhat noded sutural spiral, and two basal spirals. The second specimen has in addition a spiral between the lower two peripheral spirals and a spiral adjoining the sutural spiral. The third specimen, which is small and incomplete, has two sutural spirals.

Another species from the Cebada member of the Careaga sandstone, *Homalopoma* cf. *H. carpenteri*, is represented by an imperfect specimen. It is closely related to the Recent California *H. carpenteri* and the Recent Japanese *H. corallina*.[60] The sculpture of the fossil consists of fine spirals except on the periphery where there are both fine and heavy spirals. Recent specimens of *H. carpenteri* and *H. corallina* examined have heavy spirals between the periphery and suture.

Littorinidae.—The genus *Littorina* is represented by only one specimen, collected from the Graciosa member of the Cebada sandstone. Identified as *Littorina* cf. *L. petricola* (pl. 19, fig. 12), this specimen is greatly worn and the spire is broken and corroded. The shell may have been in that condition during life. The low spire, thick shell, and small aperture suggest relationship to *L. petricola*, from the Pliocene(?) Empire formation of Oregon. No trace of sculpture is visible on the Graciosa fossil, whereas even worn specimens of *L. petricola* show at least faint spiral sculpture. *L. mariana*, a Pliocene species from the San Joaquin Valley, has a higher spire, thinner shell, and larger aperture.[61]

[59] Bartsch, Paul, New mollusks of the family *Vitrinellidae* from the west coast of America: U. S. Nat. Mus. Proc., vol. 32, p. 169, 1907.

[60] Reeve, L. A., Conchologia Iconica, *Turbo*, pl. 12, fig. 56, 1848.

[61] For a recent discussion and illustrations of *L. mariana* see Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 84, pl. 4, figs. 4–6, pl. 8, figs. 1–6, pl. 29, figs. 8, 9, 1940 (1941).

Fossaridae.—A variety of the Recent *Iselica fenestrata* (pl. 13, figs. 17, 18) is represented by a specimen in a California Institute of Technology collection from Fugler Point. It is more strongly shouldered than Recent specimens of that species and lacks the sutural spiral.

Amnicolidae.—Amnicolid molds were found at locality 211 in strata mapped as the upper part of the Graciosa coarse-grained member of the Careaga sandstone. They are fairly common in the Paso Robles formation and are present in the Orcutt sand at locality 257. The only preserved shells are from the Paso Robles at locality 255 and the Orcutt sand at locality 256, both in the Purisima Hills. The small amnicolid from those localities is identified as a small variety of *Amnicola longinqua* (pl. 18, figs. 9, 10). *A. longinqua* is abundant in the Pliocene and Pleistocene(?) Tulare formation of the Kettleman Hills[62] and is living in southern California.

Alabinidae?.—*Diala* cf. *D. marmorea*, from the Cebada member of the Careaga sandstone, has a more rapidly tapering spire than most Recent specimens of *D. marmorea* and *D. acuta*. The base of the fossils is angulated, like the base of the type of *D. acuta*, whereas the base of the type of *D. marmorea* is rounded. The systematic value of the outline of the base, however, is, uncertain.[63]

Cerithiidae.—The genus *Bittium* occurs in diatomaceous mudstone of the Sisquoc formation at localities where shells are preserved because of impregnation with asphalt, is abundant in the Foxen mudstone of the Casmalia Hills and locally in the Cebada member of the Careaga sandstone, and is represented by a few imperfect specimens from the Graciosa member of the Careaga sandstone. The typical form of *Bittium casmaliense* (pl. 11, figs. 7, 8) occurs in the formations and members mentioned. That form lacks secondary spirals, the space between the primary spiral being sculptured with microscopic spiral striae. The type, which is corroded and shows only faint traces of the microscopic spiral striae, is from Arnold's collection from the railroad cut near Shuman, presumably from the Cebada member. A specimen from the Foxen mudstone shows a protoconch of 1½ inflated smooth whorls (pl. 11, fig. 8). *B. casmaliense arnoldi* (pl. 13, fig. 16) is sculptured with strong secondary spirals and the later whorls of large specimens may have in addition tertiary spirals. This form occurs in the formations and members mentioned with the exception of the Graciosa member. The type of *B. arnoldi* is from Arnold's Waldorf asphalt mine collection, which contains about 150 specimens of *Bittium*. Most of them represent *B. casmaliense* proper, some are more or less intermediate between *B. casmaliense* proper and *B.*

[62] Idem, p. 85, pl. 4, figs. 23–27.

[63] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), p. 67, 1946.

arnoldi, and 14 represent *B. arnoldi*. There is no indication that the numerous specimens in Arnold's collection were examined at the time these two forms of *Bittium* were described. In view of the occurrence of intermediate forms in this collection as well as in others, *B. arnoldi* is considered a variety of *B. casmaliense*. *B. casmaliense* proper has sculpture similar to that of the Recent *B. sanjuanense*, from San Juan Island in the Strait of Georgia, Washington, whereas the sculpture of forms intermediate between *B. casmaliense* proper and *B. casmaliense arnoldi* is similar to that of *B. challisae*, also from San Juan Island.

Vermetidae.—Thick-walled large tubes from oil-impreganted diatomaceous strata of the Sisquoc formation at locality 73*a*, from the Foxen mudstone at the Waldorf asphalt mine, and from the Cebada member of the Careaga sandstone at locality 171 lack sculpture and are probably a smooth variety of the Recent *Aletes squamigerus*. Similar tubes occur in the early Pleistocene Lomita marl of the San Pedro district.[64] The few Recent smooth specimens of *A. squamigerus* available are not as large or as thick-walled as the fossils, which resemble tubes of the mud-boring Indo-Pacific pelecypod *Kuphus*.

Turritellidae.—*Turritella cooperi* is represented by numerous specimens that show a wide range of variation in sculpture. A weakly sculptured form collected from the Foxen mudstone at the Waldorf asphalt mine has sculpture like that of the prevailing Recent form. A specimen of this form was illustrated by Arnold.[65] It also occurs in the Graciosa member of the Careaga sandstone and is represented probably by poorly preserved material from oil-impregnated diatomaceous mudstone of the Sisquoc formation. A strongly sculptured variety (pl. 13, figs. 12, 14, 15) is widespread and locally abundant in the Cebada member of the Careaga sandstone. It is sculptured with two strong primary spirals that are faintly or distinctly noded. The secondary spirals are generally weak, but one or more may be accentuated. The strongly sculptured Santa Maria fossils closely resemble in size and sculpture a shell from San Pedro, presumably a Recent shell, in the collection of the U. S. National Museum (216774). Smaller fossils from the late Pleistocene Palos Verdes sand of the San Pedro district [66] have similar sculpture. *T. nova*, from the Pliocene of the Coalinga district, is probably a form of *T. cooperi*. It has two heavy primary spirals that apparently are not noded. A variety of *T. cooperi* sculptured with one or two strong secondary spirals between two non-noded primary spirals is represented by a worn incomplete specimen from the Cebada member of the Careaga sandstone and by a specimen in similar condition from the Graciosa member. The poorly preserved type of *T. cooperi fernandoensis*, from Pliocene strata at Elsmere Canyon, has strong secondary spirals.

A second species of *Turritella*, represented by an incomplete specimen from the Cebada member at Fugler Point, is identified as *Turritella gonostoma hemphilli* [67] (pl. 13, fig. 13). It has rapidly enlarging early whorls and flat later whorls. The earliest preserved whorls are sculptured with a median and a basal primary spiral. At a later stage a primary spiral between them is added. With further growth the primary spirals are weaker, especially the original strong median spiral. Very fine secondary spirals cover the whorls from suture to suture. This specimen is a topotype of *Turritella vanvlecki teglandae*.[68] Characters that may serve to distinguish *teglandae* from *hemphilli* are not apparent. Inasmuch as the type of *hemphilli*, from the San Diego formation at Pacific Beach, is in better condition than the type of *teglandae*, *hemphilli* is given precedence. Both *teglandae* and *hemphilli* were described as subspecies of *T. vanvlecki*, which was based on Pliocene material from the San Joaquin Valley. The rapidly enlarging early whorls and the flat later whorls suggest a closer relationship to the Recent *T. gonostoma* from the Gulf of California. *T. vanvlecki* itself, however, is related to *T. gonostoma*. Recent specimens of *T. gonostoma* generally have a posterior primary spiral on the later whorls and are larger than the California fossils. *T. gonostoma*, or a comparable form, is recorded from the Pliocene of the Los Angeles Basin.[69]

Crepidulidae.—*Crepidula princeps* (pl. 8, figs. 3, 4, 9; pl. 10, fig. 4; pl. 11, fig. 5) ranges from a horizon near the base of diatomaceous strata of the Sisquoc formation upward into the Graciosa member of the Careaga sandstone. It is most abundant in the Foxen mudstone of the Casmalia Hills. At many localities, particularly in diatomaceous strata of the Sisquoc formation and in the Tinaquaic sandstone member of the Sisquoc, the specimens are doubtfully identified molds. Preserved shell material was found in oil-impregnated diatomaceous mudstone of the Sisquoc at the NTU mine in the Casmalia Hills (locality 56) and at locality 113*b* in the Purisima Hills near Redrock Mountain. This exceptionally large species is characterized by a thick deck that has a wide asymmetric indentation on the adapical side of a median plane.[70] On the hidden face of the deck a shallow furrow corresponds to the apex of the indentation and along the furrow the deck is thinner than elsewhere. Incom-

[64] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol Survey Prof. Paper 207), p. 69.

[65] Arnold, Ralph, and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull. 322), pl. 21, fig. 11, 1907.

[66] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), p. 70, pl. 35, fig. 9, 1946.

[67] Applin, E. R., in Merriam, C. W., Fossil Turritellas from the Pacific coast region of North America: California Univ., Dept. Geol. Sci. Bull., vol. 26, pp. 126–127, pl. 37, fig. 13, 1941.

[68] Merriam, C. W., idem, p. 126, pl. 37, figs. 4, 6–10.

[69] Soper, E. K. and Grant, U. S., Geology and paleontology of a portion of Los Angeles, Calif.: Geol. Soc. Am. Bull., vol. 43, pp. 1062, 1066, 1932 (1933). Woodring, W. P., Lower Pliocene mollusks and echinoids from the Los Angeles Basin, Calif.: U. S. Geol. Surv. Prof. Paper 190, p. 20, 1938.

[70] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), p. 70, 1946.

plete specimens and fragments that show the hidden face of the deck (pl. 8, fig. 3) are readily determinable. *Crepidula princeps* is recorded from the Miocene, is widespread in the Pliocene, especially in the upper Pliocene, and occurs in formations assigned to the early Pleistocene. It apparently has no close living relatives.

Five other species of crepidulids (*Crepidula adunca*, *C.* cf. *C. excavata*, *C. aculeata*, *C. nummaria*, and *Crepipatella* cf. *C. lingulata*) were found only in the Cebada member of the Careaga sandstone.

Calyptraeidae.—A smooth low-spired *Calyptraea*, *C.* cf. *C. fastigiata*, occurs in diatomaceous strata of the Sisquoc formation and in the Cebada member of the Careaga sandstone. It appears to be similar to the Recent northern *C. fastigiata*. It has a lower spire than *C.* cf. *C. inornata* from the Pliocene of the Kettleman Hills.[71] The characters of *C. inornata*, however, are not certainly known.

A strongly ribbed *Trochita* from the Foxen mudstone and Cebada member is identified as a small variety of *T. radians* (pl. 13, fig. 19). The fossils closely resemble the Recent *T. radians* [72] from the Pacific coast of South America, but adult Recent specimens are much larger. The largest fossil from the Santa Maria district is about twice as large as the specimen shown on plate 13, figure 19. *Trochita radians*, or a comparable form, occurs in the Pliocene of the Los Angeles and Ventura Basins.[73] *Trochita* is extinct along the California coast.

A strongly ribbed *Crucibulum*, represented by a corroded specimen from the Cebada member, is similar to small specimens of the Recent *Crucibulum imbricatum* from the Pacific coast of Mexico and Central America. *C. imbricatum* is recorded from late Pliocene strata in Los Angeles.[74] Strongly ribbed species of *Crucibulum* also are extinct along the California coast.

Naticidae.—The genera *Cryptonatica*, *Neverita*, and *Lunatia* occur in the Foxen mudstone and in the Cebada and Graciosa members of the Careaga sandstone, and *Sinum* in both members of the Careaga. *Cryptonatica* is locally abundant in the Foxen mudstone and Cebada member; *Neverita* is the most abundant naticid genus in the Graciosa member; *Lunatia* and *Sinum* are represented by only a few specimens. In addition to the identified material, many collections contain exfoliated naticids or molds that are not determined generically. Such material includes molds from the Tinaquaic sandstone member of the Sisquoc formation and from limestone concretions in diatomaceous mudstone of the Sisquoc.

[71] Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 86, pl. 11, fig. 7, pl. 15, fig. 10, pl. 20, fig. 6, 1940 (1941).

[72] For a recent discussion of this species see Rehder, H. A., The molluscan genus *Trochita* Schumacher, with a note on *Bicatillus* Swainson: Biol. Soc. Washington Proc.. vol. 56, pp. 42–43, 1943.

[73] In addition to the records cited by Grant and Gale (San Diego Soc. Nat. History Mem., vol. 1, p. 795, 1931), see Moody, C. L., Fauna of the Fernando of Los Angeles: California Univ., Dept. Geol. Bull., vol. 10, p. 43, 1916; Woodring, W. P., op. cit. (U. S Geol. Survey Prof. Paper 190), p. 20.

[74] Soper, E. K., and Grant, U. S., op. cit., p. 1063.

The *Cryptonatica* is identified as a small variety of *C. aleutica* (pl. 10, fig. 1). The fossils have the thick shell and thick wide umbilical callus of Recent specimens of *C. aleutica*, which ranges from Bering Sea southward at least to Washington and perhaps to southern California as a small moderate-depth race. There appears to be no justification for Dall's statement that the type of *C. russa* has been found. The specimen to which he evidently referred when he described *C. aleutica* is in the U. S. National Museum (188401). According to the label and catalog entry, it is from the Jeffreys collection, was collected by Stimpson at Bering Strait, and was identified by Stimpson. Jeffreys presumably doubted the identification, as the catalog entry has a question mark after the name and a question mark on the label was apparently deleted. "Author's topotype" is added to the label in Dall's writing. This specimen is thin-shelled and has a thin relatively narrow umbilical callus, and is presumably *C. clausa*, as Dall thought. Nevertheless Dall's name *C. aleutica* is used for the species he had previously identified as *C. russa*, for the characters of *C. russa* are not certainly known. Gould's citation of the Arctic Ocean as the locality for *C. russa* suggests that it is the species identified as *C. clausa*, though he differentiated it from *C. clausa*. Unworn Recent specimens of both *C. aleutica* and *C. clausa* have faint minutely wavy microscopic spiral striae. Willett [75] has pointed out that California fossils recorded as *C. clausa* are probably *C. russa*; that is, *C. aleutica* of the present report. Should a name be desired for the small variety of *C. aleutica* in the Santa Maria district and elsewhere, the name "*Natica* (*Tectonatica*)" *dalli* [76] is available. The nomenclatorial recognition of species or varieties, for the differentiation of which no characters other than difference in size are apparent, is questionable. The names *dalli* and *coosensis* were proposed as a substitute for Dall's *Natica* (*Cryptonatica*) *consors*, based on material from the Pliocene(?) Empire formation of Oregon, Dall's name being a homonym of Wood's [77] *Natica multipunctata* var. *consors*. Though Wood's *consors* was a manuscript name and was not used by him in the explanation of the illustrations, his mention of it constitutes validation.

In the Santa Maria district the small variety of *Cryptonatica aleutica* is represented by shells and opercula. The specimen shown on plate 10, figure 1, is from Arnold's collection from the Waldorf asphalt mine and is the largest of the Santa Maria fossils. At the present time *Cryptonatica* is a moderate-depth genus along the California coast and the Recent shells are smaller than the largest Santa Maria fossils.

[75] Willett, George, Additions to knowledge of the fossil invertebrate fauna of California: Southern California Acad. Sci. Bull., vol. 36, p. 63, 1937.

[76] Cossmann, M., Essais de paléoconchologie comparée, vol. 13, p. 121, 1925. *Cryptonatica coosensis* is a later substitute name (Finlay, H. J., New specific names for austral Mollusca: New Zealand Inst. Trans., vol. 57, p. 499, 1927).

[77] Wood, S. V., A monograph of the Crag Mollusca; pt. 1, Univalves, Paleontographical Soc., p. 148, 1848.

The Recent Californian species *Neverita reclusiana* (pl. 20, fig. 4) is represented by numerous specimens, being especially abundant in tar sand of the Graciosa member of the Careaga sandstone on Graciosa Ridge. The tonguelike extension of the umbilical callus above the callus groove suggests that the fossils are most similar to the variety *alta*.[78] The largest Santa Maria specimens, which have a height of 40 to 50 millimeters, are poorly preserved.

The few representatives of the genus *Lunatia* are identified as *L.* cf. *L. lewisii* (pl. 12, fig. 1). The only large specimens are doubtfully identified molds. Small specimens are more strongly shouldered than *Neverita reclusiana* and have a narrower umbilical callus than that species. The callus, however, is similar to that of *Neverita reclusiana* in being grooved. Most of the fossils have a wider callus than Recent specimens of *L. lewisii* of comparable size. In the Recent fauna *Lunatia* has a more northern range than *Neverita*, the ranges of the two genera overlapping. The specimen from the Waldorf mine figured by Arnold[79] as *L. lewisii* is probably a *Cryptonatica* with exceptionally high spire and exceptionally narrow umbilical callus. The callus is not grooved and the umbilicus is not open.

A small *Sinum* in Mr. Alex Clark's collection from the Cebada member of the Careaga sandstone at Fugler Point is identified as *S. scopulosum* (pl. 12, fig. 5). The type of *S. Scopulosum*, from the Miocene Astoria formation of Oregon, is in the U. S. National Museum (3553). It is an internal mold to which a little shell is attached, enough to show the sculpture. This species appears to range from the Oligocene(?) to the Recent, the Recent form being known as *S. californicum*. Adult Recent specimens are twice as large as the Santa Maria fossil. Unidentified molds of *Sinum* were found in the Graciosa member at locality 199.

Cypraeidae.—*Trivia* cf. *T. sanguinea* (pl. 12, figs. 21, 22) is represented by a small specimen from the Cebada member of the Careaga sandstone. It evidently is more similar to the Mexican *T. sanguinea* than to the southern California *T. ritteri*, as it has a faint dorsal groove, a relatively wide outer lip, and the concealed spire does not form a protuberance. The faint dorsal groove is possibly accentuated somewhat by slight wear.

Erato cf. *E. scabriuscula* (pl. 13, fig. 20), also from the Cebada member, appears to have southern affinities like *Trivia* cf. *T. sanguinea*, with which it occurs at locality 177. This *Erato* is more slender than the California *E. vitellina* and has a higher spire. In outline it is more similar to *E. scabriuscula*, which ranges from Mexico to northern South America. The fossils are somewhat more inflated and show no trace of the faint pustules visible on unworn specimens of that species. The fossils, however, are slightly worn. *E. vitellina* is recorded in association with *Trivia ritteri* in late Pliocene strata in Los Angeles.[80]

Cymatiidae.—"*Gyrineum*" *mediocre lewisii* (pl. 12, figs. 13, 15; pl. 13, figs. 23, 24, 26, 27) is represented by incomplete material from the Foxen mudstone at the Waldorf asphalt mine and from the Cebada member of the Careaga sandstone. The three specimens shown on plates 12 and 13 were collected by Mr. Alex Clark at Fugler Point, the type locality of "*Gyrineum*" *lewisii*. The varices are in two opposite series. Those of adjoining whorls generally are offset somewhat, exact alinement being exceptional. The early whorls are sculptured with low axial ribs, closely spaced primary and secondary spiral cords separated by narrow grooves, and microscopic spiral striae. With further growth the axial ribs disappear and the spiral sculpture consists of narrow grooves and miscroscopic striae. The outer and inner lips are denticulate. The lips of the very large specimen shown on plate 12, figures 13, and 15, however, are almost smooth. The fossils from the Empire formation of Oregon on which "*Gyrineum*" *mediocre* was based are poorly preserved. The peculiar adult sculpture, including microscopic spiral striae, however, indicates a close relationship to the fossils from the Santa Maria district. The Santa Maria form is considered a variety of "*G.*" *medicore* characterized by larger size, higher spire, and wider sutural shelf. According to Hertlein and Grant,[81] it occurs in the San Diego formatio. "*Ranella*" *marshalli*, from the Miocene(?) of Washington, is probably related, but the characters are indeterminable on the basis of the type. The illustration of the Fugler Point fossil that Carson figured as a young specimen of "*G.*" *lewisii* suggests a form of *Fusitriton oregonensis* on which varices are alined in a virtually continuous series. The type and only specimen of "*G.* (*mediocre* var.?)" *corbiculatum*, from the Empire formation, is considered a form of *Fusitriton oregonensis*, or of *F. pacifica* should that species prove to be distinct. Generic assignment of "*Gyrineum*" *mediocre lewisii* is uncertain. It does not seem to be congeneric with the small strongly sculptured *Murex gyrinus*, the type of *Gyrineum*, or with the long-canaled *Ranella gigantea*, the type of *Ranella*. It is one of the few Santa Maria species that does not have even remote living relatives so far as known.

Two small incomplete specimens in Arnold's collection from the Waldorf asphalt mine are identified as "*Gyrineum*" cf. "*G.*" *elsmerense*. The only varix is at or near the outer lip. The sculpture consists of low broad axial ribs, narrow spirals, and fine closely spaced axial threads. The sculpture is similar to that of

[78] For a discussion of Pleistocene and Recent forms of *Neverita reclusiana* see Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), pp. 71-72, 1946.

[79] Arnold, Ralph, and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull. 322) pl. 21, fig. 3, 1907.

[80] Soper, E. K., and Grant, U. S., Geology and paleontology of a portion of Los Angeles, Calif.: Geol. Soc. Am. Bull., vol. 43, p. 1062, 1932 (1933).

[81] Hertlein, L. G., and Grant, U. S., IV, The geology and paleontology of the marine Pliocene of San Diego, Calif.; pt. 1, Geology: San Diego Soc. Nat. History Mem., vol. 2, p. 49, 1944.

Arnold's figured *"Tritonium"* sp. from Pliocene strata at Elsmere Canyon. Arnold's specimen, which also has a varix only near the outer lip, is from the type locality of *"G." elsmerense* and is doubtless that species. The illustration of the somewhat larger imperfect specimen that served as the type of *"G." elsmerense* shows two opposite varices on at least the last whorl. No close living relative of this species is recognized. Its affinities, however, are uncertain owing to the incomplete material. *Gyrineum* proper of the same size as the Santa Maria fossils and Arnold's Elsmere Canyon specimen has two opposite series of varices.

Incomplete and presumably immature representatives of the genus *Fusitriton* in Arnold's Waldorf asphalt mine collection and from the Cebada member of the Careaga sandstone at locality 177 are comparable to *Fusitriton oregonensis*. Arnold's small figured specimen from the Waldorf mine has exceptionally strong axial ribs. A fragment of a larger specimen in the same collection has more subdued ribs, and another has faint ribs. *F. oregonensis*, or comparable forms, is widely distributed in the Pliocene of the Pacific coast. At the present time this species is essentially northern. It ranges from Bering Sea southward to San Nicolas Island and Santa Catalina Island off southern California, the depth range increasing southward, and southward in the western Pacific to Japan.

Architectonicidae.—An apical fragment of the genus *Architectonica* is in a California Institute of Technology collection from the Cebada member of the Careaga sandstone at Fugler Point. This southern genus is rare in the California Pliocene, being recorded only from San Diego. At the present time it does not range north of Magdalena Bay, Lower California.

Epitoniidae.—*Opalia varicostata* (pl. 10, fig. 2) occurs in the Foxen mudstone at the Waldorf asphalt mine and in the Cebada member of the Careaga sandstone, and is represented by a doubtfully identified fragment from the Graciosa member of the Careaga. It is a well-defined Pliocene species that is larger and more heavily ribbed than *O. wroblewskyi*, its closest living relative. *Opalia varicostata anomala*, which lacks ribs, is represented by a specimen in Arnold's collection from the railroad cut near Shuman, evidently from the Cebada member. At Pacific Beach near San Diego, the type locality of both *varicostata* proper and *anomala*, they intergrade. Both forms have a microscopic clothlike sculpture.

Fusinidae.—Arnold's collections from the Pennsylvania and Waldorf asphalt mines and collections from the Cebada member of the Careaga sandstone contain imperfect remains of the genus *Barbarofusus*. The strongly shouldered whorls suggest comparison with *B. arnoldi*,[82] but the relations are uncertain.

"Nassidae".—*"Nassa" moraniana* (pl. 14, figs. 13, 14; pl. 17, figs. 7, 8; pl. 19, fig. 4) is the most widespread and locally the most abundant gastropod in the Graciosa member of the Careaga sandstone, is widely distributed but not abundant in the Cebada member, and was found at a few localities in limestone concretions in diatomaceous mudstone of the Sisquoc formation. It is especially abundant in tar sand of the Graciosa member on Graciosa Ridge, where hundreds of specimens ranging in length from 2 to 34 millimeters were collected. This *"Nassa"* is large and strongly noded, and adult shells have lirations on the inner lip. It is probably the species that Conrad described as *Schizopyga californiana*. Conrad's type material from a locality "12 miles back from Santa Clara overlying coal" [83] is lost, however, and until a neotype is designated the unequivocal name *"Nassa" moraniana* is preferable. Specimens of a Pliocene *"Nassa"* from a locality about 20 miles south of Santa Clara (near center of sec. 26, T. 10 S., R. 1 W., New Almaden quadrangle), kindly forwarded by Dr. P. W. Reinhart, have the sculpture of *"N." moraniana* and are reasonably similar to Conrad's poor figure of *Schizopyga californiana*. The only specimen that shows the inner lip lacks lirations on the lip, owing possibly to immaturity. *"N." moraniana* is widely distributed in the California Pliocene, is not found in the Pleistocene of the San Pedro district,[84] and is not known to be living. *"Alectrion" grammatus*, the type material of which is from the Stearns collection and is said to have been collected from Pleistocene strata at Santa Barbara, is *"N." moraniana*. The occurrence of this species at Santa Barbara has not been confirmed. The Recent species that has been designated *"N." californiana* is more slender, less strongly noded; and has more widely spaced axial ribs, and fewer and weaker lirations on the inner lip. It doubtless needs a new name.

An unidentified large *"Nassa"* (pl. 7, figs. 3, 4) is represented by numerous molds from the Tinaquaic sandstone member of the Sisquoc formation. Fragmentary remains showing sculpture indicate that the axial ribs are farther apart than those of *"N." moraniana* and that the spirals are not strongly noded. Internal molds, many of which are phosphatic, show primary spirals, or primary and secondary spirals, and no nodes, whereas internal molds of *"N." moraniana* show primary spirals and nodes between them. This contrast in internal molds, showing in reverse the sculpture of the interior of the whorl and giving an indication of the external sculpture, is shown by the illustrations on plate 7, figures 3, 4, and plate 14, figures 13, 14. Though the affinities of this *"Nassa"* are undetermined, it appears to be characteristic of the Tinaquaic.

[82] For a discussion and illustrations of Pleistocene specimens of this species from the San Pedro district see Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), p. 73, pl. 34, figs. 10, 11, 1946.

[83] Newberry, J. S., Report upon the geology of the route (Williamson's survey in California and Oregon): U. S. Pacific R. R. Expl., vol. 6, pt. 2, p. 67, 1856 (1857).

[84] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), p. 74, 1946.

Fragments from the Cebada member of the Careaga sandstone at Fugler Point are comparable to the Recent "*Nassa*" *fossata*. This species is large and has lirations on the inner lip. The later whorls have a shoulder and subdued axial sculpture.

"*Nassa*" *waldorfensis* (pl. 8, fig. 14; pl. 10, fig. 9; pl. 15, fig. 4; pl. 19, figs. 3, 5) occurs in diatomaceous mudstone of the Sisquoc formation, and is abundant in the Foxen mudstone of the Casmalia Hills and in the Cebada member of the Careaga sandstone at the railroad cut near Shuman. It was found in the Graciosa member, but is much less common than "*N.*" *moraniana*. Specimens from the Graciosa are larger and in general more coarsely sculptured than those from other units. The type, selected from Arnold's Waldorf asphalt mine collection, has exceptionally wide-spaced ribs as compared with about 100 specimens in his collection from that locality and numerous specimens from other localities. "*N.*" *waldorfensis* is smaller and more slender than "*N.*" *moraniana*, and the inner lip bears only a swelling above the basal fold and an elongate parietal denticle. It is closely related to the Recent "*N.*" *mendica*, which typically has more widely spaced ribs and generally one or two fine spirals adjoining the suture. A form of "*N.*" *waldorfensis* that has very closely spaced ribs and coarsely noded spirals occurs in the *Acila* zone of the upper Pliocene San Joaquin formation in the Kettleman Hills.[85]

A small "*Nassa*" that is abundant in the Cebada member at locality 177 and occurs in that member at Fugler Point is identified as a small variety of "*Nassa*" *mendica* (pl. 15, figs. 5, 6). It is differentiated from "*N.*" *waldorfensis* on the basis of the characters mentioned in the preceding paragraph. The fossils are smaller than Recent specimens. "*N.*" *mendica cooperi*, which has heavy widely spaced ribs, was found at the same localities. Like "*N.*" *mendica* proper, with which it is associated, this form is smaller than Recent specimens.

Neptuneidae.—The northern genus *Neptunea* is represented by two fragmentary specimens in Arnold's collection from the Foxen mudstone at the Waldorf asphalt mine. One specimen is closely comparable to *Neptunea stantoni* from the Purisima and Merced formations. It is weakly sculptured, the only strong spirals being those bounding an area between the sutural depression and the shoulder. Faint widely spaced spirals lie below the shoulder. The sculpture is closely similar to that of the Recent *N. magna*, from Bering Sea and the Sea of Okhotsk, and *N. unica*, from northern Japanese waters. *N. stantoni*, however, as pointed out by Arnold in his description of it, has a longer and narrower canal than *N. magna*. It also lacks the microscopic sculpture of the Recent species. It is doubtful whether the fossil and Recent forms are closely related.

[85] Stewart, Ralph, in Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 87, pl. 39, fig. 4, 1940 (1941).

The other specimen from the Waldorf mine is identified as *Neptunea?* sp. It is slender and is sculptured with widely spaced narrow strong spiral cords and growth lamellae. The internal mold of the early whorls shows subdued axial ribs. The affinities of this species are undetermined.

A *Calicantharus*, identified as *C. fortis* var. cf. *angulata* (pl. 14, fig. 10; pl. 15, figs. 14, 15) is represented by an incomplete specimen in a California Institute of Technology collection from the Cebada member of the Careaga sandstone at Fugler Point, by a smaller but more complete specimen in Mr. Alex Clark's collection from the same locality, and by fragments from the Graciosa member. The shoulder is angular and the axial ribs are greatly subdued on the later whorls. The variety *angulata*, based on Pliocene material from a locality near San Fernando Pass in Los Angeles County, has a similar angular shoulder, but the axial ribs are even more subdued. "*Neptunea*" *humerosa*, which apparently is associated with *angulata* at localities near San Fernando Pass, has a rounded shoulder and no axials on the later whorls. "*Siphonalia*" *gilberti*, from Pliocene strata in Los Angeles, has an angular shoulder and relatively strong axial ribs on the later whorls. The relations of these Pliocene forms to one another and to *C. fortis* proper have not been determined, but they evidently are closely related to *C. fortis* proper and perhaps are to be classified as varieties of that species. *Calicantharus fortis* occurs in the Pleistocene of the San Pedro district [86] and is the last known survivor of the genus in the restricted sense.

Calicantharus portolaensis (pl. 14, figs. 8, 9) occurs in the Cebada member of the Careaga sandstone at Fugler Point, and is already recorded from that locality by Carson.[87] The Santa Maria specimens are smaller than the type from the Etchegoin formation of the Coalinga district. This relatively slender species has closely spaced spirals and subdued axials that disappear on the body whorl. Very fine spirals are present between most of the primary spirals, but there is no well-defined differentiation into primary and secondary spirals. The Recent "*Searlesia*" *dira*, which ranges from Alaska to Monterey, has a general resemblance to *C. portolaensis*. The Recent species, however, has a shallower siphonal notch and flatter siphonal fasciole, and is probably at least subgenerically removed.

Calicantharus molds from the Tinaquaic sandstone member of the Sisquoc formation, listed as *C.* cf. *C. portolaensis*, represent a form that is larger than that species, and differentiation of the spirals into primaries and secondaries is apparently more definite. An incomplete specimen from the Graciosa member of the Careaga sandstone, *Calicantharus?* sp., is more

[86] Woodring, W. P., Bramlette, M. W., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), p. 75, pl. 29, figs. 28, 29, 1946.

[87] Carson, C. M., Some new species from the Pliocene of southern California, with a few changes in nomenclature: Southern California Acad. Sci. Bull., vol. 24, p. 34, 1925.

inflated than *C. portolaensis* and has wider and more persistent axials. It is not as inflated as *C. kettlemanensis* and the axials are not as wide. *C. kettlemanensis* is a Pliocene species from the Etchegoin formation of the Kettleman Hills and has been assigned recently to the genus *Siphonalia.*[88] The Graciosa specimen may possibly be a *Kelletia,* but the canal is not preserved.

Muricidae.—A large muricid in a California Institute of Technology collection from the Cebada member of the Careaga sandstone at Fugler Point, identified as *Jaton* cf. *J. carpenteri* (pl. 15, figs. 9, 11), evidently is a *Jaton* rather than a *Pterorytis* ["*Purpura*"] despite the size and thickness of the shell, as there is no indication of a spine near the base of the outer lip. The spiral sculpture is weak, but is more distinct than that of the Recent *J. carpenteri,* which is recorded from the late Pliocene of Los Angeles.[89] The early whorls are not preserved on the large specimen of *Jaton* cf. *J. carpenteri.* Arnold's "*Ocinebra micheli*" var. *waldorfensis* may be a young shell of that form representing a stage preceding the development of varices. The type is a small specimen from Arnold's Waldorf asphalt mine collection. A somewhat larger specimen in the same collection shows the earliest varices and also shows that the axial between the varices flattens and the spirals become weak as the varices appear, the development of sculpture being similar to that of *J. carpenteri.* Should the suggestion be substantiated that "*Ocinebra micheli*" var. *waldorfensis* is the young of the large *Jaton,* then the large *Jaton* will be known as *Jaton waldorfensis.*

The genus *Tritonalia* is represented by several species from the Cebada member of the Careaga sandstone, most of the specimens being small or imperfect. *Tritonalia* cf. *T. barbarensis* is represented, however, by well-preserved material. The spirals are more strongly differentiated into a few widely spaced primaries and weak secondaries than on any of the few Recent shells available.

The only *Boreotrophon* collected during the field work for the present report is a small specimen from oil-impregnated diatomaceous mudstone of the Sisquoc formation. Identified as *Boreotrophon* cf. *B. stuarti,* it is more strongly shouldered than the small race of *B. stuarti* living at moderate depths off the California coast, and has a secondary spiral between the primaries.

An inflated variety of the Recent Alaskan *Boreotrophon multicostatus* (pl. 15, figs. 22, 24) is represented by a well-preserved specimen in Mr. Alex Clark's collection from Fugler Point. This species has a strongly turreted spire and greatly subdued spiral sculpture. The fossil is slightly smaller than large Alaskan specimens and is slightly more inflated. It is, however, much larger and much more inflated than the small race of *B. multicostatus* living off the coast of Washington and northern California.

Thaididae.—The collections at hand contain small or incomplete specimens of the genus *Nucella* from the Foxen mudstone and both members of the Careaga sandstone. They are identified as *Nucella lamellosa shumanensis* and *N. lamellosa collomi.* The type of both varieties is from the Careaga sandstone at the railroad cut near Shuman. *N. lamellosa shumanensis* is large, weakly sculptured, and lacks axial lamellae. Aside from the larger size it is similar to some of the weakly sculptured varieties of the very variable Recent *N. lamellosa,* A form from the Etchegoin formation of the Kettleman Hills, which is of comparable size but has stronger spirals, has been identified as a sculptured variety of *N. etchegoinensis.*[90] *N. etchegoinensis*[91] itself, however, is doubtless to be regarded as a virtually smooth form of *N. lamellosa.* *N. lamellosa collomi* also is large, but is sculptured with closely spaced spirals and closely spaced axial lamellae producing a minutely scaly sculpture. It is well differentiated from Recent varieties of *N. lamellosa,* none of which has closely spaced spirals and closely spaced axials.

Cancellariidae.—The fauna of the Cebada member of the Careaga sandstone at Fugler Point includes seven species of cancellarids, which represent six genera or subgenera. Three of the seven, however, were not collected during the field work for the present report.

The most noteworthy cancellarid is a new species, *Cancellaria lipara* (pl. 16, figs. 13, 14), based on a specimen collected by Mr. Alex Clark at Fugler Point. It has a very low spire, low axials that disappear on the body whorl, and narrow spirals. The spire is worn or corroded. The columellar folds are low and strongly oblique, the parietal callus is heavy, and the interior of the outer lip is lirate. The low spire and low strongly oblique columellar folds suggest relationship to *C. solida,* a Recent species ranging from the Gulf of California to northern Peru, the body whorl of which is practically smooth. *C. solida* is the type of the subgenus *Pyruclia.*[92] *Cancellaria lipara* evidently is represented by a worn specimen, smaller than the type, in the Hemphill collection of Pliocene fossils from a well at San Diego (U. S. Nat. Mus. 56027). No allies of this well-defined species have survived along the California coast.

Large "Cancellarias" of the *tritonidea* group occur in the Careaga sandstone, three forms being recognized. "*Cancellaria*" *rapa,* which lacks nodes, is represented probably by a poorly preserved specimen in Arnold's Fugler Point collection. "*C.*" *elodiae,* from that locality, also lacks nodes and is evidently "*C.*" *rapa.* Based

[88] Stewart, Ralph, in Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 87, pl. 31, fig. 1, 7, 1940 (1941).

[89] Soper, E. K., and Grant, U. S., Geology and paleontology of a portion of Los Angeles, Calif.: Geol. Soc. Am. Bull., vol. 43, p. 1062, 1932 (1933).

[90] Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 88, pl. 36, figs. 1, 7, 1940 (1941).

[91] Idem, p. 88, pl. 24, figs. 16–18.

[92] Olsson, A. A., Contributions to the Tertiary paleontology of northern Peru; part 5, The Peruvian Miocene: Bull. Am. Paleontology, vol. 19, no. 68, p. 160, 1932.

on material from an undesignated horizon in the Pliocene of the Coalinga district, "*C.*" *rapa* has been found recently in the *Pecten* zone of the late Pliocene San Joaquin formation.[93] "*Cancellaria*" *rapa perrini* (pl. 17, figs. 1, 2; pl. 18, figs. 2, 3; pl. 19, fig. 10), the most abundant form in the collections at hand, is characterized by nodes and a shoulder on the later whorls. The type was collected at Fugler Point. The stage at which the nodes are introduced is variable, being very late on the specimen shown on plate 18, figures 2, 3. The earliest whorls are not preserved; at least some young shells (pl. 17, figs. 1, 2), however, are slightly shouldered. Two specimens of medium size from locality 204 show no nodes but are associated with noded specimens and presumably represent a form noded at a late stage. Poorly preserved specimens from Fugler Point that are strongly shouldered and strongly noded at an early stage are identified as "*Cancellaria*" cf. "*C.*" *tritonidea* (pl. 16, fig. 5). "*C.*" *sanctaemariae*, also from Fugler Point, has nodes and shoulder at an early stage, but its relation to "*C.*" *tritonidea* is uncertain. In the Pleistocene of the San Pedro district,[94] the type locality, "*Cancellaria*" *tritonidea* is exceptionally large and the spirals are more strongly differentiated into two or three ranks than those of "*C.*" *rapa* and "*C.*" *rapa perrini*. The *tritonidea* group is widespread in the California Pliocene and survived until the late Pleistocene, but has no living representatives in California waters. "*C.*" *cassidiformis*, ranging from Lower California to Peru, and the Japanese "*C.*" *spengleriana* are apparently the closest living relatives. The relations of the many California fossil forms that have been named are uncertain and there is some justification for the view adopted by Grant and Gale that they are to be treated as forms of *tritonidea*.

"*Cancellaria*" *arnoldi* (pl. 10, fig. 10; pl. 15, figs. 18, 20) has a strongly turreted spire and strong retractive axial ribs. It is represented in Arnold's collection from the Foxen mudstone at the Waldorf asphalt mine and occurs in the Cebada and Graciosa members of the Careaga sandstone, being rare in the Graciosa. The exceptionally large and well-preserved specimen shown on plate 15, figure 20, was collected by Mr. Alex Clark at Fugler Point. It is much larger than the type, a small specimen (height 22.7 millimeters) from the Hemphill collection of Pliocene fossils from a well at San Diego. Despite its small size, the apertural features of the type, including a thick parietal callus, are mature. On the type the axial ribs are weak on the last half of the body whorl, whereas they are strong on all the whorls of Mr. Clark's large specimen. That the type may be exceptional is indicated by another specimen in the Hemphill collection from the same well at San Diego (U. S. Nat. Mus. 56026). Though it is almost as large as the type (height 20.8 millimeters), the apertural features are immature and the ribs on the body whorl are strong. A poorly preserved specimen in Arnold's collection from oil-impregnated diatomaceous mudstone of the Sisquoc formation at the Pennsylvania asphalt mine evidently is a form of "*C.*" *arnoldi* that has closely spaced subdued ribs on the body whorl. "*Cancellaria*" *arnoldi* heretofore was recorded only at the type locality. It has no known close living relatives on the Pacific coast.

"*Cancellaria*" *hemphilli* (pl. 15, figs. 16, 17) was not found during the field work for the present report, but occurs at Fugler Point, where the well-preserved illustrated fossils were collected by Mr. Alex Clark. This distinctive species has a deep sutural channel, strong, widely spaced vertical axial ribs, and subdued spirals. Like "*C.*" *arnoldi*, the type of "*C.*" *hemphilli* is from the Hemphill collection of Pliocene fossils from a well at San Diego. No living Pacific coast species remotely resembles it. This is the first record for a locality north of the Ventura Basin.

Crawfordina fugleri (pl. 16, fig. 7) appears to be rare, that type, from Fugler Point, being the only representative in the National Museum collections. The illustrated topotype, available through the kindness of Mr. Alex Clark, is considerably larger than the type (height 21.9 millimeters). Though *C. fugleri* is closely related to the Recent California *Crawfordina crawfordiana*, it has a more strongly turreted spire than the Recent species and more numerous narrower axial ribs than the usual Recent form. The poorly preserved fossils from the Empire formation of Oregon on which "*Cancellaria oregonensis*" was based, evidently are more similar to *Crawfordina crawfordiana* than is *Crawfordina fugleri*.

An immature small *Admete* collected at Fugler Point by Mr. Alex Clark is identified as *A. gracilior* (pl. 15, fig. 10). Though no specimens are available from the Pleistocene Santa Barbara formation at Santa Barbara, the type locality of *A. gracilior*, the Santa Maria species is the species from the Pleistocene of the San Pedro district accepted by Arnold as *A. gracilior*. The relations of two named but unfigured Recent forms, *A. rhyssa* and *A. woodworthi*, to *A. gracilior* are undetermined, but one or both are probably *gracilior*. These Recent forms have been dredged at depths of 10 to 81 fathoms off the California coast.

Columbellidae.—Mitrella gausapata (pl. 15, fig. 7) was found in diatomaceous mudstone of the Sisquoc formation, the Foxen mudstone, and the Careaga sandstone. In the Recent fauna *M. gausapata* intergrades with *M. carinata*, which has a shoulder on the body whorl, and is generally regarded as a subspecies or variety of *M. carinata* that ranges farther north than the typical form. The fossils are slightly larger than Recent specimens. Well-preserved fossils show faint microscopic

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[93] Stewart, Ralph, op. cit. (U. S. Goel. Survey Prof. Paper 195), p. 88, pl. 15, figs. 1, 7.

[94] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), p. 76, pl. 35, fig. 21, 1946.

spiral sculpture, which is not apparent on Recent specimens that are only slightly worn or are covered with the epidermis. Should characters other than the slight difference in size and the lack of gradation toward *M. carinata* be recognized, the name *M. richthofeni* is doubtless available for the Pliocene fossils. That name was based on Pliocene fossils from Sonoma County and the San Francisco region, but the type has not been found.[95]

A slender *Mitrella* from the Cebada at locality 177 and Fugler Point is identified as a variety of *Mitrella tuberosa* (pl. 15, figs. 23, 25). The fossils are larger and more inflated than Recent shells, and large specimens have more inflated whorls and a less distinct angulation on the body whorl.

The genus *Amphissa* is rare, being represented by a poorly preserved specimen in Arnold's Waldorf asphalt mine collection and by a few imperfect shells from the Cebada at Fugler Point comparable to the Recent *A. versicolor*.

Volutidae.—A well-preserved small specimen in Arnold's Pennsylvania asphalt mine collection, poorly preserved material in his Waldorf mine collection, a fragment from the Cebada member of the Careaga sandstone at locality 177, and specimens from the Cebada at Fugler Point are referred to *Psephaea oregonensis* (pl. 14, figs. 1, 2, 4, 5; pl. 15, figs. 19, 21). The figured specimens, more complete than any collected during the field work for the present report, were collected by Mr. Alex Clark at Fugler Point. The type of *P. oregonensis* is from the Purisima formation at Año Nuevo Point in the Santa Cruz quadrangle. Arnold's publication [96] on fossils from the Santa Cruz Mountains in which the name "*Miopleiona*" *oregonensis* Dall first appeared, was issued August 8, 1908, whereas Dall's Professional Paper 59,[97] in which the species was described, was published April 2, 1909. The specimen of "*M.*" *oregonensis* figured by Arnold therefore is the type. As a matter of fact, Dall's "*M.*" *oregonensis*, figured as a fossil from the Empire formation at Coos Bay, Oregon, and as one of the "types," is unlike any of the five apparently conspecific but poorly preserved fossils from Coos Bay under the catalog number cited (153894). It is the specimen figured by Arnold (catalog number 165469), and has the same matrix and preservation as the type of "*Chrysodomus*" *stantoni*, from the same Santa Cruz locality. Through an error, however, it has the Coos Bay locality number 2954, but that number was crossed out presumably when the catalog number was added in 1908. Even if the date of publication is ignored, the type is from the Purisima formation.

The genus *Psephaea*, or *Miopleiona*, as it has been generally designated in California literature, is represented on the Pacific coast from late Oligocene (or early Miocene) to late Pliocene time, *P. oregonensis* being the last species. The genus survived until the present time, however, in Japanese waters. As pointed out by Grant and Gale, *P. oregonensis* is closely related to the living Japanese *P. prevostiana*. The whorls of *P. oregonensis* are less shouldered, and the ribs are heavier and continue to the suture with virtually undiminished strength. The apparent absence on the fossils of the faint spiral sculpture visible on the early whorls of *P. prevostiana* may be a matter of imperfect preservation. The Recent Japanese "*Voluta*" *concinna*, the type of *Psephaea*, has a relatively strong shoulder and the axials form subdued nodes on the shoulder. "*Rostellaria*" *indurata*, the type of *Miopleiona*, lacks a shoulder, but so far as known is otherwise similar to *Psephaea*. Only the internal molds of *P. indurata*, a species from the Miocene of Astoria, Oreg., are available. It is more slender than *P. oregonensis*, but its characters are not well known. The specimen from Freshwater Bay, Washington, which is sculptured with relatively strong spirals and was used by Dall [98] in defining *P. indurata*, is presumably *P. weaveri*.[99] The exterior of specimens of *P. indurata* from Astoria has not yet been described.

Olividae.—A slender variety of the Recent *Olivella biplicata* (pl. 19, figs. 7, 11) occurs in the Cebada member of the Careaga sandstone and is widespread in the Graciosa member. The fossils are not as large as adult Recent shells and are more slender than most Recent shells of the same size. A small slender *Olivella* that has a thin parietal callus is comparable to immature specimens of the Recent *Olivella baetica* (pl. 15, fig. 8). It is represented in Arnold's Waldorf asphalt mine collection and is abundant in the Cebada member at locality 177.

Turridae.—An inflated variety of *Megasurcula carpenteriana* (pl. 17, fig. 9) was found in both members of the Careaga sandstone. The Santa Maria fossils are more inflated than Recent specimens and are evidently more inflated than the type from the Pleistocene Santa Barbara formation. The earliest whorls are worn and corroded. Intermediate whorls that are not strongly worn show subdued narrow axials on and below the shoulder. Should it be desirable to use a varietal name for the Santa Maria form, "*Bathytoma*" *carpenteriana fernandoana* is available, the type being a small incomplete specimen from the Graciosa member.

Megasurcula carpenteriana tryoniana is differentiated from *M. carpenteriana* proper by the presence of nodes on the shoulder. A form of the variety *tryoniana*

[95] Stewart, R. B., Gabb's California fossil type gastropods: Acad. Nat. Sci. Philadelphia Proc., vol. 78, p. 291, 1926 (1927).

[96] Arnold, Ralph, Descriptions of new Cretaceous and Tertiary fossils from the Santa Cruz Mountains, Calif.: U. S. Nat. Mus. Proc., vol. 34, pp. 345–390, pls. 31–37, 1908.

[97] Dall, W. H., Contributions to the Tertiary paleontology of the Pacific Coast; I, The Miocene of Astoria and Coos Bay, Oregon: U. S. Geol. Survey Prof. Paper 59, 278 pp., 23 pls., 14 figs., 1909.

[98] Dall, W. H., op. cit., p. 35, pl. 18, fig. 6.

[99] Tegland, N. M., The fauna of the type Blakeley upper Oligocene of Washington: California Univ., Dept. Geol. Sci. Bull., vol. 23, p. 127, pl. 11, figs. 1–5, 1933.

(pl. 11, fig. 6), characterized by a strong shoulder, is in Arnold's Waldorf asphalt mine collection and may be represented by a corroded fragment from the Cebada member of the Careaga sandstone at locality 177. The shoulder is stronger than on Pleistocene fossils from the San Pedro district, the type locality, and is also stronger than on the few Recent shells available.

Specimens in Arnold's Waldorf asphalt mine collection, including his figured "*Drillia*" *johnsoni* and the type of his "*Drillia*" *waldorfensis*, and from the Cebada are interpreted as representing a very variable species identified provisionally as *Elaeocyma* cf. *E. empyrosia*. Most of these fossils are inflated, more inflated than the Recent *E. empyrosia*. The type and only specimen of "*Drillia*" *waldorfensis*, however, is very slender, but evidently is exceptional. The anal fasciole of the fossils is flat to strongly concave. The spiral sculpture varies from very faint, as on the type of "*Drillia*" *waldorfensis* and on more inflated specimens, to moderately strong. The growth lines cut obliquely across the axial ribs except on the last whorl or two of adult shells. Recent specimens of *Elaeocyma empyrosia* do not show such a wide range of variation. They are moderately slender and have faint spiral sculpture except on the base of the body whorl. The type of "*Drillia*" *johnsoni*, from the late Pleistocene Palos Verdes sand of the San Pedro district, is inflated like most of the Santa Maria specimens, but is in a poor state of preservation. The illustration of "*Drillia*" *fleenerensis*, from the Pliocene of the Eel River basin, indicates that it is similar to forms of *Elaeocyma* cf. *E. empyrosia* that have faint spiral sculpture.

"*Drillia*" *graciosana* (pl. 17, figs. 3–6, 10) is abundant in the Graciosa member of the Careaga sandstone on Graciosa Ridge, and is represented by a mold from the Graciosa of the Purisima Hills and by a mold from the top of the Cebada member. The shells are more or less worn. The outline ranges from slender to inflated and from slightly shouldered to strongly shouldered. The axial and spiral sculpture is heavy and crude. The type is small, slender, and greatly worn. No close living relative is recognized. "*Drillia*" *incisa* and its allies are more slender and more delicately sculptured. "*Drillia*" *incisa* and its allies were referred to *Moniliopsis* by Dall, but are not congeneric with the Eocene type of *Moniliopsis*, "*Pleurotoma*" *elaborata*, which has a deep narrow notch above the shoulder and a many-whorled protoconch, the last quarter whorl of which is sculptured with axial riblets. The generic name *Ophiodermella*[1] has recently been proposed for this Recent Pacific coast genus. "*Drillia*" *mercedensis*, from the Pliocene of the Santa Rosa district, is "*D.*" *graciosana*. "*D.*" *mercedensis* has been recorded from Pliocene formations in several coastal districts and in the San Joaquin Valley. "*D.*" *graciosona* evidently was named again as "*D.*" *mercedensis* because Arnold's illustration of the worn type is unrecognizable.

The genera *Mangelia*, "*Mitromorpha*," and *Glyphostoma* were found only in the Cebada member of the Careaga sandstone at locality 177 and Fugler Point. One form of *Mangelia* is the angulated variety of *Mangelia variegata*, according to Willett's[2] interpretation; that is, it is the Recent form for which the name *Mangelia angulata* and the substitute name "*Mangilia*" *barbarensis* have been used. Another *Mangelia* is identified as an inflated variety of the Recent *Mangelia interlirata*.

A variety of "*Mitromorpha*" *intermedia* is more inflated than the typical form, from the early Pleistocene San Pedro sand, and has wider axial ribs. "*M.*" *intermedia* is evidently not congeneric with the type of *Mitromorpha*, *M. filosa*, which has a shorter and less cylindrical protoconch, denticles on the interior of the outer lip, and a relatively heavy parietal callus. "*M.*" *intermedia* is generally considered a variety of *M. gracilior*. The latter species, however, has a small protoconch, weak axial ribs, and closely spaced spiral ribs. A Recent form of "*M.*" *intermedia*, or a closely related species, characterized by narrow spirals, is represented in the National Museum collection by material dredged off Santa Rosa Island and off San Diego at depths of 53 to 110 fathoms.

Glyphostoma conradiana is characterized by growth puckers on the anal fasciole. Most of the Santa Maria specimens have heavier axial ribs and less numerous secondary spirals than the only available specimen from the Santa Barbara formation at Santa Barbara, the type locality. The imperfect specimen from the *Acila* zone of the Kettleman Hills recently illustrated as "*Pleurotoma*" cf. "*P.*" *coalingensis*[3] is evidently *Glyphostoma conradiana*. Closely related forms are living at moderate depths along the California coast, *G. cymodoce* being very similar, though more slender. *G. conradiana* appears to represent a minor group under *Glyphostoma*. It has growth puckers on the anal fasciole similar to those of *Gylphostoma*, but the protoconch is more cylindrical and the aperture is weakly armed.

The northern genus *Propebela* ("*Bela*" and "*Lora*" of California literature) is represented by an undetermined species in Arnold's Waldorf asphalt mine collection and in the collection from the Cebada member at locality 177. It has a strongly turreted spire, strong axial ribs, and well-defined secondary spirals above the shoulder. It bears a strong general resemblance to *P. turricula*, the type of the genus, and its circumboreal allies. Species similar to the Santa Maria form are found off the Pacific coast from Alaska to California, but it is

[1] Bartsch, Paul, Some turrid mollusks of Monterey Bay and vicinity: Biol. Soc. Washington Proc., vol. 57, p. 61, 1944. Type, *Ophiodermella ophioderma* (Dall).

[2] Willett, George, An upper Pleistocene fauna from the Baldwin Hills, Los Angeles County, Calif.: San Diego Soc. Natural Hist. Trans., vol. 8, no. 30, p. 394, 1937.

[3] Steward, Ralph, in Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 33 (table), pl. 11, fig. 4, 1940 (1941).

impractical at the present time to attempt to determine its affinities. The genus ranges southward with increasing depth, having been dredged at depths of 60 to 870 fathoms off the California coast.

Terebridae.—*Strioterebrum martini* (pl. 16, fig. 21) was found in both members of the Careaga sandstone, but is rare. It is a well-defined species characterized by a narrow sutural band, numerous strong axial ribs, and only a faint suggestion of spiral sculpture on the flanks of the ribs. No close living relative has been recognized. This is the first record for *S. martini* from a locality north of the Ventura Basin.

Acteonidae.—The genus *Acteon*, which is rare in California Pliocene faunas, is represented by two small specimens from the Cebada member of the Careaga sandstone. One, from locality 177, is comparable to immature shells of the Recent *A. punctocaelatus*. The other, from Fugler Point, is more inflated and has a lower spire than immature shells of that species.

Acteocinidae.—The genus *Acteocina* is likewise rare in California Pliocene faunas and is represented by material from the Cebada member. An incomplete presumably immature specimen from locality 177 is identified as *Acteocina* cf. *A. culcitella*. Poorly preserved material from Fugler Point may represent the same form.

Scaphandridae.—*Cylichna* is still another genus that is rare in California Pliocene faunas. Two incomplete specimens from the Cebada at locality 177 are comparable to the Recent *Cylichna attonsa*. That species, which is found at moderate depths off the California coast, is relatively thin-shelled and slender.

Fresh-water pulmonates.—Fresh-water pulmonates were found as molds at locality 211 in strata mapped as the upper part of the Graciosa member of the Careaga sandstone and are present in the Paso Robles formation and Orcutt sand.

A small lymnaeid from the Paso Robles formation was described by Arnold as "*Lymnaea*" *alamosensis* (pl. 18, fig. 6). If internal molds from the Orcutt sand belong to this species, the Paso Robles shells in the collections at hand and the type are immature. The relations of "*L.*" *alamosensis* to Recent species are undetermined.

Two small planorbids, *Gyraulus* cf. *G. vermicularis* (pl. 18, figs. 5, 8) and *Menetus* cf. *M. cooperi* (pl. 18, figs. 4, 7), were found in the Paso Robles formation and Orcutt sand, and fragments of a large species, *Helisoma* sp., are in a collection from the Paso Robles formation. The small species, and doubtless also the large species, are closely comparable to Recent California forms. *Menetus* cf. *M. cooperi* has microscopic spiral striae and the largest shells are weakly carinate.

A small slender unidentified *Physa* (pl. 18, fig. 11) is present in both the Paso Robles and Orcutt. The fossils from both formations are probably immature.

PELECYPODS

Nuculanidae.—A small strongly rostrate and strongly sculptured *Nuculana* from the Graciosa coarse-grained member of the Careaga sandstone at the railroad cut near Shuman (localities 196*b*, 193*c*) is identified as *Nuculana* cf. *N. leonina*. In external characters, it closely resembles the much larger Recent northern species *N. leonina*. *N. leonina* is larger than the more common *N. hamata* and has a wider rostrum, which is squarely truncated, as is that of *N. hamata*. *N. leonina* has the narrow asymmetric chondrophore characteristic of *Nuculana*. No similar species are recorded from formations of Pliocene age in California.

Four species of *Saccella* are recognized in the Santa Maria district. Three appear to have survived until the present time in California or nearby waters and the fourth is related to a living California species. *S. cellulita* (pl. 15, figs. 3, 26) occurs in the Foxen mudstone, the Cebada fine-grained member of the Careaga sandstone, and probably in the upper part of the Sisquoc formation. The outline suggests that of *S. taphria*, but the concentric rugae are finer. The irregular *Acila*-like radial sculpture on the lunule and escutcheon, however, is the most characteristic feature of the northern *S. cellulita*. This species has not heretofore been recorded from the Pliocene. *Saccella taphria* (pl. 21, fig. 7), the common Recent California species, is widely distributed in both members of the Careaga sandstone.

Saccella orcutti (pl. 8, figs. 5, 7, 8, 13; pl. 10, fig. 3) is widespread in diatomaceous strata of the Sisquoc formation, was found in the Foxen mudstone only at the type locality, and occurs in the Cebada member of the Careaga sandstone at a few localities. Most of the Sisquoc material consists of molds, but numerous well-preserved shells, many of which are paired, were collected from oil-impregnated mudstone at the dump of the old Pennsylvania asphalt mine (locality 73) and at locality 74. The type, from the Waldorf asphalt mine, is immature, elongate, and coarsely sculptured. A larger specimen from the type lot is shown on plate 10, figure 3. Twenty specimens are in collections from the type locality. They are elongate and strongly and coarsely sculptured except one, which is almost smooth aside from sculpture near the ventral margin. The few Careaga fossils also are elongate. The more numerous Sisquoc shells from localities 73 and 74 show a greater range of variation. The outline varies from short (pl. 8, fig. 7), the usual form, to elongate (pl. 8, fig. 5). Some immature shells are coarsely sculptured (pl. 8, fig. 8), but most immature and mature shells have strong moderately coarse sculpture. One immature shell, however, is almost smooth (pl. 8, fig. 13). The short form was figured by Arnold[4] as "*Leda*" *taphria*. His specimen was collected at the Pennsyl-

[4] Arnold, Ralph and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull. 322), pl. 22, fig. 3a, 3b, 1907.

vania asphalt mine, the locality that furnished the specimens shown on plate 8 of the present report, not at Fugler Point as stated in the explanation of the plate. The short form of *S. orcutti* resembles closely the Recent northern *S. penderi*, but has coarser and generally stronger sculpture.

A small species that is relatively elongate and has finer sculpture than *S. orcutti* is identified as *S. redondoensis* (pl. 16, fig. 18). It was found in the Cebada member of the Careaga sandstone at locality 177 and is probably present at Fugler Point. Most of the fossils show microscopic punctae on the ventral side of the concentric rugae on the dorsal part of the shell, possibly due to slight corrosion, but not on the umbo. A few of the Recent shells examined show similar punctae. The recently named *S. redondoensis* [5] is the living California species formerly identified as "*Leda*" *acuta*.

Yoldia gala (pl. 8, figs. 1, 2; pl. 9, figs. 9, 10), a new species, is the most characteristic megafossil in the diatomaceous strata of the Sisquoc formation. It is moderately large, elongate, and weakly sculptured, the sculpture consisting of low concentric rugae of varying width on the ventral half or less. Though this species is represented by numerous well-preserved molds, the only shell material consists of patches on a left valve from the NTU mine (locality 56). The sculpture is generally impressed on internal molds. This *Yoldia* is the "*Nuculana* sp." of the preliminary report on the Santa Maria district.[6] The outline suggests *Yoldia* and the chondrophore is long and symmetrical, like that of *Yoldia*. It is not certain, however, that the chondrophore is as wide as that of *Yoldia*. The pallial sinus is not discernible on any of the fossils. *Yoldia gala* is perhaps related to *Yoldia astoriana*, from the Miocene Astoria formation of Oregon, but is larger and more elongate, its posterior end is not so abruptly upturned, and it evidently lacks the impressed lunule and escutcheon of *Y. astoriana*. No specimens in the type lot of *Y. astoriana* (the type lot of Conrad's *Nucula impressa*, a homonym) is as large as the dimensions cited by Conrad ("length 1 inch, breadth very nearly half an inch"), who may have based his measurements on his figure 7*d*. The originals on which his figures 7*c* and 7*d* were based, however, may be with other specimens under U. S. National Museum catalog numbers 3490 and 3491, respectively, the figures being enlarged and restored. The specimen well illustrated by Weaver [7] as the "holotype," possibly the original of Conrad's figure 7*d*, had already been chosen as the lectotype.[8] A mold of paired valves in attached position in the type lot (3491) shows a deep wide pallial sinus, like that of *Yoldia*. *Yoldia gala* is also larger and more elongate than "*Leda*" *subimpressa*, from the Pliocene(?) Empire formation of Oregon. "*Leda*" *subimpressa* appears to be closely related to *Yoldia astoriana* and may be the same species, as has been claimed. Arnold's *Yoldia impressa*, from the Monterey shale of the Santa Cruz Mountains, has strong regular concentric rugae and is probably a *Nuculana*. No Recent California allies of *Yoldia gala* are recognized in the U. S. National Museum collections. *Y. limatula*, which has been dredged as far south as San Diego in deep water (417 fathoms), has a shallow ventral notch near the anterior end of the shell. Northern specimens of *Y. limatula* are much larger than *Y. gala*, but those from British Columbia to San Diego are not larger. Specimens of *Y. gardneri* [9] (possibly an elongate form of *limatula*) from British Columbia are not available.

Yoldia cf. *Y. supramontereyensis* is represented by incomplete molds from both members of the Careaga sandstone. *Y. supramontereyensis*, which was based on Miocene material, has a longer and wider posterior end than the living California *Y. cooperi*. The molds from the Santa Maria district that show the posterior end suggest *Y. supramontereyensis*. Y. *cooperi* is the type of the subgenus *Kalayoldia*, characterized by a strongly oblique chondrophore, very deep pallial sinus, upturned posterior end, and strong concentric sculpture.

Arcidae.—Arca santamariensis (pl. 14, figs. 6, 7) was found only at Fugler Point, the type locality. The posterior slope of this small species has a depression at each end, the intervening area being swollen. It resembles the Recent southern *A. mutabilis*, which lacks the depressions on the posterior slope.

Imperfect specimens of *Arca sisquocensis* are in Arnold's Waldorf asphalt mine collection and were collected from the Cebada member of the Careaga sandstone at locality 177 and the type locality, Fugler Point. The posterior slope of this *Arca* is practically flat or slightly concave. It has no known Recent allies on the Pacific coast, but is closely related to the Recent Japanese *A. kobeltiana*.[10] Adult shells of *A. sisquocensis* have a wider posterior slope than that of *A. kobeltiana*, the posterior ridge being more strongly curved. Both species have a flange on the muscle scars, indicating that they do not represent *Arca* in the restricted sense. *A. sisquocensis* is recorded from Pleistocene strata (late Pliocene of some geologists) at Santa Barbara and in the San Pedro district.

[5] Burch, J. Q., Conchological Club Southern California Minutes, No. 33, p. 9, 1944 (mimeographed).

[6] Woodring, W. P., Bramlette, M. N. and Lohman, K. E., Stratigraphy and paleontology of Santa Maria district, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 10, p. 1352, 1943.

[7] Weaver, C. E., Paleontology of the marine Tertiary formations of Oregon and Washington: Univ. Washington, Pub. in Geology, vol. 5, p. 42, pl. 4, figs. 9, 10, 1942 (1943).

[8] Grant, U. S., IV, and Gale, H. R., Catalogue of the marine Pliocene and Pleistocene Mollusca of California. San Diego Soc. Nat. History Mem., vol. 1, p. 955 (explanation of pl. 32, fig. 46), 1931.

[9] Oldroyd, I. S., Two new West American species of Nuculanidae: Nautilus, vol. 49, p. 14, fig. 1, 1935.

[10] Pilsbry, H. A., New Japanese marine Mollusca; Pelecypoda: Acad. Nat. Sci. Philadelphia Proc., vol. 56, p. 559, pl. 40, figs. 16–19, 1904.

Barbatia pseudoillota (pl. 15, figs. 12, 13) is a third small arcid from the unusual Cebada locality, Fugler Point, which is the type locality. Like many other species from Fugler Point, it occurs also at locality 177. It is closely allied to the Recent southern *B. illota*, but is less elongate. *B. pseudoillota* is the type of the subgenus *Fugleria*. That subgenus may prove to be useful for small very short species of *Barbatia*. On fully adult shells of *B. illota* a narrow band of ligament extends in front of the umbo, as on small specimens of *Arca barbata*, the type of *Barbatia*. On such shells of *B. illota* the hinge is edentulous, except at the extremities.

Anadara trilineata, which has no living counterpart on the Pacific coast, is one of the most common fossils in the Santa Maria district. In the absence of type or topotype material,[11] Arnold's identification of fossils from the Kettleman Hills in the San Joaquin Valley is used as a standard for naming the Santa Maria representatives of this species, which is cited as *Anadara trilineata* (Conrad) of Arnold. Most of the Santa Maria specimens consist of molds, many of which are equivocally identified, but well-preserved shells were found at some localities. The elongate inequilateral form of *A. trilineata* (pl. 9, fig. 2; pl. 11, fig. 4; pl. 16, fig. 19), traditionally accepted as the typical form, occurs in the Tinaquaic sandstone member of the Sisquoc formation, in diatomaceous strata of the Sisquoc, in the Foxen mudstone, and in the Careaga sandstone. The exceptionally large left valve shown on plate 16, figure 19, was collected by Mr. Alex Clark at Fugler Point. A less abundant short inequilateral variety (pl. 9, fig. 5) also occurs in the formations and members just mentioned. Arnold's figured specimen is an example of the short variety from the Cebada at Fugler Point. Though one or the other form is generally found at any one locality, both are associated at some localities throughout their stratigraphic range. The NTU mine (locality 56), however, is the only locality where the short variety is abundant. Twenty-one specimens, all short, are in the collection from that locality.

A variety of *A. trilineata* that is practically equilateral, *A. trilineata* variety cf. *canalis*, was found in the Tinaquaic sandstone member and in sand interbedded with silty diatomaceous strata of the Sisquoc formation. At each of the three localities where it is represented, it is associated with the typical form. On the basis of the collections at hand, the *canalis*-like variety has the same relative stratigraphic position as a similar variety in the Kettleman Hills.[12] The variety *canalis*, however, is recorded from the Cebada member of the Careaga sandstone at Fugler Point.[13]

[11] Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 89, 1940 (1941).

[12] Op. cit., pp. 89-90.

[13] Reinhart, P. W., Mesozoic and Cenozoic Arcidae from the Pacific slope of North America: Geol. Soc. America Special Paper 47, p. 61, 1943.

Glycymeridae.—The genus *Glycymeris* is represented by small or imperfect specimens from a few localities in the Foxen and Careaga formations. The only large specimens, identified as *Glycymeris* cf. *G. grewingki*, are from the Graciosa member of the Careaga sandstone at the railroad cut near Shuman (locality 196*b*). *G. grewingki* was based on fossils from the Pliocene(?) Empire formation of Oregon.

Mytilidae.—*Mytilus* is rare in the Santa Maria district. Molds of a very large species, *Mytilus* cf. *M. coalingensis*, were found in the Careaga sandstone and fragmentary remains of apparently the same species occur in the Foxen mudstone. Molds from two of the three localities in the Careaga are wider than *M. coalingensis* from the Etchegoin formation of the Kettleman Hills. *M. coalingensis* belongs to a group of Miocene and Pliocene species that left no survivors on the Pacific coast.

Molds of *Volsella*, some of which have patches of the thin shell, are widespread in the Tinaquaic sandstone member of the Sisquoc formation and occur in the Foxen mudstone and Careaga sandstone. Undistorted complete molds are identified as *Volsella* cf. *V. capax*, being comparable to the broad Recent *V. capax* from southern California. A few of the fossils suggest the narrow Recent *V. recta*, but some of them are distorted and perhaps all are.

A right valve of a *Crenella*, collected from the Cebada member of the Careaga sandstone at the railroad cut near Shuman, is comparable to the small Pacific coast species considered identical with *C. decussata* of the North Atlantic. This genus has not been recorded heretofore from the California Pliocene.

Pectinidae.—Fragmentary remains from the Foxen mudstone and Cebada member of the Careaga sandstone are questionably identified as *Pecten stearnsii*. They are without much doubt that species, which has numerous ribs (23 to 26) and a groove on the ribs of the right (inflated) valve. *P. stearnsii* was based on material from the Pliocene San Diego formation at San Diego and survived until the Pleistocene in the San Pedro district.[14] A Recent form, *P. diegensis*, dredged at moderate depths off the coast of southern California, is so similar that perhaps it is to be treated as a subspecies of *stearnsii*.

Though *Pecten hemphilli* (pl. 16, figs. 15, 16; pl. 21, fig. 8) is one of the most abundant of the Pectinidae in the Careaga sandstone, particularly in calcareous sandstone of the Cebada member in the western Casmalia Hills, much of the material is fragmentary and none of it is entirely complete. A fragment of a right valve from the Sisquoc formation at the NTU mine is comparable to this species. *Pecten hemphilli*, from the Pliocene San Diego formation at San Diego, and *Pecten*

[14] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), p. 80, pl. 30, figs. 9, 10, pl. 32, figs. 14, 15, 1946.

bellus, from the Pleistocene (late Pliocene of some geologists) Santa Barbara formation at Santa Barbara, are very closely related and at some localities are said to intergrade. A series of 19 right and 36 left valves from San Diego and 9 right and 9 left valves from Santa Barbara show no gradation. Though Jordan and Hertlein recorded *P. bellus* from San Diego, only *P. hemphilli* is represented in the National Museum collections from that locality. The identifiable Santa Maria fossils are *P. hemphilli*, or a form of *hemphilli*, and the Santa Maria collections include no *bellus*-like form. Large specimens of *P. bellus* (height 90 millimeters) are half again as large as the largest *P. hemphilli* (height 60 millimeters). The channels on the dorsal part of the interior of both valves of large *P. hemphilli* are stronger than on those of *P. bellus* of the same size. The ribs on the right (inflated) valve of *P. hemphilli* are more rounded than the flat-topped ribs of *P. bellus*, and on both valves, particularly near the ventral margin, the ribs of *P. hemphilli* are narrower. The ribs on the left (flat) valve of Santa Maria specimens are somewhat narrower than on those from San Diego, and on the left valve shown on plate 16, figure 16, the only nearly complete large left valve, they are exceptionally narrow. The *hemphilli-bellus* group has no living allies in California or nearby waters, but the recent Japanese *P. albicans*,[15] generally known as *P. laqueatus*, is evidently closely allied, more closely to *P. bellus* than to *P. hemphilli*. It has fewer main ribs than *P. bellus*, the ribs being wider on the right valve and farther apart on the left; the right valve is more inflated and the left valve more uniformly flat or somewhat concave.

Poorly preserved specimens from the Cebada member of the Careaga sandstone at locality 183 and a fragment in Arnold's Fugler Point collection may represent an *Aequipecten* of the *A. circularis* group.

The Recent California *Chlamys hastatus*, a relatively small species that has numerous scaly ribs, occurs probably in diatomaceous strata of the Sisquoc formation, in the Foxen mudstone, and is fairly common in the Cebada member of the Careaga sandstone. Fragments and molds suggest that a small *Chlamys*, possibly this species, is rare in the Graciosa member of the Careaga sandstone. None of the largest Santa Maria fossils is complete. *Pecten* (*Chalmys*) *lawsoni*, based on an incomplete valve from Fugler Point, is considered a synonym of *C. hastatus*.

Two forms of a large *Chlamys* are recognized, *Chlamys parmeleei* in the Cebada member of the Careaga sandstone and *Chlamys parmeleei etchegoini* in the Foxen mudstone. *C. parmeleei* (pl. 16, fig. 20), which was based on a small valve from the Pliocene San Diego formation, has concentric swellings, whereas *C. parmeleei etchegoini* lacks the swellings. *Chlamys wattsi*, from the San Joaquin formation of the Coalinga district, is evidently the same as *C. parmeleei*. The type of *C. etchegoini* also is from the San Joaquin formation. *Chlamys parmeleei* is another example of a California Pliocene species that has a close living relative in Japanese waters but not on the California coast. It is very similar to the Japanese *C. swiftii*, so similar that the view that it is to be classified as a variety or subspecies of *swiftii* may be justified. The dorsal (umbonal) part of the shell of large specimens of *C. parmeleei* is more inflated than that of *C. swiftii* and is more strongly set off from the ears.[16] *Chlamys parmeleei* was found only at Fugler Point and locality 177. The figured specimen, larger than any collected during the field work for the present report, was collected by Mr. Alex Clark at Fugler Point. *C. parmeleei etchegoini* is represented by two incomplete valves. *C. swiftii* is the type of the subgenus *Swiftopecten*.[17] The wide primary ribs and large size appear to be the only characters to differentiate this minor group of *Chlamys*.

Three species of the genus *Patinopecten* are present in the Santa Maria district: *Patinopecten lohri* in the Tinaquaic sandstone member of the Sisquoc formation and a comparable form in diatomaceous strata of the Sisquoc; a variety of *Patinopecten dilleri* in diatomaceous strata of the Sisquoc, and *P. dilleri* proper in the Foxen mudstone and the Cebada member of the Careaga sandstone; and *Patinopecten healeyi* in the Foxen mudstone and both members of the Careaga. Though their ranges overlap, these three species are stratigraphically useful, *P. lohri* being found in the oldest formation containing marine Pliocene fossils, *P. healeyi* in the youngest, and *P. dilleri* in intervening strata.

Patinopecten lohri (pl. 7, figs. 7, 9) and *P. healeyi* (pl. 19, fig. 9; pl. 21, fig. 9) are closely related, but have no close living allies. The ribs on large left valves of *P. lohri* are wide and divided, whereas on *P. healeyi* they are narrow and not divided, or on some very large left valves are moderately wide and faintly divided by one or more shallow grooves. Right valves of *P. lohri* generally have a strong secondary rib in the space between the primary ribs, whereas on right valves of *P. healeyi* secondary ribs are absent or, if present, generally are weak. Some right valves of *P. lohri*, however, lack secondary ribs or have weak secondaries. Left valves of both species have secondaries. Owing to the presence of divided ribs on both valves of *P. lohri*, right and left valves of that species are difficult to distinguish unless the ears are preserved, whereas right and left valves of *P. healeyi* are readily differentiated.

The type of *P. lohri*, from "Foxen's Ranch," was presumably collected from the Tinaquaic sandstone

[15] For the name of this species see Rehder, H. A., A new pectinid shell from the Pacific Ocean, with a note on the genus *Pallium* Schroeter: Nautilus, vol. 58, p. 54, 1944.

[16] Stewart, Ralph, in Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 91, 1940 (1941).

[17] Hertlein, L. G., The Templeton Crocker expedition of the California Academy of Sciences, 1932; The Recent Pectinidae: California Acad. Sci. Proc., vol. 21, No. 25, p. 319, 1935. Hertlein, L. G. Three new sections and rectifications of some specific names in the Pectinidae: Nautilus, vol. 50, p. 24, 1936.

member of the Sisquoc formation somewhere near Foxen Canyon. Though this species was found at five localities in that member, it is not abundant and no complete large valve was collected. The stage at which the ribs are divided is variable. They are divided at an early stage in the right valve shown on plate 7, figure 9, but, according to Arnold's illustrations, they are divided at a later stage on the type. The two branches of the primary ribs and the secondary ribs on specimens from the Etchegoin formation of the Kettleman Hills [18] are of more nearly equal width and uniform spacing than on Santa Maria specimens. The incomplete material from diatomaceous strata of the Sisquoc formation is identified as *Patinopecten* cf. *P. lohri.* Molds from locality 113 near Redrock Mountain show a few secondary ribs or none. Both molds and shell fragments from the NTU mine (locality 56) show the same features, but one shell fragment has strong secondaries. Incomplete as these fossils are, they are without much doubt a form of *P. lohri.*

Patinopecten healeyi was originally based on fossils from the San Diego formation at San Diego. The interspaces on right valves from the Santa Maria district are narrower than on San Diego right valves; in fact, they are very narrow on many Santa Maria specimens. The figured specimens, more complete than large valves found during the field work for the present report, were collected by Arnold and Anderson at the railroad cut near Shuman.

Patinopecten dilleri (pl. 11, figs. 1, 9) is widespread in the Foxen mudstone of the Casmalia Hills and an incomplete left valve was found in the Cebada member of the Careaga sandstone at locality 172 in the Orcutt field. The Foxen mudstone material collected is incomplete or fragmentary. The well-preserved paired specimen shown on plate 11, figures 1, 9, was formerly in the collection of Mr. Alex Clark and was collected by Mr. L. M. Clark from calcareous sandstone of the Foxen 1.8 miles S. 35° E. from Casmalia, a short distance beyond the limits of the mapped area. Though no well-preserved left valve from the type region, the Eel River basin of northern California, is available, this species is identified with considerable confidence. In fact, the only available left valve from the type region is the mold, to which some inner shell material clings, paired with the type right valve. It shows no secondary ribs. On Santa Maria specimens, ribs of the left valve, corresponding to the interspaces of the right, are narrower and more rounded than the flat-topped ribs of the right valve. The scaly lamellae on the ribs are the most characteristic feature of *P. dilleri.* They are worn off on some ribs, particularly on the crest of right ribs, and are absent on the extreme dorsal (umbonal) part of valves. The absence of strong growth lines, which elsewhere accompany lamellae, in the extreme dorsal part suggest that lamellae never were present on that part of the shell. The first left valve of *P. dilleri* to be illustrated was collected at a locality near Laguna Ojo de Liebre (Scammon Lagoon) in Lower California, 1,000 miles south of the type locality. It closely resembles specimens from the Santa Maria district. The expectation that the species is to be found in intervening areas is fulfilled by a specimen from the hills north of Simi Valley, in Ventura County, and by another from San Diego, both in the collections of the University of California at Los Angeles. Both have weak sculpture on the posterior ears, whereas the posterior ears of Santa Maria valves and of the left valve from Lower California have strong lamellar ribs.

Patinopecten dilleri is very closely related to *P. coosensis,* from the Pliocene(?) Empire formation of Oregon. The view that *dilleri* is to be treated as a variety or subspecies of *coosensis,* which was adopted by Grant and Gale, has some justification. Four large specimens from Coos Bay, including those illustrated by Arnold and Dall, have no lamellae, but they have strong growth lines that roughen the shell. Though these fossils are well-preserved, they may originally have had lamellae that were worn down during life. Two of four right valves have weakly divided ribs and some ribs on the other two show a faint groove near the ventral margin. So far as known, the ribs of *P. dilleri* are not divided. *Patinopecten purisimaensis,* from the Pliocene Purisima formation, also is very closely related. The faint groove or grooves on the ribs of the right valve of the type suggest it is a form of *P. coosensis* that has fewer ribs than the typical form. The type of *P. purisimaensis* has lamellae on the flanks of some right ribs. *Patinopecten dilleri* has no known living close relatives.

The lamellar-ribbed *Patinopecten* from diatomaceous strata of the Sisquoc formation at the NTU mine (locality 56) is identified as *P. dilleri* variety (pl. 9, figs. 6–8)—a variety characterized by secondary ribs on the left valve and by minute, almost microscopic, lamellae on minute ribs in the interspaces on the left valve. The number of secondary ribs is not uniform, varying from a few to many. Though an incomplete left valve from the Foxen mudstone has one, or possibly two, secondary ribs, two other left valves and fragments from two additional Foxen localities show none, and no known left valve of *P. dilleri* proper has minute lamellar ribs. Four fragments of left valves from locality 56 show no minute lamellar ribs, possibly a matter of imperfect preservation, but these fragments have secondary ribs. *Patinopecten dilleri* proper evidently is not present at locality 56. Three incomplete immature right valves from this locality do not show any characters to differentiate them from *P. dilleri* proper. The ventral interior margin of the large right valve shown in the lower part of figure 8 on plate 9,

[18] Stewart, Ralph, op. cit., p. 91, pl. 35, figs. 2–5, 1940 (1941).

however, has more ribs than *P. dilleri* proper, presumably through the addition of secondary ribs. This variety, unnamed because none of the fossils is complete enough to serve as a satisfactory name-bearer, may be of stratigraphic value in the Santa Maria district.

The genus *Lyropecten* is represented in the Careaga sandstone by a large species, *Lyropecten cerrosensis* (pl. 21, fig. 1). The ribs, interspaces, discs, and ears are sculptured with riblets, those on the ribs generally being faint because of wear. In some interspaces one secondary rib is stronger than others, but it does not completely fill the interspace as in the smaller Miocene *L. estrellanus*. *Lyropecten terminus*, from the Pliocene of the Salinas Valley, is smaller than *L. cerrosensis* and has a relatively strong secondary rib. It evidently is more closely related to *L. estrellanus* than is *L. cerrosensis*, which may be descended from the Miocene *L. crassicardo*.[19] *L. cerrosensis* was based originally on fossils from the Pliocene of Isla Cedros (Cedros Island), off Lower California. It is the last known *Lyropecten* proper to have lived in California seas. The genus in the restricted sense became extinct at about the end of the Pliocene.

Ostreidae.—A nonplicate oyster found in oil-impregnated diatomaceous mudstone of the Sisquoc formation at two localities in the Orcutt field and in the Cebada member of the Careaga sandstone at locality 177, also in the Orcutt field, is identified as *Ostrea erici* (pl. 8, figs. 17, 18; pl. 9, figs. 1, 3, 4). This species is sculptured with lamellae of varying strength. The umbonal part of the shell is thick and composed of numerous shell lamellae. On the attached (left) valve the outer lamellae form a more or less distinct "wing" adjoining the attachment area. The ligamental groove is narrow and gradually tapering. The inner margin below the ligament area is smooth on large shells and smooth or faintly denticulate on small shells. An incomplete left valve from locality 74 suggests a height of at least 75 millimeters. The type of *O. erici* is from the Pliocene near Laguna Ojo de Liebre, Lower California. It has recently been recorded from late Pliocene strata in Los Angeles,[20] and a specimen from San Diego is in the collection of the University of California at Los Angeles. No similar Recent species is known in California or adjoining areas.

Ostrea vespertina (pl. 16, figs. 4, 17), the common plicate oyster in the Pliocene of coastal California and the San Joaquin Valley, is widespread and locally abundant in the Careaga sandstone of the Casmalia Hills, but is rare elsewhere in that formation. Small valves of a comparable form, probably the same species, are rare in the Foxen mudstone. Left valves are strongly to moderately plicate; right valves are moderately plicate to warped, some small right valves being practically flat. The ligamental groove is shallow, relatively wide, and rapidly tapering. The inner margin below the ligament area is generally strongly denticulate, but is weakly denticulate to smooth, or practically smooth, on a few valves. With few exceptions, the umbo is twisted in a counterclockwise direction when the shells are viewed in attached position. The type material of *O. vespertina* is from the Imperial formation of the Colorado Desert,[21] of disputed Miocene or Pliocene age. The Recent species identified by Dall as *O. palmula*, said to range from Puget Sound to Mexico, has more numerous plications than the Santa Maria fossils and is considerably smaller.

Carditidae.—The Recent California species *Glans subquadrata* is represented by a few worn or immature valves from the Cebada member of the Careaga sandstone at Fugler Point and locality 177. A minute left valve from Fugler Point has a well-preserved prodissoconch sculptured with strong concentric lamellae. Well-preserved minute Recent shells show the same prodissoconch sculpture. This is the first Pliocene record for *G. subquadrata*.

Cyclocardia californica (pl. 8, fig. 16; pl. 10, figs. 7, 8; pl. 11, figs. 2, 3; pl. 15, figs. 1, 2; pl. 21, fig. 5) occurs in diatomaceous strata of the Sisquoc formation, is abundant in the Foxen mudstone at the Waldorf asphalt mine, and is abundant locally in both members of the Careaga sandstone, particularly at the railroad cut near Shuman. The type locality is "five miles southwest [southeast] of Guadalupe." According to the preservation and matrix of the type and other specimens in the type lot, the type locality is the Waldorf asphalt mine. This species is characterized by widely spaced coarse nodes. The nodes are subdued or absent toward the ventral margin of large shells and on a few shells they are subdued at an early stage (pl. 11, fig. 2; pl. 15, fig. 1). Arnold's collection from the type locality shows a considerable range of variation in outline and in the width of interspaces. The type is exceptionally elongate and has exceptionally wide interspaces. Arnold's figured specimen and that shown on plate 10, figures 7, 8, both from the type locality, are more representative. Large collections from the Careaga sandstone show more uniform characters. The figured specimen from the Sisquoc formation (pl. 8, fig. 16) is exceptionally large. No form of Recent *Cyclocardia* in the Pacific coast U. S. National Museum collection has widely spaced coarse nodes. Most Pleistocene specimens from the San Pedro district and the few available fossils from the Pleistocene of Santa Barbara, the type locality of *C. occidentalis* and *C. monilicosta*, have closely spaced nodes like a comparable living form. Nevertheless, a Pleistocene form from the San Pedro district, identified as *Cyclocardia*

[19] Woodring, W. P., Lower Pliocene mollusks and echinoids from the Los Angeles Basin, Calif.: U. S. Geol. Survey Prof. Paper 190, p. 33, 1938.

[20] Willett, George, Additional notes on the Pliocene molluscan fauna of Los Angeles: Southern California Acad. Sci. Bull., vol. 45, p. 29, 1946.

[21] Woodring, W. P., op cit. (U. S. Geol. Survey Prof. Paper 190), p. 43, 1938.

aff. *C. occidentalis*,[22] has widely spaced coarse nodes and closely resembles small elongate specimens from the Santa Maria district.

A small right valve and corresponding left valve of the Recent California species *Axinopsis viridis* were collected recently at the dump of the Waldorf asphalt mine. This species has not been recorded heretofore from formations of Pliocene age in California. The type lot of *A. serricatus* consists of three valves from Puget Sound. They are less inflated, less elongate, and thicker-shelled than *A. viridis*.

A small presumably immature valve from the dump of the Waldorf asphalt mine and a still smaller valve from the Cebada member of the Careaga sandstone at locality 166 are identified as *Miodontiscus* cf. *M. prolongatus*. *M. prolongatus* is a northern species ranging from southeastern Alaska to Monterey. "*Venericardia*" *yatesi*, from the Santa Barbara formation, is considered a synonym.

Thyasiridae.—The genus *Thyasira* is represented in Arnold's Waldorf asphalt mine collection by three valves identified as *Thyasira* cf. *T. gouldii*. The anterior end is longer than that of the Recent California species referred to *T. gouldii*, which was based on material from the coast of New England and may be a form of the north European *T. flexuosa*.

Lucinidae.—*Lucinisca nuttallii antecedens* (pl. 20, fig. 3; pl. 21, fig. 6) is rare in oil-impregnated diatomaceous strata of the Sisquoc formation and in the Foxen mudstone, and is fairly widespread in both members of the Careaga sandstone. Many of the Careaga fossils are indefinitely identified molds, but some molds from the Cebada member are well-preserved and shells are common in tar sand of the Graciosa member on Graciosa Ridge in the Orcutt field. The type of *L. nuttallii antecedens* is a poorly preserved left valve from the Careaga sandstone at the Alcatraz asphalt mine, east of the area covered by the present report. As shown by a well-preserved left valve in Arnold's collection from the type locality and by numerous specimens from other localities in the Santa Maria district, the umbo of this variety, and also of the living *L. nuttallii*, is sculptured with closely spaced concentric lamellae (pl. 21, fig. 6). On the fossils the closely spaced lamellae are succeeded by widely spaced lamellae, more widely spaced than on the Recent form, and those in turn by lamellae of variable spacing. The widely spaced lamellae suggest *L. centrifuga*, a Recent species from Lower California and the Gulf of California, but that species has widely spaced lamellae on the umbo. The type of *L. nuttallii antecedens* and other large specimens, notably a left valve from the Sisquoc formation at the Pennsylvania asphalt mine, are more inflated than the Recent *L. nuttallii*. That character, however, is not uniform. The largest Santa Maria fossil has a height of about 30 millimeters, whereas the largest Recent shell available has a height of 25.5 millimeters. Though Dall cited the southern limit of *L. nuttallii* as Mazatlán, Mexico, the *Lucinisca* from Lower California and the Gulf of California in the U. S. National Museum collection is the closely related but distinct *L. centrifuga*, described as a variety of *nuttallii*.

The genus *Lucinoma* occurs in the Tinaquaic sandstone member of the Sisquoc formation, in diatomaceous strata of the Sisquoc, in the Foxen mudstone, and in the Careaga sandstone. Many of the fossils consist of molds or are incomplete, and are not definitely determinable. The most satisfactory specimens are from the Graciosa member of the Careaga sandstone at the railroad cut near Schuman. The identifiable fossils are closely comparable to the living *L. annulata* and are identified as *Lucinoma* cf. *L. annulata* (pl. 19, fig. 8). They may represent the Recent form without any qualifications, but at least some have a more deeply concave anterior dorsal margin than Recent shells. The relations of Miocene, Pliocene, and Recent forms, however, are not satisfactorily determined.[23] Miocene fossils are generally identified as *L. acutilineata*, Pliocene fossils as that species or *L. annulata*. *L. annulata* ranges from southeastern Alaska to southern California. The southernmost large specimen available, comparable in size to Santa Maria fossils, is from Bodega Harbor in northern California.

A small lucinid that occurs in the Foxen mudstone at the Waldorf asphalt mine and in the Careaga sandstone is identified as *Parvilucina* cf. *P. tenuisculpta*. Though this species, or comparable molds, was found at six localities, only eleven specimens are in the collections. All the fossils are small, the left valve figured by Arnold [24] as "*Phacoides*" *intensus* (height 6.7 millimeters) being the largest. The fossils are half as large as the typical form of *Parvilucina tenuisculpta* (height 14 millimeters) from northern waters, Oregon and northward. The apparently stronger concentric sculpture of the fossils is misleading, as the umbonal part of large Recent shells generally is corroded. The fossils, however, are closely comparable to a small race of *P. tenuisculpta* from depths of 10 to 110 fathoms off southern California, but not all the Recent *Parvilucina* from those depths off southern California are small. The type of "*Phacoides*" *intensus* (height 4.5 millimeters) and two smaller valves were recovered from Pliocene strata encountered in a well at San Diego. Should numerous collections of Pliocene fossils consist only of small specimens, as indicated by the collections now available, the name *Parvilucina tenuisculpta intensa* may be useful for the small Pliocene form. *P. approximata*, a small species living in the Gulf of Cali-

[22] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op cit. (U. S. Geol. Survey Prof. Paper 207) p. 82, pl. 33, fig. 4, 1946.

[23] Woodring, W. P. op. cit. (U. S. Geol. Survey Prof. Paper 190), pp. 52–53, 1938.

[24] Arnold, Ralph and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull. 322), pl. 23, figs. 9a, 9b, 1907.

fornia and off Lower California, has stronger radial sculpture.

Ungulinidae.—An incomplete left valve, *Diplodonta* sp., collected from the Cebada member of the Careaga sandstone at Fugler Point is the sole representative of the family Ungulinidae. It appears to represent a new species that is more elongate than described Miocene, Pliocene, and Recent species from the Pacific coast.

Leptonidae.—The genera *Kellia* and *Rochefortia*, both heretofore unrecorded from formations of Pliocene age in California, are rare. The living California species identified as *Kellia laperousii* occurs in the Foxen mudstone at the Waldorf asphalt mine, and is represented by an incomplete valve from the Cebada member of the Careaga sandstone at locality 177. The Foxen mudstone specimens are more elongate than most Recent shells, but the outline of Recent shells is variable. The Recent California species *Rochefortia tumida* was found in the Graciosa member of the Careaga sandstone at the railroad cut near Shuman.

Cyrenidae.—The uppermost part of the Graciosa member of the Careaga sandstone, or the basal part of the Paso Robles formation at locality 228 in the Purisima Hills yielded a mold that may represent the brackish-water genus *Corbicula*.

Sphaeriidae.—Small trigonal molds from the locality just mentioned are possibly to be referred to the fresh-water genus *Sphaerium*. An unidentified species of the minute fresh-water genus *Pisidium* occurs in the Orcutt sand at locality 256.

Tellinidae.—Twelve species of *Tellina* and *Macoma* are recognized in the Santa Maria district. *Tellina* cf. *T. aragonia* is represented by a mold from diatomaceous strata of the Sisquoc formation. It is more elongate and more inequilateral than *T. aragonia*, the anterior end being very long. The mold, however, may be distorted. *T. aragonia* occurs in the Empire and Jacalitos formations.

A large tellinid from diatomaceous strata of the Sisquoc formation and the Foxen mudstone is identified as *Tellina* cf. *T. lutea* (pl. 8, fig. 15). The Sisquoc form is closely comparable to the living Arctic and Alaskan *T. lutea* and is evidently related to the California Miocene *T. oldroydi*. The Japanese Recent *T. venulosa* has closely spaced concentric rugae on at least part of the shell. The Foxen form at locality 142 is more inflated than the Sisquoc form and more closely resembles the Pliocene tellinid from the Kettleman Hills, described as *Tellina?* cf. *T.? oldroydi*.[25] The Santa Maria fossils are molds, with the exception of an incomplete paired shell in Arnold's Waldorf asphalt mine collection, which has a wider posterior truncation than other Santa Maria specimens. No known survivors of this group of tellinids is living south of Alaska.

Three species of *Tellina*, all comparable to Recent California species, were found in the Careaga sandstone: *Tellina* cf. *T. idae*, *Tellina* cf. *T. buttoni*, and *Tellina* cf. *T. bodegensis*. Aside from three valves from the Cebada member at locality 177 identified as *T.* cf. *T. buttoni*, the fossils are molds. There appear to be no Pliocene records of *T. buttoni*. The largest specimens of *T.* cf. *T. bodegensis* are somewhat larger than the largest Recent shells in the U. S. National Museum collection.

Bivalves of the *Macoma nasuta* group are common fossils in the Santa Maria district. Molds from the Tinaquaic sandstone member of the Sisquoc that have a strongly bent posterior end are most similar in outline to the Recent *M. nasuta*. They are identified, however, as *Macoma* cf. *M. nasuta*, as their interior characters are not known. The form of *M. nasuta* in the Careaga sandstone is *M. nasuta kelseyi* (pl. 20, figs. 2, 8). This variety is fairly common in the Cebada member and is widespread in the Graciosa member. Many of the fossils are indefinitely identified molds, but numerous shells were collected from tar sand of the Graciosa on Graciosa Ridge. The large size, thick shell, and slightly bent posterior end differentiate the fossils from the Recent form. As shown by Dall's illustration of the type and by plate 20, figure 2, the pallial sinus reaches the anterior adductor scar on the left valve, as on the left valve of *M. nasuta*. The type of *M. nasuta kelseyi* was collected by Stearns in San Diego Park, now Balboa Park, at San Diego. The type and five other specimens are in the type lot selected by Dall, and 15 additional specimens have the same locality number (2459). Unless fossils from different localities were mixed, this is a Pliocene locality, not Pleistocene as has been supposed. *Patinopecten healeyi*, the Pliocene form of *Dosinia ponderosa* that occurs in the Santa Maria district, and numerous specimens of *Miltha* are in the collection from locality 2459. *Macoma nasuta kelseyi* is reported to be living in Pugent Sound. *Macoma astori*, from the Empire formation of Oregon, has a thick shell and slightly bent posterior end, and may possibly be a small form of *M. nasuta kelseyi*.

A paired specimen, found in sand interbedded with silty diatomaceous strata of the Sisquoc formation near the Sisquoc River, may represent a new species of *Macoma* (pl. 8, figs. 10, 11). The strongly bent posterior end suggests alliance with *M. nasuta*. The fossil, however, is elongate and very inequilateral, the anterior end being exceptionally long. In the absence of additional material, it is not known whether this fossil is exceptional.

Arnold's specimen figured as *Macoma nasuta*,[26] collected at the Waldorf asphalt mine, is not allied to that species, as the pallial sinus falls short of the

[25] Stewart, Ralph, in Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 92, pl. 14, fig. 8, pl. 33, fig. 5, 1940 (1941).

[26] Arnold, Ralph, and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull. 322), pl. 22, fig. 5, 1907.

anterior adductor scar on the left valve. It is related to the living northern species *Macoma brota*, being most similar to three valves of medium size dredged at a depth of 110 fathoms in Queen Charlotte Sound, British Columbia (U. S. Nat. Mus. 22196). Like other species found at the Waldorf mine, *M.* cf. *M. brota* occurs in the Cebada member of the Careaga sandstone at locality 177 and at Fugler Point. It is represented, however, at those localities by incomplete shells. It may also be present in diatomaceous strata of the Sisquoc formation. The fossils and the Recent species have a relatively wide posterior truncation.

A small unidentified *Macoma* is represented by molds in diatomaceous strata of the Sisquoc formation. It may be related to one of the small thin-shelled forms occurring at moderate depths off California, but the Recent forms are not satisfactorily identified.

Three other species of *Macoma*, all represented by molds, are closely comparable to Recent Californian species: *Macoma* cf. *M. yoldiformis*, *Macoma* cf. *M. indentata*, and *Macoma* cf. *M. secta*. They occur in the Careaga sandstone, *M.* cf. *M. indentata* also being found in the Tinaquaic sandstone member of the Sisquoc formation.

Semelidae.—*Semele* cf. *S. rubropicta* (pl. 14, fig. 12) occurs in the Foxen mudstone at the Waldorf asphalt mine, in the Cebada member of the Careaga sandstone at Fugler Point and locality 177, and may be present in diatomaceous strata of the Sisquoc formation. Though the sculpture of Santa Maria fossils and Recent specimens is variable, even on right and left valves of the same Recent shell, no Recent shell in the collection of the U. S. National Museum has concentric sculpture as strong as that of the figured specimen. The figured specimen, larger than any collected during the field work for the present report, was collected by Mr. Alex Clark at Fugler Point. A comparable *Semele* from the *Acila* zone of the San Joaquin formation in the Kettleman Hills, also identified as *Semele* cf. *S. rubropicta*,[27] has weak concentric sculpture.

A second species of *Semele*, sculptured with closely spaced concentric lamellae, may be represented by an incomplete right valve in Arnold's Waldorf asphalt mine collection. It is probably the *Semele* n. sp.?[28] from the Etchegoin formation of the Kettleman Hills, which is closely related to the living Japanese *S. duplicata*.

Cumingia californica was found in the Cebada member of the Careaga sandstone at Fugler Point and locality 177. All the specimens collected are incomplete, but Arnold[29] illustrated a complete small left valve from Fugler Point. Both thick-shelled and thin-shelled specimens were collected at locality 178. Dall used the name *C. lamellosa* for this species. The type locality of *C. lamellosa*, however, is Chile and it is doubtful whether the Californian form is conspecific.[30]

Mactridae.—Molds and incomplete hinge fragments of two large species of *Spisula* (*Spisula* cf. *S. hemphilli* and *Spisula* cf. *S. catilliformis*) were found in the Careaga sandstone, *S.* cf. *S. hemphilli* occurring also in the Tinaquaic sandstone member of the Sisquoc formation. Both are comparable to living California species, for which the names used by Dall are adopted. The two fossil species are differentiated by the more deeply concave anterior dorsal margin of *S.* cf. *S. hemphilli*, which also is generally more elongate. *S.* cf. *S. hemphilli* is Arnold's *S. sisquocensis*, and *S.* cf. *S. catilliformis* is his *S. catilliformis* variety *alcatrazensis*. The types of Arnold's forms were found in the Careaga sandstone at the Alcatraz asphalt mine, east of the area covered by the present report. The type of *S. sisquocensis* is the only specimen of that form now in the collection from the type locality. *S. catilliformis* variety *alcatrazensis* is represented presumably by one other specimen. It is, however, very short, almost circular—a remarkable outline for a *Spisula*. The outline of both fossil species is variable. No Recent specimen of *S. catilliformis* is as short as the shortest fossils referred to *S.* cf. *S. catilliformis*, not including the exceptionally short specimen from the Alcatraz mine. An unidentified short *Macoma*-like *Spisula?* of medium size occurs in the Tinaquaic sandstone member of the Sisquoc formation.

The genus *Pseudocardium* has a widespread but discontinuous distribution in the Graciosa member of the Careaga sandstone and is probably present in the Tinaquaic sandstone member of the Sisquoc formation. Preserved shells were found at four localities. Molds that show the long, heavy laterals, however, are identified with considerable confidence. The *Pseudocardium* of the Santa Maria district is practically equilateral. Like the similar form in the Etchegoin formation of the Kettleman Hills,[31] it is identified as *Pseudocardium densatum* variety cf. *gabbii* (pl. 17, fig. 14; pl. 19, fig. 2). The characters of *P. densatum*, as that name is used in the present report, are based primarily on Pliocene fossils from the Coalinga district identified by Arnold. The status of *P. densatum* is the same as that of *Anadara trilineata;* the type is not known to be extant and the genus is not known to occur at the alleged type locality, Santa Barbara. The Santa Maria shells are small or of medium size, but some molds are moderately large (length 63 millimeters). None of the Santa Maria fossils is thick-shelled like the usual form in the San Joaquin Valley. This northern genus was heretofore not recorded from any locality in coastal California south of the Sargent oil field in Santa Clara County.

[27] Stewart, Ralph, in Woodring, W. P., Stewart, Ralph, and Richards, R. S., op. cit. (U. S. Geol. Survey Prof. Paper 195) p. 33 (list), pl. 11, fig. 8, 1940 (1941).

[28] Idem, table opposite p. 66 (list), pl. 33, fig. 4.

[29] Arnold, Ralph, and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull. 322), pl. 23, fig. 5, 1907. This record is omitted in the Grant and Gale catalog.

[30] Strong, A. M., in Burch, J. Q., Conchological Club Southern California Minutes, No. 43, p. 19, 1945 (mimeographed).

[31] Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), pp. 93–94, 1940 (1941).

It is not known in the eastern Pacific after Pliocene time, but evidently survived in Japanese waters, where it appears to be represented by *P. sachalinensis*.[32]

A large mactrid that has a siphonal gape, *Schizothaerus* cf. *S. nuttallii*, is the most common large bivalve. Molds are widespread in the Tinaquaic sandstone member of the Sisquoc formation, and molds and hinge fragments in the Careaga sandstone, particularly in the Graciosa member. Molds also were found at one locality in the basal Foxen mudstone. The length of the anterior end is more variable than shown by specimens of the living California species *S. nuttallii*. Small Pliocene California schizotheres are generally designated *S. pajaroanus*. The type of *S. pajaroanus*, collected along the Pajaro River in Santa Cruz County, is short and has a short anterior end. The relations of this form to short specimens of *S. nuttallii* are undetermined. According to MacGinitie,[33] in Elkhorn Slough, an estuary near Monterey, schizotheres living in hard clay are small and rounded (suggesting a form like the type of *S. pajaroanus*), whereas those whose burrows are in loose sand are large and elongate. Arnold's figured *S. pajaroanus*, from the Pliocene of the Santa Cruz quadrangle, is considered a small *S. nuttallii* with a short anterior end. It is more elongate than the type of *S. pajaroanus*.

Veneridae.—A variety of *Dosinia ponderosa* (pl. 16, fig. 6; pl. 19, fig. 1; pl. 20, fig. 7) is fairly common in the Careaga sandstone. The lunule is not as deep as that of the living *D. ponderosa* and the anterior lateral is farther from the anterior cardinal. The variety from the Santa Maria district is the same as that from Balboa Park, San Diego, described and illustrated by Grant and Gale as *D. ponderosa* variety *jacalitosana*. The type of *D. jacalitosana*, from the Jacalitos formation of the Coalinga district, is elongate, inflated, and has a wide moderately deep lunule; the hinge is not preserved. It is not known whether the type is an unusual specimen. The Pliocene *Dosinia* from San Diego is represented by well-preserved specimens under locality numbers 2459 (San Diego Park, the type locality of *Macoma nasuta kelseyi*) and 2662 (City Park, San Diego), both referring to the present Balboa Park. If this variety is unnamed, it should be named on the basis of material from San Diego. Its relations to the numerous named Miocene forms, however, are undetermined. Arnold's figured *D. ponderosa* from the Alcatraz asphalt mine and another specimen from that locality are more elongate than any collected during the field work for the present report. In the Recent fauna *D. ponderosa* is a southern species ranging from Laguna Ojo de Liebre, Lower California to northern Peru. In late Pleistocene time, however, it ranged far northward to Santa Monica, California.[34]

Thick-shelled bivalves from the Graciosa member of the Careaga sandstone in the Purisima Hills are referred to *Pachydesma crassatelloides* (pl. 18, fig. 1), the living Pismo clam. The fossils are more elongate than many Recent specimens, but the outline of Recent specimens is variable.

Fragmentary remains and molds from the Careaga sandstone are identified as *Saxidomus* cf. *S. nuttalli*. Arnold collected two incomplete left valves at the railroad cut near Shuman, which he referred to *S. gracilis*, considered a synonym of *S. nuttalli*. One of these valves is exceptionally thick shelled, thicker than any Recent shell in the U. S. National Museum collection.

Compsomyax cf. *C. subdiaphana* occurs in the formations that contain marine Pliocene fossils, except the Foxen mudstone. The material consists of molds and a few incomplete shells. Molds are fairly common in diatomaceous strata of the Sisquoc formation. The outline of the fossils and of Recent shells is variable, some molds from the Tinaquaic sandstone member of the Sisquoc formation being very short. Two of Conrad's California fossil species described earlier than *C. subdiaphana* are perhaps closely comparable to that species: "*Lutraria*" *traskei* (presumably a typographic error for *traskii*) and "*Dosinia*" *longula*. The type of "*Lutraria*" *traskei*, from a locality between Carmel (Conrad called it Carmello) and Monterey, is preserved in shale of Monterey lithology. The matrix of the type of "*Dosinia*" *longula*, collected from the bed of the Salinas River, is white sandstone similar to the Santa Margarita sandstone. Both types, which are in the U. S. National Museum, are so inadequate that the names may be considered nomina dubia.

Lirophora cf. *L. mariae* is represented by a small mold from the Graciosa member of the Careaga sandstone at locality 233 in the Purisima Hills. It is comparable to *L. mariae*, a species living along the coast of Mexico and Central America. The lamellae, however, are more closely spaced than those of the Recent species. The genus *Lirophora*, now not found north of Lower California, has not been recorded heretofore from the California Pliocene, but is present at a few localities in the California Miocene. *Lirophora* has long been considered a subgenus of *Chione*. The sculpture, however, is so different from that of *Chione* that generic rank appears to be justified. Though *Chione* has not yet been found in the Santa Maria district, it is to be expected there, as it occurs in the Pliocene as far north as Coos Bay, Oregon.

A short, thick-shelled *Protothaca*, referred to *Protothaca staleyi* (pl. 21, figs. 2–4), is widely distributed in

[32] Stewart, Ralph, op. cit., (U. S. Geol. Survey Prof. Paper 195), p. 94.

[33] MacGinitie, G. E., Ecological aspects of a California marine estuary: Am. Midland Naturalist, vol. 16, p. 729, 1935.

[34] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), pp. 84, 105, 106, pl. 36, figs. 15, 16, 1946.

the Tinaquaic sandstone member of the Sisquoc formation and the Careaga sandstone. The Tinaquaic fossils and also the Cebada fossils consist of molds, with the exception of a few incomplete Cebada shells. Many of the Graciosa fossils also consist of molds, but numerous shells, many broken, were collected from that member. In fact, this species is one of the most abundant bivalves in the Graciosa on Graciosa Ridge and elsewhere. Though the neotype of *P. staleyi*, from the Pliocene of Sonoma County, California, has obscure radial sculpture, a specimen from the type region illustrated by Howe has stronger radials. The Santa Maria fossils have a heavy hinge and a short pallial sinus like Howe's illustrated topotype. Many of them, including some large specimens, have stronger fluting on the inner face of the lunular border than large specimens of any species of *Protothaca* living along the coast of California and nearby. On the basis of external characters the Santa Maria fossils are considered conspecific with Coos Bay fossils referred by Dall to "*Chione*" *staleyi*, the interior of available Coos Bay specimens being inaccessible. Though specimens from the type locality of *P. staleyi* variety *hannibali*, the Eel River basin of northern California, have not been examined, the variable outline of Santa Maria and Coos Bay fossils suggests that this variety cannot consistently be differentiated from *P. staleyi* proper. The sinus of the Etchegoin form from the Kettleman Hills, identified as "*Venerupis*" *laciniata* variety *hannibali*,[35] is obscure. The outline of the shell, however, suggests alliance with the Recent *P. laciniata*. The Santa Maria *Protothaca* may be more closely related to the very thick-shelled dwarf form in the San Joaquin formation of the Kettleman Hills, "*Venerupis*" *grata* variety *tarda*,[36] which has a short sinus. The short sinus of the Santa Maria fossils indicates that they are more closely allied to the Recent southern *P. grata* than to the living California species *P. staminea* and *P. laciniata*. A shell fragment from the Cebada member of the Careaga sandstone at locality 177 has a deeply impressed lunule and represents evidently a different form. *Protothaca* is given generic rank, instead of subgeneric rank under *Venerupis*. As compared with the European *Venerupis*, *Protothaca* has a fluted inner margin, including the lunular border, suggesting closer relationship to *Venus* and *Chione*, narrower pallial sinus, and more distinct lunule.

A large elongate *Protothaca*, identified as *Protothaca* cf. *P. tenerrima*, has the same stratigraphic destribution as *P. staleyi* and probably also occurs in the Foxen mudstone. Though the fossils are without much doubt the living California species designated *P. tennerrima*, they are molds and incomplete shells. Arnold's figured well-preserved paired specimen from the Alcatraz asphalt mine is indistinguishable from Recent shells, at least on the basis of external characters.

A small venerid, *Transennella* cf. *T. tantilla*, occurs in the formation containing Pliocene marine fossils. It is one of the most common fossils in diatomaceous strata of the Sisquoc formation. The fossils probably represent the living California species *T. tantilla*. None, however, is as thick-shelled as the Recent form and with few exceptions they are smaller. Well-preserved shells in tar sand of the Graciosa member of the Careaga sandstone on Graciosa Ridge are very small and have a trigonal outline. The type of *T. californica*, a small right valve from the San Joaquin formation of the Coalinga district, has a more inflated umbo than Recent specimens of *T. tantilla*.

Petricolidae.—A paired incomplete specimen in Arnold's Fugler Point collection and a doubtful incomplete valve from the Cebada member of the Careaga sandstone at locality 177 are identified as *Petricola* cf. *P. carditoides*. They are closely comparable to the living California species *P. carditoides*, but are too incomplete for certain identification. *Petricola* cf. *P. buwaldi* is represented by an incomplete valve in Arnold's Fugler Point collection and by a paired specimen from the Graciosa member of the Careaga sandstone at locality 208. This form has low wide radial ribs, wider than those of the Recent California *P. denticulata*, and may be related to *P. buwaldi* from the late Miocene San Pablo formation. The Santa Maria fossils are elongate, whereas the type of *P. buwaldi* is short. The outline of *Petricola*, however, depends on the shape of the hole in which the animal lived. The specimen from the Graciosa is embedded in a *Pholadidea* burrow and part of the *Pholadidea* shell still surrounds the *Petricola*.

Cardiidae.—Both the northern genus *Cerastoderma* and the southern genus *Trachycardium* are present in the Santa Maria district, *Cerastoderma* being more abundant than *Trachycardium*. The *Cerastoderma* remains, collected from the Tinaquaic sandstone member of the Sisquoc formation and the Careaga sandstone, are poorly preserved. They are identified as *Cerastoderma* cf. *C. meekianum*. Complete molds show the high narrow umbo and *Venericardia*-like outline of *C. meekianum*, which was based on Pliocene material from the Eel River basin of northern California. The eastern Pacific species of *Cerastoderma* form a well-defined group, for which the name *Clinocardium* has been proposed.[37] Subgeneric rank for *Clinocardium* under *Cerastoderma* is preferred to indicate the close relationship with *Cerastoderma*.

Trachycardium cf. *T. quadragenarium* is represented by incomplete specimens from the Cebada member of the Careaga sandstone at locality 177. On an incomplete paired shell and on two additional fragments the spines on the anterior ribs are elongate and

[35] Stewart, Ralph, in Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 94, pl. 29, fig. 5, 1940 (1941).
[36] Idem, p. 94, pl. 13, figs. 10–13.

[37] Keen, A. M., A new pelecypod genus of the family Cardiidae: San Diego Soc. Nat. History Trans., vol. 8, no. 17, pp. 119–120, 1936.

extend across the ribs, whereas on the Recent *T. quadragenarium* the spines on the anterior ribs are short and are on the anterior half of the ribs. *T. quadragenarium* is the type of the subgenus *Dallocardia*.

Chamidae.—The Cebada member of the Careaga sandstone at Fugler Point and locality 177 yielded small valves of a *Chama* comparable to the common living California species *C. pellucida*.

Myacidae.—Remains of the northern genus *Mya* are rare in the Careaga sandstone and occur in the Foxen mudstone. They are incomplete, too incomplete to determine their affinities.

Cryptomya was found at almost every locality where mollusks were collected from the Tinaquaic sandstone member of the Sisquoc formation. It is present also in diatomaceous strata of the Sisquoc and is common in the Careaga sandstone. The Santa Maria fossils, most of which are molds and none of which is entirely complete are identified as *Cryptomya* cf. *C. californica* (pl. 7, fig. 2). They show a considerable range of variation in size and outline. At least some of the fossils preserved as incomplete shells show faint radial sculpture on the posterior part of the shell like that of unworn Recent shells. Though names have been proposed for Miocene and Pliocene forms of *Cryptomya*, it has not yet been shown that they can consistently be differentiated from the living form.

Platyodon cf. *P. colobus* is represented by four poorly preserved paired specimens dug from their burrows at the base of the Graciosa member of the Careaga sandstone at locality 199 on Graciosa Ridge. This *Platyodon* is evidently an exceptionally large form of *P. colobus*,[38] a species from the San Joaquin formation of the Kettleman Hills, the short outline and strong inflation suggesting that species. The Santa Maria fossils are half again as large as Kettleman Hills specimens.

A right valve in Arnold's Waldorf asphalt mine collection and a doubtful mold from the Cebada member of the Careaga sandstone are identified as *Sphenia* cf. *S. globula*. The Foxen mudstone shell is even shorter than the Recent California species *S. globula*. The genus *Sphenia* has not been recorded heretofore in California Pliocene faunas.

Solenidae.—On the basis of its straight dorsal margin, a species of the genus *Solen* occurring in the Tinaquaic sandstone member of the Sisquoc formation and in the Careaga sandstone is referred to *Solen perrini*. The straight dorsal margin suggests that *S. perrini* is more closely related to the Recent Japanese *S. krusensternii*[39] than to the living Californian species *S. sicarius*. The small Recent California *S. rosaceus* has a straight dorsal margin, but the anterior end has a less distinct groove than that of *S. perrini* and *S. sicarius*. *S. perrini* was described as a species from the late Miocene San Pablo formation.

Siliqua cf. *S. media* (pl. 7, figs. 1, 5) is one of the most abundant fossils in the Tinaquaic sandstone member of the Sisquoc formation, was found at one locality in diatomaceous strata of the Sisquoc, and is common in the Careaga sandstone. The fossil *Siliqua* is more closely related to the living Arctic and Alaskan *S. media*, as identified by Dall, than to the living California *S. lucida*, which is small and has a truncated posterior end. The fossils evidently have a narrower internal rib than *S. media*. Though they are of varying size, none is as large as large Recent shells. The *Siliqua* sp.[40] from the Etchegoin formation of the Kettleman Hills is considered conspecific with the Santa Maria form.

Panopidae.—The northern genus *Panomya* is represented by a poorly preserved incomplete valve in Arnold's Fugler Point collection. It evidently is related to the Recent *P. beringianus* and may be a small variety of that species comparable to the small variety in the Pleistocene Timms Point silt of the San Pedro district.[41] The genus is not known to occur south of Puget Sound at the present time, but during Pliocene and Pleistocene time it lived as far south as the Los Angeles basin.

Pholadidae.—*Pholadidea penita* (pl. 8, fig. 6; pl. 14, fig. 3) was found in the formations and members containing marine Pliocene fossils, with the exception of the Tinaquaic sandstone member of the Sisquoc formation. It is abundant in Arnold's collection from diatomaceous strata of the Sisquoc formation at the Pennsylvania asphalt mine, in his collection from the Foxen mudstone at the Waldorf asphalt mine, and in the Cebada member of the Careaga sandstone at locality 177. Nearly all the fossils are paired and some were found in their burrows. Some of the fossils are not as elongate as Recent shells, but the outline of fossil and Recent specimens is variable.

Pandoridae.—Molds found in limestone concretions in diatomaceous strata of the Sisquoc formation at two localities near Gato Ridge and incomplete shells in Arnold's Waldorf asphalt mine collection are identified as *Pandora* cf. *P. filosa* (pl. 8, fig. 12). The fossils have distinct radial grooves between the adductor muscle scars, showing as ridges on molds of the interior. On Recent shells the grooves are of variable strength or are absent. A mold of the exterior of the flat right valve has widely spaced narrow radial threads like those of Recent specimens. *P. filosa* is the type of the subgenus *Kennerlia*.

Pandora punctata (pl. 17, fig. 13) is fairly common in the Graciosa member of the Careaga sandstone and comparable molds were found at one locality in the

[38] Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol Survey Prof. Paper 195), p. 95, pl. 21, figs. 1, 2, 1940 (1941).

[39] Schrenck, L. v., Reisen und Forschungen im Amur-Lande, vol. 2, p. 594, pl. 25, figs. 9–12, St. Petersburg, 1867.

[40] Stewart, Ralph, in Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 95, pl. 33, fig. 3, 1940 (1941).

[41] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), p. 85, pl. 33, figs. 13, 14, 1946.

Cebada member. The fossils that show the interior have a few to many punctae. Recent shells also have a few to many punctae, or rarely none. *P. punctata* is the type of the subgenus *Heteroclidus*. Its relations to the Miocene(?) *P. scapha* are undetermined.

BARNACLES

Two species of *Balanus* are recognized in the collections from the Foxen mudstone and Careaga sandstone: a moderately large species and a small species. The moderately large species is identified as *Balanus* cf. *B. aquila*. On the basis of the incomplete material, consisting of crudely ribbed porous compartments, it appears to be comparable to the Recent California species *B. aquila*.

The small barnacle is identified as a new variety of the Recent northern *Balanus hesperius*, named *Balanus hesperius proinus* (pl. 14, figs. 11, 15; pl. 16, figs. 1–3, 8–12). At locality 236 in the Casmalia Hills, the type locality, this small barnacle is common on oyster shells. Several hundred of the thick minute opercular valves were recovered from barncales at that locality and many still have a full set of valves in place. Both ribbed and smooth forms of *B. hesperius proinus* are present at locality 236, the ribbed form being more common. The transverse ridges on the scuta are more closely spaced than on *B. hesperius* proper and the callus between the articular ridge and the deeply sunken adductor muscle scar is less distinctly cut into pendant ridges. The small barnacle from the San Joaquin formation of the Kettleman Hills, recorded as *B. hesperius* variety,[42] is *B. hesperius proinus*.

ENVIRONMENT SUGGESTED BY FOSSILS

About three-quarters of the marine Pliocene megafossils of the Santa Maria district are Recent species living along the Pacific coast of North America, or are closely related to such Recent species. Most of the latter group are so closely related to Recent species that they are not differentiated from them on the basis of available material. Some information is recorded concerning the distribution, habitat, and habits of the Recent species that may serve as a base for attempts to reconstruct the environment of the fossil faunas insofar as it can be reconstructed. Except for a few selected localities, ecologic information on Recent species is relatively meager. As a result of the recently issued publications of the Conchological Club of Southern California, assembled under the editorship of John Q. Burch,[43] more information is now available than heretofore. These publications summarize the collecting records of members of the Club, including Mr. Burch's own extensive dredging records at moderate depths, mostly off Monterey and off Redondo Beach.

For the purpose of this discussion "shallow water" is defined as extending from high-tide line to 10 fathoms, thus including the intertidal zone, "moderate depth" from 10 to 100 fathoms, and "deep water" greater than 100 fathoms. More data are available on depth than on other ecologic factors and for this reason depth is given undue weight in the discussion that follows. Though depth evidently is less significant than temperature in the distribution of marine invertebrates, there is generally a close correlation between depth and temperature in the depth range represented by the Santa Maria faunas.

POINT SAL FORMATION AND MONTEREY SHALE

The foraminiferal faunas of the Point Sal formation and Monterey shale suggest the border line between moderate depth and deep water; that is, depths possibly near 100 fathoms. The Point Sal and lower Monterey faunas have warm-water affinities absent in the younger faunas. The abundance of *Globigerina* in the Point Sal formation indicates more open-sea conditions than for other formations of the Santa Maria district.

SISQUOC FORMATION

MARGINAL FACIES

No species in the meager megafauna of the Tinaquaic sandstone member of the Sisquoc formation is unequivocally identified as Recent. Nevertheless nine of the eleven species compared with living forms are doubtless still living—all so identified except *Lucinoma* cf. *L. annulata* and *Siliqua* cf. *S. media*. The modern analogs of Tinaquaic fossils indicate that the fauna consists predominantly of shallow-water species and species that range from shallow water to moderate depth. The abundance of *Volsella* cf. *V. capax*, *Macoma* cf. *M. nasuta*, *Schizothaerus* cf. *S. nuttallii*, and *Cryptomya* cf. *C. californica* also suggests shallow water. *Calyptraea* sp. and "*Nassa*" sp. are possible moderate-depth exceptions. The *Calyptraea* is probably the form recorded from younger formations of the Santa Maria district as *Calyptraea* cf. *C. fastigiata*. *Calyptraea fastigiata* has been dredged off the California coast at depths of 31 to 75 fathoms. The "*Nassa*," represented by molds, is at least remotely related to the Recent "*Nassa californiana*," which has a depth range of 13 to 142 fathoms.

The sand dollar *Dendraster* cf. *D. coalingaensis* occurs in sandstone of coarser grain than the prevailing sandstone of the Tinaquaic and is not associated with other fossils. This coarse-grained sandstone may represent shallower water than most of the member. The few Tinaquaic Foraminifera also indicate shallow water.

BASIN FACIES

It is apparent from the table opposite page 35 that megafossils were found in the fine-grained basin facies

[42] Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geol. Survey Prof. Paper 195), p. 97, 1940 (1941).

[43] Burch, J. Q., Distributional list of the West American marine mollusks from San Diego, California, to the Polar Sea; pt. 1, Pelecypoda: Conchological Club Southern California Minutes, Nos. 33–44, 1944–1945; pt. 2, Scaphopoda, Gastropoda; Idem, Nos. 46–62, 1945–1946 (mimeographed, each number separately paginated).

of the Sisquoc formation at a considerable number of localities in every region where it crops out. Nevertheless they are relatively rare, and a superficial examination would suggest that the fine-grained facies is practically barren of them. Though they are relatively rare, they are as a general rule more abundant than in the Monterey shale, certainly much more abundant than in the Monterey of the Santa Maria district. The thin-bedded or laminated strata of the Monterey, the prevailing type in that formation, are thought to have been deposited at depths beyond the limits of appreciable wave and current action, an environment unfavorable for aeration of bottom waters and therefore unfavorable for bottom-dwelling animals.[44] In marked contrast to the Monterey, most of the mudstone of the Sisquoc formation is massive, though the annual spring flowering of diatoms characteristic of present temperate seas was presumably an adequate potential source of laminae. The diatomaceous mud, forming the bulk of the basin facies of the Sisquoc, evidently was deposited within the maximum limit of ordinary effective wave action (about 50 fathoms) and certainly within the limit of effective current action. The relatively rare laminated sediments of the Sisquoc formation suggest that wave and current action were not invariably effective, on account of greater depth, or on account of temporary or local conditions controlling wave and current movement.

The fine-grained sediments of the Sisquoc formation were deposited as diatomaceous mud evidently more or less agitated by waves and currents. Such an environment is not favorable for bottom-dwelling animals, either burrowing animals or those living on the surface of the sediments. According to MacGinitie,[45] no burrowers can live where the bottom is covered with soft ooze 6 inches or more thick, and a thickness of less than 6 inches excludes most burrowing forms. The widespread occurrence of mollusks in the diatomaceous mudstone of the Sisquoc formation indicates that at certain places and at certain times the bottom was firm enough to support a population that was not exceptional.

At most localities where megafossils occur in the basin facies of the Sisquoc only one, or at most a few, species is represented, bivalves being far more common than gastropods. At the unusual localities where more than a few species were found, gastropods are fairly common and the faunal facies is much like that of the overlying Foxen mudstone. These unusual localities, all in oil-impregnated mudstone, are close to the top of the formation or within a few hundred feet of the top. The possibility that the fossils at those localities are not Sisquoc fossils but originally were in younger formations does not appear to need consideration, for there is no field or other evidence to support that view. At localities on Graciosa Ridge where fossils and sediments from a younger formation occur in the Sisquoc the field evidence is unequivocal (p. 45).

According to the present depth distribution of Sisquoc species that are still living or are closely allied to living forms, the fauna of the basin facies of the Sisquoc, at least that in the upper part of the formation, is interpreted as a moderate-depth fauna, representing depths of between 25 and 50 fathoms. The few species in the lower part of the formation occur also in the upper part and suggest the same depth range. *Zirfaea* cf. *Z. pilsbryi* is the only basin-facies species whose modern analog appears to be found only in shallow water. It is uncertain whether this species, represented by two fragments in Arnold's Pennsylvania asphalt mine collection, actually lived in association with the other species collected at that locality. Much of the Sisquoc fauna has an unexpected but deceptive shallow-water aspect. *Aletes squamigerus?*, *Cryptomya* cf. *C. californica*, and *Pholadidea penita* are generally considered indicative of shallow water. Though these species, or their modern analogs, live in shallow water, they range down to moderate depth. Dead valves of *Cryptomya californica* have been dredged off Redondo Beach at depths as great as 50 fathoms or even greater. It is by no means certain, however, that this species lives at such depths, but it evidently lives at depths greater than 10 fathoms. Oysters also generally live in shallow water of varying degrees of salinity. Some species, however, are known to occur in the open ocean at moderate depth. The Sisquoc oyster, *Ostrea erici*, found only at the dump of the Pennsylvania asphalt mine, is not closely related to any living Pacific coast form.

The absence of pectinids of the genus *Delectopecten*, that is, pectinids related to *D. peckhami*, is a noteworthy negative feature of the fauna in the basin facies of the Sisquoc formation. *Delectopecten* is the most common mollusk in the Monterey shale of most Coast Range districts and occurs also in Pliocene formations that include no Monterey-like sediments: the deep-water Repetto formation of the Los Angeles basin and the moderately deep-water to moderate-depth Pico formation of the Los Angeles and Ventura basins. It was not found, however, in the Monterey shale of the Santa Maria district, but the Monterey of the Santa Maria district is of limited outcrop extent as compared with the Sisquoc formation. *Delectopecten* has been dredged at depths of 30 to 100 fathoms off the California coast. It is found also, and apparently more commonly, at depths greater than 100 fathoms. Its absence in the Sisquoc formation, and also the character of the sediments themselves, suggest that the Sisquoc fine-grained sediments were deposited at a depth less than the Monterey fine-grained sediments.

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[44] Bramlette, M. N., The Monterey formation of California and the origin of its siliceous rocks: U. S. Geological Survey Prof. Paper 212, pp. 9–10, 1946.

[45] MacGinitie, G. E., Littoral marine communities: Am. Midland Naturalist, vol. 21, p. 42, 1939.

The Foraminifera of the basin facies of the Sisquoc, like the mollusks, indicate moderate depths. Locality 93, at the north border of the western Purisima Hills, is an exception. The species at that locality are of more shallow-water aspect.

FOXEN MUDSTONE

Practically all the Foxen megafossils are from the Casmalia Hills, an area that may not be entirely typical for the formation. The fauna of the Foxen mudstone is the oldest in the Santa Maria district in which bivalves do not greatly outnumber gastropods, the number of species in the two groups being approximately equal. All except three collections are from the upper part of the formation. The number of species at any locality is small, except at the dump of the Waldorf asphalt mine. Assignment of the fossils from this locality to the Foxen is an inference not now subject to field confirmation. The inference is supported, however, by the matrix of the fossils and by foraminifera in the matrix. Though the fossils from the dump at the Waldorf mine are without any reasonable doubt Foxen fossils, they may represent a considerable stratigraphic range, but they are probably from the upper half.

The small fauna known to be from the upper part of the Foxen mudstone indicates a relatively shallow facies. Nearly all the species, or their modern analogs, now range from shallow water to water of moderate depth. This small fauna, however, is not typical of shallow water. It suggests the border line between shallow water and moderate depth to a maximum of about 25 fathoms. The upper part of the Foxen, like the upper part of the Sisquoc formation, contains species generally considered indicative of shallow water, notably *Aletes squamigerus?* and *Pododesmus macroschisma?*, both of which are probably identical with Recent forms that range into water of moderate depth. The sand dollar *Merriamaster* is extinct, but elsewhere is associated with moderate-depth species.

The depth facies of the fossils from the Waldorf mine is practically the same as that of the upper part of the Sisquoc; that is, they suggest moderate depth, between 25 and 50 fathoms. About half of the species that are still living, or are closely related to living species, are moderate-depth forms and about half range from shallow water to moderate depth. The Waldorf fossils include an unidentified *Mya*, but it is improbable that the presence of this genus in the Foxen indicates brackish water or seepage of fresh water.

The few species from the basal part of the Foxen mudstone at localities 142 and 149 do not indicate a deeper facies than the upper part; if anything, they indicate a shallower facies. *Nucella lamellosa shumanensis?* from locality 149 appears to be a large weakly sculptured form of the Recent *N. lamellosa*, which lives on rocks or shells in the intertidal zone and in shallow water below low-tide line.

As pointed out by Canfield,[46] Foxen Foraminifera suggest decreasing depth facies upward in the formation. The fauna from the basal part closely resembles the moderate-depth fauna in the upper part of the Sisquoc formation. Higher strata in the lower part of the Foxen contain moderate-depth to shallow-water faunas characterized by the abundance of *Uvigerina* and *Bulimina*. Increasingly sandy strata in the upper part of the formation contain an *Elphidium-Nonion* fauna of more shallow-water facies.

CAREAGA SANDSTONE

CEBADA FINE-GRAINED MEMBER

Gastropods outnumber bivalves in the Cebada fine-grained member of the Careaga sandstone. The Cebada fossils at most localities suggest somewhat shallower water than those of the Foxen mudstone, a range of a few fathoms to possibly 15 or 20. About 12 percent of the species that are still living or have close modern analogs are shallow-water forms, 53 percent range from shallow water to moderate depth, and 35 percent are found at moderate depth. The percentage figures for the same groups in the Foxen are 7, 48, and 45, respectively. One Cebada species, *Metgathura crenulata?*, appears to be now a strictly intertidal form. Fossils from two localities, locality 177 and Fugler Point, suggest a greater maximum depth range, about 25 fathoms, the estimated minimum for the Foxen fossils from the Waldorf mine. Both localities have been cited repeatedly as unusual for the preservation and the large number of species. The fossils from locality 177 were collected at the dump of an asphalt mine. They might be regarded with suspicion, as the asphalt contains pieces of Foxen mudstone (p. 45). The matrix of the fossils, however, is fine-grained sand like that of the Cebada. At Fugler Point the fossils occur in definite beds and to a minor extent in cross-cutting asphalt veins. The similarity in faunal facies shown by the Foxen fossils from the Waldorf mine and by the Cebada fossils from locality 177 and Fugler Point is shown by the following table. None of the species listed was found at other localities in the Foxen mudstone, and only two (*Puncturella cooperi aphales* and *"Gyrineum" mediocre lewisii*, the former in Arnold's collection from the railroad cut near Shuman) are present at other Cebada localities. Of the species listed those that have modern analogs belong in the moderate-depth group, except *Arca sisquocensis* and *Kellia laperousii*. *Arca sisquocensis* has no Recent allies on the Pacific coast; *Kellia laperousii* ranges from the intertidal zone to a depth of 35 fathoms.

[46] Canfield, C. R., Subsurface stratigraphy of Santa Maria Valley oil field and adjacent parts of Santa Maria Valley, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 23, p. 59. 1939.

Species found in Foxen mudstone at Waldorf mine and in Cebada fine-grained member of Careaga sandstone at locality 177 and Fugler Point

Species	Locality		
	Waldorf mine	177	Fugler Point
Gastropods:			
Puncturella cucullata (Gould)	X	?	?
Puncturella cooperi aphales Woodring, n. var	X	X	X
Turcica imperialis brevis Stewart	?	?	X
"Gyrineum" mediocre lewisii Carson	X	X	X
Fusitriton cf. *F. oregonensis* (Redfield)	X	X	----
Jaton cf. *J. carpenteri* (Dall)	?	----	X
Psephaea oregonensis (Dall)	X	X	X
Megasurcula carpenteriana tryoniana (Gabb), strongly shouldered form	X	?	----
Propebela sp	X	X	----
Pelecypods:			
Saccella cellulita (Dall)	X	X	X
Arca sisquocensis Reinhart	X	X	X
Kellia laperousii (Deshayes)	X	X	----
Macoma cf. *M. brota* Dall	X	X	X
Semele cf. *S. rubropicta* Dall	X	X	X

The abundance of the brachiopod *Terebratalia occidentalis* in bed 2 (locality 178*b*) of the Fugler Point section recorded on page 47 and its absence or scarcity in the other fossiliferous beds at that locality are noteworthy features. This brachiopod has a depth range of about 30 to 75 fathoms.

An unidentified *Mya* occurs at locality 169 in the western Casmalia Hills. Like the *Mya* in the Foxen mudstone, it is associated with marine species and is evidently not indicative of brackish water or seepage of fresh water.

Great numbers of the small barnacle *Balanus hesperius proinus*, many of which have opercular valves in place, are found on oyster shells at locality 236 in calcareous sandstone of fine-grained facies in undifferentiated Careaga strata. These oyster shells were lying in quiet water, for otherwise the opercular valves would be lost, as they usually are in fossil barnacles. Some of the oyster valves, for the most part upper valves, have barnacles on both surfaces, suggesting that the barnacles settled on them while the valves were open after death of the oysters and before disintegration of the ligament. The valves evidently remained in that position during life of the barnacles, possibly through the accumulation of enough sand to keep them propped open. Forms of the Recent *B. hesperius* have been dredged at depths of 7 to 91 fathoms.

The meager Cebada foraminiferal fauna is of shallow-water aspect.

GRACIOSA COARSE-GRAINED MEMBER

Gastropods are again outnumbered by bivalves in the Graciosa coarse-grained member of the Careaga sandstone, the ratio being the same as in the fine-grained facies of the Sisquoc formation, despite the ecologically dissimilar sediments and fauna. The Graciosa fauna is dominantly of shallow-water facies. About 24 percent of the species identical with, or closely similar to, modern species are found in shallow-water, 63 percent belong in the shallow-water to moderate-depth group, and 13 percent in the moderate-depth group. A shallow-water facies for the Graciosa fossils is suggested immediately by the wide distribution and local abundance of the sand dollar *Dendraster ashleyi*. The closely related modern *D. excentricus* lives along sandy shores just below low-tide line. The only species of the littoral genus *Littorina*, represented by one specimen, occurs in the Graciosa. The thick-shelled Pismo clam, *Pachydesma crassatelloides*, which lives on sandy beaches exposed to the full surf, was not found in other formations or members. *Pandora punctata*, present at seven localities in the Graciosa and two localities in the Cebada, lives in shallower water than any other species of the genus on the Pacific coast.

Half of the eight species in the moderate-depth group of the Graciosa were found only in the Casmalia Hills, or in the Casmalia Hills and the western Solomon Hills. At some localities in the western part of the Santa Maria district, and perhaps elsewhere, the depth apparently was somewhat greater than 10 fathoms. *Nuculàna* cf. *N. leonina*, the only species from the Santa Maria district that has deep-water affinities, is a notable exception to the general shallow-water aspect. This species, found at the railroad cut near Shuman (localities 196*b*, 196*c*), is closely related to *N. leonina*, which has a known depth range of 152 to 750 fathoms. Inasmuch as a depth as great as 25 fathoms is improbable even in the Casmalia Hills, *Nuculana* cf. *N. leonina*, which is associated with the shallow-water *Olivella biplicata*, *Macoma nasuta kelseyi*, *Schizothaerus*, *Mya*, and *Dendraster ashleyi*, evidently is an unreliable depth indicator, or did not live with the species with which it is now associated.

Beds of sand containing *Dendraster ashleyi* in great abundance have no mollusks or practically none. The uniform abundance of *"Nassa," Macoma*, and *Protothaca* is characteristic of the tar sand on Graciosa Ridge.

Much of the coarse-grained sand in the upper part of the Graciosa may be nonmarine. At locality 211 in the eastern Solomon Hills south of the West Cat Canyon field, strata mapped as the upper part of the Graciosa include limestone containing fresh-water gastropods. Brackish-water and fresh-water fossils from locality 228 in the Purisima Hills represent the uppermost part of the Graciosa or the basal part of the Paso Robles formation. Remains of land mammals occur at locality 231*a* in the upper part of the Graciosa of the Purisima Hills. Though float whale remains were found nearby, no other marine fossils are known from the upper part of the Graciosa.

PASO ROBLES FORMATION

The Paso Robles formation contains a meager fauna of fresh-water mollusks and ostracodes. This meager fauna suggests that the lakes and ponds in which the fossiliferous clay, marl, and limestone accumulated were small and probably lacked an abundant aquatic flora. The nonfossiliferous cross-bedded sand and gravel forming the bulk of the formation are presumably stream deposits.

The basal part of the Paso Robles in the western Casmalia Hills includes thin tongues of marine sand containing a few shallow-water marine mollusks. Marine tongues are recognized also in the subsurface section of the adjoining part of the Santa Maria Valley.

ORCUTT SAND

The sand and gravel of the Orcutt were deposited by streams on an extensive smoothly beveled surface. Clay of limited extent in the western Purisima Hills contains a very meager fresh-water fauna that lacks some of the planorbids found in the Paso Robles formation. The clay evidently was deposited in small ephemeral ponds.

MARINE TERRACE DEPOSITS

The marine terrace deposits are characterized by the abundance of rock-cliff and tide-pool species, the usual facies for marine terrace deposits along the mountainous California coast.[47] The fauna of the terrace deposits, however, includes some species that live below low-tide line outside tide pools. These forms presumably were transported by storm waves and mixed with the rock-cliff and tide-pool species.

The terrace fossils are species that are still living or probably still living, some of the specimens being too imperfect for certain identification. Those that are identified as Recent species, or compared with them, are within their present latitude range with the exception of *Siliqua* cf. *S. patula*, and it is hardly an exception. The present recorded southern limit of *S. patula* is Oceano, 10 miles north of the mouth of Santa Maria River.

NORTHERN AND SOUTHERN SPECIES IN MARINE PLIOCENE FORMATIONS

The marine Pliocene formations of the Santa Maria district—or rather the formations containing marine Pliocene fossils, for the Sisquoc formation is considered of late Miocene to middle Pliocene age—contain species that are south of their present range and others that are north of their present range, or forms that are related to species now found farther north and farther south. The northern species are as follows:

[47] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., Geology and paleontology of Palos Verdes Hills, Calif.: U. S. Geological Survey Prof. Paper 207, pp. 93–95, 1946.

Northern species in Pliocene formations of Santa Maria district

Species	Formation and member					Present known range
	Sisquoc formation		Foxen mudstone	Careaga sandstone		
	Tinaquaic sandstone member	Diatomaceous strata		Cebada fine-grained member	Graciosa coarse-grained member	
Gastropods:						
Cryptonatica aleutica Dall, small var.			X	X	X	A small form of *C. aleutica*, which ranges from Nunivak Island, Bering Sea, to Puget Sound.
Neptunea cf. *N. stantoni* (Arnold)			X			Related to *N. magna*, Bering Sea and Sea of Okhotsk.
Boreotrophon multicostatus (Eschscholtz), inflated var.				X		A form of *B. multicostatus*, Nunivak Island, Alaska, to Shelter Cove, Mendocino Co., Calif. (Dall cited San Pedro as the southern limit, but the specimen from San Pedro evidently is a fossil).
Pelecypods:						
Nuculana cf. *N. leonina* (Dall)					X	Closely related to *N. leonina*, Strait of Juan de Fuca, Wash., to Piedras Blancas, San Luis Obispo Co., Calif.
Saccella cellulita (Dall)		?	X	X		Craig,, Alaska, to Puget Sound.
Miodontiscus cf. *M. prolongatus* (Carpenter).			X	X		Probably identical with *M. prolongatus*, Middleton Island, Gulf of Alaska to Carmel, Calif.
Tellina cf. *T. lutea* (Wood)		X	X			Closely related to *T. lutea*, Arctic Ocean and Bering Sea to Cook Inlet, Alaska.
Macoma nasuta kelseyi Dall				cf.	X	Reported to be living in Puget Sound.
Macoma cf. *M. brota* Dall		?	X	X		Closely related to *M. brota*, Arctic Ocean and Bering Sea to Puget Sound.
Siliqua cf. *S. media* (Sowerby)	X	X		X	X	Closely related to *S. media*, Arctic Ocean and Bering Sea to Cook Inlet, Alaska.
Panomya cf. *P. beringianus* Dall				X		Related to *P. beringianus*, Pribilof Islands, Bering Sea, to Puget Sound. (Recorded from Puget Sound as *P. ampla*.) Puget Sound is southern limit of genus.

The genus *Patinopecten*, represented by species in all the Pliocene formations, is now a northern genus not found south of Point Reyes, Calif. The Santa Maria species of this genus, however, are not closely related to *P. caurinus*, the only species of the genus living on the Pacific coast. *Mya* also is a northern genus, the southern limit of which is Elkhorn Slough, Monterey County, Calif. Unidentified species of *Mya* occur in the Foxen mudstone and in both members of the Careaga sandstone.

Some species that are no longer living may be considered of northern affinities because of their known distribution in Pliocene formations, being found only north of the Santa Maria district. Such species are as follows:

Extinct species of northern affinities in Pliocene formations of Santa Maria district

Species	Formation and member					Pliocene distribution outside Santa Maria district
	Sisquoc formation		Foxen mudstone	Careaga sandstone		
	Tinaquaic sandstone member	Diatomaceous strata		Cebada fine-grained member	Graciosa coarse-grained member	
Gastropods:						
"*Gyrineum*" *mediocre lewisii* Carson	------	------	X	X	------	A variety of "*G*". *mediocre*, Coos Bay, Oregon.
Neptunes cf. *N. stantoni* (Arnold)[1]	------	------	X	------	------	Probably identical with *N. stantoni*, San Francisco peninsula; Santa Cruz Mountains.
Calicantharus portolaensis (Arnold)	------	------	------	X	------	?San Francisco peninsula; Santa Cruz Mountains; San Joaquin Valley.
Psephaea oregonensis (Dall)	------	X	X	X	------	Coos Bay, Oregon; Santa Cruz Mountains.
Pelecypod: *Pseudocardium densatum* (Conrad) of Arnold, var. cf. *gabbii* Rémond.	?	------	------	------	X	Coos Bay, Oregon; Sargent district, Santa Clara Co.; San Joaquin Valley.

[1] Related to Recent northern species.

Living and extinct species that are to be regarded as southern are shown in the following tables. The unidentified Cebada *Architectonica* is to be grouped with the southern species, for the present northern limit of this genus is Magdalena Bay, Lower California.

The largest number of both northern and southern species, including extinct species of northern and southern affinities, are found in the Cebada member of the Careaga sandstone, which has the largest fauna. In terms of the fauna from each formation and member, the highest percentage of northern species is in the basin facies of the Sisquoc formation (12 percent) and in the Foxen mudstone (11 percent), and the lowest in both members of the Careaga sandstone (7 percent). The highest percentage of southern species is in the Cebada (12 percent), and the lowest in the basin facies of the Sisquoc (7 percent) and in the Foxen mudstone (7 percent).

Not only are northern and southern species in the same formation and member, they are at the same locality and in the same bed. There is no reason to doubt that they were living together, unless it be assumed that they represent a mixture of hypothetical alternating northern and southern faunas. That assumption is supported only by the conviction that northern and southern species should not have lived together, and would remove the matter from the field of rational discussion. The occurrence of northern and southern species in the same fauna is not unusual for California late Tertiary and Pleistocene faunas; indeed, it is the usual condition and has been the source of much discussion concerning interpretation of the Pleistocene fossils of the San Pedro district.[48]

If the Pliocene faunas of California show a cooling of the sea in late Pliocene time, heralding the oncoming first glaciation of the Pleistocene, as has been inferred for the Pliocene faunas of the Ventura basin and San Joaquin Valley basin,[49] the Santa Maria district with its succession of Pliocene faunas should convincingly show this relationship. That they do not show it is apparent from the preceding tables. They show practically the opposite, for the highest percentage of northern species and the lowest percentage of southern species are in the basin facies of the Sisquoc formation and in the Foxen mudstone. With the exception of the Cebada member of the Careaga sandstone, however, the difference in percentage of southern species in these faunas is so small that it is not significant. Though some northern and southern species are only a few tens of miles beyond their present range, the northern species include some of genuine Arctic affinities, if they are correctly identified: *Tellina* cf. *T. lutea*, *Macoma* cf. *M. brota*, *Siliqua* cf. *S. media*, and *Panomya* cf. *P. beringianus*. And the southern species include representatives of the genera *Architectonica*, *Dosinia*, and *Lirophora*, all of which now live in warmer waters 500 miles or more south of the Santa Maria district. *Trochita radians*, which ranges from

[48] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geological Survey Prof. Paper 207), pp. 100–103, 1946.

[49] Gale, H. R., in Grant, U. S., IV, and Gale, H. R., Catalogue of the marine Pliocene and Pleistocene Mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, pp. 35, 53, 60, 1931.

Southern species in Pliocene formations of Santa Maria district

Species	Formation and member: Sisquoc formation: Tinaquaic sandstone member	Sisquoc formation: Diatomaceous strata	Foxen mudstone	Careaga sandstone: Cebada fine-grained member	Careaga sandstone: Graciosa coarse-grained member	Present known range
Gastropods:						
Turcica imperialis brevis Stewart			?	X		A variety of a form of the Japanese *T. imperialis* from Cabo San Lucas, Lower California.
Turritella gonostoma hemphilli Applin				X		A variety of *T. gonostoma*, Cabo San Lucas, Lower California to Acapulco, Mexico.
Trochita radians (Lamarck), small var			X	X		A variety of *T. radians*, Manta, Ecuador, to Valparaiso, Chile.
Crucibulum cf. *C. imbricatum* (Sowerby)				X		Probably identical with *C. imbricatum*, Gulf of California to Callao, Peru.
Trivia cf. *T. sanguinea* (Gray)				X		Evidently more closely related to *T. sanguinea*, Santa Catalina Island to Peru, than to Californian *T. ritteri*.
Erato cf. *E. scabriuscula* Gray				X		More closely related to *E. scabriuscula*, Cabo San Lucas, Lower California, to Peru, than to Californian *E. vitellina*.
Cancellaria lipara Woodring, n. sp				X		Related to *C. solida*, Gulf of California to Zorritos, Peru.
Pelecypods:						
Arca santamariensis Reinhart				X		Very closely related to *A. mutabilis*, Gulf of California to Paita, Peru.
Barbatia pseudoillota Reinhart				X		Very closely related to *B. illota*, Gulf of California to Panama.
Tellina cf. *T. idae* Dall				X		Probably identical with *T. idae*, Santa Barbara Islands and Santa Monica, Calif., to Newport Bay, Calif.
Spisula cf. *S. hemphilli* (Dall)	X			X	X	Probably identical with *S. hemphilli*, Redondo Beach, Calif., to Corinto, Nicaragua.
Dosina ponderosa (Gray), var				X	X	A variety of *D. ponderosa*, Laguna Ojo de Liebre, Lower California, to Paita, Peru. Laguna Ojo de Liebre is northern limit of genus.
Lirophora cf. *L. mariae* (d'Orbigny)					X	Very closely related to *L. mariae*, Magdalena Bay, Lower California, and Gulf of California to Panama. Magdalena Bay is northern limit of genus.
Protothaca staleyi (Gabb)	X			cf.	X	Evidently more closely related to *P. grata*, Bahía Tórtolo, Lower California, to Panama, than to Californian *P. staminea*.

Extinct species of southern affinities in Pliocene formations of Santa Maria district

Species	Formation and member: Sisquoc formation: Tinaquaic sandstone member	Sisquoc formation: Diatomaceous strata	Foxen mudstone	Careaga sandstone: Cebada fine-grained member	Careaga sandstone: Graciosa coarse-grained member	Pliocene distribution outside Santa Maria district
Gastropods:						
Turritella gonostoma hemphilli Applin [1]				X		Los Angeles Basin; San Diego.
Trochita radians (Lamarck), small var [1]			X	X		Ventura Basin; Los Angeles Basin.
Crucibulum cf. *C. imbricatum* (Sowerby) [1].				X		Los Angeles Basin.
"*Gyrineum*" cf. "*G.*" *elsmerense* English			X			Perhaps identical with "*G.*" *elsmerense*, Ventura Basin.
Cancellaria lipara Woodring, n. sp.[1]				X		San Diego.
"*Cancellaria*" *arnoldi* Dall		cf.	X	X	X	Do.
"*Cancellaria*" *hemphilli* Dall				X		Ventura Basin; Los Angeles Basin; San Diego.
Strioterebrum martini (English)				X	X	Ventura Basin; San Diego.
Pelecypods:						
Pecten stearnsii Dall?			X	X		Ventura Basin; Los Angeles Basin; San Diego.
Pecten hemphilli Dall		cf.		X	X	Near Santa Barbara; Ventura Basin; Los Angeles Basin; San Diego.
Lyropecten cerrosensis (Gabb)				X	X	Ventura Basin; Los Angeles Basin; San Diego; Isla Cedros, off Lower California.
Ostrea erici Hertlein		X		X		San Diego; near Laguna Ojo de Liebre, Lower California.
Dosinia ponderosa (Gray), var [1]				X	X	San Diego.

[1] Related to Recent southern form.

the equator to latitude 33° south, overstrains the interpretation of the southern species as indicators of warm water.

It might be claimed that none of the marine formations of the Santa Maria district is as young as late Pliocene and therefore would not be expected to show a cool-water fauna. If the lower part of the Santa Barbara formation is to be accepted as a faunal standard for late Pliocene, that claim would be reasonable. Arguments for assigning the entire Santa Barbara formation to the Pleistocene have recently been discussed elsewhere.[50]

It is, of course, improper to attempt to compare the temperature facies of the Santa Maria faunas in terms of latitude, for they are of different depth facies and of notably different size. It is hardly worth while to compute the median of midpoints of the faunas, a method used in the most recent discussion of a climatic-chronologic classification of late Pliocene and Pleistocene faunas [51] of southern California. That discussion, like previous discussions of similar interpretations, ignores the depth facies of the faunas dealt with. The Tinaquaic sandstone member of the Sisquoc formation and the Graciosa coarse-grained member of the Careaga sandstone are inferred to represent a shallow-water facies; they are the only units that have sand dollars of the genus *Dendraster*. Despite the difference in size of these two faunas, they have the same percentage of southern species (8 percent) and practically the same of northern species (8 percent and 7 percent, respectively). The basin facies of the Sisquoc formation and the Foxen mudstone fossils from the Waldorf mine have the same estimated maximum depth range of about 50 fathoms. Again despite the considerable difference in size of these two faunas, they have the largest percentage of northern species (12 percent and 11 percent, respectively) and the smallest of southern (7 percent for both).

The more northern aspect of the faunas from the basin facies of the Sisquoc formation and Foxen mudstone is attributed in large measure to their moderate-depth facies. Both faunas include extinct species that have southern affinities on the basis of their Pliocene distribution. The basin facies of the Sisquoc has no Recent southern forms and the Foxen has two: *Turcica imperialis brevis?* and the small variety of *Trochita radians*, neither of which, however, is typical of warm water. *Turcica imperialis brevis?* is as closely related to the Recent Japanese *T. imperialis* as to the Cabo San Lucas 66-fathom form of *T. imperialis*, and *Trochita radians* ranges practically as far south of the equator as the Santa Maria district is north of it. The shallow-water faunas on the contrary include northern as well as southern species. The association of northern and southern species throws doubt on the assumption that the present range of identical or closely related species can be used as a close guide in reconstruction of environments. Some of the Santa Maria Pliocene genera and species are no longer living in the latitude of Santa Maria, presumably because their present distribution is controlled by new physiological characters that are not correlated with available new morphological characters. If some species have evolved physiologically so that they can no longer live in the latitude of Santa Maria, others, or the same species, have doubtless evolved so that their depth range is now different from what it was during Pliocene time. *Nuculana* cf. *N. leonina*, which has deep-water affinities but probably did not live in deep water at the Graciosa locality where it occurs, may be an example.

AGE AND CORRELATION OF FORMATIONS

KNOXVILLE FORMATION

The Knoxville formation of the Point Sal area contains a small slender *Aucella* identified as *Aucella* cf. *A. piochii*. Elsewhere in the Coast Ranges, aucellae of that type are associated with ammonities of late Jurassic (Portlandian) age. Extensive descriptions of the Knoxville of the Coast Ranges have been published recently by Taliaferro,[52] who restricts the term Knoxville to the lower (Upper Jurassic) part of the section that has been included under it.

LOSPE FORMATION

Though the Lospe formation was searched for vertebrate remains, none was found. Its age therefore is unknown other than that it is younger than late Jurassic and older than early middle Miocene. It is presumably the equivalent of an undetermined part of the Sespe formation of the Santa Ynez Mountains and of districts southeast of that range. In fact, if nonmarine strata underlie marine Miocene in the subsurface section of the Purisima Hills, their designation as Lospe or Sespe would be arbitrary. Like the Sespe, the Lospe formation may include deposits of diverse age ranging from late Eocene to early Miocene. The Lospe formation underlies the early middle Miocene Point Sal formation apparently without marked discontinuity, suggesting that at least the upper part of the formation, perhaps the entire formation, is early Miocene, the equivalent of the marine Vaqueros sandstone. For the time being the Lospe is designated early Miocene(?).

If sediments were being deposited in the Santa Maria district while the Obispo tuff member of the Monterey formation was being laid down both north and south of the district, the tuff should be represented. The

[50] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geological Survey Prof. Paper 207), pp. 98, 104–105, 1946.

[51] Schenck, H. G., Geologic application of biometrical analysis of molluscan assemblages: Jour. Paleontology, vol. 19, pp. 511–516, 1945.

[52] Taliaferro, N. L., Geologic history and structure of the central Coast Ranges of California: California Div. Mines Bull. 118, pp. 125–127, 1941; Geologic history and correlation of the Jurassic of southwestern Oregon and California: Geol. Soc. America Bull., vol. 53, pp. 83–87, 1942; Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., vol. 27, pp. 195–219, 1943.

Obispo tuff [53] is several hundred feet thick in the type region near San Luis Obispo, is probably represented by the thick tuff bed at the junction of Cuyama and Sisquoc Rivers,[54] and is identified at numerous localities on the south slope of the Santa Ynez Mountains, decreasing in thickness eastward. It is in the upper part of the *Uvigerinella obesa* zone not far below the *Siphogenerina hughesi* zone; that is, it is close to the boundary between Kleinpell's Saucesian and Relizian stages, or in other words, close to the boundary between lower Miocene and middle Miocene. The tuff in the Lospe formation may possibly represent the Obispo tuff. The tuff in the Lospe, however, occurs as lenses through a thickness of about 1,800 feet and the beds of tuff are separated by deposits that contain no notable amount of tuffaceous material, whereas the Obispo tuff evidently represents a single ash fall.

POINT SAL FORMATION

The Point Sal formation contains Foraminifera of the *Siphogenerina hughesi* zone, the lower part of Kleinpell's Relizian stage, of early middle Miocene age. The *Siphogenerina hughesi* zone is widespread in California.[55]

MONTEREY SHALE

The lower member of the Monterey shale is of middle Miocene age, representing the upper part of the Relizian and all of the Luisian. The foraminiferal zones recognized in the lower member of the Monterey have an extensive distribution and essentially uniform development in California.[56]

Foraminifera are rare and poorly preserved in the middle member of the Monterey shale in the Casmalia Hills, the main outcrop area. A collection from the eastern Purisima Hills indicates that the middle member there is of early Mohnian age (early late Miocene).

A few crushed arenaceous Foraminifera were found in the upper member of the Monterey shale in the Casmalia Hills. The large fauna from the upper member in the eastern Purisima Hills is of late Miocene age. It represents the upper part of the *Bolivina hughesi* zone, of late Mohnian age, and also in part a younger faunal division found in about 1,000 feet of strata between the *Bolivina hughesi* zone proper and the *Bolivina obliqua* zone in their type regions on the north slope of the Santa Monica Mountains. The intervening strata were thought to be virtually barren of Foraminifera when Kleinpell [57] defined those zones. "*Ellipsoglandulina*" *fragilis*, *Hopkinsina magnifica*, and *Pulvinulinella purisima* are characteristic of this intermediate faunal division in the Santa Maria district and in other areas, including the north slope of the Santa Monica Mountains. Kleinpell assigned the *Bolivina obliqua* zone to the lower part of his Delmontian stage. Assignment, however, of the intermediate faunal division to the lower Delmontian and the *Bolivina obliqua* zone to the upper Delmontian appears to be preferable. The intermediate faunal division is represented at locality 21, in the Casmalia Hills, in strata mapped with the Todos Santos claystone member of the Sisquoc formation.

Mohnian and to a greater extent Delmontian foraminiferal faunas, though widely distributed in California, have a greater geographic diversity than the early and middle Miocene faunas.

SISQUOC FORMATION

BASIN FACIES

The lower and middle parts of the basin facies of the Sisquoc formation contain Foraminifera of the *Bolivina obliqua* zone. The fauna from those parts of the Sisquoc is similar to that in the Reef Ridge shale of the San Joaquin Valley, which likewise is assigned to the *Bolivina obliqua* zone,[58] indicating correlation with the Reef Ridge shale. The Foraminifera of the *Bolivina obliqua* zone include species of Miocene aspect. As mentioned in the preceding discussion of the age and correlation of the upper member of the Monterey shale, assignment of the zone to the upper Delmontian is preferred to assignment to the lower Delmontian.

The foraminiferal fauna from the upper few hundred feet of the basin facies is too meager and too restricted geographically to afford much basis for age determination and correlation. Though the species of *Bolivina* have more of a late Miocene than a Pliocene aspect, the fauna is presumably early or middle Pliocene.

The only considerable collections of megafossils are from the upper few hundred feet. The fauna is small as compared with later faunas, but includes "*Nassa*" *moraniana*, "*Nassa*" *waldorfensis*, "*Cancellaria*" cf. "*C.*" *arnoldi*, *Psephaea oregonensis*, *Anadara trilineata*, *Pecten* cf. *P. hemphilli*, *Patinopecten* cf. *P. lohri*, a variety of *P. dilleri*, *Ostrea erici*, and *Tellina* cf. *T. aragonia*, all of which point to a Pliocene age. Moreover, the species mentioned, with the exception of *Anadara trilineata* (early to late Pliocene), *Pecten* cf. *P. hemphilli* (early(?) to late Pliocene), *Patinopecten* cf. *P. lohri* (early and middle Pliocene), and *Tellina* cf. *T. aragonia* (early Pliocene in San Joaquin Valley), point to an age not older than middle Pliocene. In fact, aside from *Yoldia gala* (unknown elsewhere except in foothills adjoining Salinas Valley), *Patinopecten* cf. *P. lohri*, and *Tellina* cf. *T. aragonia*, the fauna in the upper part of the Sisquoc is much like that in the upper part of the Foxen mudstone and in the Cebada fine-grained member of the Careaga sandstone, both of which are assigned to the late Pliocene.

[53] Bramlette, M. N., The Monterey formation of California and the origin of its siliceous rocks: U. S. Geological Survey Prof. Paper 212, pp. 22–23, 1946.

[54] Arnold, Ralph, and Anderson, Robert, op. cit. (U. S. Geological Survey Bull. 322), pl. 3, *A*, 1907.

[55] Kleinpell, R. M., Miocene stratigraphy of California, pp. 117–121, Tulsa, Am. Assoc. Petroleum Geologists, 1938.

[56] Idem, pp. 117–127.

[57] Idem, pp. 130, 134.

[58] Kleinpell, R. M., in Woodring, W. P., Stewart, Ralph, and Richards, R. W. op. cit. (U. S. Geological Survey Prof. Paper 195), pp. 121–122, 1940 (1941).

The few megafossils from the middle part of the basin facies include *Anadara* cf. *A. trilineata* and *Patinopecten* cf. *P. lohri* (locality 113 in the Purisima Hills near Redrock Mountain) and therefore have Pliocene affinities. Records of *Anadara trilineata* from the Miocene have been questioned by Reinhart.[59] Some Miocene species, however, are so similar to *A. trilineata* that identification of imperfect or immature specimens may be doubtful. The genus *Patinopecten* is unknown in the California late Miocene. *Crepidula* cf. *C. princeps*, *Calyptraea* cf. *C. fastigiata*, and *Anadara* cf. *A. trilineata* occur in the lower part of the Sisquoc in the Purisima Hills immediately east of the mapped area. No megafossils of definite Miocene affinities are known to occur in the basin facies of the Sisquoc formation. The most typical late Miocene megafossils, however, are species of *Astrodapsis*, *Lyropecten*, and *Ostrea*. As they are of shallow-water aspect, they are not to be expected in the basin facies of the Sisquoc formation whatever its age may be.

The distinctive Sisquoc diatom *Lithodesmium cornigerum* is recorded from strata in the San Joaquin Valley assigned to the Etchegoin [60] and is represented by fragments from the lower part of the Etchegoin formations (middle Pliocene) of the Kettleman Hills.[61] *Hemidiscus ovalis* and *Raphoneis fatula*, two species from the late Pliocene San Joaquin formation,[62] occur in silty diatomaceous strata in the syncline near Sisquoc River.

According to the preceding discussion, the lower and middle parts of the basin facies of the Sisquoc formation contain Foraminifera of Miocene affinities and a few megafossils that have Pliocene affinities, and the upper part has Foraminifera of undetermined age relations and megafossils that are considered middle Pliocene. In view of these relations, the basin facies is considered of late Miocene to middle Pliocene age. In the preliminary account [63] the basin facies was designated as late Miocene(?) to middle Pliocene. Though future work elsewhere may indicate that the *Bolivina obliqua* zone, or part of it, is to be correlated with strata classified as early Pliocene on the basis of larger invertebrate and vertebrate fossils, the Reef Ridge shale, correlated with the lower and middle parts of the basin facies, is now considered late Miocene.

Massive silty more or less diatomaceous mudstone at the exposed top of the Miocene section in two districts in Santa Barbara County may be the equivalent of the basal part of the Sisquoc formation. Such strata are found on the coast in the trough of a syncline a mile north of Point Conception and in the trough of a syncline a few miles south of Santa Ynez River near Lompoc.[64] In both districts the silty mudstone is barren, or practically barren, of Foraminifera and has no megafossils. The diatoms may afford a basis for a determination of the age relations. The silty somewhat diatomaceous mudstone in the syncline near Lompoc overlies the 1,000-foot diatomite and diatomaceous mudstone of the Monterey shale exposed in the well-known Lompoc quarries. The diatomite and diatomaceous mudstone, also barren of Foraminifera, are probably of early Delmontian age. They overlie a 1,000-foot section of alternating units of porcelaneous shale and diatomaceous shale containing late Mohnian Foraminifera of the *Bolivina hughesi* zone, which occur also in the upper part of the underlying main body of porcelaneous and cherty shale.[65] Highly diatomaceous strata exposed in a bluff on the north side of Santa Ynez River, 2½ miles east of Lompoc and 1½ miles beyond the south border of the mapped area, include deposits of late Mohnian age (*Bolivina hughesi* zone), overlain by the probable equivalent of the diatomite of the Lompoc quarries and by still younger deposits that are without much doubt part of the Sisquoc formation.

Porcelaneous mudstone forming the 1,600-foot upper barren division of Kleinpell's upper member of the Monterey shale in Reliz Canyon,[66] in Monterey County on the west side of the Salinas Valley, contains the characteristic Sisquoc species *Yoldia gala* and also *Anadara* cf. *A. trilineata*. The porcelaneous mudstone overlies porcelaneous shale containing a few Foraminifera assigned by Kleinpell to his lower Delmontian stage. Though the range of *Yoldia gala* outside the Santa Maria district is unknown, its occurrence and the stratigraphic position of the mudstone suggest correlation with the Sisquoc formation. Sandstone overlying the mudstone has been assigned to the late Miocene Santa Margarita sandstone, presumably because of the occurrence of the barnacle *Tamiosoma*. *Tamiosoma*, however, is found in the early and middle Pliocene of the San Joaquin Valley and occurs on the east side of the Salinas Valley in Reed's Pancho Rico formation in association with early Pliocene species. In fact, the well-preserved specimens of *Tamiosoma* described and figured by Pilsbry [67] are from Reed's Pancho Rico formation. On the east side of the Salinas Valley this formation includes silty diatomaceous mudstone and apparently equivalent porcelaneous mudstone, which is McLure-like and probably has been re-

[59] Reinhart, P. W., Mesozoic and Cenezoic Arcidae from the Pacific slope of North America: Geol. Soc. America Special Paper 47, p. 58, 1943.

[60] Hanna, G. D., Observations on *Lithodesmium cornigerum* Brun: Jour. Paleontology, vol. 4, p. 190, 1930. (The Etchegoin of this paper presumably includes the equivalent of the Jacalitos formation.)

[61] Lohman, K. E., Pliocene diatoms from the Kettleman Hills, Calif.: U. S. Geological Survey Prof. Paper 189, p. 85, 1938.

[62] Idem, pp. 91, 93.

[63] Woodring, W. P., Bramlette, M. N., and Lohman, K. E., Stratigraphy and paleontology of Santa Maria district, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 27, p. 1352, 1943.

[64] Bramlette, M. N., The Monterey formation of California and the origin of its siliceous rocks: U. S. Geological Survey Prof. Paper 212, pp. 6–7, 1946.

[65] Idem, p. 7.

[66] Kleinpell, R. M., op. cit. (Miocene stratigraphy of California), pp. 7–9, figs. 3, 4, 1938.

[67] Pilsbry, H. A., The sessile barnacles (Cirripedia) contained in the collections of the U. S. National Museum, including a monograph of the American species: U. S. Nat. Mus. Bull. 93, pp. 125–127, pl. 28, figs. 1–3, pl. 29, 1916.

ferred to the late Miocene McLure shale member of the Monterey by some geologists.

MARGINAL FACIES

The small fauna from the upper half of the Tinaquaic sandstone member of the Sisquoc formation is considered of middle Pliocene age and is correlated with at least part of the Etchegoin formation. *Patinopecten lohri* and *Pseudocardium densatum* var. cf. *gabbii?* indicate early or middle Pliocene, but the fauna includes no distinctive early Pliocene species. The sand dollar *Dendraster* cf. *D. coalingaensis*, however, suggests the late Pliocene San Joaquin formation. Diatoms from the Tinaquaic include *Rhaphoneis angularis*, which occurs in the Etchegoin and San Joaquin formations.[68]

The only known localities where early Pliocene fossils are found in the Tinaquaic sandstone are outside the mapped area. Calcareous coarse-grained sandstone on the south side of Sisquoc River, 0.8 mile east-northeast of the mouth of Round Corral Canyon and 2¼ miles beyond the east border of the mapped area, contains *Astrodapsis* cf. *A. arnoldi* and *Lyropecten* cf. *L. terminus*. This fossiliferous sandstone is included in the Tinaquaic member of the Sisquoc and is correlated with the early Pliocene Jacalitos formation of the San Joaquin Valley and with early Pliocene strata in Reed's Pancho Rico formation of the Salinas Valley. According to a communication from Mr. L. M. Clark, who first reported early Pliocene fossils from the Santa Maria district, they occur also in calcareous sandstone in a sharply folded syncline between Round Corral Canyon and La Zaca Creek.

The lower half of the Tinaquaic member of the Sisquoc east of Foxen Canyon, in which no megafossils were found, may be early Pliocene. It is more probable, however, that the early Pliocene strata are overlapped in that area. Westward overlap of progressively higher Tinaquaic strata is indicated by the abbreviated section on the west side of Foxen Canyon, where fossiliferous sandstone of the Tinaquaic member, representing evidently only the uppermost part, rests directly on the Monterey shale.

Reed's Pancho Rico formation,[69] which has been referred to both the Miocene and Pliocene, crops out in extensive areas on the east side of Salinas Valley. It there overlies the late Miocene Santa Margarita sandstone and consists of sandstone, diatomaceous mudstone, and somewhat porcelanous mudstone. The sandstone in at least the lower part of the formation is characterized by an early Pliocene fauna including *Astrodapsis arnoldi* (and forms of *A. arnoldi* that have been named *A. arnoldi depressus*, *A. arnoldi crassus*, *A. arnoldi spatiosus*, and *A. salinasensis*), *Dendraster* cf. *D. coalingaensis*, *Patinopecten lohri*, *Lyropecten terminus*, and *Ostrea atwoodii*. As stated in a preceding paragraph, the lower part of the Tinaquaic sandstone member of the Sisquoc formation is correlated with this part of the formation. How much of Reed's Pancho Rico formation is to be included in the early Pliocene has not been determined. The formation may include deposits of middle Pliocene age and possibly even of late Pliocene age. A *Lyropecten* allied to *L. terminus*, and *Ostrea atwoodii* occur in both early and middle Pliocene in the San Joaquin Valley.

[68] Lohman, K. E., op. cit., p. 92.

[69] For a recent discussion of this formation see Bramlette, M. N., and Daviess, S. N., Geology and oil possibilities of the Salinas Valley, Calif.: U. S. Geol. Survey, Oil and Gas Invest., Prelim. Map 24, 1945

FOXEN MUDSTONE AND CAREAGA SANDSTONE

Foraminifera from the lower part of the Foxen mudstone may be of middle Pliocene age. This suggestion, however, is based on similarity of the fauna from the basal part of the Foxen to that in the upper few hundred feet of the Sisquoc formation and on stratigraphic considerations rather than on faunal similarities with middle Pliocene strata elsewhere, for some of the relatively few Foxen species are geographically restricted. The few megafossils from the lower part of the Foxen are not conclusive. *Patinopecten healeyi*, which was found in the basal part of the Foxen at locality 149, is widespread in the late Pliocene, but apparently occurs in strata that may be as old as early Pliocene in the Ventura Basin. The diatom flora in the Foxen along the Orcutt-Lompoc Highway is similar to that from the late Pliocene San Joaquin formation, the principal difference being the much larger number of pelagic diatoms in the Foxen. *Coscinodiscus cirrus*, which occurs in the Foxen, is a species from the San Joaquin formation.[70]

The megafauna from the upper part of the Foxen and those from both members of the Careaga sandstone are very similar so far as age and correlation are concerned. They are assigned to the late Pliocene. The largest Foxen collection, that from the Waldorf asphalt mine, is of uncertain stratigraphic position, but is probably from the upper half of the formation. At all events it includes no species of distinct middle Pliocene affinities.

The upper part of the Foxen mudstone and the Careaga sandstone are correlated with the San Joaquin formation of the San Joaquin Valley and the upper part of the San Diego formation at San Diego. The occurrence in the Santa Maria district and in the San Joaquin Valley of species that have a restricted stratigraphic distribution is as follows:

[70] Lohman, K. E., op. cit., p. 90.

Occurrence in Santa Maria district and San Joaquin Valley of Pliocene species with restricted stratigraphic distribution

Species	Santa Maria district					San Joaquin Valley
	Sisquoc formation			Careaga sandstone		
	Tinaquaic sandstone member	Diatomaceous strata	Foxen mudstone	Cebada fine-grained member	Graciosa coarse-grained member	
Echinoids:						
Astrodapsis arnoldi Pack [1]	[1] cf.					Jacalitos formation.
Dendraster coalingaensis Twitchell	cf.					Uppermost part of Etchegoin formation (var. *macer*) and San Joaquin formation.
Merriamaster perrini (Weaver)			cf.			Upper part of San Joaquin formation.
Gastropods:						
Turcica imperialis brevis Stewart			?	X		Do.
Opalia varicostata Stearns			X	X	?	Etchegoin and San Joaquin formations.
"*Nassa*" *moraniana* Martin		X		X	X	Etchegoin formation.
"*Nassa*" *waldorfensis* Arnold		X	X	X	X	Upper part of San Joaquin formation (cf.)
Calicantharus portolaensis (Arnold)	cf.	sp.		X	?sp.	Jacalitos and Etchegoin formations.
"*Cancellaria*" *rapa* Nomland				?		Upper part of San Joaquin formation.
Pelecypods:						
Mytilus coalingensis Arnold			cf	cf.	cf.	Jacalitos and Etchegoin formations.
Chlamys parmeleei (Dall)				X		Jacalitos formation and upper part of San Joaquin formation.
Chlamys parmeleei etchegoini (Anderson).			X			Etchegoin formation and upper part of San Joaquin formation.
Patinopecten lohri (Hertlein)	X	cf.				Jacalitos and Etchegoin formations.
Patinopecten healeyi (Arnold)			X	X	X	Upper part of San Joaquin formation (cf.)
Lyropecten terminus (Arnold) [1]	[1] cf.					A form allied to *P. terminus* in Jacalitos formation and reported from lower part of Etchegoin formation.
Tellina aragonia Dall		cf.				Jacalitos formation.
Pseudocardium densatum (Conrad) of Arnold, var. cf. *gabbii* Rémond.	?				X	Jacalitos and Etchegoin formations.
Platyodon colobus Woodring					cf.	Lower part of San Joaquin formation.
Siliqua cf. *S. media* (Sowerby)	X	X		X	X	Etchegoin formation.

[1] Not represented in mapped area.

The number of species that occur in the upper part of the Foxen, the Cebada, or Graciosa, or in any combination of these three units, and in the San Joaquin formation, is larger than the number found in those units in the Santa Maria district and in formations older than the San Joaquin in the San Joaquin Valley. The stratigraphic distribution of some species in the two districts, however, is conflicting. Correlation of the upper part of the Foxen mudstone and the Careaga sandstone with the San Joaquin formation is based principally on the occurrence of *Merriamaster* cf. *M. perrini* in the upper part of the Foxen and on the distribution of *Patinopecten lohri* and *P. healeyi* in the two districts. If this correlation is accepted, "*Nassa*" *moraniana*, *Calicantharus portolaensis*, large *Mytilus* of the *M. coalingensis* group, *Pseudocardium densatum*, and *Siliqua* cf. *S. media* survived longer in coastal California than in the San Joaquin Valley, as did the genera *Lyropecten* and *Dosinia*, both of which are characteristic of the Jacalitos formation, the former surviving until early Etchegoin time. The most serious discrepancy is the occurrence of *Pseudocardium densatum* in the Graciosa coarse-grained member of the Careaga sandstone. This species, as is the genus itself, is a useful and wisespread indicator of pre-San Joaquin age in the San Joaquin Valley. The stratigraphic sequence of species of *Dendraster*, arranged according to the degree of eccentricity of the apical system, is reversed in the two districts. The moderately eccentric *D.* cf. *D. coalingaensis* occurs in the Tinaquaic sandstone member of the Sisquoc formation and the very eccentric *D. ashleyi* in the Graciosa member of the Careaga sandstone. In the San Joaquin Valley, the very eccentric *D. gibbsii* ocurrs in the Jacalitos and Etchegoin formations and lower part of the San Joaquin formation, and the moderately eccentric *D. coalingaensis* in the San Joaquin formation, a variety ranging down into the uppermost part of the Etchegoin. This reversal is not as serious as it appears to be at first glance, for the moderately eccentric *D. jacalitosensis*, evidently an early member of the *D. coalingaensis* group, is found in the Jacalitos formation. Despite its eccentricity, the thin-margined *D. ashleyi* is probably more closely related to the thin-margined *D. coalingaensis* than to the thick-margined *D. gibbsii*.

It is apparent from the preceding table and discussion that a close agreement with the succession of Pliocene faunas in the San Joaquin Valley is not apparent. Perhaps none is to be expected. The Pliocene sea of the San Joaquin Valley was part of an inland sea, whereas the Santa Maria basin was an embayment close to the open ocean. It may be noted that the upper part of the San Joaquin formation has more faunal affinities with the Santa Maria district than the lower part of the formation, for the upper part has two faunas, those of the *Pecten* and *Acila* zones, more closely comparable to a fauna living in the open ocean.

Distinctive Pliocene species found both in the Santa Maria district and in the San Diego formation of the San Diego district are listed in the following table:

Distinctive Pliocene species in Santa Maria district and in San Diego formation of San Diego district

Species	Santa Maria district					San Diego district
	Sisquoc formation		Foxen mudstone	Careaga sandstone		
	Tinaquaic sandstone member	Diatomaceous strata		Cebada fine-grained member	Graciosa coarse-grained member	
Echinoids:						
Dendraster ashleyi (Arnold)	------	------	------	------	X	Inland localities.
Merriamaster cf. *M. perrini* (Weaver)	------	------	X	------	------	Closely related to *M. pacificus*, Pacific Beach and inland.
Gastropods:						
Turcia imperialis brevis Stewart	------	------	?	X	------	Pacific Beach (U. S. Geol. Survey locality 2657).
Turritella gonostoma hemphilli Applin	------	------	------	X	------	Pacific Beach.
"*Gyrineum*" *mediocre lewisii* Carson	------	------	X	X	------	Well in Balboa Park.[1]
Opalia varicostata Stearns	------	------	X	X	?	Pacific Beach.
Opalia varicostata anomala Stearns	------	------	------	X	------	Do.
"*Nassa*" *moraniana* Martin	------	X	------	X	X	Large form at U. S. Geol. Survey localities 2635 ("8 miles from San Diego, altitude 500 feet"), 2674 (National City), 7311 ("Fossil Canyon," about 3¼ miles east of Chula Vista), all inland.
Cancellaria lipara Woodring	------	------	------	X	------	A form of this species from well in Balboa Park (U. S. Nat. Mus. collection).
"*Cancellaria*" *arnoldi* Dall	------	cf.	X	X	X	Well in Balboa Park.
"*Cancellaria*" *hemphilli* Dall	------	------	------	X	------	Do.
Strioterebrum martini (English)	------	------	------	X	X	Do.[1]
Pelecypods:						
Pecten stearnsii Dall	------	------	?	?	------	Pacific Beach and inland.
Pecten hemphilli Dall	------	cf.	------	X	X	Do.
Chlamys parmeleei (Dall)	------	------	------	X	------	Do.
Patinopecten healeyi (Arnold)	------	------	X	X	X	Do.
Patinopecten dilleri (Dall)	------	var.	X	X	------	India and Upas Streets, San Diego (collection of Univ. Calif. at Los Angeles).
Lyropecten cerrosensis (Gabb)	------	------	------	X	X	Pacific Beach; U. S. Geol. Survey locality 2474 (second bench back on mesa, ¾ mile northeast of Pacific Beach).
Ostrea erici Hertlein	------	X	------	X	------	India and Upas Streets, San Diego (collection of Univ. Calif. at Los Angeles).
Macoma nasuta kelseyi Dall	------	------	------	cf.	X	U. S. Geol. Survey locality 2459 (Balboa Park).
Dosinia ponderosa (Gray), var	------	------	------	X	X	U. S. Geol. Survey localities 2459, 2662 (Balboa Park).

[1] Recorded by Hertlein, L. G., and Grant, U. S., IV, The geology and paleontology of the marine Pliocene of San Diego, Calif.; pt. 1, Geology: San Diego Soc. Nat. History Mem., vol. 2, p. 49, 1944.

Despite the much greater distance between the Santa Maria and San Diego districts, as compared with the distance between the Santa Maria district and the San Joaquin Valley, the list of species occurring in the San Diego district is larger than the list for the San Joaquin Valley. Not only is the number of species larger, their distribution in the Santa Maria district is more consistent. All the species listed from the San Diego district occur in the upper part of the Foxen mudstone or in the Careaga sandstone, or in both, only a few ranging down into the upper part of the Sisquoc formation.

The San Diego formation is considered middle Pliocene by some geologists who consider the lower part, or all, of the Santa Barbara formation late Pliocene.[71] The same geologists, however, assign the San Joaquin formation to the late Pliocene, and the San Joaquin formation has been correlated with the fossiliferous part of the San Diego formation at Pacific Beach.[72] That correlation is still considered reasonable.

It has been suggested that the San Diego formation may include three faunal zones and may represent much of the Pliocene.[73] Though this suggestion is supported by the early Pliocene affinities of the *Trophosycon*-bearing strata included in the San Diego formation and by assignment of the Pacific Beach faunal zone to the late Pliocene, modifications are needed in the light of Hertlein and Grant's recent description of the geology of the San Diego district[74] and in view of the distribution of species in the Santa Maria basin. The presence in the upper part of the Foxen and in the Careaga of species occurring in strata penetrated by an early water well in

[71] Grant, U. S., IV, and Hertlein, L. G., Pliocene correlation chart: California Div. Mines Bull. 118, pt. 2, pp. 201–202, fig. 85 (correl. chart), 1941.

[72] Woodring, W. P., Stewart, Ralph, and Richards, R. W., op. cit. (U. S. Geological Survey Prof. Paper 195), pp. 112–114, table opposite p. 112, 1940 (1941).

[73] Idem.

[74] Hertlein, L. G., and Grant, U. S., IV, The geology and paleontology of the marin, Pliocene of San Diego, Calif.; pt. 1, Geology: San Diego Soc. Nat. History Meme. vol. 2, pp. 46–63, figs. 1–6, 1944.

the present Balboa Park (species associated in the Santa Maria district with others from Pacific Beach) does not bear out the suggestion that the well penetrated the equivalent of the Etchegoin formation. According to Hertlein and Grant's structure section, the fossiliferous bed that furnished most of the species from the well is about 50 to 70 feet below sea level at the well. Its stratigraphic relations to the fossiliferous strata at Pacific Beach appear to be indeterminable, because the fauna revealed by the well has not been found at outcrop localities and because Pacific Beach is separated from Balboa Park, and other localities on San Diego Mesa, by Mission Valley. It is not now apparent whether a faunal zone to be correlated with the Etchegoin formation is represented in the San Diego formation, unless it be represented by the strata containing the large form of "*Nassa*" *moraniana* found in the lower part of the Etchegoin and the Jacalitos. On the contrary, many of the species in the upper part of the Foxen and the Careaga may have been living at the present site of San Diego during middle Pliocene time, or *Trophosycon* may have survived longer there than elsewhere.

Some of the species from the Santa Maria district, all of which occur at San Diego, are present in Pliocene deposits on Isla Cedros, off the coast of Lower California, and at Mesa del Elephante (Elephant Mesa) on the mainland of Lower California south of Laguna Ojo de Liebre. Isla Cedros is the type locality of *Lyropecten cerrosensis*. It is there associated with *Pecten stearnsii*, *Patinopecten healeyi*, and *Merriamaster pacificus*, which is closely related to *M. perrini*. The type of *Ostrea erici* is from Mesa del Elephante, where it occurs with *Patinopecten dilleri*. These Pliocene deposits in Lower California, like much of the San Diego formation, are assigned to the late Pliocene. The late Miocene and early Pliocene genus *Astrodapsis* is reported from Isla Cedros and Pacific Beach at San Diego. The sand dollars referred to that genus are probably forms of *Merriamaster*.

Faunal similarities between the Santa Maria district and the Los Angeles and Ventura basins are less marked than those between the Santa Maria and San Diego districts. Much of the Pliocene of the Los Angeles and Ventura basins represents a greater depth facies than in the other two districts. That does not account, however, for the absence of many Santa Maria and San Diego species, as both basins have some marginal Pliocene faunas of comparable moderate-depth to shallow-water facies. Two localities, both referred to the late Pliocene, show the closest similarity: Temescal Canyon, near Santa Monica on the west border of the Los Angeles basin, and the south slope of the Santa Susana Mountains on the south border of the Ventura basin. *Terebratalia occidentalis*, *Pecten stearnsii*, *P. hemphilli*, *Chlamys parmeleei*, *Patinopecten healeyi*, and *Lyropecten cerrosensis* are present at both localities, *Merriamaster pacificus* and *Patinopecten dilleri* at the Ventura basin locality.

Distinctive species of the Santa Maria district are found at other places in the Los Angeles and Ventura basins, but nowhere is there a notable concentration of such species and nowhere is a threefold faunal division of the Pliocene apparent. A late Pliocene fauna in the Pico formation of Los Angeles includes a form of *Turritella gonostoma*, a small variety of *Trochita radians*, *Crucibulum imbricatum*, "*Nassa*" *moraniana*, *Patinopecten healeyi*, and *Ostrea erici*.[75] *Turritella* cf. *T. gonostoma*, *Trochita* cf. *T. radians*, "*Nassa*" cf. "*N.*" *moraniana*, and "*Cancellaria*" *hemphilli* occur in older strata in the Repetto Hills, near Los Angeles, at the top of the Repetto formation, which is thought to represent the early half of the Pliocene. *Lyropecten cerrosensis* is present in the upper part of the Repetto of Los Angeles. The *Astrodapsis*-*Trophosycon*-bearing strata of early Pliocene affinities at Elsmere Canyon, in the eastern Ventura basin, contain "*Gyrineum*" *elsmerense* and *Lyropecten cerrosensis*. Strata of middle or late Pliocene age, or both, farther west in the eastern Ventura basin contain a small variety of *Trochita radians*, "*Nassa*" *waldorfensis*, "*Cancellaria*" *hemphilli*, *Strioterebrum martini*, *Pecten stearnsii*, *P. hemphilli?*, *Chlamys parmeleei* and variety *etchegoini*, *Patinopecten healeyi*, and *Lyropecten cerrosensis*. The species just mentioned occur in the Santa Maria district in formations assigned to the late Pliocene. If the strata in the Ventura basin containing them are middle Pliocene, which appears to be a reasonable assignment provided the fauna at Elsmere Canyon is early Pliocene, the range of these species extends to lower horizons than in the Santa Maria district, and close correlation with the upper part of the San Diego formation is less definite.

Pseudocardium densatum is recorded from the Sargent oil field in Santa Clara County, north of Santa Maria. The Santa Maria and Sargent districts are the only areas in coastal California where this species and the genus itself are known to occur. More detailed information on the stratigraphy and zonal paleontology of the Sargent district is desirable. Two faunas in the Sargent district already listed evidently correspond to the middle Pliocene and late Pliocene, respectively, of the Santa Maria district.

"*Nassa*" *moraniana*, *Neptunea stantoni*, *Calicantharus portolaensis*, and *Psephaea oregonensis* occur in the Purisima formation of the Santa Cruz Mountains. Both *Patinopecten healeyi* and *P. lohri* are recorded from the Purisima. Details of the stratigraphy and zonal paleontology of the Purisima formation are still unknown. The formation includes a lower diatomaceous mudstone member and may represent practically all of the Pliocene.

The type of *Patinopecten dilleri* is from Martin's

[75] Recorded recently by Willet, George, Additional notes on the Pliocene molluscan fauna of Los Angeles city: Southern California Acad. Sci. Bull., vol. 45, pp. 28–32, 1946.

lower division of Lawson's Wildcat series in the Eel River basin of northern California. The fauna from Martin's upper division includes *Protothaca staleyi*. The faunas of the Eel River basin have too many species of northern affinities for a profitable comparison with the faunas of the Santa Maria district.

The fauna of the Empire formation of Coos Bay, Oregon, which has been assigned to both the Miocene and the Pliocene, has diverse age relations. The species described by Dall as *"Phalium" turricula*, *"P." aequisulcatum*, and *"Eudolium" oregonense* represent cassid genera of Oligocene and Miocene affinities unknown in the Pliocene elsewhere on the Pacific coast. The bulk of the fauna, perhaps all the remaining species, favors a Pliocene age, possibly a considerable range in the Pliocene. *"Chrysodomus" imperalis*, a well-defined species, occurs in the Jacalitos formation. *Tellina aragonia* also occurs in the Jacalitos formation and a comparable form in the upper part of the Sisquoc formation. *Littorina petricola*, *"Gyrineum" mediocre*, *Psephaea oregonensis*, *Pseudocardium densatum*, and *Protothaca staleyi* are represented by identical or comparable forms in the Careaga sandstone. The Santa Maria form of *"Gyrineum" mediocre* (*"G." mediocre lewisii*) ranges down into the upper part of the Foxen, *Psephaea oregonensis* into the upper part of the basin facies of the Sisquoc formation, and *Pseudocardium densatum* (identification doubtful) and *Protothaca staleyi* into the Tinaquaic sandstone member of the Sisquoc.

SUMMARY OF CORRELATION OF POST-MONTEREY MARINE FORMATIONS

Correlation of the post-Monterey marine formations is summarized in the following table. Only the

Suggested correlation of post-Monterey marine formations of Santa Maria district

		Santa Maria district		Salinas Valley	San Joaquin Valley	San Diego district
Pleistocene.		Paso Robles formation (nonmarine)		Paso Robles formation (nonmarine)	Tulare formation (nonmarine)	Terrace deposits.
Pliocene.	Late.	——?——?—— Careaga sandstone. Graciosa coarse-grained member. *Dendraster ashleyi*, *"Nassa" moraniana*, *"N." waldorfensis*, *"Cancellaria" rapa perrini*, *Pecten hemphilli*, *Patinopecten healeyi*, *Lyropecten cerrosensis*, *Pseudocardium densatum* var. cf. *gabbii*. Cebada fine-grained member. *Elphidiella hannai*, *Turccia imperialis brevis*, *"Gyrineum" mediocre lewisii*, *"Nassa" moraniana*, *"N." waldorfensis*, *Calicantharus portolaensis*, *Cancellaria lipara*, *"Cancellaria" rapa?* and var. *perrini*, *"C." arnoldi*, *"C." hemphilli*, *Psephaea oregonensis*, *Pecten stearnsii? P. hemphilli*, *Chlamys parmeleei*, *Patinopecten healeyi*, *P. dilleri*, *Lyropecten cerrosensis*, *Ostrea erici*.		——?—— Reed's Pancho Rico formation. Possibly present or represented in lower part of Paso Robles formation.	——?—— San Joaquin formation. *Dentraster coalingaensis*, *D. gibbsii* small var., *Merriamaster perrini*, *Turcia imperialis brevis*, *"Nassa"* cf. *"N." waldorfensis*, *"Cancellaria" rapa*, *Pecten coalingaensis*, *Chlamys parmeleei*; and var. *etchegonini*, *Patinopecten* cf. *P. healeyi*.	——?—— San Diego formation. *Dendraster ashleyi*, *Merriamaster pacificus*, *Turccia imperialis brevis*, *"Gyrineum" mediocre lewisii*, *Calicantharus diegoensis*, *Cancellaria* cf. *C. lipara*, *"Cancellaria" arnoldi*, *"C." hemphilli*, *Pecten stearnsii*, *P. hemphilli*, *Chlamys parmeleei*, *Patinopecten healeyi*, *P. dilleri*, *Lyropecten cerrosensis*, *Ostrea erici*.
	Late.	Foxen mudstone. *Elphidium hughesi*, *Nonion* cf. *N. scaphum*, *Merriamaster* cf. *M. perrini*, *Turcica imperialis brevis?*, *"Gyrineum" mediocre lewisii*, *"Nassa" waldorfensis*, *"Cancellaria" arnoldi*, *Psephaea oregonensis*, *Pecten stearnsii?*, *Chlamys parmeleei etchegoini*, *Patinopecten healeyi*, *P. dilleri*.				
	Middle.	*Bolivina obliqua* var., *B. foxenensis*, *Urigerina foxenensis*, *Virgulina californiensis* var. *purisima*, *Patinopecten healeyi*.		Probably present.	Etchegoin formation. *Dendraster gibbsii*, *D. coalingaensis macer*, *"Nassa" moraniana*, *Calicantharus kettlemanensis*, *C. portolaensis*, *Chlamys parmeleei etchegoini*. *Patinopecten lohri*, *Lyropecten* cf. *L. terminus*, *Ostrea atwoodii*, *Pseudocardium densatum*.	*"Nassa" moraniana*, large var.
	Middle.	——?—— Sisquoc formation (basin facies). *Bolivina obliqua* var., *B. rankini*, *Buliminella curta*, *Virgulina californiensis* var. *purisima*, *Yoldia gala*, *Anadara trilineata*, *Patinopecten* cf. *lohri*, *P. dilleri* var.	——?—— Tinaquaic sandstone member of Sisquoc formation (marginal facies) *Elphidella* aff. *E. hannai*, *Nonion belridgensis*, *Dendraster* cf. *D. coalingaensis*, *Anadara trilineata*, *Patinopecten lohri*, *Pseudocardium densatum* var. cf. *gabbii?*			
	Early.	*Bolivina obliqua*, *B. rankini*, *Buliminella curta*, *Virgulina californiensis*, *Patinopecten* cf. *P. lohri*.		*Astrodapsis arnoldi* and vars., *Dendraster* cf. *D. coalingaensis*, *"Nassa"* cf. *"N" moraniana*, *Patinopecten lohri*, *Lyropecten terminus*, *Ostrea atwoodii*. ? Porcelaneous mudstone. *Yoldia, gala*, *Anadara* cf. *A. trilineata*.	Jacalitos formation. *Astrodapsis arnoldi* and vars., *Dendraster gibbsii*, *D. jacalitosensis*, *"Nassa" moraniana*, *Trophosycon* cf. *T. "nodiferum,"* *Calicantharus portolaensis*, *Chlamys parmeleei*, *Patinopecten lohri*, *Lyropecten* cf. *L. terminus*, *Ostrea atwoodii*, *Tellina aragonia*, *Pseudocardium densatum*.	*Trophosycon* cf. *T. "nodiferum."* ——?——
Late Miocene.		*Bolivina obliqua*, *B. rankini*, *B. ticensis*, *Buliminella curta*, *B. elegantissima*, *Nonion belridgensis*, *Nonionella miocenica* and var., *Virgulina californiensis*, *Crepidula* cf. *C. princeps*, *Calyptraea* cf. *C. fastigiata* *Anadara* cf. *A. trilineata*.	——?—— Absent(?)		Reef Ridge shale. *Bolivina obliqua*, *B. vaughani*, *Bulimina montereyana*, *Buliminella curta*, *B. elegantissima*, *"Buliminella" dubia*, *Nonion belridgensis*, *Nonionella miocenica*, *Virgulina californiensis grandis*.	Absent.
		Upper member of Monterey shale (late Miocene).		Upper member of Monterey shale (late Miocene).	McLure member of Monterey shale (late Miocene).	Formations of Eocene age and older.

Salinas Valley, the San Joaquin Valley, and the San Diego district are included in the table. Other regions are omitted because information is insufficient or faunal data are inconclusive and conflicting. Correlation with the San Diego district may be less conclusive and more conflicting than it now appears to be. On the basis of a three-fold faunal division of the Pliocene, correlation with the San Joaquin Valley is most satisfactory, but still somewhat conflicting. The inconclusive and conflicting features are due to restricted geographic distribution and presumably to varying stratigraphic range of species in different regions. In the San Joaquin Valley *Ostrea atwoodii* is an early and middle Pliocene species. This species is found in the Salinas Valley in at least the early Pliocene part of Reed's Pancho Rico formation. It is also present in the Huasna syncline, about 15 miles north of Santa Maria River. In both regions it is associated with *Patinopecten lohri,* as in the San Joaquin Valley, but has not been found farther south. So far as now known, *Patinopecten lohri* and *P. healeyi* have a mutually exclusive stratigraphic range in the San Joaquin Valley and Santa Maria district. *P. lohri* evidently does not occur in coastal California south of the Santa Maria district and *P. healeyi* evidently has a range to lower horizons south of the Santa Maria district. Even the *Patinopecten* recorded from Elsmere Canyon as *P. lohri,* and associated with some species of lower Pliocene affinities, appears to be *P. healeyi.* Both species are recorded from the Purisima formation.

Though the evidence for correlation with the Pliocene of the Ventura and Los Angeles basins is confusing, two localities in those basins (the south slope of the Santa Susana Mountains and Temescal Canyon) have faunas strongly suggesting the late Pliocene of the Santa Maria district. At both localities, however, the fauna is meager, consisting principally of brachiopods and pectinids. At both localities the Pliocene strata are transgressive.

However confusing correlations may be, the Pliocene formations of the Santa Maria district have a considerable number of well-defined species not known to be living, the presence of any of which, except "*Cancellaria*" cf. "*C.*" *tritonidea,* is strong presumptive evidence for a Pliocene age. "*C.*" *tritonidea* is a Pleistocene species, but has close Pliocene allies.

Well-defined species, not known to be living, in Pliocene formations of Santa Maria district

Echinoid: *Merriamaster* cf. *M. perrini* (Weaver).
Gastropods:
- "*Gyrineum*" *mediocre lewisii* Carson.
- "*Gyrineum*" cf. "*G.*" *elsmerense* English.
- *Opalia varicostata* Stearns and var. *anomala* Stearns.
- "*Nassa*" *moraniana* Martin.
- *Cancellaria lipara* Woodring, n. sp.
- "*Cancellaria*" *rapa* Nomland? and var. *perrini* Carson.
- "*Cancellaria*" cf. "*C.*" *tritonidea* Gabb.
- "*Cancellaria*" *arnoldi* Dall.
- "*Cancellaria*" *hemphilli* Dall.
- "*Drillia*" *graciosana* Arnold.
- *Strioterebrum martini* (English).

Pelecypods:
- *Yoldia gala* Woodring, n. sp.
- *Anadara trilineata* (Conrad) of Arnold and var. cf. *canalis* (Conrad).
- *Mytilus* cf. *M. coalingensis* Arnold.
- *Pecten hemphilli* Dall.
- *Patinopecten lohri* (Hertlein).
- *Patinopecten healeyi* (Arnold).
- *Patinopecten dilleri* (Dall).
- *Lyropecten cerrosensis* (Gabb).
- *Ostrea erici* Hertlein.
- *Platyodon* cf. *P. colobus* Woodring.

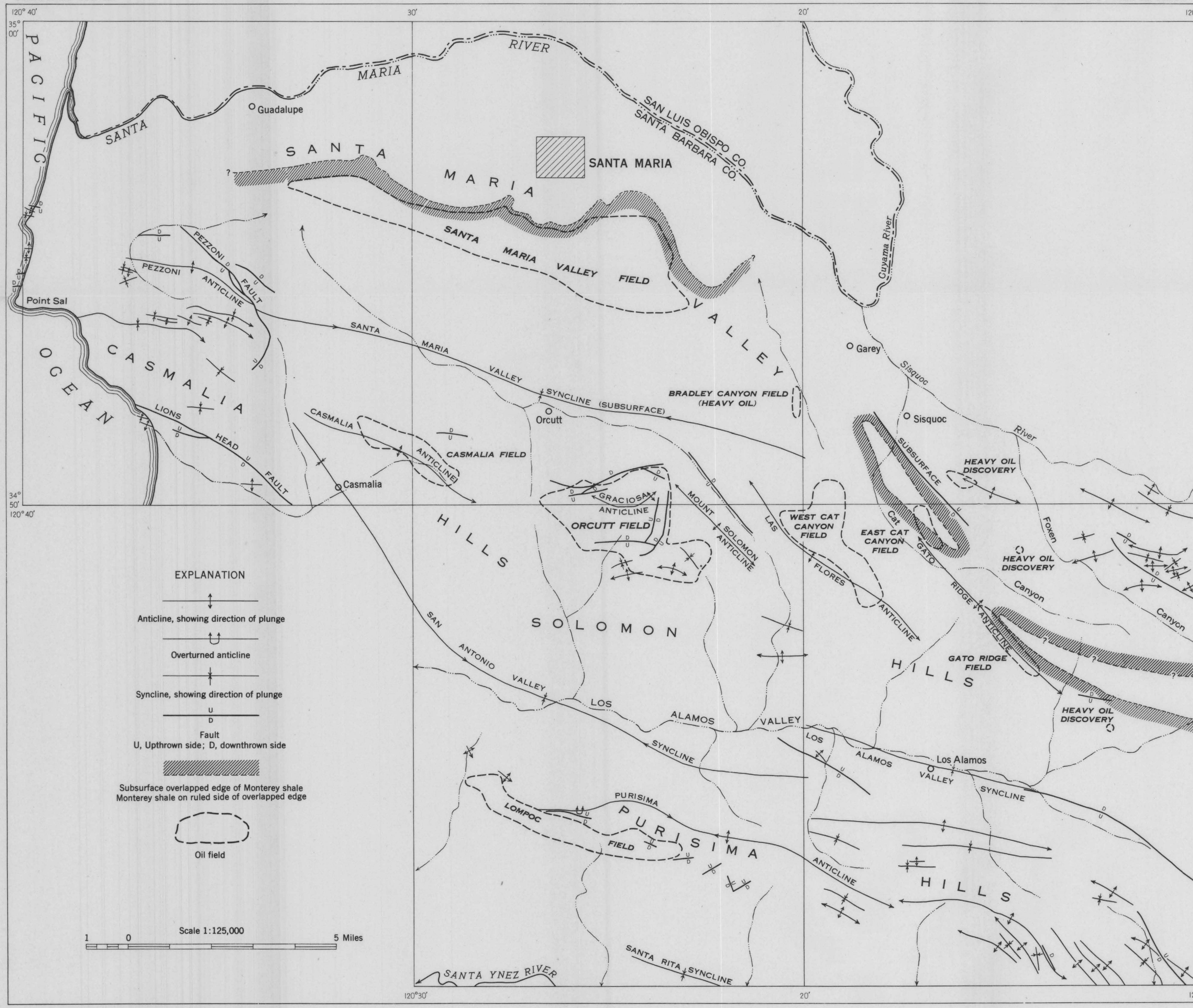
Four species in the preceding list have a remarkable distribution. *Patinopecten dilleri* has a latitude range of 1,000 miles from the Eel River basin, in northern California, to Mesa del Elephant, near Laguna Ojo de Liebre in Lower California. It has been found, however, in only five regions and, except in the Santa Maria district, at only one locality in each region. "*Gyrineum*" *mediocre lewisii* is present at San Diego and "*G.*" *mediocre* proper at Coos Bay, Oregon. *Cancellaria lipara* and "*Cancellaria*" *arnoldi* so far have been found only in the Santa Maria and San Diego districts.

The following species have no known close living allies in the eastern Pacific. Again with the exception of "*Cancellaria*" cf. "*C.*" *tritonidea,* they may be accepted as strong indicators of Pliocene age.

Pliocene species of the Santa Maria district that have no known close living allies in the eastern Pacific

Echinoid: *Merriamaster* cf. *M. perrini* (Weaver). Genus not known to be living.
Gastropods:
- "*Gyrineum*" *mediocre lewisii* Carson. Genus not known to be living in eastern Pacific.
- "*Gyrineum*" cf. "*G.*" *elsmerense* English. Genus not known to be living in eastern Pacific.
- "*Cancellaria*" *rapa* Nomland? and var. *perrini* Carson.
- "*Cancellaria*" cf. "*C.*" *tritonidea* Gabb.
- "*Cancellaria*" *arnoldi* Dall.
- "*Cancellaria*" *hemphilli* Dall.
- *Psephaea oregonensis* (Dall). Genus not known to be living in eastern Pacific.
- "*Drillia*" *graciosana* Arnold.
- *Strioterebrum martini* (English).

Pelecypods:
- *Yoldia gala* Woodring, n. sp.
- *Arca sisquocensis* Reinhart.
- *Anadara trilineata* (Conrad) of Arnold and var. cf. *canalis* (Conrad).
- *Mytilus* cf. *M. coalingensis* Arnold.
- *Pecten hemphilli* Dall.
- *Chlamys parmeleei* (Dall) and var. *etchegoini* (Anderson).
- *Patinopecten lohri* (Hertlein).
- *Patinopecten healeyi* (Arnold).
- *Patinopecten dilleri* (Dall).
- *Lyropecten cerrosensis* (Gabb). Genus in restricted sense not known to be living.
- *Ostrea erici* Hertlein.
- *Pseudocardium densatum* (Conrad) of Arnold var. cf. *gabbii* Rémond. Genus not known to be living in eastern Pacific.



MAP OF SANTA MARIA DISTRICT, CALIFORNIA, SHOWING STRUCTURAL FEATURES AND OIL FIELDS

864171 O - 50 (Face p. 108)

Of the species in the above list the following have close living allies in Japanese waters:

Pliocene species of the Santa Maria district that have no known close living allies in the eastern Pacific but have close living allies in Japanese waters

Pliocene species of Santa Maria district	Living Japanese species
Gastropod: *Psephaea oregonensis* (Dall).	*P. prevostiana* (Crosse).
Pelecypods:	
Arca sisquocensis Reinhart	*A. kobeltiana* Pilsbry.
Pecten hemphilli Dall	*P. albicans* (Schröter).
Chlamys parmeleei (Dall)	*C. swiftii* (Bernardi).
Pseudocardium densatum (Conrad) of Arnold var. of. *gabbii* Rémond.	*P. sachalinensis* (Schrenck).

Data on the geologic history and distribution of these species, or their allies, in Japan is desirable.

PASO ROBLES FORMATION

The fauna of the nonmarine Paso Robles formation is too meager to afford a basis for age determination. The formation is presumably of about the same age as the nonmarine Tulare formation of the Kettleman Hills in the San Joaquin Valley, which, like the Paso Robles formation, conformably overlies marine late Pliocene but has a large fresh-water fauna. Professor Stock, of the California Institute of Technology, reports that remains of a ground sloth of Pleistocene type have been found near Edna, 15 miles north of Santa Maria River, presumably in the Paso Robles formation. The Geological Survey's current age assignment for the Paso Robles formation of the Salinas Valley, the type region, is late Pliocene and Pleistocene (?). That assignment is tentatively accepted for the Paso Robles of the Santa Maria district. As indicated on the correlation chart on page 106, however, the base of the formation is probably at a lower horizon in the Salinas Valley than in the Santa Maria district. The age assignment late Pliocene(?) and Pleistocene may be a better designation for the Santa Maria district.

ORCUTT SAND AND YOUNGER TERRACE DEPOSITS

The Orcutt sand and terrace deposits younger than the Orcutt are somewhat arbitrarily considered late Pleistocene. They are later than widespread strong deformation and erosion. In the Ventura basin comparable deformation is dated as middle Pleistocene. The few nonmarine fossils in the Orcutt sand and the more numerous marine fossils in marine terrace deposits are inadequate for age differentiation within the Pleistocene, or even to separate Pleistocene from Recent. The Orcutt sand presumably yielded the Pleistocene tapir tooth collected along Corralillos Canyon.[76] An incomplete femur of a camelid of the genus *Camelops*, identified and referred to the Pleistocene by C. W. Gilmore, was found in deposits on the lowest stream terrace in the Santa Ynez Valley about 3 miles west of Buellton.[77]

IGNEOUS ROCKS

IGNEOUS ROCKS OF THE FRANCISCAN FORMATION

The igneous rocks of the Franciscan formation, the basement on which the sedimentary formations rest, crop out on Point Sal Ridge and in adjoining areas along and near the coast. They were described many years ago by Fairbanks,[78] but were not studied during the field work for the present report. As observed casually during the mapping of the formations lying on them, they consist chiefly of altered basalt, gabbro that is generally greatly altered, and minor areas of peridotite and serpentine. Although these igneous rocks, particularly the intrusives, may be younger than the Franciscan proper, they are for convenience grouped with the Franciscan.

MIOCENE(?) AUGITE ANDESITE

Augite andesite, intruding shale of the Knoxville formation, crops out in two very small adjoining areas immediately east of Point Sal Ridge. This locality was described by Fairbanks,[79] who designated the intrusive as "dark basaltic rock." A. O. Woodford, who collected and examined specimens, furnished the following description:

The texture is fine-grained, almost diabasic. The rock shows little, if any, flow structure. Feldspar, in laths mostly 0.15 to 0.4 millimeter long, constitutes about 60 percent of the rock. All the feldspar is oligoclase, 20 to 22 percent An. Interstitial minerals, all moderately abundant, consist of pyroxene (evidently augite), magnetite, chlorite, quartz, and calcite. Part of the calcite replaces feldspar, the remainder may be cavity-fill. Some of the chlorite is in rosettes, filling cavities. Phenocrysts of diopside, two millimeters in diameter and pale green in hand specimen, are rare. In thin-section they are colorless, with $\alpha=1.668\pm0.002$, the angle $Z\wedge c$ 40° to 42°, optic sign apparently positive, and considerable dispersion of the optic axes ($\rho>v$).

This rock, according to Professor Woodford, is an augite andesite of unusual type. The abundant magnetite suggests an excess of iron, but the dominant and unusually sodic feldspar and the presence of some quartz indicate an acid andesite. If the pyroxene, and especially the diopside phenocrysts, were not so fresh, a spilitic alteration might be suspected. Owing to the very different composition of the feldspar, the absence

[76] Stirton, R. A., and Weddle, H. W., The California tapir, *Tapirus haysii californicus* Merriam, from Santa Barbara County, Calif.: California Univ., Dept. Geol. Sciences, Bull., vol. 18, pp. 225-226, 1 fig., 1929.

[77] Upson, J. E., Thomasson, H. G., Jr., and others, Geology and water resources of the Santa Ynez River Valley, Santa Barbara County, Calif.: U. S. Geol. Survey, Water-Supply Paper 1107 (in preparation).

[78] Fairbanks, H. W., Geology of Point Sal: California Univ., Dept. Geology, Bull., vol. 2, pp. 40-90, 1896.

[79] Idem, pp. 38-40.

of analcite, the rarity of apatite, and probably a lesser amount and more diopsidic composition of pyroxene, the rock is not close to Fairbank's augite teschenite of the Point Sal area.

Though the augite andesite is without much doubt Miocene, it is designated Miocene(?), for there is no field evidence for its age, other than that it is later than the Knoxville formation.

MIOCENE DIABASE

Sills, and to a minor extent irregular bodies, of diabase intrude the Point Sal formation. Diabase forms the bold headland on the south side of Point Sal Landing and extends inland for a distance of two miles along the strike. This rock was described at considerable length by Fairbanks [80] under the name "augite teschenite." He found analcite and apatite to be abundant, and the feldspar to be basic labradorite.

STRUCTURE

REGIONAL RELATIONS

The Santa Maria district, comprising the triangular westward-widening lowland between the Santa Ynez Mountains and the San Rafael Mountains, coincides with a late Tertiary and early Pleistocene depositional basin—the Santa Maria basin. As pointed out by Reed and Hollister, [81] the Santa Maria Valley, at the north border of the district and of the basin, is the boundary between two structural provinces. To the north in the San Rafael Mountains and also in the Santa Lucia Mountains, valleys and hills are either synclines or anticlines. In the Santa Maria district, on the contrary, major valleys coincide generally with major synclines, and the hills are anticlinal, that is, as in other California late Tertiary and early Pleistocene basins, the last period of deformation was so recent that in general the topography faithfully reflects the structure. The Santa Maria Valley itself is a syncline. Unlike valleys farther south in the district, however, it lies athwart an older uplift. Also unlike most of the valleys farther south, the axis of the syncline is not in the middle of the valley, but is far to the south close to the bordering hills. Indeed, in the western Casmalia Hills it is beneath the hills where the bordering anticline is overturned (structure section *A–A′*, pl. 2). Along the north border of part of the Purisima Hills a major syncline is likewise overridden by an anticline (structure section *E–E′*, pl. 2).

The geologic map (pl. 1) and the small-scale structural map (pl. 6) show that the major structural features of the district have a general west-northwestward trend parallel to the elongation of the lowland itself and of the basin. Minor westward-trending and northward-trending folds and faults, however, extend across the trend of the major features. The district includes areas of wide open folds and also areas of narrow closely spaced and steeply tilted folds, as well as some overturned major anticlines, most of the latter overturned northward. The closely spaced folds coincide almost invariably with outcrops of the Miocene Monterey shale and Point Sal formation.

STRUCTURAL HISTORY

Mesozoic and early Tertiary.—Inasmuch as the only known Mesozoic or early Tertiary rocks in the district are the Jurassic(?) igneous rocks of the Franciscan formation and the sedimentary rocks of the late Jurassic Knoxville formation, the Mesozoic and early Tertiary structural history is obscure. The Franciscan and Knoxville were probably uplifted during Taliaferro's [82] Diablan orogeny at the end of the Jurassic to form a land area that presumably endured during early Cretaceous and perhaps during much of late Cretaceous time. If sediments were laid down while 10,000 feet of late Cretaceous rocks were deposited in the adjoining San Rafael Mountains, they were eroded following uplift at the close of the Cretaceous, when Reed and Hollister's [83] San Rafael uplift was formed. The district is inferred to have been part of a land area of Franciscan and Knoxville rocks at the south border of the San Rafael uplift during all of early Tertiary time.

Early and middle Miocene.—Deposition began on the former long-enduring positive area when the nonmarine sediments of the early Miocene(?) Lospe formation were laid down. These deposits are overlain by the marine deposits of the early middle Miocene Point Sal formation and the late middle and late Miocene Monterey shale. The Point Sal sea advanced northward beyond the limits of the Lospe formation and the Monterey sea still farther northward, both formations overlapping onto the basement of Franciscan and Knoxville rocks on the north limb of the Santa Maria Valley syncline; that is, toward the axis of the San Rafael uplift (structure sections *A-A′*, *B-B′*, pl. 2; Point Sal formation not present along line of sections).

Repeated movements are inferred to have taken place in the area of basement rocks west of the district presumably extending westward beyond the present coast. Along Point Sal Ridge, the only part of that area now above sea level, each of the three Tertiary formations so far mentioned (Lospe, Point Sal and Monterey) overlaps, or appears to overlap, the next older formation, or still older formations, and at some localities each is interpreted to rest directly on the basement.

Late Miocene local deformation.—Toward the close of the Miocene, between deposition of the late Miocene

[80] Op. cit. pp. 19–38.

[81] Reed, R. D., and Hollister, J. S., Structural evolution of southern California, pp. 92–94, Tulsa, Am. Assoc. Petroleum Geologists, 1936.

[82] Taliaferro, N.L., Geologic history and structure of the central Coast Ranges of California: California Div. Mines Bull. 118, pp. 127–128, 1941. Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 2, pp. 216–217, 1943.

[83] Reed, R.D., and Hollister, J. S., op. cit., p. 98, figs. 6–8, 11, 12, 1936.

upper member of the Monterey shale and deposition of the late Miocene to middle Pliocene Sisquoc formation, ridges appeared on the floor of the sea in the basin. At the same time deformation took place in the northeastern part of the district. In that area the marginal Tinaquaic sandstone member of the Sisquoc formation rests unconformably on the Monterey shale, the discordance being locally as much as 40° (structure sections *E–E′*, *F–F′*, pl. 2). On Gato Ridge, an anticline or a faulted structural high in the basin (structure section *E–E′*, pl. 2), and on a nearby basement high (structure section *F–F′*, pl. 2), the basin facies of the Sisquoc formation also lies on the Monterey with marked discordance. On the north limb of the Santa Maria Valley syncline, where the Point Sal formation, or more generally the Monterey shale, overlies the basement, the Sisquoc formation likewise overlaps onto the basement, thus forming the overlap trap for the oil in the Monterey in the Santa Maria Valley field, the largest oil field in the district (structure sections *A–A′*, *B–B′*, pl. 2). Movement in the basement area west of Point Sal Ridge is indicated by coarse detritus from the Monterey in the upper part of the Sisquoc in the western Casmalia Hills.

Pliocene movements.—Mild deformation continued at intervals during Pliocene time. The submarine ridges were then growing. The middle(?) and late Pliocene Foxen mudstone is missing on them, and is missing on Gato Ridge and the nearby basement high already mentioned, as well as farther northeast (structure sections *E–E′*, *F–F′*, pl. 2). The Foxen overlaps the Sisquoc formation on the north limb of the Santa Maria Valley syncline (structure sections *A–A′*, *B–B′*, *C–C′*, pl. 2). In the western Casamalia Hills the Foxen mudstone, like the Sisquoc formation, contains coarse detritus from the Monterey, pointing to continuing movement in the now-submerged basement area west of Point Sal Ridge.

Mild deformation continued during late Pliocene time, when the Pliocene sea had its greatest extent and the Santa Maria basin was fully outlined. The Cebada fine-grained member of the late Pliocene Careaga sandstone is missing on the growing submarine ridges, including the structurally highest part of the Graciosa Ridge anticline and the crest of the western Purisima anticline, where the Graciosa coarse-grained member of the Careaga sandstone overlies the Sisquoc formation. In the northeastern part of the district either member of the Careaga overlies discordantly the Monterey shale (structure section *E–E′*, pl. 2).

Middle(?) Pleistocene deformation.—After deposition of the Careaga sandstone, the nonmarine Paso Robles formation was laid down. Then followed the only period of strong general deformation in the known Tertiary and Pleistocene history of the district. The present structural features of the district were formed at that time, and the submarine ridges appeared as fully grown anticlines. The Paso Robles formation is folded, locally overturned (structure section *E–E′*, pl. 2), and faulted. Dating of the deformation is uncertain, because of uncertainty concerning the age of the Paso Robles formation. The deformation, however, is without much doubt of the same age as the well-dated strong middle Pleistocene deformation in the Ventura Basin, south of the Santa Ynez Mountains.

Late Pleistocene movements.—The Orcutt sand, a terrace deposit rather arbitrarily assigned to the late Pleistocene, bevels the Paso Robles and older formations. The Orcutt sand itself is tilted as much as 12° on the flanks of anticlines, indicating renewed growth of those folds, presumably in late Pleistocene time. Movement along at least one fault evidently took place in post-Orcutt time, for along the north border of the Orcutt field the Orcutt sand appears to be faulted against the Sisquoc formation and Careaga sandstone. Terrace deposits possibly younger than the Orcutt sand are arched in a low anticline west of lower Foxen Canyon.

STRUCTURAL FEATURES

PURISIMA HILLS

The Purisima Hills are anticlinal, being bounded on the north by the San Antonio and Los Alamos synclines and on the south by the Santa Rita syncline. The structure of the western part of the hills is dominated by the Purisima anticline, which has a central sag, where the base of the Careaga sandstone is structurally lower than farther east and west. The surface crest of the western part of the anticline is overturned southward and the south limb is displaced by a reverse fault (structure section *C–C′*, pl. 2). The subsurface crest is thought to be farther south, beneath the lowland covered by the Orcutt sand. Unconformable overlap of the Graciosa coarse-grained member of the Careaga sandstone and also regional southward thinning account for the marked difference in thickness of the Sisquoc formation on the limbs of the anticline. The structure of the extreme western part of the hills, north of the west end of the Lompoc field, was not satisfactorily determined, much of the area being covered by the Orcutt sand.

The outcrop area of Monterey shale in the eastern Purisima Hills, like other Monterey areas, is characterized by minor folds. One of the anticlines, extending westward immediately north of Redrock Mountain, was shown on the preliminary edition of the geologic map as an eastward extension of the Purisima anticline. These two anticlines are now shown on plate 1 as lying en échelon. Their relations, however, are uncertain, as minor folds that may be present are likely to be obscured by the massive mudstone of the Sisquoc formation.

The first anticline south of Los Alamos is overturned northward (structure section *E–E′*, pl. 1).

The adjoining asymmetric Los Alamos syncline is faulted east of Los Alamos, the north limb evidently being downthrown. Immediately south of the fault the Paso Robles formation dips 40° to 70° northward, whereas to the north it dips only a few degrees southward (structure section *F–F′*, pl. 2). A linear sag (along which occur some undrained depressions) lies along this fault, 4 miles east of Los Alamos.

CASMALIA HILLS AND SOLOMON HILLS

The Casmalia Hills and Solomon Hills form a continuous series of anticlinal uplifts between the Santa Maria Valley syncline and the San Antonio and Los Alamos synclines. The two sets of hills are separated by a structural and topographic sag (the course of State Highway 1 between Orcutt and Harris) extending northward across the trend of the major folds.

Casmalia Hills.—The western Casmalia Hills, the only part of the district where the igneous rocks of the Franciscan formation and the Knoxville, Lospe, and Point Sal formations crop out, is, of course, the structurally highest part of the district. There is, however, no well-defined major anticline. The Knoxville, Lospe, and Point Sal formations and Monterey shale wrap around the plunging east end of Point Sal Ridge in a complex pattern, marked apparently by overlaps. Some grounds are evident for interpreting Point Sal Ridge as an upthrust mass, the south border and most of the east border of which is limited by a fault. If that interpretation is substantiated, the interpretation of overlaps is erroneous. Outcrop areas of the Point Sal formation and Monterey shale have numerous minor folds, many of which are more steeply folded than the low minor anticline shown on plate 8 *A*. The most persistent minor folds in the Monterey shale are shown on the geologic map (pl. 1) and on the small-scale structural map (pl. 6). Those in the Point Sal formation are seen to be very variable in the few areas where exposures are adequate. More strike and dip readings were recorded, for example, along the canyons traversing the belt of narrow folds on the south slope of Mount Lospe, than can be shown on a 1:24,000 map.

As shown in structure section *A–A′* of plate 2, the structurally high area of basement and overlying rocks in the western Casmalia Hills is bounded to the south and north by faults. The south border fault is the Lions Head fault, a steep normal fault, a view of which is shown on figure 8 *B*. Where the fault emerges on the coast, it is marked by a zone of breccia 50 feet wide. The Pezzoni fault, or fault zone, is the north border fault. Between Corralillos Canyon and the canyon emerging from the hills at Waldorf, the Pezzoni fault is a northwestward trending steep reverse fault at the surface, or a complex series of steep reverse faults bounding narrow fault slices. The northeastward-trending fault, considered the continuation of the Pezzoni fault, on the contrary, is a well-defined steep normal fault. It may be a different fault, evidence in the intervening area being meager and inconclusive. No evidence was recognized, however, to support the view that the Pezzoni fault continues southeastward, with decreasing displacement, beyond the locality where it is shown as bending southward to join the normal fault.

Though the Pezzoni anticline is represented on the maps by a continuous dashed axis, it is improbable that it is single continuous fold. Throughout most of its length the axis, or axes, is in the Point Sal formation. The scattered strike and dip readings indicate a complex series of minor folds. Nevertheless, there is a general anticlinal axis diverging westward from the Pezzoni fault. Subsurface data show that the anticline is strongly asymmetric and is overturned northward where the axis is close to the Pezzoni fault, overriding the axis of the Santa Maria Valley syncline.

The Casmalia anticline is a broad fold that plunges southeastward (structure section *B–B′*, pl. 2). Toward the northwest it appears to merge into a structural terrace and finally into a homocline modified by minor wrinkles.

Solomon Hills.—The Graciosa anticline, or dome, is the structurally highest fold in the western Solomon Hills. Unlike the other major anticlines in the district, it trends westward and has an arcuate axis, convex southward. It is bounded on the north by a normal fault, along which the late Pleistocene Orcutt sand appears to be dropped against the Sisquoc formation (fig. 8 *C*) and Careaga sandstone. The springs forming the marshes near the abandoned Union Oil Co. Hartnell No. 3 well presumably represent ground water rising along the fault. An ill-defined low minor anticline, evidently consisting of two short axes lying en echelon, is recognized in the Shell Oil Co.'s Careaga lease in the southern part of the Orcutt field. A westward-trending normal fault, downthrown to the north, lies north of the syncline accompanying the western minor anticline. Along the east border of the Orcutt field the Careaga sandstone is dropped against the Sisquoc formation in a well-defined graben located in the Newlove lease of the Union Oil Co.

The Mount Solomon anticline, unlike the Graciosa anticline, conforms to the structural pattern of the district. The base of the Paso Robles formation is about 250 feet higher structurally on the Mount Solomon anticline than on the Graciosa anticline. Owing to pronounced eastward thickening of the Foxen mudstone and Sisquoc formation, however, the top of the Sisquoc formation is more than 1,000 feet lower structurally on the Mount Solomon anticline than on the Graciosa anticline. North of the plunging northwest end of the Mount Solomon anticline, the Cebada fine-grained member of the Careaga sandstone, and farther east the Graciosa coarse-grained member of the Careaga and the Paso Robles formation, strike parallel to the axis of the anticline, whereas the Orcutt sand

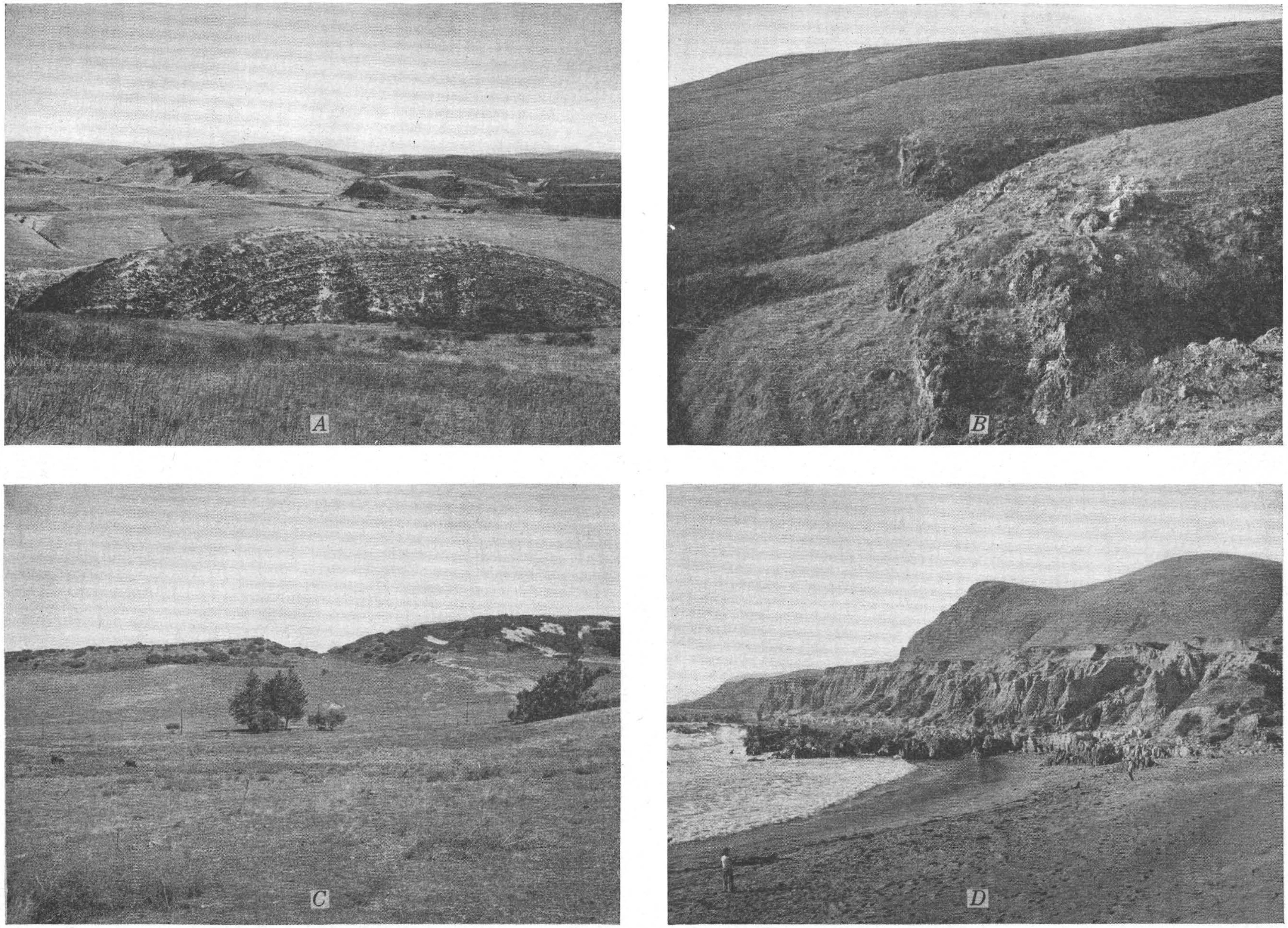


FIGURE 8.—Structural and physiographic features of Casmalia Hills and Graciosa Ridge. *A*, Minor anticline in middle member of Monterey shale, Casmalia Hills. Casmalia in middle background. *B*, Lions Head fault, Casmalia Hills. Ledge-forming igneous rocks of the Franciscan formation on foot wall, lower member of Monterey shale on hanging wall. *C*, Orcutt sand (to left of gap) faulted against Sisquoc formation, north slope of Graciosa Ridge. *D*, Lowest marine terrace, Casmalia Hills. Lions Head in middle background.

obliquely truncates them, the difference in strike being 55°. This pronounced unconformity indicates that the most recent late Pleistocene movement was along the trend of the Graciosa anticline, which first appeared as an embryonic submarine anticline in middle Pliocene time. The Mount Solomon anticline evidently first became a structural feature during the middle(?) Pleistocene deformation and remained quiescent during the later mild deformation.

The structural depression east of the Mount Solomon anticline was shown as a normal syncline on the preliminary edition of the geologic map. Subsurface data, however, indicate that the syncline is faulted, and it is so shown on the geologic map (pl. 1), the east limb being downthrown.

The Las Flores anticline is a low fold with a wide crest, so wide that the surface axis is difficult to identify. The location of the axis toward the southeast end of the anticline is uncertain. It may be farther north than shown. It is drawn toward the wide outcrop area of the Graciosa coarse-grained member of the Careaga sandstone southwest of the Gato Ridge field. That wide outcrop, however, may be due to a slight bulge or structural terrace south of the trend of the Las Flores anticline. Inasmuch as the outcrop area of the Graciosa is covered with a mantle of loose sand, the relations appear to be indeterminate. If the numerous springs at the east end of the Graciosa outcrop area, near the site of Bel-Air Oil Co. Price No. 1 well, have any structural control, it was not recognized. Whatever the surface relations may be, the subsurface data indicate a continuous southwestward dip. The subsurface crest of the Las Flores anticline is northeast of the surface crest (structure section *D–D′*, pl. 2).

No syncline is shown between the Las Flores and Gato Ridge anticlines. The structural sag between them is so shallow and so wide that the approximate axis could be located only by instrumentally determined altitudes on the base of the Graciosa coarse-grained member of the Careaga sandstone.

The Gato Ridge anticline has a narrow well-defined crest south of Cat Canyon. To the north, however, it flares out and rapidly disappears. The subsurface structure is not fully known (structure section *E–E′*, pl. 2). There may be a subsurface narrow steeply folded anticline, or a fault may mark the south boundary of a structural high of old rocks. That there may be little relation between surface and subsurface structure toward the border of the basin is indicated by the pronounced subsurface high southeast of Gato Ridge, shown in structure section *F–F′* of plate 2.

FOXEN CANYON-SISQUOC RIVER AREA

The outcrop area of the Monterey shale east of Foxen Canyon has the usual minor folds and one major fault. Folds in the Tinaquaic sandstone member of the Sisquoc formation are in general more extensive and not so closely spaced. The gentle anticline west of lower Foxen Canyon appears to be well substantiated, but is based on dips of only a few degrees in terrace deposits and should be confirmed by instrumentally determined altitudes on the base of the terrace deposits. Its relations to the subsurface high, located to the south, are unknown.

SANTA MARIA VALLEY

The axis of the Santa Maria Valley syncline is evident only on the basis of subsurface data. It lies close to the bordering hills, and, as already mentioned, is beneath the hills as it approaches the overturned Pezzoni anticline.

Drilling in the Santa Maria Valley field has revealed minor normal faults, which are said to be more numerous than indicated on subsurface maps published to date. Most of them have a northeastward trend, but at least one trends northwestward. The rectangular offsets in the overlapped edge of the Monterey shale, shown on plate 6, are due to these faults.

PHYSIOGRAPHY

GENERAL FEATURES

It has already been pointed out that the major valleys in the Santa Maria district, south of the Santa Maria Valley, coincide in general with synclines. Los Alamos Valley, the longest valley, is synclinal. It includes, however, two synclines lying en échelon. The two main highways, U. S. Highway 101 and State Highway 1, cross the Solomon Hills in topographic sags that correspond to structural sags.

The course of Foxen Canyon shows no structural control. It is presumably the former outlet of La Zaca Creek, a larger stream that emerges from the San Rafael Mountains 4 miles east-southeast of the intersection of Foxen Canyon and the east border of the mapped area. At some former time La Zaca Creek probably drained also into Los Alamos Valley by way of Canada de los Alisos or some nearby stream. The extensive terrace deposits along U. S. Highway 101, immediately northwest of Los Alamos, were evidently laid down along the shifting course of this large stream. At all events, the present course of La Zaca Creek was recently established by piracy on the part of a minor southward-flowing tributary of Santa Ynez River. La Zaca Creek is now in a position to capture much of the drainage of upper Los Alamos Valley by headward breaching of the low divide along U. S. Highway 101 at the east border of the mapped area.

The Sisquoc formation underlies the highest and most rugged parts of the Purisima Hills, the Solomon Hills, and much of the Casmalia Hills. Even the soft diatomaceous mudstone of the Sisquoc formation is tough rock. The narrow strike valley on the north slope of the Purisima Hills, shown on figure 2 *A*, is due to the readily eroded sand of the Cebada fine-grained member of the Careaga sandstone overlying the Sisquoc formation. The cuesta north of the valley is held up by conglomerate and gravel in the Graciosa coarse-grained member of the Careaga sandstone.

The peculiar mesalike summit of Mount Solomon (fig. 2 *B*) in the Solomon Hills evidently owes its origin to spalling along vertical joints in partly silicified calcareous clay at the base of the Paso Robles formation, and in cemented coarse-grained sandstone and conglomerate of the Paso Robles formation overlying the basal clay.

MARINE AND STREAM TERRACES

The surface on which the terrace deposits designated the Orcutt sand were deposited is very extensive, but it is locally deformed and only remnants are now preserved. It extended from the foot of the San Rafael Mountains westward to the coast. Toward the coast it evidently changes from a stream-cut surface to a wave-cut surface, presumably the highest wave-cut surface on San Antonio terrace and its southward continuation, Burton Mesa. San Antonio terrace and Burton Mesa, however, have not yet been studied to determine whether more than one marine terrace platform, concealed by the nonmarine terrace cover, is represented. (See p. 52.)

Though the surface on which the Orcutt sand lies is considered the highest and oldest of the terrace surfaces in the Santa Maria district, the terrace remnant on the south side of Corralillos Canyon, 2¼ miles west-southwest of the intersection of the canyon road and the Southern Pacific Railroad, is estimated to be about 200 feet above the base of the Orcutt sand on the north side of the canyon. The terrace remnant lies immediately south of the eastward projection of a fault downthrown to the north. It was not determined, however, whether the apparent discrepancy in terrace relations is due to post-terrace movement along the fault.

Five marine terraces appear to be represented on the south slope of Mount Lospe. The second in upward sequence, however, is a minor terrace identified only in one small remnant 1¼ miles southeast of Point Sal Landing. Though a fairly large remnant of the fourth terrace is present 1¼ miles southwest of Mount Lospe, this terrace was not recognized elsewhere. As a matter of fact, no serious attempt was made to correlate the terrace remnants. Throughout the coastal area southeast of Point Sal Landing there are only three extensive terraces; they are designated the high terrace, the intermediate terrace (evidently the third of the five mentioned), and the low terrace, the last being the one immediately adjoining the coast south of Lions Head and elsewhere. A well-preserved remnant of the high terrace is shown on figure 9, *C*. The terrace platform in that view is at an altitude of about 800 feet, the upper surface of the terrace deposits is 50 feet higher. The photographs on figure 9, *A*, *B*, are views of the intermediate terrace, which is the most extensive. The platform near its inner edge at fossil locality 261 is at an altitude of 600 feet. The cultivated mesa half a mile southeast of Casmalia, at the south border of the mapped area (visible in the background of the view on figure 8, *A*, back of Casmalia) appears to be part of this terrace. No marine deposits, however, were recognized on the terrace platform at that locality. If the correlation is correct, the terrace may be inland from the boundary between wave-cut terrace and stream-cut terrace. Figure 8 *D* is a view of the low terrace at Lions Head. The altitude of its platform increases from about 50 feet along the present sea-cliff to 125 feet at its landward border. The stream-cut and stream-filled channel, well exposed in a railroad cut [84] 3,500 feet east-northeast of Casmalia, was formed when the sea was apparently at the level of the low terrace.

INDURATED LAYER (HARDPAN(?) OF "FOSSIL SOIL")

Small outcrops of an indurated layer at or close to the present land surface are scattered throughout the district. They are most conspicuous in areas underlain by low-dipping strata of the upper part of the Graciosa coarse-grained member of the Careaga sandstone, Paso Robles formation, Orcutt sand, and terrace deposits younger than the Orcutt, particularly in areas of low relief between Los Alamos Valley and Foxen Canyon. These stratigraphic units are normally entirely unconsolidated and have few natural outcrops in areas of low relief, whereas the indurated layer is consolidated and may form the only obvious rock outcrops in extensive areas.

The indurated layer is a few feet to 15 feet thick, generally not more than 5 feet. At many localities, particularly where the bedrock is sand or gravel, it is a few feet to 10 feet below the surface; at numerous other localities it forms the surface. It consists of many separate layers, closely simulating depositional layers, all bound together with cement of varying hardness to form a single conspicuous indurated "layer" harder than underlying bedrock strata, and harder than overlying bedrock strata or soil wherever it is not at the surface. The material making up the indurated layer consists predominantly of sand and silt, but generally includes pebbles or angular rock fragments. It includes, however, varying amounts of clay, which is most abundant where the bedrock is mudstone. The prevailing color is rusty brown, owing to the presence of some ferruginous cement, but a mottled brownish and grayish color is not unusual. Cylindrical tubes that appear to be casts of rootlets were observed at many localities.

[84] Arnold, Ralph, and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull. 322) pl. 8, *B*, 1907.

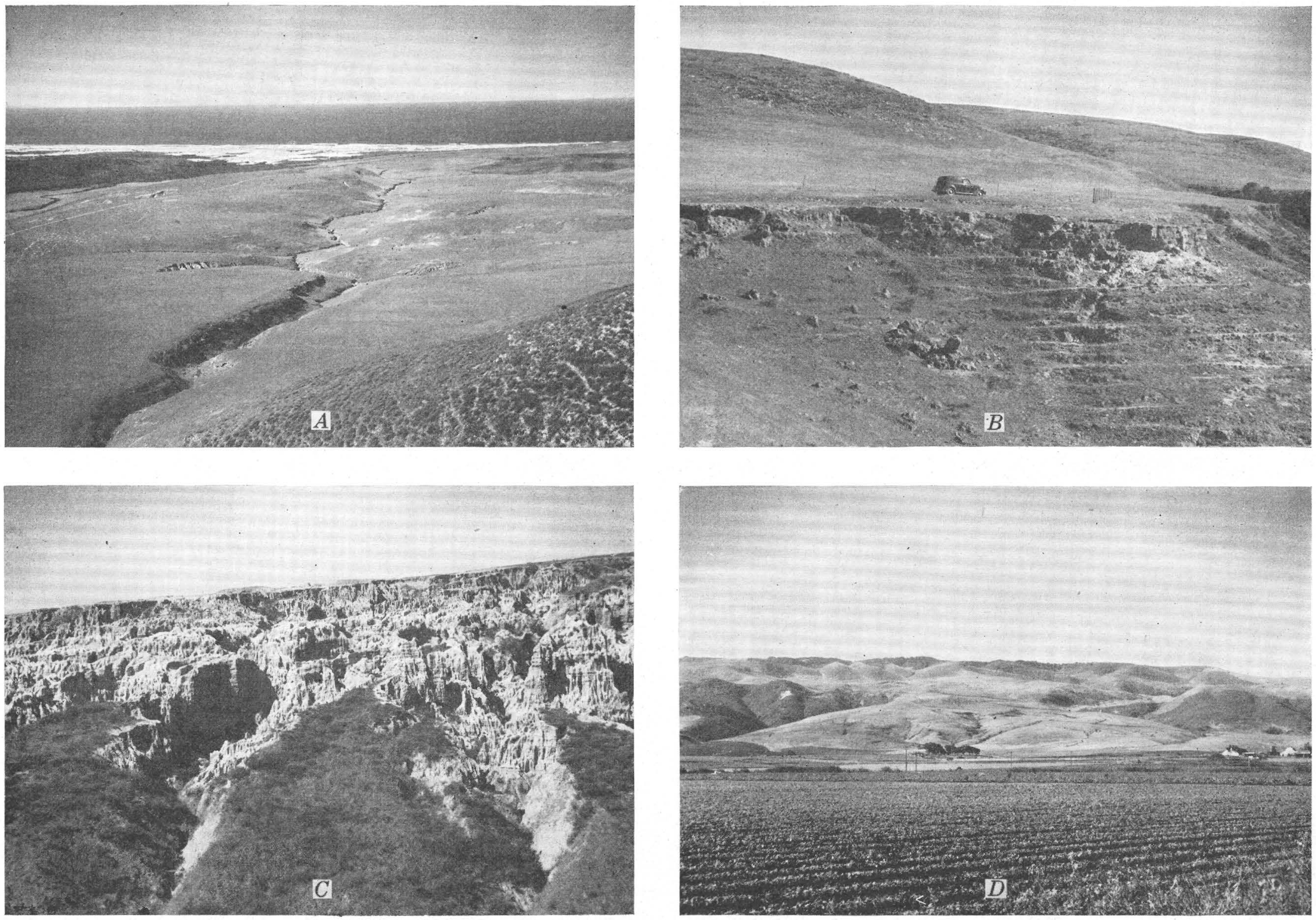


FIGURE 9.—Physiographic features of Casmalia Hills. *A, B,* Intermediate marine terrace. *C,* High-level marine terrace and fluted sand of nonmarine terrace cover. *D,* Landslide on north slope of western Casmalia Hills.

The indurated layer is conspicuous on many terraces, such as the intermediate marine terrace shown on figure 9, *B*. It is developed, however, not only on terrace treads, as in the view just mentioned, but also on terrace risers. It appears to be parallel to a former surface that at some places coincides with the present surface. It therefore may bear any relation to the dip of the bedrock strata on which it is developed. Attitudes read on the indurated layer would lead to the erroneous conclusion that many ridges are anticlines. A combination of bedrock dips and dips read on the indurated layer is reported to have led to the location of at least one unsuccessful oil well.

A penetrating description and analysis of the indurated layer was published many years ago by Louderback,[85] who aptly used the term "pseudostrata" for the false strata of which it is composed. He found the cement to be opaline silica and attributed the formation of the pseudostrata to deposition of the opaline cement by downward percolating water. According to Louderback's interpretation, precipitation during the rainy season is sufficient to dissolve and transport the cement, but is not great enough to flush out the cement-bearing waters. Louderback pointed out that the pseudostrata are formed by processes analogous to those involved in the formation of hardpan in soils, but according to his observations, the pseudostrata occur below the soil profile.[86]

It has been claimed [87] that the indurated layer is an ancient hardpan, the incomplete skeleton of a former soil profile developed on a former surface of less relief than the present surface. The grounds for this claim are briefly summarized as follows: The indurated layer was not observed to extend down the slopes of modern arroyos and canyons, which appear to be destroying the surface on which it was developed. The layer is not invariably below the present soil profile. In areas where the relief is greater than in the district studied by Louderback it is generally at the surface. If the layer is now forming, as Louderback evidently thought, it may be expected to be present in other districts in coastal southern California, wherever the relief and bedrock strata are similar to those in the Santa Maria district. However that may be, the physiographic, petrologic, and chemical studies that would be necessary to determine its origin were not made during the course of the work for the present report. For the time being the nongenetic term "indurated layer" or Louderback's term "pseudostrata" is preferable. Remnants of the layer are so widely distributed that, should it be found to have been developed on a former surface, mapping of the remnants would lead to a close reconstruction of the surface.

[85] Louderback, G. D., Pseudostratification in Santa Barbara County, Calif.: California Univ., Dept. Geology, Bull., vol. 7, pp. 21–38, pls. 3–6, 1912.

[86] Idem., pp. 28–29.

[87] Woodring, W. P., Ancient soil and ancient dune sand in the Santa Maria district, Calif. (abstract): Washington Acad. Sci. Jour., vol. 32, no. 9, p. 281, 1942. Woodring, W. P., Bramlette, M. N., and Lohman, K. E., op. cit. (Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 10), pp. 1,341–1,343, 1943.

SAND DUNES

Sand dunes, formed by the prevailing northwesterly winds sweeping in from the ocean, extend inland from the coast at the north and south borders of the mapped area. Most of the dunes that are well preserved may be classified under two main groups: transverse dunes, that is, transverse to the prevailing wind, and dunes that have a bow-shaped head from which two arms diverge to windward. Dunes of the second group have in general a crude parabolic outline and the term "parabolic dune," used by Hack [88] in his description of similar dunes in the Navajo country, may be applied to them. The outline of parabolic dunes is modified by overlapping dunes of the same type. Some well-preserved dunes, however, are irregular and wave-like, and fall into neither of the above groups.

Three age sets of dunes are recognized: old, intermediate, and modern. They form in general parallel belts succeeding one another inland in order of increasing age. There is probably no great difference in age between the modern and intermediate dunes; indeed, they may be of essentially the same age.

The modern dunes are the active dunes that are bare or have sparse scattered vegetation. They form a narrow belt immediately adjoining the coast between Point Sal and Santa Maria River, and on San Antonio terrace. In the mapped area the maximum width of the belt is 1½ miles. These dunes are for the most part coalescing parabolic dunes that have heads of varying width, and the dunes themselves trend N. 40° W. to N. 50° W. Immediately north of Point Sal the trend is N. 30° W. to N. 35° W., owing presumably to local deflection. A short narrow belt of transverse dunes, the dunes in which trend N. 55° E., to N. 60° E., lies inland from Mussel Rock, and merges northward into wavelike dunes of irregular outline and trend. These transverse dunes are remarkable, for they have a gentle southeast slope and a very steep northwest slope; that is, at least at the time when the airplane photographs were taken in 1938 and when the dunes were examined in 1940, they were migrating northwestward into the prevailing wind. Their retrograde migration is due presumably to strong eddies produced by the 150-foot to 200-foot sea cliff on which they lie. The sea cliff decreases in altitude northward and disappears approximately opposite the north end of the transverse dunes. These dunes probably move in both directions, against the wind when the maximum wind velocity is at the level of the ocean, and with the wind when the maximum velocity is at an altitude great enough for the wind to overtop the cliff.

[88] Hack, J. T., Dunes of the western Navajo country: Geog. Rev., vol. 31, no. 2, pp. 242–243, 1941.

The intermediate dunes are more or less anchored by vegetation, and are perfectly preserved. They form a belt, partly overlapped by modern dunes, immediately south of Santa Maria River and on San Antonio terrace. South of Santa Maria River their inland border is three-quarters of a mile to 1½ miles inland. The intermediate dunes are elongate parabolic dunes that generally have relatively wide heads. They trend N. 45° W. to N. 55° W. Isolated or coalescing areas, in which modern dunes are forming as a result of sand blowing out of intermediate dunes, are represented as far from the coast as the inland border of the intermediate dunes. These well-defined intermediate dunes are more strongly developed north and south of the mapped area than within it.

The old dunes are anchored by vegetation and their shape is for the most part poorly preserved. They are overlapped by intermediate or modern dunes. Small modern dunes, formed by deflation, are found in the old dunes at distances as much as 2¾ miles from the coast. The old dunes are far more extensive than the other two groups. They cover many square miles on a terrace bordering Santa Maria Valley and extend inland to the bluff overlooking the junction of Cuyama and Sisquoc Rivers at Garey, 20 miles inland. South of Santa Maria the belt of old dunes is as much as 5 miles wide. West of Betteravia it has doubtless been narrowed by the shifting course of Santa Maria River. Near the coast the old dunes are transverse dunes roughly parallel to the modern transverse dunes. Elsewhere they were probably parabolic dunes, but their outline has been greatly modified by rill and stream erosion. They show, however, elongate lineaments trending N. 50° W. to N. 60° W. These old dunes form a belt of irregular hummocky topography, including small basins that have no outlet. Old dunes in a more advanced stage of decay cover part of Burton Mesa in the coastal district south of the mapped area.

Lima beans, barley, and other crops are grown on the old dunes without irrigation. Deflation resulting from cultivation is not apparent, except possibly near the coast, but the effectiveness of the wind in most of the cultivated areas is modified by eucalyptus windbreaks. In uncultivated areas the dunes have an effective relatively dense cover of natural vegetation. The present protective cover of vegetation was, of course, lacking when the dunes were formed. The change in status may be due to a cutting off of the supply of sand or to a climatic change. Perhaps a sand-covered beach, much wider than the present very narrow beach that supplies the sand for the narrow belt of modern dunes, furnished the sand for the old dunes during a period when the sea stood lower than now. Or, most of the sand for the old dunes may have been derived from the Orcutt sand, on which the old dunes lie; in fact, the upper part of the Orcutt itself may include some windblown sand. In that event, the present inactivity of the old dunes is likely to be the result of a climatic change, greater precipitation or decreased wind velocity, or both. Inactive dunes are found elsewhere along the coast of southern California, as for example, between the north border of the Palos Verdes Hills and Playa del Rey, in Los Angeles County.[89]

LANDSLIDES AND EARTH FLOWS

Landslides and earth flows are common, particularly in the Point Sal formation and Foxen mudstone. The most extensive slides are on the north slope of the western Casmalia Hills, where two generations of slides are recognized; both are formed by mudstone of the Point Sal formation. The western younger slide is shown on figure 9 *D*.

OCCURRENCE OF OIL

Oil has been produced in the Santa Maria district since 1901, when the Orcutt field was discovered. The production to the end of 1947 totaled 269,657,000 barrels.

The nomenclature used in the present report for fields and pools is that adopted by a joint committee of the Pacific Section, American Association of Petroleum Geologists, and the Conservation Committee of California Oil Producers.[90] The Orcutt field was long designated the Santa Maria field by some geologists and producers. The designation "Orcutt field", however, was generally adopted after discovery of the Santa Maria Valley field, though the old designation is still in use. East Cat Canyon, West Cat Canyon, and Gato Ridge are considered areas of the Cat Canyon field by some, and are grouped as the undifferentiated Cat Canyon field by the State Division of Oil and Gas.

The production figures in the table that follows are those compiled by the Conservation Committee of California Oil Producers.[91] Semiannual and cumulative production data, and also much other useful information, may be found in the annual January–June and July–December issues of California Oil Fields, published by the State Division of Oil and Gas, and in the annual production summaries of the Petroleum Division, American Institute of Mining and Metallurgical Engineers.

The principal oil zones in the major fields are in the Monterey shale. The Monterey, indeed, is more important economically than is apparent in the preceding table, for in those fields where the Monterey and other formations are productive, the Monterey is of far greater importance than the others. The chief reservoir in the Monterey is fractured chert and cherty shale, corresponding lithologically to the middle member of the outcrop section. As pointed out by Wissler and

[89] Woodring, W. P., Bramlette, M. N., and Kew, W. S. W., op. cit. (U. S. Geol. Survey Prof. Paper 207), pp. 107–108, 1946.

[90] Anonymous, Classification of oil discoveries and fields: Petroleum World, vol. 43, no. 11, pp. 72–75, 1946. A list of field and pool names is issued annually by the Classification Committee of the Pacific Section, American Association of Petroleum Geologists.

[91] Conservation Comm. California Oil Producers, Ann. Rev. California crude oil production, 1947 [1948].

Oil production of fields in Santa Maria district

Field and pool	Year of discovery	Production, 1947 (thousands of barrels)	Total production to end of 1947 (thousands of barrels)	Gravity of oil (degrees, A.P.I.)	Productive formation
Orcutt field	1901	1, 636	105, 832	14–29	Sisquoc, Monterey, Point Sal.
Lompoc field	1903	1, 660	14, 601	15–24	Sisquoc, Monterey.
West Cat Canyon field:					
Pliocene pool	1908	526	18, 411	11–16	Sisquoc.
Las Flores pool	1938	3, 717	12, 159	13–22	Monterey.
East Cat Canyon field	1909	181	4, 425	9–12	Sisquoc.
Casmalia field:					
Sisquoc-Monterey pool	1917	199	15, 395	8. 5–23	Sisquoc, Monterey
Arellanes pool	1946	19	58	19. 9–21. 6	Lospe.
Gato Ridge field	1931	1, 314	14, 210	12–13	Monterey.
Santa Maria Valley field	1934	9, 519	84, 112	12–18. 5	Monterey, Point Sal, Knoxville.
Bradley Canyon field	1942		26		Sisquoc, Monterey.
Other fields (see p. 135)		69	70		
Zaca Creek field (east of mapped area)		179	358		Monterey.
Total production		19, 019	269, 657		

Dreyer,[91a] the stratigraphic position of the chert zone, as it is generally designated, varies from place to place in different parts of Kleinpell's Mohnian stage (early late Miocene). In the Santa Maria Valley and Gato Ridge fields it is in the *Bolivina hughesi* zone in the upper Mohnian (but extends to lower horizons at Gato Ridge), whereas in the Orcutt field it is in the lower Mohnian *Bulimina uvigerinaformis* and *Baggina californica* zones. The middle member of the Monterey in the outcrop section, at least in the eastern Purisima Hills, is also of early Mohnian age.

The oil throughout most of the district is heavy. During the early 1920's marketing conditions for oil of that grade were so unfavorable that most of the wells were shut in and development was at a low ebb. During the 1930's many formerly shut-in wells were reconditioned in several fields, and during the war most of the Santa Maria fields, like other California fields, were in full production. In 1946–47, development continued at an accelerated pace in all the fields, except the East Cat Canyon and Casmalia fields and the heavy-oil Bradley Canyon field.

The occurrence of oil and the subsurface stratigraphy are summarized in the following discussion. Other information, insofar as available, may be found in the reports cited under each field. Much of the data in the summaries is drawn, for the most part without further credit, from the reports cited and from Wissler and Dreyer's discussion [92] of subsurface correlations.

It should be pointed out that subsurface geologists and micropaleontologists place the boundary between the Foxen mudstone and Sisquoc formation at the base of a tar sand that is readily identified on electric logs and is designated the Foxen tar sand.[93] Core material from Standard Oil Co. Las Flores No. 1 well, the discovery well of the Las Flores (Monterey) pool in the West Cat Canyon field, indicates that at least in that field the tar sand is about 1,000 feet below the base of the Foxen mudstone as mapped in outcrop sections during the field work for the present report. The characteristic Sisquoc bivalve *Yoldia gala* was found at depths of 1,600 to 1,620 and 1,700 to 1,720 feet in that well. In the well, as in outcrop sections, it is associated with *Bolivina obliqua* and other foraminifera of the *Bolivina obliqua* zone, the fossils occurring in somewhat platy shale like that of the Sisquoc formation. The tar sand may possibly be the equivalent of the zone of breccia and conglomerate, composed of debris from the Monterey, in the upper part of the Sisquoc of the western Casmalia Hills. Though the tar sand is a useful formation boundary in subsurface work, the subsurface boundary evidently does not agree with the outcrop boundary, as recognized in surface mapping. Inasmuch as the structure sections of plate 2 are based on a combination of outcrop and subsurface data, the Foxen-Sisquoc boundary shown on them is presumably shifted downward stratigraphically in passing from outcrop sections to subsurface sections controlled by well data.

The subsurface parts of the structure sections on plate 2 are doubtless oversimplified, except on the north limb of the Santa Maria Valley syncline, which overlies the south border of a relatively stable basement region, where the formations overlying the basement are thin. Dip records from many wells indicate that the wells penetrate minor folds in the Monterey shale and also in the Sisquoc formation. Inasmuch as any representation of such minor folds would be speculative and inasmuch as they have no effect on the regional structure, no attempt is made to show them on the structure sections. Possible omission or misinterpretation of other folds and also of faults may be more serious in a study of oil possibilities.

[91a] Wissler, S. G., and Dreyer, F. E., Correlation of the oil fields of the Santa Maria district: California Div. Mines Bull. 118, pt. 2, preprint, p. 236, 1941.

[92] Idem, pp. 235–238, fig. 95.

[93] Idem, p. 236, footnote.

This discussion, except the table on page 118, was prepared in January 1947. Later development is summarized under the heading "Development in 1947–48."

ORCUTT FIELD

The Orcutt field,[94] or Santa Maria field as it was formerly designated, is the oldest field in the district, and is the only field that has so far yielded more than 100,000,000 barrels of oil. At present, however, it is producing more water than oil. Early prospecting was stimulated by the widespread occurrence of tar sand and asphalt on Graciosa Ridge. The locations of the first wells, drilled by the Western Union Oil Co., were presumably based on the inference that oil may be found down-dip from the deposits of tar sand and asphalt on and near the crest of Graciosa Ridge. Wells No. 1 and No. 2 (now Shell Oil Co. Careaga No. 1 and No. 2), were unsuccessful. Well No. 3 (now Shell Oil Co. Careaga No. 3), completed in 1901, was the discovery well, and was still carried as a producing well in 1947. During the later part of 1945, development was most active since the early 1920's, particularly on the Newlove lease of the Union Oil Co.

The field has had one exceptional well. Union Oil Co. Hartnell No. 1 well, the first large California gusher, completed in 1904, flowed at a daily rate of 10,000 barrels for several months. Some wells drilled between 1902 and 1910 still have a daily production of 50 to 100 barrels. Most of the wells were drilled before it was customary to take cores. Union Oil Co. Newlove No. 51 well was continuously cored, and the age relations of the oil zones are based principally on foraminiferal samples from that well.

The Orcutt field is located on the Graciosa anticline, or dome, which has a relatively gentle south limb and a moderately steep north limb bounded by a fault downthrown to the north (structure section *C–C′*, pl. 2). The oil occurs in three zones. The First Zone, productive only far down on the south limb, is in sand and fractured shale in the basal part of the Sisquoc formation and in the uppermost part of the Monterey shale. The Second Zone, formerly the principal zone but now practically depleted, is in chert and cherty shale of the Monterey, in the lower Mohnian *Bulimina uvigerinaformis* and *Baggina californica* zones and in late Luisian fractured shale characterized by the abundance of *Siphogenerina*. The Third Zone consists of lenses of sand in the basal part of the Monterey and sand in the uppermost 150 feet of the Point Sal formation. The Third Zone is now yielding most of the oil, but not in the part of the field along the line of structure section *C–C′* (pl. 2). At least in the eastern part of the field, only a thin section of the Point Sal formation is represented. Shell Oil Co. Careaga No. A–1 well penetrated a considerable thickness of nonmarine strata of the Lospe formation and was evidently bottomed not far above the top of the basement. Rice Ranch Oil Co. Brookshire No. 4 well is reported to have penetrated the Lospe formation at a depth of about 3,800 feet and then to have reentered the Monterey shale at about 3,900 feet. Union Oil Co. Dome No. 15 well also reached the Lospe formation.

Oil from the First Zone has a gravity range of 14° to 19° (A.P.I.), that from the Second Zone 22° to 27.5°, and that from the Third Zone 24° to 29°. The field has been a steady producer of gas, the gas-oil ratios ranging from 700 to 1,000 cubic feet per barrel of oil.

LOMPOC FIELD

Union Oil Co. Hill No. 1 well, the discovery well of the Lompoc field,[95] was drilled in 1903. It was located close to asphalt deposits in the Foxen mudstone on the south limb of the surface trace of the Purisima anticline. Many wells drilled since then along and near the surface trace of the anticlinal axis have been unsuccessful. During the war, after many years of inactivity or minor activity, some shut-in wells on the Purisima lease of the Union Oil Co. were cleaned out, deepened, and reconditioned as satisfactory producers. In 1945 the Union Oil Co. started a drilling campaign on its Purisima and Hill leases, and that campaign was still continuing in 1947. Most of the wells drilled in 1945–47 have initial daily production of 100 to 300 barrels. The decline in the production rate of wells is very gradual, owing to the wide spacing of wells. Union Oil Co. Hill No. 4 well flowed for 20 years, which is said to be a record for a flowing well in California. After it was shut in during the period when the field was repressured with gas and oil, its daily rate of production was 200 barrels more than the former rate.

Subsurface data resulting from the recent drilling campaign have not yet been released. Dolman [96] and Dibblee [97] interpreted the subsurface data to indicate that the field is on the relatively broad subsurface crest of the Purisima anticline (structure section *C–C′*, pl. 2). Owing to the unconformable overlap of the Graciosa coarse-grained member of the Careaga sandstone and also to regional northward thickening, the Sisquoc formation is much thinner on the south limb of the anticline than on the north limb. Union Oil Co. Purisima No. 19 well penetrated 140 feet of strata variously interpreted as volcanics, nonmarine deposits

[94] Arnold, Ralph, and Anderson, Robert, op. cit. (U. S. Geol. Survey Bull. 322), pp. 92–104, 1907. Collom, R. E., Report covering the oil fields of the Santa Maria district: California Min. Bur. Bull. 73 (First Rept. State Oil and Gas Supervisor), pp. 198–203, fig. 20, 1917. Hoots, H. W., and Herold, S. C., Natural gas resources of California, in Geology of Natural Gas, pp. 157–158, Tulsa, Am. Assoc. Petroleum Geologists, 1935. Dryer, F. E., Santa Maria (Orcutt) oil field: California Div. Mines Bull. 118, pt. 3, p. 431, 1943.

[95] Arnold, Ralph, and Anderson, Robert, op. cit., pp. 105–107, 1907. Dolman, S. G., Lompoc oil field, Santa Barbara County, Calif.: California Oil Fields (California Div. Oil and Gas), vol. 17, No. 4, pp. 13–19, 3 pls., 1932 Hoots, H. W., and Herold, S. C., op. cit., pp. 158–159, 1935. Dibblee, T. W., Jr., Lompoc oil field: California Div. Mines Bull. 118, pt. 3, pp. 427–429, fig. 177, 1943.

[96] Dolman, S. G., op. cit.

[97] Dibblee, T. W., Jr., op. cit.

of the Lospe (or Sespe) formation, or basement. A. E. Bell Corp. Lompoc No. 7 well cored similar material at a depth of 4,993 feet. Union Oil Co. Purisima No. 20 well, drilled in 1946, is reported to have also penetrated a pre-Monterey formation, but the data are still unavailable. Pending more definite information, the rocks underlying the Monterey shale are doubtfully shown on structure section *C–C′* of plate 2 as volcanics. Volcanics at the base of the Monterey are widespread in the Santa Rosa Hills,[98] along Santa Ynez River, and in the Lompoc Hills south of the river.

The oil zone is reported to be in fractured chert and cherty shale in the upper part of the Monterey shale. The gravity range is 15° to 24° (A. P. I.) The gas-oil ratio is estimated to be 300 cubic feet per barrel of oil. During the 1920's and early 1930's, when the field was shut in, it was used for subsurface storage of gas and oil from other fields.

WEST CAT CANYON FIELD[99]

At the time when the preliminary account[1] was written, the productive area now included in the West Cat Canyon field was classified as three fields or areas—West Cat Canyon, Doheny-Bell, and Las Flores. Development since then has united these formerly separate fields, or areas, into one field, which takes the name of the oldest field.

Palmer Union Oil Co. Palmer No. 1 well (now Palmer Stendel Oil Corp. Blochman No. 1) is the discovery well. It was drilled in 1908 and had an initial daily production of 150 barrels. After it was cleaned out, it flowed at a daily rate of 6,000 to 10,000 barrels, and for two years flowed at a daily rate of about 1,500 barrels. Eventually it sanded up, the casing collapsed, and it was abandoned. Mr. Blochman, the original owner of the land, orally reported in 1940 that a driller from the Orcutt field thought a location along a line between the Orcutt field and the Alcatraz asphalt mine (east of the mapped area) would be favorable for the discovery of oil. Though that account may be legendary, an oil field was found at a geologically unfavorable location. Nevertheless the field would eventually have been found by prospecting closer to the surface trace of the axis of the Las Flores anticline. Palmer Stendel Oil Corp. Blochman No. 2 well built up to 8,500 barrels daily and in 1947 was still producing a small amount of oil. Union Oil Co. Bell No. 5 well flowed for some time at a daily rate of 5,000 to 6,000 barrels. The wells just mentioned, however, are exceptional. Many wells in the northwestern part of the field are abandoned and others were shut in for many years.

Before 1938 sand lenses in the middle and lower parts of the Sisquoc formation were the source of oil in the original area and also in the then separate Doheny-Bell area. The original area is located far out on the northeast limb of the Las Flores anticline, the Doheny-Bell area on the northeast limb and crest. The lensing out of the porous sand is evidently the chief factor in the trapping of the oil. This zone is now designated the Pliocene pool. The gravity of the oil ranges from 11° to 16° (API). Union Oil Co. Bell No. 31 well is the most recent well to be completed in the Pliocene pool. It was completed in 1946 with an initial daily yield of 40 barrels, cutting 25.8 percent water.

In 1938 Standard Oil Co. Las Flores No. 1 well proved a deeper and much more important zone in fractured chert and cherty shale of the lower Mohnian *Bulimina uvigerinaformis* zone of the Monterey shale—the Las Flores pool. The vertical hole of the discovery well was dry, but when the hole was deflected so as to bottom about a quarter of a mile northeast of the rig, it was successfully completed with an initial daily production of 450 barrels of practically clean 14° (API) oil. This discovery suggested that the Las Flores pool might be expected to be productive over an extensive area along and near the subsurface crest of the Las Flores anticline, which lies northeast of the surface crest (structure section *D–D′*, pl. 2). That expectation has been realized by subsequent development, during which wells with initial daily yields of 150 to 1,600 barrels, mostly 250 to 600 barrels, of 13° to 22° (API) oil, have been completed in an area having a length of 3 miles and a width of a mile to a mile and a quarter. The drilling program has been proceeding at an orderly pace, principally because most of the potentially productive acreage is in the hands of one company. Though the West Cat Canyon field had declined to minor productivity, the Las Flores pool is transforming it into one of the major fields in the district. The limits of the pool have not yet been defined, except by the vertical hole of the discovery well, by the Pacific Western Oil Corp. Los Alamos No. 18 well, by the Union Oil Company Bell No. 26 well, and by A. E. Bell Corp. Gilmore No. 1 well. Crown Oil Co. Hilo-Gilmore No. 1, a northeastern outpost well, was completed in 1945 with an initial daily yield of 190 barrels of 13.2° (API) oil, cutting 13.2 percent water. Standard Oil Co. Las Flores No. 6 well, located in the midst of productive territory, could not be satisfactorily completed and encountered only salt water with a trace of oil.

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[98] Woodring, W. P., Loofbourow, J. S., Jr., and Bramlette, M. N., Geology of the Santa Rosa Hills-eastern Purisima Hills district, Santa Barbara County, Calif.: U. S. Geol. Survey, Oil and Gas Invest., Prelim. Map 26, 1 sheet, scale 1:48,000, 1945.

[99] Collom, R. E., Report covering the oil fields of the Santa Maria district: California Min. Bur. Bull. 73 (First Rept. State Oil and Gas Supervisor), pp. 203–204, fig. 21, 1917. Collom, R. E., Santa Barbara, San Luis Obispo, Monterey, and Santa Clara Counties: Idem, Bull. 82 (Second Rept. State Oil and Gas Supervisor), pp. 210–219, 1918. Manlove, Charles, West Cat Canyon area of the Cat Canyon oil field: California Div. Mines Bull. 118, pt. 3, pp. 432–434, fig. 178, 1943.

[1] Woodring, W. P., Bramlette, M. N., and Lohman, K. E., op. cit. (Am. Assoc. Petroleum Geologists Bull., vol. 27, no. 10), fig. 1, 1943.

EAST CAT CANYON FIELD

The East Cat Canyon field [2] is a minor field, in which heavy oil occurs in sand (the Brooks sand) in the lower part of the Sisquoc formation. The field is located on the northeast limb of the Gato Ridge anticline, opposite the surface trace of the plunging northeast end, and beyond its end. If there is any truth in the report that the West Cat Canyon field was discovered by locating a well along a line between the Orcutt field and the Alcatraz asphalt mine, perhaps the same reasoning led to the discovery of the East Cat Canyon field. At all events, it lies along the same line and the location had no geological promise.

The discovery well, Brooks Oil Co. No. 1 (now Fullerton Oil Co. No. 1, converted into a water well), was drilled in 1909 and had an initial daily yield of 150 barrels of 10° (API) oil. The oil from this and subsequent wells is so heavy (9° to 12°, API) that superheated distillate is used to bring it to the surface and to move it through the pipe line. Practically all the wells were shut in for several years in the 1930's and there was no drilling activity for many years, except that Union Oil Co. reentered O. C. Fields Gasoline Corp. Williams No. 1 well in 1944 to retest the Brooks sand. Five wells have tested the Monterey, but found only traces of very heavy oil. The deepest well, Palmer Union Oil Co. Stendel No. 20 (now Palmer Stendel Oil Corp. Stendel No. 20), was drilled about 1929 to a depth of 7,199 feet. In this well the Obispo tuff member of the Monterey shale was found to overlie hard sandstone and shale generally classified as basement. The top of these basement(?) rocks was encountered at a depth of 4,862 feet.

The subsurface stratigraphy is not well known. Though the entire Monterey shale may be present, it is abbreviated, being represented by a thickness of 900 to 1,000 feet. The Point Sal formation has not been identified, but the basement(?) strata are perhaps referable to it. Cross [3] interpreted the basal sand of the Sisquoc formation as unconformably overlapping against the Monterey shale.

CASMALIA FIELD

The Casmalia field [4] is located on the broad crest and north limb of the Casmalia anticline (structure section *B–B'*, pl. 2). Prospecting began early in the century. The field dates from 1917, however, when the Doheney Pacific Petroleum Co. completed its Soladino No. 2 well (now Richfield Oil Corp. Soladino No. 2), which had a daily yield of about 400 barrels of heavy (9°, API) oil. The greatest activity was in 1917–18. In the early 1920's, as in other older fields of the district, most of the wells were shut in. In 1938 some wells in the western part of the field and a few in the eastern part were producing, but by 1940 all the eastern wells were shut in or abandoned, and few wells have been drilled since then. Most of the shut-in wells probably could not be reconditioned.

Before 1946 the only productive zone was what is now designated the Siquoc-Monterey pool. It consists of fractured platy brown shale in the basal part of the Sisquoc formation and fractured similar shale and also cherty shale in the upper part of the Monterey. The oil has a considerable gravity range, 8.5° to 9° (API) in the western half of the field, 10° in the central part, and 20° to 23° in the eastern part. The heavy oil in the western part has been most consistently produced. It supplies a refinery that is located in the field along the Southern Pacific Railroad and specializes in asphaltic products.

In 1944, Richfield Oil Corp. drilled its Escolle No. 1 well, the first deep test, in the eastern part of the field. It penetrated the entire Point Sal formation, 700 feet thick, was bottomed 460 feet below the top of the Lospe formation, but found nothing promising. In 1946, Bell-Casmite Oil Co. Arellanes No. 2 well was completed in fractured calcareous sandstone of the Lospe formation with a daily yield of 320 barrels of 19.9° (API) oil, cutting 20 percent water. In May 1946, it was producing 287 barrels daily of 21.6° (API) oil, cutting 22.6 percent water. The next well drilled, Bell-Casmite Oil Co. Morganti No. 6, found the Lospe formation unproductive, and was plugged back and completed in the Point Sal formation at a daily rate of 75 barrels of 35° (API) oil, cutting 16 percent water. In August 1946, the water had increased to 30 percent. The pool in the Lospe formation is designated the Arellanes pool; the pool in the Point Sal formation is probably not important enough to name. The Arellanes No. 2 well is the first well in the Santa Maria district to find oil in the nonmarine Lospe formation, and the oil from the Point Sal formation produced by the Morganti No. 6 well is the lightest oil so far discovered in the district. The oil in the Arellanes pool presumably migrated from the Point Sal formation. The Lospe formation itself is an unlikely source of oil, and no known source rocks underlie it. Whether either pool will add substantially to the reserves of the field is not now apparent.

GATO RIDGE FIELD [5]

Active prospecting of the well-defined Gato Ridge anticline was under way by 1911. Practically all the

[2] Collom, R. E., Santa Barbara, San Luis Obispo, Monterey, and Santa Clara Counties: California Min. Bur. Bull. 82 (second Rept. State Oil and Gas Supervisor), pp. 210–219, 1918. Cross, R. K., East Cat Canyon area of the Cat Canyon oil field: California Div. Mines Bull. 118, pt. 3, pp. 435–437, figs. 179, 180, 1943.

[3] Cross, R. K., op. cit., fig. 180.

[4] Bell, W. H., Santa Barbara, San Luis Obispo, Monterey, and Santa Clara Counties: California Min. Bur. Bull. 84 (Third Rept. State Oil and Gas Supervisor), pp. 361–369, fig. 13, 1918. Bell, W. H., Casmalia Oil Field: California Oil Fields (California Div. Oil and Gas), vol. 5, No. 10, pp. 10–42, 2 pls., 1920. Porter, W. W., II Crsmalia Oil Field: California Div. Mines Bull. 118, pt. 3, p. 430, 1943.

[5] Cross, R. K., Gato Ridge area of the Cat Canyon oil field: California Div. Mines Bull. 118, pt. 3, pp. 438–439, fig. 181, 1943.

early wells encountered shows of heavy oil and a few produced a small amount. Barnsdall-Rio Grande Oil Co. Tognazzini No. 1 (now Barnsdall Oil Co. Tognazzini No. 1), completed in 1931 with a daily yield of 1,100 barrels of 13° (API) oil, was the first commercially successful well. The productive area is very narrow, but has been extended southeastward. The oil occurs in fractured chert and cherty shale of the Monterey, in the upper Mohnian *Bolivina hughesi* zone and at intervals in older zones. The oil is heavy, 12° to a little more than 13° (API). A few wells at the northwest end of the field produce a small amount of heavier oil from the basal sand of the Sisquoc formation.

The Sisquoc formation overlies the Monterey shale with marked discordance (structure section *E–E′*, pl. 2). The structure in the Monterey and older formations is not certainly known. There may be a closely folded anticline in the Monterey, or possibly a subsurface fault at the southwest border of a high of older rocks, the fault approximately underlying the surface anticlinal axis. Barnsdall Oil Co. Tognazzini Nos. 1, 4, and 17 wells reached the Point Sal formation, but steep dips were encountered. Standard Oil Co. Tognazzini No. 43A well encountered serpentine and altered lava.

SANTA MARIA VALLEY FIELD

By the time the Gato Ridge field was discovered, all the major anticlines of the Santa Maria district, and a considerable number of minor anticlines, had been tested. Within a year or two, however, geologists were searching for stratigraphic traps, which are much more difficult to find than anticlines. Discovery of the Santa Maria Valley field [6] is an example of the combination of geologic analysis and imagination required in work of that type. Geologists of the Superior Oil Co., who planned and started the campaign, and geologists of the Union Oil Co., who continued it, deserve much credit for the finding of the Santa Maria Valley field, not only the largest field in the district in area and productive capacity but also the largest overlap field so far discovered in coastal California, and one of the last great fields found in the state up to 1947.

A thick outcrop and subsurface Tertiary section, including the oil-bearing Monterey shale, is found immediately south of the Santa Maria Valley, whereas not far north of Santa Maria River the basement crops out. It was evident therefore that beneath the intervening alluvium-floored valley the Teritary formations disappear through overlap, or along a fault or series of faults. Enough subsurface information, however unsatisfactory according to modern standards, was available to indicate that the basement was not present just below the alluvium in the northern half of the valley. In 1932 the Superior Oil Co. drilled to basement ten relatively shallow core holes in the eastern part of the valley near Santa Maria River. These core holes showed that the Monterey shale is overlapped by the Sisquoc formation, and that in turn by the Foxen mudstone. The search was then resolved into the finding of the overlapped edge of the Monterey shale and drilling south of the overlapped edge in order to determine whether oil, moving northward up dip, was trapped by the fine-grained strata of the Sisquoc formation beveling the Monterey. The last and deepest Superior core hole drilled, Bradley No. 1, in sec. 19, T. 10 N., R. 33 W., was well located for the last step in the campaign. It penetrated the Monterey and, according to reports, might have been the discovery well, had it been thoroughly tested. Union Oil Co. Moretti No. 1 well, (sec. 24, T. 10 N., R. 34 W.; now No. 1–1), completed in 1934 with a daily yield of 50 barrels of 16° (A. P. I.) oil, was the discovery well. The moderate yield of heavy oil did not cause much excitement. The Union Oil Co. continued drilling, however, and when its Adam No. 1 well (sec. 24, T. 10 N., R. 34 W.) was completed in 1936 yielding a daily rate of 2,375 barrels of 16.4° (A. P. I.) oil, it was evident that a major field had been found. Development proceeded rapidly until the early part of 1938 and has continued at a more leisurely pace since then; a considerable acreage of virtually proven land still remained undrilled in 1947. The limits of the field have been partly defined. Except in the Beacon area, along U. S. Highway 101, where the land is divided into small lots, well spacing is in general based on one well to 10 acres.

As shown on structure sections *A–A′* and *B–B′* of plate 2, the Santa Maria Valley field is located on the north limb of the Santa Maria Valley syncline. The northward overlap of the Point Sal formation, Monterey shale, and Sisquoc formation, and the marked southward thickening of those and overlying formations are shown on the structure sections mentioned and also on *C–C′*. (The Point Sal formation is represented only in the southeastern part of the field.) Minor faults are said to be more numerous and to have a more pronounced effect on the productivity of wells than is evident from reports and maps so far published. The chief reservoir is fractured chert and cherty shale of the Monterey, in the late Mohnian *Bolivina hughesi* zone. There are, however, generally two zones in the Monterey. The upper zone extends from fractured platy shale at the top of the Monterey (Canfield's [7] Santa Margarita(?) formation), downward through fractured platy shale characterized by arenaceous Foraminifera (Canfield's arenaceous zone), and includ-

[6] Canfield, C. R., Subsurface stratigraphy of Santa Maria Valley oil field and adjacent parts of Santa Maria Valley, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 23, no. 1, pp. 45–81, 8 figs., 1939. Frame, R. G., Santa Maria Valley oil field: California Oil Fields (California Div. Oil and Gas), vol. 24, no. 2, pp. 27–47, 9 pls., 1938 (1941). Canfield, C. R., Santa Maria Valley oil field: California Div. Mines Bull. 118, pt. 3, pp. 440–442, figs. 182–183, 1943. Cabeen, W. R., and Sullwold, H. H., Jr., California basement production possibilities: Oil Weekly, vol. 122, no. 8, pp. 17–25, 5 figs., 1946.

[7] Canfield, C. R., op. cit. (Am. Assoc. Petroleum Geologists Bull., vol. 23, no. 1), pp. 62–66, pl. 3, 1939.

ing the underlying fractured chert and cherty shale of the *Bolivina hughesi* zone (Canfield's cherty or *Bolivina tumida* zone). The lower zone is in the lower part of the Monterey, embracing fractured semiplaty phosphatic shale (Canfield's dark brown or *Siphogenerina* zone) and the underlying basal sand of variable thickness Canfield's oil sand zone), both of Luisian age. In the southeastern part of the field, minor production is obtained from fractured calcareous sandstone in the Point Sal formation (Canfield's siltstone and shell zone). The oil from the Monterey and Point Sal formations has a gravity range of 12° to 18.5° (API), averaging 16.5°. Gas-oil ratios are low, not more than 200 to 350 cubic feet per barrel of oil.

Canfield's nomenclature for subdivisions of the Monterey, based on combined lithologic and faunal (foraminiferal) features, is widely used not only in the valley but in the entire district. As a result, operators and engineers are likely to be misled into thinking that the subsurface stratigraphy is remarkably uniform throughout the district.

The discovery of oil in the Knoxville formation is the most recent development in the Santa Maria Valley field. The finding of this zone, as described by Cabeen and Sullwold,[8] illustrates the element of chance, or good fortune, that may be involved in locating a commercial pool. The discovery well, W. R. Gerard Acquistapace No. 1, in sec. 22, T. 10 N., R. 34 W., was drilled in 1942–43, on land quitclaimed by a major company, as an offset to a well then yielding 15 barrels daily. The well came in as a gas well with a daily production of 10,000,000 cubic feet. It soon went to oil, flowing at a daily rate of 2,500 barrels of clean 18.5° (API) oil. The operator, following the usual practice, had set as the objective of drilling the productive interval of the well being offset. Unknown to the operator, however, the new well was on the upthrown side of a fault, and therefore unintentionally took in 90 feet of basement, both the basement and the Monterey shale being open to production. Up to that time wells had, as a matter of course, been bottomed just below the top of the basement, for the basement, which was going under the general name of "Franciscan," was considered as unlikely a reservoir of oil as any other basement. When geologists were engaged to study the well, it was evident from the pressure and the productive rate that the oil was not coming from the partly depleted Monterey shale. The operator therefore was advised to carry No. 2 well deeper into the basement. It was completed with 415 feet of basement and the usual Miocene interval open. It was a very successful well, producing when completed at a daily rate of 2,800 barrels, whereas the yield of the offset Monterey well was reduced to a daily rate of 5 barrels. The showing of these two wells set off a minor drilling campaign, including the deepening of some old wells, which was still under way in 1947, and has resulted in the development of three areas of basement production, all in the north central part of the field. The thickness of basement rocks open to production ranges from about 100 to as much as 1,200 feet.

Up to the time when the discovery well of the deeper pool was drilled, the basement in the Santa Maria Valley field was designated "Franciscan", though it was known to include strata containing arenaceous Foraminifera.[9] As additional core material became available, it was evident that the oil-bearing basement rocks are presumably to be assigned to the Knoxville formation. A mold of *Aucella* cf. *A. piochii* was recovered from Union Oil Co. Cooke No. 2 well (sec. 30, T. 10 N., R. 33 W.), at a depth of 2,763 feet, 8 feet below the top of the Knoxville, but no fossils have been recovered in the productive areas. The reservoir in the Knoxville formation consists of fractured hard, thoroughly cemented calcareous sandstone and sandy limestone. The productivity of wells, which is variable, therefore depends on the degree of fracturing, as in the chert and cherty shale of the main zone of the Monterey shale. In areas where the Knoxville, below the overlapping younger formations, consists of dark-colored sheared and slickensided shale, the formation is barren.

A sample from the Knoxville formation penetrated by Union Oil Co. Bettiga No. 3 well (sec. 24, T. 10 N., R. 34 W.) at a depth of 4,425 to 4,431 feet, was examined by A. O. Woodford, who prepared the following description. The rock is a poorly sorted sandy limestone. Most of the grains have a diameter of 50 to 450 microns. Calcite cement is unusually abundant, and calcite occurs also as veinlets containing occasional sand grains. A series of traverses across a thin section indicates the following approximate mineral composition.

Mineral composition of sandy limestone from Knoxville formation

	Approximate percentage by volume
Quartz	14.5
Rock grains, including chert	2.4
Feldspar (orthoclase 9 grains, plagioclase 2 grains)	2.2
Mica (muscovite 5 grains, biotite 2 grains)	.6
Opaques (mostly black iron oxide, but including some pyrite)	.5
Calcite cement	79.8

Though calcite veinlets were avoided in the traverses, the core sample has much more calcite cement than the outcrop sample of sandstone from the Knoxville described on page 13. The core sample is also coarser-grained and has considerably fewer chert grains; and the proportions of plagioclase and orthoclase are reversed in the two samples. Muscovite is fairly conspicuous in both samples.

[8] Cabeen, W. R., and Sullwold, H. H., Jr., op. cit., pp. 19-20, figs. 2, 3, 1946.

[9] Canfield, C. R., op. cit. (Am. Assoc. Petroleum Geologists Bull., vol. 23, No. 1) p. 68, 1939.

Another sample from the same well, taken at a depth of 2,539 to 2,546 feet, was found by A. O. Woodford to be very greatly altered diabase. The hand specimen is greenish gray, and shows irregular reddish-brown streaks and some megacopically evident white veinlets. In thin section the rock is seen to be composed of feathery feldspar laths, perhaps entirely altered, in an opaque matrix. The rock is broken into minute fragments, cemented by quartz, calcite, and chlorite forming a complex system of veinlets. Most of the veinlets are composed of fine-grained cherty quartz. Quartz-calcite and quartz-chlorite veinlets are less common, and very thin chlorite veinlets are rare. Small rounded quartz areas, which have a diameter of 40 to 80 microns are possibly filled amygdules. Though amygdules are practically unknown in diabase, it is improbable that the rock is other than very greatly altered diabase. A small specimen of the shale in contact with the diabase was examined in thin section. It is mostly opaque fine-grained shale containing a few transparent or translucent silt grains. One lamina of fine-grained sandy siltstone is made up of quartz, and possibly feldspar, grains ranging in diameter from 20 to 100 microns. Calcite, quartz, and calcite-quartz patches in the shale are similar in composition and grain to the veinlets in the diabase. They may be replaced fossils or fragments of veinlets.

Production data for the zone in the Knoxville formation are not available and the pool has not been formally named, for the usual practice is to have the Monterey interval and a varying thickness of the Knoxville formation open to production. So far as known, Sunray Oil Company Giacomini No. 2 (projected sec. 24, T. 10 N., R. 35 W.) is the only well that has only Knoxville open. In fact, it is not certain that all the wells shown on plate 1 as producing from the Knoxville are actually getting Knoxville oil. They penetrated the Knoxville and have it open. On the contrary, a few wells, which are known to have reached the Knoxville formation and have some Knoxville open, are not shown as Knoxville-zone wells, as it is virtually certain they are not producing from that formation.

As explained by Cabeen and Sullwold,[10] the oil in the Knoxville formation presumably has migrated into open fractures in the basement from the Miocene strata overlapping against the basement. The reservoir is probably sealed up-dip by lower porosity and permeability, the result of less fracturing, or of sealing of fractures by minerals forming the veinlets or by tar.

DISCOVERIES OF HEAVY OIL

During the period from 1942 to 1945 five discoveries of heavy oil have been made in the Santa Maria district, four within the mapped area and one a few miles to the east. These discoveries are now (1947) subcommercial, because the oil is too heavy to produce profitably. Under different marketing conditions, or with improved methods of extraction, they may become commercial. These discoveries are located on the small-scale map (pl. 6) and are briefly discussed in the following paragraphs. The wells mentioned, like other wells in the district, are shown on the geologic map (pl. 1).

One of the discoveries within the mapped area has been dignified with a field name, the Bradley Canyon field, because it has produced a small amount of oil. It is located along Bradley Canyon in Santa Maria Valley, southeast of the Santa Maria Valley field. It includes two wells, now shut in: Union Oil Co.'s quitclaimed Santa Maria Realty No. 1 and Standard Oil Co. South Basin-Lloyd Community No. 1. Oil was discovered in the Sisquoc formation in one well and in the Monterey shale in the other. The Standard Oil Co. well was drilled in 1942 to a depth of 7,250 feet, was plugged back to 4,704 feet, and completed in sand in the middle part of the Sisquoc formation, resting directly on the Monterey shale, at a daily rate of 137 barrels of 7.3° (API) oil, cutting 60 percent water. The Union Oil Co. well (depth 5,403 feet) was completed in 1944 in the Monterey shale and had an initial daily yield of 105 barrels of 5.6° (API) oil, cutting 18 percent water and including 67 barrels of injected crude oil.

The discovery in sec. 20, T. 9 N., R. 32 W., near Sisquoc River, is northeast of a high of old rocks, against which the Monterey shale is overlapped by the Sisquoc formation. Data concerning the wells within the discovery area, however, have not been released. Evidence for overlap on the south flank of the high is afforded by the records of Standard Oil Co. Palmer Union No. 1 well (sec. 13, T. 9 N., R. 33 W.), in which the Sisquoc formation rests on strata in the lower part of the Monterey, and of O. C. Fields Gasoline Corp. Palmer Stendel No. 24–1 well (sec. 24, T. 9 N., R. 33 W.), which penetrated the Obispo tuff member of the Monterey shale directly below the Sisquoc formation. The discovery area includes only two shut-in wells: Union Oil Co. NcNee No. 3 and the same company's McCroskey No. 1, both drilled in 1944. Both wells have a daily productive capacity of between 100 and 200 barrels of 8° to 10° (API) oil, including some injected crude oil. Union Oil Co. McNee No. 2 well, the discovery well, also encountered heavy oil, but has been abandoned.

Four-Five-Six Oil Co. Wickenden No. 1 well was drilled in 1944–45, to a depth of 4,606 feet, on the Tinaquaic grant, between Cat Canyon and Foxen Canyon, and abandoned after establishing a daily productive capacity of 90 barrels of 6.5° (API) oil, cutting 10 percent water. The oil occurs in fractured chert and shale of the Monterey, the productive in-

[10] Cabeen, W. R., and Sullwold, H. H., Jr., op. cit.

terval being at a depth of 2,986 to 4,606 feet. The subsurface structure is unknown.

The discovery located on the La Laguna grant, northeast of Los Alamos, is on the south flank of a basement high (structure section F–F′, pl. 2). The presence of the basement close to the surface was suggested by the unsatisfactory record of an old well, Princess Oil Co. Muscio No. 1. The basement high and the overlap of the Monterey shale by the Sisquoc formation were proved by three wells drilled by the General Petroleum Corp. in 1942–43. Giorgi No. 1 encountered the basement, directly below the outcropping Sisquoc formation, at a depth of 975 feet. Wickenden No. 1 found the Sisquoc formation to lie on a thin section of Point Sal formation. The vertical hole of Wickenden No. 2 was too far south, but the hole was redrilled deflected northward and penetrated the chert zone of the Monterey. The well has a potential daily capacity of 20 to 40 barrels of 12° (API) oil, with the aid of distillate, but has been abandoned. The amount of water is variable. The Zaca Creek field, located 3½ miles southeast of the Wickenden No. 2 well and a mile beyond the east border of the mapped area, is presumably on the south flank of the same structural high. In 1947 the Zaca Creek field produced 179,000 barrels of heavy oil. At the end of 1947 the total production was 358,000 barrels.

OIL POSSIBILITIES IN DEEPER ZONES

The Sisquoc formation and Monterey shale are the chief oil-bearing formations of the district. Nevertheless, every formation from Sisquoc to Knoxville, inclusive, is productive in one or more fields. The subsurface geologists' basal tar sand of the Foxen mudstone has also been tested and found to contain very heavy oil. In those fields where formations older than the Sisquoc or Monterey have not yet been tested, there is always the possibility of finding deeper pools. The Point Sal formation is the most promising pre-Monterey formation. In the northern part of the outcrop area in the western Casmalia Hills, much of the thin-bedded sandstone of the Point Sal formation is saturated with oil. Though Union Oil Co. Bell No. 29 well, which reached the basement, unsuccessfully tested the Point Sal formation in the West Cat Canyon field, further testing of the formation in that field is justified. Additional testing of the Point Sal formation will doubtless be undertaken in the Casmalia field, where a recently drilled well is now producing a small amount of relatively light oil from it. Sands in the uppermost part of the Point Sal formation are included in the Third Zone of the Orcutt field. Though two wells in that field have penetrated the entire formation, possibilities of deeper production in parts of the field where the Point Sal information is thicker than along the line of structure section *C–C′*, of plate 2, has presumably not yet been exhausted.

The Lospe, Knoxville, and Franciscan formations, which are unlikely original sources of oil, can no longer be ignored in areas where younger oil-bearing formations overlap against them. The region near the foot of the San Rafael Mountains east of the mapped area, where the surface geology and Continental Oil Co. La Laguna No. 1 and No. 2 wells proved overlap of the Monterey shale by the Sisquoc formation, is one of the areas where oil may have migrated into the basement. Though that area is part of an extensive region characterized by Monterey oil of heavy grade, basement possibilities may deserve consideration.

OIL POSSIBILITIES IN UNPROVEN AREAS

It may be assumed that the Monterey shale will continue to be the chief objective of prospecting in the Santa Maria district. Two matters weigh heavily in prospecting for oil in the Monterey: the degree of fracturing of the rocks and the gravity of the oil. Chert and cherty shale are the most readily fractured rocks in the Monterey and are therefore the principal reservoir. Other things being equal, the productivity varies directly with the degree of fracturing. The fracturing is variable, even in adjoining wells, as in the Santa Maria Valley field. No study so far as known has been made to determine whether degree of fracturing can be correlated with observable surface or subsurface geological features.

Very heavy oil, not now (1947) commercial, has been found in the Monterey in the northeastern part of the district. The heavy-oil discoveries extending from the Bradley Canyon field southeastward to the Zaca Creek field are representative of oil of that grade. The Monterey oil of the Gato Ridge field is not far over the border line on the commercial side, and the Sisquoc oil of the East Cat Canyon field is on the border line. Location near the margin of the Pliocene basin does not appear to be the controlling factor, for the Santa Maria Valley field, which is at the north border of the basin, has lighter oil than the regions just mentioned. The northeastern part of the district is the region where deformation was most marked toward the close of the Miocene, between deposition of the Monterey shale and the Sisquoc formation. Perhaps the Monterey oil that is now very heavy accumulated soon after the late Miocene period of deformation, whereas the somewhat lighter oil elsewhere presumably accumulated after the middle(?) Pleistocene deformation. However that may be, the northeastern part of the district is unfavorable for prospecting in the Monterey, except for very heavy oil.

Despite long-continued drilling, the major anticlines in the Purisima Hills, including the Purisima anticline east of the Lompoc field, have not yielded commercial amounts of oil. It has not been determined whether the failure of test wells in this otherwise favorable area is due to meager fracturing or to local absence of a well-defined chert zone in the Monterey. Sands in the lower part of the Monterey that yielded shows of oil in Standard Oil Co. Buell No. 1–C well, drilled in 1924–25, deserve further testing.

The suggestion has been made [11] that oil may be trapped in the lower Miocene Vaqueros sandstone, or in sands of the overlying Rincon mudstone, on the south flank of the eastern Purisima Hills, because of overlap by the Monterey shale. Richfield Oil Co., Skytt No. 1 well, drilled in 1945 near Santa Ynez River, 2½ miles beyond the south border of the mapped area, found that the Monterey rests directly on the Knoxville formation. Though the Vaqueros and Rincon crop out only 1½ miles south of the well, they evidently do not extend north of the axis of the Santa Rita syncline in that area. The basement surface, however, may be irregular, and there is still a possibility that oil may be trapped in pre-Monterey sediments lying in depressions in the basement. The possibility within the mapped area, however, is remote.

Among areas of possible interest, three within, or near, the mapped area appear to be favorable for prospecting on the basis of surface geology: an area east of Foxen Canyon, where oil may be trapped in the basal part of the Tinaquaic sandstone member of the Sisquoc formation by westward overlap of successively higher Tinaquaic strata onto the Monterey; an area south of the Lions Head fault, where oil may be trapped by the fault; and an offshore extension of the north border of Point Sal Ridge, where oil may possibly be trapped in the Monterey by overlap of the Sisquoc formation.

East of the mapped area, early Pliocene megafossils occur in calcareous sandstone in the basal part of the Tinaquaic sandstone member of the Sisquoc formation. Within the mapped area east of Foxen Canyon, middle Pliocene megafossils are found in the upper half of the member. None was found in the lower half, and that part is perhaps early Pliocene. It is more probable, however, that the early Pliocene part is overlapped. Westward overlap of successively higher Tinaquaic strata onto the Monterey shale in the mapped area is indicated by relations east and west of Foxen Canyon. West of Foxen Canyon, strata near the top of the Tinaquaic member rest directly on the Monterey. The Tinaquaic member consists mostly of sandstone, but siltstone and silty sandstone like that in the lower part east of Foxen Canyon may seal well-sorted sandstone. The presence of oil in the Tinaquaic member is indicated by a local basal tar sand east of Foxen Canyon. The area available for prospecting is not large. Union Oil Co. Sisquoc No. 1 core hole was drilled presumably for information concerning the overlap.

[11] Woodring, W. P., Loofbourow, J. S., Jr., and Bramlette, M. N., Geology of Santa Rosa Hills-eastern Purisima Hills district, Santa Barbara County, Calif.; U. S. Geol. Survey, Oil and Gas Invest., Prelim. Map 26, 1 sheet, scale 1:48,000, 1945.

The Sisquoc formation south of the Lions Head fault, west of Casmalia, has a general southward dip interrupted locally by minor wrinkles. If oil moved northward up dip in the underlying Monterey shale it presumably is trapped by the fault. The area suitable for prospecting, however, is not extensive.

As outlined in the discussion of the structural history (pp. 109–110), Point Sal Ridge is the east end of a basement high of Franciscan and Knoxville rocks, which during Tertiary time presumably extended seaward beyond the present coast. Movements are inferred to have taken place along this positive area during Miocene time. The Lospe and Point Sal formations and Monterey shale are interpreted as overlapping the next older formation, or still older formations, so that at some localities each rests on the basement. Movements during Pliocene time are indicated by coarse Monterey detritus in the upper part of the Sisquoc formation and in the Foxen mudstone. Beginning at the first exposures east of Corralillos Canyon, the upper part of the Sisquoc includes a zone of breccia and conglomerate, made up of Monterey detritus, and interbedded mudstone. This zone, which has a maximum thickness of 200 feet, extends southeastward for a distance of a mile, decreasing southeastward in thickness and grain size. Fine-grained Monterey detritus is present as much as 3½ miles southeast of Corralillos Canyon. Five miles southeast of Corralillos Canyon, the Foxen mudstone contains huge boulders of contorted chert from the middle member of the Monterey shale.

The detritus in both the Sisquoc and Foxen formations was derived from the Monterey at localities where they overlap onto the Monterey. The Sisquoc may possibly have overlapped the Monterey at the east end of Point Sal Ridge, but the relations there are now, of course, indeterminable. The westward increase in thickness and grain size of the detritus in the upper part of the Sisquoc formation suggests a western source, presumably now offshore, and therefore a western location for the overlap. The very coarse detritus in the Foxen was found only in one small area. It may possibly have been derived from a local source, not far west of the locality where the boulders now occur, in an area now eroded.

Core drilling in the dune-sand area between Corralillos Canyon and the coast is not likely to reveal the inferred overlap, but should show whether the zone of Monterey detritus extends westward. Core drilling in Santa Maria Valley west of the Santa Maria Valley field may be necessary to eliminate a possible northern source. If the results of such a program still suggest a western source, drilling offshore in search of a possible overlap field similar to the Santa Maria Valley field might be undertaken, in the event that technical difficulties involved in drilling in the open ocean in moderately deep water are overcome.

Subsurface and geophysical data doubtless will reveal promising areas that are not apparent from surface geology alone. The present report emphasizes the surface geology, as other data are partly or entirely unavailable.

WILDCAT WELLS

Data concerning wildcat wells, arranged alphabetically by operators, are presented in the table on pages 128–134. Except as noted in the table, wildcats drilled before September 1945, were located in the field. The location of both wildcat and producing wells drilled between that date and January 15, 1947, was plotted on the basis of information in the weekly reports of California Oil News, issued by California Oil World News Service.

No trace of some wells shown on published maps could be found. Such wells are omitted, unless some other record of them is available. There is, however, considerable uncertainty concerning the location, or even the authenticity, of a considerable number of early wells. Within the limits of available information, wells are designated by the name of the operator holding them at the time when they were completed. Dry holes a short distance beyond the limits of producing fields are not included in the table. Land-net data in parentheses after the name of a land grant refer to the projected land net shown on map Nos. 2, 3, and 51 of the State Division of Oil and Gas. The projected land net is not based on any surveys and is not shown on the map accompanying the present report (pl. 1), but is consistently used by the State agency and by operators on account of its obvious usefulness.

Wildcat wells drilled in Santa Maria district

[Land-net data in parentheses indicate projected land net used by State Division of Oil and Gas and by operators. Altitude and depth in feet. Depth in stratigraphic columns refers to top of formation. Question mark in stratigraphic columns indicates top of formation was penetrated, or is inferred to have been penetrated, but depth is unknown or is not available]

Operator	Well	Location	Year drilled	Altitude	Total depth	Sisquoc formation	Monterey shale	Point Sal formation	Lospe formation	Basement	Oil and gas shows	Remarks
Anderson, J. I., & Southern California Petroleum Corp.	Archambeault No. 1	Purisima Hills, La Laguna grant (sec. 3-7-32).	1944	1,275	4,765		4,000±				Tar in fractures	Bottomed in hard cherty shale, dip 65°. Plugged to 1,170, redrilled toward south to 2,500, but deflection could not be maintained.
Anderson, J. I., & Southern California Petroleum Corp.	Archambeault No. 2	Purisima Hills, La Laguna grant (sec. 3-7-32).	1944	1,125	6,017		3,850				Shows in fractured brown shale.	
Arnold, E. C., Oil Corp.	Arnold-Apache No. 2	Solomon Hills, Los Alamos grant (sec. 8-8-33).	1937	800±	6,373		4,805					No chert zone. Possibly bottomed in Point Sal formation.
Associated Oil Co.	Buell Ranch No. 1	Purisima Hills, San Carlos de Jonata grant (sec. 21-7-32).	1908?	1,050±	1,900±		?					Also designated Buel Ranch Oil Co. Buel No. 1.
Associated Oil Co.	Buell Ranch No. 2	Purisima Hills, San Carlos de Jonata grant (sec. 21-7-32).	1908?	1,125±	1,900±		?					Also designated Buell Ranch Oil Co. Buell No. 2.
Associated Oil Co.	Lucas No. 1	North of Orcutt field, sec. 15-9-34.	1905	450±	860							Also designated Lucas Oil Co. Grossi No. 1. and Recruit Oil Co. Lucas No. 1.
Associated Oil Co.	National No. 1	Casmalia Hills, Todos Santos y San Antonio grant (sec. 27-9-34).	1906	600±	3,825	?	?				Flowed oil and water: Oil seeping from casing in 1938.	Also designated Associated Oil Co. Escolle No. 1 and Union Oil Co. National No. 1.
Associated Oil Co.	Newhall No. 1	Casmalia Hills, Todos Santos y San Antonio grant (sec. 29-9-34).	1905	750±	3,896		?				Tar shows	Also designated Recruit Oil Co. Newhall No. 1 and Recruit Oil Co. Escolle No. 2.
Associated Oil Co.	Peshine No. 137	Casmalia Hills, Todds Santos y San Antonio grant (sec. 19-9-34).	1918-19	600±	3,511		?				Oil and gas shows; 30 days after completion produced 300 barrels per day, 7.5°, 85 percent cut.	
Associated Oil Co.	Pezzoni No. 1	Gato Ridge, La Laguna grant (sec. 22-8-32).	1917-19	900±	3,984	?	?				Oil and gas shows	Also designated Recruit Oil Co. Pezzoni No. 1 and Barnsdall Oil Co. Associated No. 1.
Associated Oil Co.	Recruit No. 1	Casmalia Hills, Todos Santos y San Antonio grant (sec. 28-9-34).	1906	775±	3,355	?	?				Oil and gas shows	Also designated Recruit Oil Co. Escolle No. 1 and Union Oil Co. Recruit No. 1.
Associated Oil Co.	Williams No. 1	Near East Cat Canyon field, sec. 31-9-32.	1904	713	3,563	?	?				Tar shows	Also designated Recruit Oil Co. Williams No. 1, Gilmore Oil Co. Associated No. 1, and Associated Oil Co. Recruit No. 1.
Bankline Oil Co.	Silva No. 1	Santa Maria Valley, sec. 7-9-33.	1938	550	5,558	5,505						
Barca Oil Co.	Barca No. 1	Purisima Hills, Todos Santos y San Antonio grant (sec. 26-8-34).	1912?	600±	300±							
Barnsdall Oil Co.	Careaga No. 1	Purisima Hills, Los Alamos grant (sec. 31-8-33).	1932	975	5,331	100±						Bottomed in Sisquoc formation, dip 45°.
Barnsdall-Richfield Oil Corp.	Pezzoni No. 1	Gato Ridge, La Laguna grant (sec. 15-8-32).	1938	1,032	4,494		1,780					Chert zone 2,272-3,219.
Barnsdall Oil Co.	Pezzoni No. 2	Gato Ridge, La Laguna grant (sec. 15-8-32).	1944	1,030	4,006		2,151					Chert zone 2,325-3,385.
Bel-Air Oil Co.	Price No. 1	Solomon Hills, La Laguna grant (sec. 21-8-32).	1945	900±	5,166	1,180	4,340					Top of chert zone 4,530.
Bel-Air Oil Co.	Price No. 2	Solomon Hills, Los Alamos grant (sec. 17-8-32).	1945	950±	6,583	769	4,030	5,165	Absent	6,270		Top of chert zone 4366 or 4,550.
Bel-Air Oil Co.	Williams Holding Co. No. 1.	Near West Cat Canyon field, sec. 25-9-33.	1942	741	6,291	1,940±	4,265±	6,020±				Top of chert zone 5,008±.
Bradley Oil Co.	No. 1	Santa Maria Valley, sec. 33-10-33.	1912	350±	1,573							Converted to water well.
California Coast Oil Co.	Chaffin No. 1	North of Orcutt field, sec. 13-9-33.	1905?	600±	350±							Also designated Central Union Oil Co. Chaffin No. 1.
Casmalia Ranch Oil & Development Co.	Hansen No. 1	Casmalia Hills, Casmalia grant (sec. 15-9-35).	1901	350±	980?							No reliable record. No trace of well now apparent.
Casmalia Syndicate	No. 71	Casmalia Hills, Todos Santos y San Antonio grant (sec. 24-9-35).	1909	325±	2,634						Oil and gas shows	Drilled by Kern Trading and Oil Co. Also designated S. P. No. 1.
Cat Canyon Oil Co.	No. 1	Northeast of East Cat Canyon field, sec. 20-9-32.	1910	775±	300±							
Cohn & Mitchell	Biacomini No. 1	Santa Maria Valley, Punta de la Laguna grant (sec. 18-10-34).	1937	153	4,264	3,700	Absent	Absent	Absent	4,195		
Cole, Fred E.	Ferrini No. 1	Santa Maria Valley, Guadalupe grant (sec. 15-10-35).	1939	103	4,753	3,880	Absent	Absent	Absent	4,470		
Continental Oil Co.	Davis No. 1	Santa Maria Valley, sec. 28-10-33.	1943-44	349	2,779	1,561	1,642	2,560	Absent	2,738		

Dispatch Oil Co.	No. 1	Near West Cat Canyon field, sec. 23-9-33.	1912	775±	3,300	?					Oil and gas shows	Also designated Associated Oil Co. Dispatch No. 1.
Doan Oil Co.	Doan No. 1	Santa Maria Valley, sec. 17-9-33.	1916–17	850±	3,725							
Douglas-Stratton Oil Co.	Douglas-Stratton No. 1	Solomon Hills, Los Alamos grant (sec. 7-8-33).	1938	880	7,237	1,600±	5,025	6,630			Reported to have produced oil, but that report is disputed.	Chert zone and sand streaks poorly developed. Bottomed in Point Sal formation presumably few hundred feet above top of Lospe formation.
Elizalde Oil Co.	No. 1	Casmalia Hills, Punta de la Laguna grant (sec. 12-9-35).	1901	275±	1,000±							
Erickson, Gunnar	Dart No. 1	Santa Maria Valley, sec. 16-10-34.	1937	209	3,228	2,840	Absent	Absent	Absent	3,160		
Federal Oil Co.	No. 1	Purisima Hills, Los Alamos grant (sec. 4-7-33).	1910?	1,100±	5,010	?	?					Also designated General Petroleum Corp. Federal No. 1.
Field, O. C., Gasoline Corp.	Boyd Ranch No. 1	Santa Maria Valley, sec. 28-10-33.	1935	324	3,477	?	1,865	2,860	Absent	3,121		
Field, O. C., Gasoline Corp.	Careaga No. 1	Purisima Hills, Los Alamos grant (sec. 31-8-33).	1941–42	1,050±	4,986	1,430						
Field, O. C., Gasoline Corp.	Hansen No. 1	Casmalia Hills, Punta de la Laguna grant (sec. 24-9-35).	1944	388	2,370	150	1,140					
Field, O. C., Gasoline Corp.	Norswing No. 1	Santa Maria Valley, sec. 8-9-33.	1930–32	690	5,568	3,675	5,350				Oil and gas shows	Taken over by Fullerton Oil Co.
Field, O. C., Gasoline Corp.	Palmer Stendel No. 24-1	Near Cat Canyon, sec. 24-9-33.	1936–39	600±	3,363	1,450	Absent	2,674	Absent			Formation below depth of 3,300 feet has been identified as Obispo tuff and as basement.
Field, O. C., Gasoline Corp., McDuffie.	Palmer Stendel No. 13-1.	Near Cat Canyon, sec. 13-9-33.	1942	808	3,436	1,800±	2,700±					Chert Zone 2,780±–2,965. Bottomed in lower Monterey presumably close to top of Point Sal formation. Transferred to Los Gatos Oil Co.
Field, O. C., Gasoline Corp.	Santa Rita No. 1	Purisima Hills, sec. 11-7-33	1935–37	1,109	3,358		2,500±				Oil and gas shows	Formerly Freeman, M. J., La Brea No. 1.
Field, O. C., Gasoline Corp. & W. W. Porter.	No. 1	Solomon Hills, sec. 21-9-33	1936	1,000±	7,382	2,485	6,023					Top of chert zone 6,500±.
Four-Five-Six Oil Co.	Wickenden No. 1	Near Foxen Canyon, Tinaquaic grant (sec. 33-9-32).	1944–45	997	4,606	550	937				90 barrels per day, 6.5°, 10 percent cut.	Productive zone in chert, 2,986–4,606. Abandoned discovery well of heavy oil.
Foxen Oil Co.	No. 1	Near Foxen Canyon, Tinaquaic grant (sec. 6-8-31).	1907–10	1,000±	2,854						Tar and gas shows	Flowing warm sulphur water and little heavy oil in 1938.
Gato Ridge Oil Co.	No. 1	East of East Cat Canyon field, sec. 33-9-32.	1911	800±	2,155	?						Also designated Texas Co. Gato Ridge No. 1.
General Oil Co.	No. 1	Sisquoc grant (sec. 26-9-32)	1910?	900±	2,690		?					Flowed warm sulphur water.
General Petroleum Corp.	Bradley No. 1	Santa Maria Valley, sec. 6-9-33).	1924	400±	1,447							Bottomed in Paso Robles formation.
General Petroleum Corp.	Bradley No. 2	Santa Maria Valley, sec. 6-9-33).	1924–25	540±	2,063							Top of Careaga sandstone 1,291. Bradley No. 3, sec. 36-10-34, within present limit of Santa Maria Valley field, drilled to depth of 2,397 feet, penetrated top of Careaga sandstone at depth of 2,172 feet.
General Petroleum Corp.	Fox No. 1	Purisima Hills, sec. 18-7-32	1920–22	900±	3,472	[1]	?				Oil and gas shows	
General Petroleum Corp.	Giorgi No. 1	Solomon Hills, La Laguna grant (sec. 13-8-32).	1942	900±	1,254		Absent	Absent	Absent	975		
General Petroleum Corp.	Goodwin No. 1	Casmalia Hills, sec. 10-9-35	1946	584	4,673		430±	1,500±	2,200±			Top of chert zone 930±. Plugged to 1,465. Sulphur water.
General Petroleum Corp.	Guadalupe No. 1	Casmalia Hills, Guadalupe grant (sec. 33-10-35).	1925	1,100±	2,705				350±	1,065 (Knoxville fm)	Tar sands in Point Sal formation.	Top of Franciscan formation 2,663. Also designated General Pet. Corp., Pezzoni No. 1.
General Petroleum Corp.	Los Alamos No. 3	Purisima Hills, Los Alamos grant (sec. 31-8-33).	1945	1,076	6,287	1,290?						
General Petroleum Corp.	Wickenden No. 1	Solomon Hills, La Laguna grant (sec. 24-8-32).	1942–43	830±	2,905	150±	Absent	2,542	Absent	2,617		
General Petroleum Corp.	Wickenden No. 2	Solomon Hills, La Laguna grant (sec. 24-8-32).	1943	792	5,186	1,200±	3,680				20–40 barrels per day, 12°, variable cut, injected distillate.	Whipstock set at about 1,200, deflected to north. Top of Monterey 3,378 (chert zone, overlying part of Monterey missing), top of basement 4,269, (underlying about 125 feet of Point Sal formation). Productive zone in chert. Abandoned discovery well of heavy oil.
Hall-Baker Co.	Corehole Adam No. 1	Santa Maria Valley, sec. 18-9-33.	1935	577	1,997							No trace of well now apparent.

Wildcat wells drilled in Santa Maria district—Continued

Operator	Well	Location	Year drilled	Altitude	Total depth	Sisquoc formation	Monterey shale	Point Sal formation	Lospe formation	Basement	Oil and gas shows.	Remarks
Hall-Baker Co.	Corehole Delkner No. 1	Santa Maria Valley, sec. 12-9-34.	1936	400±	2,066							
Hall-Baker Co.	Corehole Fugler No. 1	Santa Maria Valley, sec. 7-9-33.	1936	400±	2,055							No trace of well now apparent.
Hall-Baker Co.	Corehole Preisker No. 1	Santa Maria Valley, sec. 12-9-34.	1936	427	2,219							
Hall-Baker Co.	Corehole Silva No. 1	Santa Maria Valley, sec. 7-9-33.	1936	584	2,019							No trace of well now apparent.
Hancock-Bush	Enos No. 1	Santa Maria Valley, sec. 13-10-34.	1936	248	2,004	1,675	Absent	1,860	Absent	1,894		Lease now held by Hancock & General.
Hancock Oil Co.	Hancock-Petroleum Securities Los Alamos No. 2.	Purisima Hills, Los Alamos grant (sec. 6-7-32).	1937	891	6,530							Bottomed in steeply dipping brown shale of Sisquoc formation.
Hogan Petroleum Co.	Zabala No. 1	Casmalia Hills, Todos Santos y San Antonio grant (sec. 33-9-34).	1939	825	4,155	410						
Hydrocarbon Products Co.	No. 1	Purisima Hills, San Carlos de Jonata grant (sec. 20-7-31).	1921-22	670	1,846						Tar and gas shows	
Italo Petroleum Corp.	Orena No. 1	Purisima Hills, Los Alamos grant (sec. 2-7-33).	1930-32	1,100±	4,975		?					Also designated N. S. Wilson No. 1.
Keystone & Earl Petroleum Co.	Paderewski No. 1	Santa Maria Valley, Punta de la Laguna grant (sec. 33-10-34).	1930	200±	4,627							Also designated Geo. O. Gorham Gorham No. 1.
Las Flores Land & Oil Co.	No. 1	Solomon Hills, Las Alamos grant (sec. 33-9-33).	1909	1,100±	4,537	?					Feb.-March, 1910, pumped 25-75 barrels per day, heavy oil.	
Las Flores Land & Oil Co.	No. 2	Solomon Hills, Los Alamos grant (sec. 27-9-33).	1909	1,200±	3,720	?					Oil and gas shows	
Las Flores Land & Oil Co.	No. 3	Solomon Hills, Los Alamos grant (sec. 4-8-34).	1911	850±	500?							Possibly No. 4.
Las Flores Land & Oil Co.	?	Solomon Hills, Los Alamos grant (sec. 28-9-33).	?	1,000±	?							No record. Possibly No. 3.
Lee, Roy	Title Guarantee & Trust Co. No. 1.	Santa Maria Valley, sec. 33-10-33.	1941	410	3,503	2,170	2,430	3,310				Top of chert zone 2,540.
Lompoc Oil & Development Co.	No. 1	Purisima Hills, sec. 8-7-33	1917-18	700±	3,883	298?	?					Taken over from Eagle Creek Co.
Lompoc Oil & Development Co.	No. 2	Purisima Hills, sec. 9-7-33	1908	1,050±	4,895	?	?				Oil and gas shows	No. 3 reported to have been drilled to depth of 3,483 feet in northwestern part of sec. 8-7-33, No. 4 to 4,070 feet in northeastern part of sec. 9-7-33.
Lompoc Petroleum Co.	Beauterbaugh No. 1	Santa Ynez Valley, Mission La Purisima grant (sec. 17-7-34).	1931	200±	905							Formerly Ernest E. Smith No. 1, Fairview Oil Co. No. 1, and R. H. McIntosh Beauterbaugh No. 1.
Lompoc Petroleum Co.	Beauterbaugh No. 2	Santa Ynez Valley, Mission La Purisima grant (sec. 17-7-34).	1933-37	175±	4,000±	?	?			?		Formerly Fairview Oil Co. No. 2 and R. H. McIntosh Beauterbaugh No. 1A.
Los Alamos Oil & Development Co.	No. 1	Purisima Hills, Los Alamos grant (sec. 32-8-33).	1905?	1,100±	2,150?	?						No reliable record. Taken over by Esperanza Consolidated Oil Co.
Los Alamos Oil & Development Co.	No. 2	Purisima Hills, Los Alamos grant (sec. 31-8-33).	1910?	950±	4,290	?	?				Reported to have produced some medium-gravity oil.	Taken over by Esperanza Consolidated Oil Co.
Marland Oil Co.	Williams No. 1	Near East Cat Canyon field, sec. 32-9-32.	1925-26	693	4,286	?	?				Reported to have produced a little oil.	Taken over successively by Associated Oil Co., Williams Holding Co., and Gilmore Oil Co.
Moore, E. H.	Union Sugar No. 1	Santa Maria Valley, Punta de la Laguna grant (sec. 25-10-35).	1936-37	171	8,135	5,635	7,675					Drilled to 3,035 feet by Shell Oil Co. (Corehole Union Sugar No. A-1).
Moore, E. H.	Union Sugar No. 5	Santa Maria Valley, Punta de la Laguna grant (sec. 25-10-35).	1937	157	6,348	4,720	6,135±					Top of chert zone 6,238.
Oak Ridge Oil Co.	No. 1	Near Gato Ridge, sec. 4-8-32.	?	950±	?							No record. Location unsatisfactory.
O'Donnell, J. E.	Helen No. 1	Purisima Hills, sec. 8-7-33	1938-39	577	4,997	?	?				Oil shows	
O'Neill, Louis B.	Orena No. 1	Purisima Hills, Los Alamos grant (sec. 26-8-33).	1929	875±	3,582	2,700±						
Oro Light & Power Co.	No. 1	Solomon Hills, sec. 21-9-33	1909	900±	2,600	?						
Pacific Slope Oil Co.	No. 1	Purisima Hills, sec. 8-7-33	1921	800±	4,000	850?	3,500?				Oil and gas shows	Stratigraphic data from structure section D-D', pl. 2. Location not confirmed in field.
Pan American Petroleum Co.	Hansen No. 1	Casmalia Hills, Punta de la Laguna grant (sec. 24-9-35).	1910-12	327	1,850						Produced a little heavy oil.	Taken over from Ensign-Baker Co.

Petroleum Midway Co.	Paderewski No. 1	Santa Maria Valley, Punta de la Laguna grant (sec. 5-9-34).	1919	210	3, 434							Location uncertain. Also designated Eagle Creek Syndicate Dargie No. 1 and Texas Co. Paderewski No. 1.
Petroleum Securities Co.	Los Alamos No. 1	Purisima Hills, Los Alamos grant (sec. 6-7-32).	1934	839	4, 808							Bottomed in steeply dipping brown shale of Sisquoc formation.
Pinal Dome Oil Co.	Graciosa No. 18	Purisima Hills, Los Alamos grant (sec. 25-8-34).	1909	600±	2, 304							Also designated Barnsdall Oil Co Pinal Dome No. 18.
Pinal Dome Oil Co.	Graciosa No. 19	Solomon Hills, Los Alamos grant (sec. 1-8-34).	1911	850±	4, 725	1, 250?	4, 000?					Also designated Union Oil Co. Graciosa No. 19. Stratigraphic data from structure section C-C′, pl. 2.
Pinal Dome Oil Co.	Graciosa No. 20	Purisima Hills, Los Alamos grant (sec. 35-8-34).	1911	1, 000±	4, 050		3, 500?					Also designated Barnsdall Oil Co. Pinal Dome No. 20. Stratigraphic data from structure section C-C′, pl. 2.
Pinal Dome Oil Co.	Tognazzini No. 1	Foxen Canyon, Tinaquaic grant (sec. 35-9-32).	1910	660	2, 100						Tar shows	Also designated Union Oil Co. Tognazzini No. 1.
Pinal Dome Oil Co.	Tognazzini No. 2	Gato Ridge, La Laguna grant (sec. 15-8-32).	1911-13	800±	3, 400		2, 350±				Oil shows	Also designated Petrol Corp. Union No. 2.
Pinal Dome Oil Co.	Tognazzini No. 3	Gato Ridge, La Laguna grant (sec. 15-8-32).	1914-15	850±	2, 410		1, 900±					Also designated Petrol Corp. Union No. 3.
Pinal Dome Oil Co.	Wickenden No. 1	Gato Ridge, La Laguna grant (sec. 22-8-32).	1911	930	4, 233		2, 350±				Oil and gas shows	Also designated Dome Oil Co. No. 1.
Princess Oil Co.	Muscio No. 1	Solomon Hills, La Laguna grant (sec. 13-8-32).	1912	1, 100±	3, 425		1, 300±	2, 100±	Absent	2, 500±		Monterey above *Siphogenerina* zone apparently missing. Also designated Western Gulf Oil Co. Princess No. 1.
Purisima Hills Oil Co.	No. 1	Purisima Hills, sec. 15—7-33	1910?	850±	3, 800?	?						No reliable record. Also designated South Coast Oil Co. No. 1.
Purisima Hills Oil Co.	No. 2	Purisima Hills, sec. 15-7-33	1910-12	650±	3, 867	?					Oil and gas shows	Also designated South Coast Oil Co. No. 2.
Recruit Oil Co.	Pezzoni No. 1	Solomon Hills, La Laguna grant (sec. 11-8-32).	1907?	875±	2, 050?							No reliable record.
Republican Petroleum Co.	Price No. 1	Gato Ridge, La Laguna grant (sec. 16-8-32).	1942	1, 127	4, 994		3, 015				Oil shows	Top of chert zone 3,800. Plugged to 4,580.
Richfield Oil Corp.	Las Flores No. 1	Solomon Hills, Los Alamos grant (sec. 10-8-33).	1944-45	607	7, 267	1, 935	5, 625	7, 095			Produced 75-100 barrels per day, 22°, for few days.	Top of chert zone 6,630.
Richfield Oil Corp.	Tinaquaic No. 1	Tinaquaic grant (sec. 36-9-32)	1938-39	925	5, 541						Tar in fractures	Top of chert zone 2,775±. Bottomed in steeply dipping Monterey shale.
Royalty Service Corp.	Careaga No. 1	Solomon Hills, Los Alamos grant (sec. 8-8-33).	1942	735±	5, 580	?	4, 520±					
Royalty Service Corp.	Sisquoc No. 1	Tinaquaic grant (sec. 35-9-32)	1934	876	4, 500							Top of chert zone 2,750±.
St. Helens Petroleum Co.	Fugler No. 1	Santa Maria Valley, sec. 35-10-33.	1913-15	200±	5, 312	1, 030?	1, 650?				Tar shows	
Santa Barbara Oil & Mining Co.	No. 1	North of Orcutt field, sec. 14-9-34.	?	600±	600?							No reliable record. Also designated Rice Ranch Oil Co. S. B. O. & M. No. 1.
Santa Maria Enterprise Oil Co.	Enterprise No. 1	Near East Cat Canyon field, sec. 31-9-32.	1911	627	3, 035	?	?				Oil and gas shows	
Santa Maria Oil Co.	Merchants No. 1	North of West Cat Canyon field, sec. 14-9-33.	1912?	650±	3, 100?	?						No reliable record. Also designated A. W. & Evelyn J. Billings Merchants No. 1.
Shaw Ranch Oil Co.	No. 2	Near Gato Ridge, Los Alamos grant (sec. 8-8-32).	1916?	1, 050±	3, 320		?				Oil and gas shows	No. 1 is now Standard Oil Co. Magenheimer No. 624.
Shell Oil Co.	Corehole Union Sugar No. A-1.	Santa Maria Valley, Punta de la Laguna grant (sec. 25-10-35).	1928	171	3, 035							Deepened by E. H. Moore (Union Sugar No. 1).
Shell Oil Co.	Corehole Union Sugar No. A-2.	Santa Maria Valley, Punta de la Laguna grant (sec. 36-10-35).	1928	179	2, 181							Location of A-2 to A-6, inclusive, not confirmed in field.
Shell Oil Co.	Corehole Union Sugar No. A-3.	Santa Maria Valley, Punta de la Laguna grant (sec. 25-10-35).	1928	162	1, 911							
Shell Oil Co.	Corehole Union Sugar No. A-4.	Santa Maria Valley, Punta de la Laguna grant (sec. 36-10-35).	1929	171	1, 897							
Shell Oil Co.	Corehole Union Sugar No. A-5.	Santa Maria Valley, Punta de la Laguna grant (sec. 25-10-35).	1929	155	2, 504							
Shell Oil Co.	Corehole Union Sugar No. A-6.	Santa Maria Valley, Punta de la Laguna grant (sec. 24-10-35).	1929	168	2, 151							
Shell Oil Co.	Newhall No. 1	Casmalia Hills, Todos Santos y San Antonio grant (sec. 29-9-34).	1918	650±	3, 951		?				Oil and gas shows	
Southern California Drilling Co.	Houk No. 1	Santa Maria Valley, sec. 9-9-33.	1936	582	5, 003	3, 293	4, 462				Oil and gas shows	Also designated Standard Oil Co. Houk 2 No. 1.
Southern California Petroleum Corp. & J. I. Anderson.	Archambeault No. 3	Purisima Hills, La Laguna grant (sec. 16-7-32).	1945	1, 075	1, 816						Oil show 1,648-1,668	Top of chert zone 1,585. Plugged to 1,674.

Wildcat wells drilled in Santa Maria district—Continued

Operator	Well	Location	Year drilled	Altitude	Total depth	Sisquoc formation	Monterey shale	Point Sal formation	Lospe formation	Basement	Oil and gas shows	Remarks
Southwestern Development Co.	Mendoza No. 1	Santa Maria Valley, sec. 13-10-34.	1941	253	1,683	?	Absent	1,565	Absent	1,663		
Sovereign Oil Co	Donovan No. 1	Guadalupe grant (sec. 20-10-35).	1929	230	5,460	?						Also designated Wildcat Oil & Dev. Co. Donovan No. 1.
Speed Oil Co	Haslam No. 1	North of Orcutt field, sec. 13-9-34.	?	600±	316?							Also designated Santa Maria Central Oil Co. Speed No. 1.
Standard Oil Co	Buell No. 1A	Purisima Hills, San Carlos de Jonata grant (sec. 22-7-32).	1922	1,025	2,095							No. 1, drilled to depth of few hundred feet, was located close to No. 1A.
Standard Oil Co	Buell No. 1C	Purisima Hills, San Carlos de Jonata grant (sec. 22-7-32).	1922–24	1,041	4,579				4,456 (Lospe?)		Oil and gas shows, particularly in sands of lower Monterey.	Top of chert? zone 917; top of lower Monterey 3,433. Deepest formation may represent volcanics at base of Monterey, Lospe, or basement. No. 1B, drilled to depth of 1,137 feet was located close to No. 1C. Also designated Los Flores Land & Oil Co. Standard No. 5.
Standard Oil Co	Las Flores No. 5	Solomon Hills, Los Alamos grant (sec. 33-9-33).	1942	1,108	5,605	1,210						Also designated Los Flores Land & Oil Co. Standard No. 5.
Standard Oil Co	Palmer Union No. 1	Near Cat Canyon, sec. 13-9-33	1926–27	772	4,752	1,390	2,650	?			Heavy oil in sands probably at base of Sisquoc formation.	Sisquoc formation overlies lower Monterey. Also designated Standard Oil Co. Standard No. 1.
Standard Oil Co	Pezzoni No. 1	Casmalia Hills, Guadalupe grant (sec. 28-10-35).	1916	673	4,435	?					Traces of oil and gas	
Standard Oil Co	Rice Ranch No. 1	North of Orcutt field, sec. 14-9-33.	1942	502	9,254	5,152	9,130					
Standard Oil Co	South Basin-Lloyd Community No. 1.	Bradley Canyon field, sec. 15-9-33.	1942	602	7,250	?	4,704				137 barrels per day, 7.3°, 60 percent cut.	Plugged to 4,704. Discovery well of Bradley Canyon field. Productive zone middle Sisquoc sand, 4,542–4,704, resting on Monterey. Shut in.
Standard Oil Co	Tognazzin No. 1	Casmalia Hills, Guadalupe grant (sec. 28-10-35).	1916–17	385	4,265	?					Traces of oil and gas	No trace of well now apparent.
Stewart-Carter Oil Co	Burton No. 1	Gato Ridge, Tinaquaic grant (sec. 4-8-32).	1936–37	1,120	3,615	?	?					
Stone Goodwin Oil Co	Goodwin No. 1	Near East Cat Canyon field, sec. 31-9-32.	1916	750±	3,458	?	?				Oil and gas shows	
Summit Oil Co	No. 1	Santa Maria Valley, sec. 11-9-33.	1914	600±	2,780							
Superior Oil Co	Corehole T. B. Adam No. 1.	Santa Maria Valley, Suey grant (sec. 36-10-33).	1932	359	533							It may be assumed that these coreholes, except Bradley No. 1, were drilled to basement. Aside from Bradley No. 1, locations not confirmed in field.
Superior Oil Co	Corehole W. C. Adam No. 1.	Santa Maria Valley, Suey grant (sec. 26-10-33).	1932	346	296							
Superior Oil Co	Corehole Bradley No. 1	Santa Maria Valley, sec. 19-10-33.	1932–33	265	2,020	1,485	1,625	1,895±				Monterey above *Siphogenerina* zone absent.
Superior Oil Co	Corehole Fugler No. 1	Santa Maria Valley, sec. 35-10-33.	1932	370	336							
Superior Oil Co	Corehole Fugler No. 2	Santa Maria Valley, sec. 35-10-33.	1932	386	473							
Superior Oil Co	Corehole Fugler No. 3	Santa Maria Valley, sec. 35-10-33.	1932	340	498							
Superior Oil Co	Corehole Garcia No. 1	Santa Maria Valley, sec. 17-10-33.	1932	290	610							
Superior Oil Co	Corehole Kelley No. 1	Santa Maria Valley, Suey grant (sec. 27-10-33).	1932	337	684							
Superior Oil Co	Corehole Kelley No. 2	Santa Maria Valley, Suey grant (sec. 27-10-33).	1932	330	960							
Superior Oil Co	Corehole Newhall Land & Farming Co. No. 1.	Santa Maria Valley, Suey grant (sec. 35-10-33).	1932	355	763							
Superior Oil Co	Corehole Newhall Land & Farming Co. No. 2.	Santa Maria Valley, Suey grant (sec. 26-10-33).	1932	350	428							
Superior Oil Co	Corehole Silva No. 1	Santa Maria Valley, sec. 20-10-33.	1932	295	922							
Superior Oil Co	Corehole Soares No. 1	Santa Maria Valley, sec. 28-10-33.	1932	321	815							
Syndicate Oil Co	No. 1	Casmalia Hills, sec. 10-9-35	?	700±	3,300		?					No reliable record.
Todos Santos Oil Co	No. 1	Purisima Hills, Todos Santos y San Antonio grant (sec. 28-8-34).	1906	800±	4,300							Location uncertain. Also designated Zabala well.
Traders Union	No. 1	Casmalia Hills, Punta de la Laguna grant (sec. 12-9-35).	1904	400±	3,350	?						

Treasure Oil Co.	No. 1	North of East Cat Canyon field, sec. 19-9-32.	?	700±	600?							No reliable record.
Union Oil Co.	Arellanes No. 1	Casmalia Hills, Punta de la Laguna grant (sec. 21-9-34).	1908	700±	1,900	?						Also designated Richfield Oil Corp. Arellanes No. 1.
Union Oil Co.	Arellanes No. 1-A	Casmalia Hills, Punta de la Laguna grant (sec. 21-9-34).	1907-11	700±	4,554	?	?					Also designated Casmalia O. & D. Soladino No. 1, Union Oil Co. Casmalia No. 1, and Richfield Oil Corp. Arellanes No. 1A.
Union Oil Co.	Burton No. 1	West of Lompoc field, Jesus Maria grant (sec. 30-8-34).	1905-08	475±	4,455	?	?	Absent	Absent?	?	Oil and gas shows	
Union Oil Co.	Claremont Arellanes No. 1.	Casmalia Hills, Punta de la Laguna grant (sec. 16-9-34).	1907	600±	4,066	?						Also designated Claremont Oil Co. Arellanes No. 1.
Union Oil Co.	Cox No. 1	Santa Maria Valley, sec. 29-10-33.	1942-43	350	2,400	2,034	Absent	Absent	Absent	2,250		
Union Oil Co.	Elizalde No. 1	Casmalia Hills, Punta de la Laguna grant (sec. 13-9-35).	1917	475±	2,088		?				Heavy oil shows	
Union Oil Co.	Elizalde No. 2	Casmalia Hills, Punta de la Laguna grant (sec. 14-9-35).	1919-20	450±	4,139		?					
Union Oil Co.	Escolle No. A-1	Casmalia Hills, Todos Santos y San Antonio grant (sec. 28-9-34).	1946	810	5,850	150	2,890	4,390	5,450			Top of chert zone 3,580.
Union Oil Co.	Fugler No. 1	Santa Maria Valley, sec. 3-9-33.	1945	505	6,480	2,725	3,290	5,430				Top of chert zone 4,700.
Union Oil Co.	Harris A-1	Purisima Hills, Los Alamos grant (sec. 35-8-34).	1947	985								Drilling.
Union Oil Co.	Le Roy No. 1	Santa Maria Valley, Punta de la Laguna grant (sec. 16-10-34).	1935	202	3,436	2,995	Absent	Absent	Absent	3,351		
Union Oil Co.	Linus Buell No. 1	Purisima Hills, San Carlos de Jonata grant (sec. 19-7-31).	1929-30	993	4,589			Absent	Absent	3,267	Oil and gas shows	Top of chert zone 275.
Union Oil Co.	McCroskey No. 1	North of East Cat Canyon field, sec. 20-9-32.	1944	800	4,600						200 barrels per day, 10°, including injected crude oil.	Stratigraphic data not available. Productive zone presumably chert zone of Monterey. Shut in.
Union Oil Co.	McNee No. 1	North of East Cat Canyon field, sec. 20-9-32.	1944	874	3,663							Stratigraphic data not available. Monterey presumably absent.
Union Oil Co.	McNee No. 2	North of East Cat Canyon field, sec. 20-9-32.	1944	800	4,034						100-150 barrels per day, 8°, including injected crude oil.	Stratigraphic data not available. Abandoned discovery well of heavy oil. Productive zone presumably chert zone of Monterey.
Union Oil Co.	McNee No. 3	North of East Cat Canyon field, sec. 20-9-32.	1944	800	4,500						100-150 barrels per day, 8°-10°, including injected crude oil.	Stratigraphic data not available. Productive zone presumably chert zone of Monterey.
Union Oil Co.	McNee No. 4	North of East Cat Canyon field, sec. 20-9-32.	1945	809	9,001							Stratigraphic data not available.
Union Oil Co.	Mathison No. 1	Santa Maria Valley, Guadalupe grant (sec. 16-10-35).	1942	91	5,522	4,313	5,071	Absent	Absent	5,476		Top of chert zone 5,071, overlying part of Monterey absent.
Union Oil Co.	Palmer-Stendel A-1	East of East Cat Canyon field, sec. 29-9-32.	1942	742	4,071							Stratigraphic data not available.
Union Oil Co.	Pezzoni No. 1	Casmalia Hills, Guadalupe grant (sec. 33-10-35).	1939	1,004	2,242	60±	Absent (see remarks)	Absent (faulted out)	495±	725± (Knoxville fm.)		Top of Franciscan 2,045. Started in middle member of Monterey shale, passed through fault into Sisquoc formation, and again through same fault into Lospe formation.
Union Oil Co.	Pezzoni No. 2	Casmalia Hills, Guadalupe grant (sec. 33-10-35).	1939	839	7,977	2,309	1,575					Sisquoc formation repeated by overturning.
Union Oil Co.	Quintero No. 1	Casmalia Hills, Punta de la Laguna grant (sec. 11-9-35).	1917-20	750±	3,451		?				Gas shows	Location uncertain. No trace of well now apparent.
Union Oil Co.	Santa Maria Realty Co. No. 1.	Bradley Canyon, sec. 10-9-33.	1944	560	5,403	3,000	3,860				105 barrels per day, 5.6°, 18 percent cut, including injected crude oil.	Top of chert zone 5,010. Quitclaimed discovery well of heavy oil in Monterey of Bradley Canyon field.
Union Oil Co.	Corehole Sisquoc No. 1	Sisquoc grant (sec. 31-9-31)	1943	900±	2,805							Stratigraphic data not available. Presumably drilled just into Monterey shale.
Union Oil Co.	Sisquoc No. 6	Sisquoc grant (sec. 25-9-32)	1946	900±	6,372							Stratigraphic data not available.
Union Oil Co.	Williams No. B-1	East of West Cat Canyon field, sec. 25-9-33.	1946	829	2,528							Stratigraphic data not available. Plugged to 2,277.
United Western Consolidated Oil Co.	Stokes No. 1	Casmalia Hills, sec. 3-9-35	1917-21	1,000±	2,470		?				Oil and gas shows	Small flow of gas used for domestic purposes in 1938.
Universal Consolidated Oil Co.	Careaga No. 1	Solomon Hills, Los Alamos grant (sec. 5-8-33).	1942	950±	6,123	?	3,955	5,640				Top of chert zone 4,915.
Valley Oil Co.	Rice No. 1	Santa Maria Valley, sec. 18-10-33.	1936	250	634	Absent	Absent	Absent	Absent	578		No trace of well now apparent.
Valoco Oil Co.	Valoco No. 1	Santa Maria Valley, sec. 28-10-33.	1938	314	1,652	1,075	1,091	1,117	Absent	1,582		Upper Monterey absent. No trace of well now apparent.
West Oil Co.	No. 1	Near Cat Canyon, sec. 18-3-32	?	550±	3,360	?	?					No trace of well now apparent.
West Oil Co.	Huasna No. 1	Casmalia Hills, Todos Santos y San Antonio grant (sec. 33-9-34).	1934	500±	4,042	?	?				Oil shows	

Wildcat wells drilled in Santa Maria district—Continued

Operator	Well	Location	Year drilled	Altitude	Total depth	Sisquoc formation	Monterey shale	Point Sal formation	Lospe formation	Basement	Oil and gas shows	Remarks
Western Gulf Oil Co.	Bradley No. 1	Santa Maria Valley, sec. 5-9-33	1930-32	680	10, 296	3, 515	4, 964					Top of chert zone 6,852. Bottomed in lower Monterey, dipping 50°-70°, presumably close to top of Point Sal formation.
Western Union Oil Co.	Careaga No. 87	Purisima Hills, Los Alamos grant (sec. 31-8-33).	1920	1, 000±	4, 014							Also designated Barnsdall Oil Co. Western Union No. 87.
Western Union Oil Co.	Harris No. 1	Purisima Hills, Los Alamos grant (sec. 36-8-34).	1919-21	1, 090	4, 807							Also designated Barnsdall Oil Co. Western Union No. 1.
Whittier Associates	Barham No. 1	Purisima Hills, La Laguna grant (sec. 11-7 32).	1943-44	1, 520	4, 847		2, 475				15 barrels per day, 14°, 15 percent cut.	Plugged to 3,057.
Whittier Associates	Barham No. 2	Purisima Hills, La Laguna grant (sec. 11-7-32).	1944	1, 365	3, 726		2, 290				Encountered some oil.	Plugged to 3,290.
Whittier Associates	Barham No. 3	Purisima Hills, La Laguna grant (sec. 11-7-32).	1946-47	1, 324	6, 870		?				Encountered some oil. Pumped off.	Plugged to 6,565.
Whittier Associates	Corehole Glenn Buell No. 1.	Purisima Hills, San Carlos de Jonata grant (sec. 15-7-32).	1945	1, 293	1, 787							
Whittier Associates	Corehole Glenn Buell No. 2.	Purisima Hills, San Carlos de Jonata grant (sec. 23-7-32).	1945	1, 039	832							
Whittier Associates	Corehole Glenn Buell No. 3.	Purisima Hills, San Carlos de Jonata grant (sec. 14-7-32).	1945	1, 621	2, 834							
Whittier Associates	Corehole Rufus Buell No. 1.	Purisima Hills, San Carlos de Jonata grant (sec. 16-7-32).	1945	1, 117	962		?					
Whittier Associates	Corehole Water Buell No. 1.	Purisima Hills, San Carlos de Jonata grant (sec. 15-7-32).	1945	1, 674	1, 198							
Williams, S. R.	Fickert No. 1	Purisima Hill, sec. 8-7-33	1943-44	950±	3, 446		3, 150±					Taken over from Fickert Oil Co.

DEVELOPMENT IN 1947–48

The discovery of the Four Deer and Guadalupe fields and the northwestward extension of the West Cat Canyon field are the most important developments in 1947–48. A discussion of fractured reservoirs in the Santa Maria district, by Regan and Hughes,[12] published early in 1949, should be consulted by anyone interested in the district and its unusual reservoirs.

Four Deer Field.—The Four Deer field is located in projected secs. 4 and 5, T. 8 N., R. 33 W., southeast of the Orcutt field. The discovery well, Sunray Oil Corp. Las Flores No. 1, was completed in June 1947, at a plugged depth of 5,478 feet, with a daily yield of 319 barrels of 36.1° (API) oil, cutting 2 percent water. It was drilled into the Lospe formation, but was plugged back and completed in a productive zone at the top of the Monterey shale immediately below the base of the Sisquoc formation. At the end of 1948, the field had 12 producing wells that had a daily yield of about 850 barrels. Two of the wells, however, are marginal wells that would not be kept in production without the others. The productive zone consists of sand, as shown by one side-wall core, and possibly also of fractured shale. Two wells are producing from a deeper chert zone. Though the discovery well was drilled in the belief that a fault, upthrown to the south, extends between it and the Orcutt field, subsurface contours are said to show that the Four Deer field lies on an anticlinal nose on the southeast plunge of the subsurface anticline of the Orcutt field. Sunray Oil Corp. Careaga No. 1 well, a structurally high well, is a small producer. Sunray Oil Corp. Careaga No. 2 well, structurally higher than the offsetting Sunray Oil Corp. Las Flores No. 8 well, which is a satisfactory producer, encountered no fluid. The records of these two structurally high wells suggest that the oil is trapped by up-dip lack of porosity and permeability. The oil of the Four Deer field is the lightest oil in the entire district.

Guadalupe field.—The first well in the Guadalupe field, which is located in the sand dunes along the coast immediately north of the mouth of the Santa Maria River, was drilled by the Sand Dune Oil Co. in 1947. It was taken over by Continental Oil Co. the same year and gun-perforated. The basal Foxen tar sand looked promising, but the well (originally Sand Dune Oil Co. Le Roy No. 1) was abandoned early in 1948. The discovery well, Conteninital Oil Co. Le Roy No. 2, was drilled and completed in the basal Foxen tar sand, in April 1948, at a depth of 2,759 feet, plugged to 2,740 feet. It had a daily yield of 48 barrels of 11.2° (API) oil, cutting 36 percent water. At the end of 1948, the field had four producing wells, the daily yield of which was about 300 barrels. The productive sand rests on the lower member of the Monterey shale, and is overlain by about 80 feet of cemented conglomerate consisting of angular chert and cherty shale debris from the Monterey shale. The conglomerate is overlain by siltstone of the Foxen mudstone. The conglomerate overlying the oil sand is like that in the zone of conglomerate and breccia in the upper part of the Sisquoc formation along Corralillos Canyon, four miles southeast of the Guadalupe field. Perhaps in that field, the section below the Foxen mudstone is condensed and the conglomerate and oil sand are actually in the upper part of the Sisquoc formation.[13]

The Le Roy No. 1 well was drilled into the Knoxville formation, which underlies the Monterey shale. In the Guadalupe field the Monterey is about 2,000 feet higher structurally than in Union Oil Co. Tognazzini No. 2 well, the westernmost well in the Santa Maria Valley field 5½ miles southeast of the Guadalupe field. The structure of the intervening area is unknown. It may be expected that the chert zone of the Monterey, which presumably reappears south of the Guadalupe field beneath the overlapping Foxen mudstone (or Sisquoc formation), will be tested in the area south of the field.

West Cat Canyon field.—General Petroleum Corp. and Douglas Oil Co. have extended the West Cat Canyon field half a mile northwest of the northwesternmost well shown on the geologic map (pl. 1). The limits of the field in that direction are still undetermined, except by the dry hole of O. C. Field Gasoline Corp. and W. W. Porter No. 1 well in sec. 21, T. 9 N., R. 33 W. In this northwestward extension of the field the top of the Monterey is higher structurally than would be expected from its altitude in the dry hole just mentioned and in productive wells south of the extension, owing presumably to a series of faults upthrown to the north. General Petroleum Corp. Los Flores No. 86–21 well (sec. 21, T. 9 N., R. 33 W.) is producing from a new zone at the top of the Monterey shale. The pool discovered by this well is designated the L. F. 86–21 pool.

Other fields.—Toward the end of 1948 production in the Lompoc field was drastically curtailed, the result of a drop in the demand for fuel oil. Only 5 wells were producing, whereas earlier about 105 wells were on production.

The two wells in the Casmalia field producing from pre-Monterey formations (one from the Point Sal formation, the other from the Lospe formation) yielded mostly water in 1948. By putting into effect improved completion techniques, Bell-Casmite Oil Co. has greatly increased the initial yield of wells completed in the Sisquoc-Monterey pool. The initial daily yield of some wells is as high as 500 barrels.

[12] Regan, L. J., Jr., and Hughes, A. W., Fractured reservoirs of Santa Maria district, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 33, no. 1, pp. 32–51, 15 figs. 1949.

[13] See p. 118 for a discussion of the possible equivalence of the subsurface basal Foxen tar sand and the outcrop zone of conglomerate and breccia in the upper part of the Sisquoc formation in the western Casmalia Hills.

Union Oil Co. has in operation a dry-ice plant to utilize a deleterious constituent in gas from the Santa Maria Valley field. The plant is operated with the propane, butane, and natural-gasoline plants on the Battles lease in sec. 25, T. 10 N., R. 34 W. Gas from the Santa Maria Valley field has an unusually high percentage of carbon dioxide, averaging 15.2 percent and as high as 25 percent in some wells. By extracting the carbon dioxide and processing it into dry ice, the B.t.u. value of the gas is increased and a marketable product is obtained. The plant has a daily capacity of about 55 tons of dry ice, and at the end of 1948 the daily production was 40 tons.

Bishop Oil Co. has on production most of the old wells in the East Cat Canyon field. As usual in fields where sand is the reservoir for heavy oil, sand extracted with the oil presents a serious problem.

The heavy-oil discovery in sec. 20, T. 9 N., R. 32 W., near Sisquoc River, mentioned on page 124, has been extended into sec. 18 and sec. 28, and has been named the Olivera Canyon field. At the end of 1948 the field had eight producing wells. The oil zone is in fractured chert of the Monterey shale. Subsurface data have not been released. Completion depths, however, indicate a monocline dipping steeply southwestward, suggesting a fault, upthrown to the northeast, between the Olivera Canyon field and the steeply dipping strata on the northeast side of the basement high lying on the east side of the East Cat Canyon field.

The heavy-oil discovery on the Tinaquic grant, near Foxen Canyon (projected sec. 33, T. 9 N., R. 32 W)., discussed on page 124, has been named the Tinaquaic field. The discovery well, drilled by Four-Five-Six Oil Co., has been taken over by Petroleum Reserve Corp. At the end of 1948 three wells were being drilled.

The name Barham Ranch field has been proposed for the small area on the north slope of the eastern Purisima Hills that includes Whittier Associates Barham Nos. 1, 2, and 3 wells (projected sec. 11, T. 7 N., R. 32 W.), all of which produced some oil. At the end of 1948 one well was being drilled.

General Petroleum Corp. took over the Realty lease in the Bradley Canyon field (sec. 10, T. 9 N., R. 33 W., mentioned on p. 124), and drilled and abandoned Realty No. 73–10 well. At the end of 1948 the field was inactive.

With the completion of its Luton No. 135 well (projected sec. 30, R. 8 N., R. 31 W.), Tide Water Associated Oil Co. extended the Zaca Creek field northwestward into the mapped area. At the end of 1948 the field had a length of 2¼ miles and a width of about ¼ mile, and included 10 producing wells and seven drilling wells. The Zaca Creek field is mentioned on page 125.

FOSSIL LOCALITIES

The fossil localities are described in the following list, and the numbers used for the localities in the present report are correlated with field numbers and with permanent locality numbers in registers of the Geological Survey, the Cenozoic invertebrate register unless otherwise specified. The numbers used in the present report are plotted on the geologic map (pl. 1), except in areas where the map is congested. The exceptions are noted in the following list, the locality data for the numbers not plotted being sufficient to identify them in the field.

Fossil localities

Number used in this report	Permanent Geological Survey No.	Field No.	Description of locality
			UPPER JURASSIC SERIES
			Knoxville formation
1			Casmalia Hills, east side of Corralillos Canyon, ⅛ mile north of locality where Point Sal road crosses Corralillos Canyon. Leached *Aucella* in weathered conglomerate. Not collected.
2	[1] 18614	W861	Casmalia Hills, west side of Corralillos Canyon, Point Sal road, 0.4 miles northwest of locality where the road crosses Corralillos Canyon.
3	[1] 18615	W865	Casmalia Hills, ravine on south side of upper Corralillos Canyon, 0.6 mile southeast of locality where Point Sal road crosses Corralillos Canyon.
			MIOCENE SERIES
			Point Sal formation
5		W850	Casmalia Hills, Point Sal Landing road, ½ mile east of Point Sal Landing.
6		W839	Casmalia Hills, south slope of Mount Lospe, a mile southwest of Mount Lospe.
7		10–6	Casmalia Hills, south slope of Mount Lospe, 0.6 miles southwest of Mount Lospe
7*a*		10+100	Same locality, 100 feet up canyon. Not plotted.
8		13	Same locality, 500 feet up canyon from locality 7.

[1] Mesozoic register.

Fossil localities—Continued

Number used in this report	Permanent Geological Survey No.	Field No.	Description of locality
			MIOCENE SERIES—Continued
			Monterey shale
			Lower member
9		W868	Casmalia Hills, coast 1.7 miles north of Point Sal.
10			Casmalia Hills, coast ⅓ mile southeast of Lions Head. Lower part of member.
10*a*			Same locality. Upper part of member. Not plotted.
10*b*			Same locality, 50 to 60 feet higher stratagraphically. Not plotted.
10*c*		L23	Casmalia Hills, south slope of Mount Lospe, 0.4 mile southeast of Mount Lospe.
10*d*		L84	Casmalia Hills, 0.9 mile northeast of Mount Lospe.
11		W107	Casmalia Hills, 1.5 miles southwest of intersection of Point Sal road and Southern Pacific railroad.
			Middle member
12		B955a	Purisima Hills, 7.6 miles southeast of Los Alamos, 200 feet southeast of site of Union Oil Co. Buell No. 1 well.
			Upper member
14		B949	Purisima Hills, 0.7 mile southeast of Redrock Mountain.
15		B945	Purisima Hills, 1.4 miles southeast of Redrock Mountain.
16		B954	Purisima Hills, a mile east of Redrock Mountain.
17		B929	Purisima Hills, 1.5 miles southeast of Redrock Mountain.
18		B901	Purisima Hills, 1.9 miles east-southeast of Redrock Mountain.
19		B923	Purisima Hills, 2.7 miles southeast of Redrock Mountain.
20		B894	Purisima Hills, 2.8 miles southeast of Redrock Mountain.
			MIOCENE AND PLIOCENE SERIES
			Sisquoc formation
			Todos Santos claystone member
21		W885	Casmalia Hills, 2.4 miles west-northwest of Casmalia.
22		W256	Casmalia Hills, 1.8 miles northwest of Casmalia.
23		W292	Casmalia Hills, ¾ mile northwest of Casmalia.
24		W247	Casmalia Hills, 1.5 miles northwest of Casmalia.
25		W251	Casmalia Hills, 1.3 miles northwest of Casmalia.
26		W231	Casmalia Hills, 1.6 miles northwest of Shuman.
27		W236	Casmalia Hills, 1¾ miles northwest of Shuman.
28		W241	Casmalia Hills, 1¼ miles west of Shuman.
29		W189	Casmalia Hills, ¾ mile northwest of Shuman.
30		W323	Casmalia Hills, 2.6 miles southeast of Shuman.
31	14894	W341	Casmalia Hills, 2½ miles east of Casmalia.
			Tinaquaic sandstone member
32	15000	R398	South of Foxen Canyon, 1.4 miles southeast of Fremont-Foxen Monument.
32*a*	14999	R397	South of Foxen Canyon, 175 feet up arroyo from locality 32. Float phosphatic molds. Not plotted.
32*b*	15007	R399	South of Foxen Canyon, 650 feet up arroyo from locality 32, about 10 feet lower stratigraphically. Not plotted.
32*c*	15012	R421	South of Foxen Canyon, 350 feet north-northeast of locality 32, at about same horizon. Not plotted.
33	15011	R416	South of Foxen Canyon, 1.8 miles southeast of Fremont-Foxen Monument.
34		R385a	South of Foxen Canyon, 1,250 feet up arroyo from locality 33.
35	14998	R385	South of Foxen Canyon, 3,800 feet northeast of locality 33.
36	15008	R403	South of Foxen Canyon, 2.5 miles southeast of Fremont-Foxen Monument.
36*a*	15010	R403b	Float about 25 feet stratigraphically below locality 36. Not plotted.
37		R394	South of Foxen Canyon, 2. 6 miles southeast of Fremont-Foxen Monument. Not collected.
38	14997	R372	South of Foxen Canyon, 3. 4 miles southeast of Fremont-Foxen Monument.
39		R294a	South of Foxen Canyon, 3. 6 miles southeast of Fremont-Foxen Monument. Collection lost. Not plotted; immediately east of mapped area.
39*a*	14993	R294b	Same locality, about 35 feet lower stratigraphically. Not plotted.
39*b*	14995	R294c	About 250 feet southeast of locality 39*a* at about same horizon. Not plotted.
39*c*	14996	R294d	Same locality, float about 15 feet lower stratigraphically. Not plotted.
40	14938	SR4	Sisquoc Ranch, 1, 050 feet southeast of Union Oil Co. Sisquoc No. 1 core hole
41	14939	SR6	Sisquoc Ranch, 1, 050 feet east-northeast of Union Oil Co. Sisquoc No. 1 core hole.
42	14940	SR7	Sisquoc Ranch, 200 feet north-northeast of locality 41. Not plotted.
43	14941	SR8	Sisquoc Ranch, 1, 250 feet northeast of Union Oil Co. Sisquoc No. 1 core hole.
44	14942	SR9	Sisquoc Ranch, 1, 400 feet northeast of Union Oil Co. Sisquoc No. 1 core hole.
45	14943	SR12	Sisquoc Ranch, 350 feet southeast of locality 46. Not plotted.
46	14944	B526	Sisquoc Ranch, 1, 950 feet north of Union Oil Co. Sisquoc No. 1 core hole.

Fossil localities—Continued

Number used in this report	Permanent Geological Survey No.	Field No.	Description of locality
			MIOCENE AND PLIOCENE SERIES—Continued
			Sisquoc formation—Continued
			Tinaquaic sandstone member—Continued
47	14960	B528	Sisquoc Ranch, ravine near Sisquoc River, 3. 6 miles east-southeast of mouth of Foxen Canyon.
48	14870	W4	Sisquoc River, 3. 2 miles east-southeast of mouth of Foxen Canyon.
49	14871	W4b	Sisquoc River, 3. 6 miles east-southeast of mouth of Foxen Canyon.
50	14872	W4c	Sisquoc River, 3. 8 miles east-southeast of mouth of Foxen Canyon.
51	14962	B540	Sisquoc Ranch, 600 feet south of locality 52.
52	14965	B543	Sisquoc River, 4 miles east-southeast of mouth of Foxen Canyon.
53	14961	B535	Sisquoc River, 4. 1 miles east-southeast of mouth of Foxen Canyon.
			Diatomaceous strata and equivalent somewhat porcelaneous mudstone.
54	14886	W126	Casmalia Hills, 1. 1 miles west of Waldorf.
55	14881	W53	Casmalia Hills, 0. 9 mile southwest of Waldorf.
56	14878	W7	Casmalia Hills, NTU mine, 2. 4 miles northwest of Shuman.
57		W171	Casmalia Hills, R. R. cut ½ mile northeast of Shuman.
57*a*		W171a	Same locality, 15 feet higher stratigraphically. Not plotted.
57*b*		W171b	Same locality, 25 feet stratigraphically above locality 57*a*. Not plotted.
58	14891	W309	Casmalia Hills, 0.8 mile southeast of Shuman.
59	14898	W433	Casmalia Hills, 1.7 miles southeast of Shuman.
60		W374	Casmalia Hills, road cut 1¾ miles east-southeast of Casmalia.
61	14895	W372	Casmalia Hills, 1.8 miles east of Casmalia.
62		W340	Casmalia Hills, 2.7 miles east-southeast of Casmalia.
63	14893	W339	Casmalia Hills, 2.9 miles east-southeast of Casmalia.
64	14892	W333	Casmalia Hills, 3 miles east of Casmalia.
65	14900	W555	Graciosa Ridge, 2.1 miles southeast of Orcutt.
66		W592	Graciosa Ridge, 2¼ miles southeast of Orcutt, 900 feet west of Union Oil Co Pinal No. 26 well.
67	14904	W585	Graciosa Ridge, 2.1 miles southeast of Orcutt.
68	14905	W587	Graciosa Ridge, 2.6 miles southeast of Orcutt.
69	14907	W589	Graciosa Ridge, 2.7 miles southeast of Orcutt.
70	14906	W588	Graciosa Ridge, 2.8 miles southeast of Orcutt. Not plotted.
71	14908	W597	Graciosa Ridge, 3 miles southeast of Orcutt, 100 feet northwest of Union Oil Co. Kaiser No. 3 well. Not plotted.
72	14901	W578	Graciosa Ridge, 3.1 miles southeast of Orcutt.
73	14902	W579	Graciosa Ridge, 3.2 miles southeast of Orcutt. Dump of Pennsylvania asphalt mine. Not plotted.
73*a*	14903	W579a	Graciosa Ridge, 3.2 miles southeast of Orcutt. Dump of Pennsylvania asphalt mine, 150 feet southeast of locality 73. Not plotted.
74	14912	W690	Graciosa Ridge, 3.9 miles southeast of Orcutt, ravine 400 feet southwest of Union Oil Co. Newlove No. 37 well.
75	15021	R256	Solomon Hills, 3 miles north of Los Alamos.
75*a*	15029	R256b	Same locality, 75 feet down canyon. Not plotted.
75*b*	15022	R256c	Same as locality 75a, 7 feet lower stratigraphically. Not plotted.
76	15026	R136	Solomon Hills, 3.8 miles north of Los Alamos.
76*a*	15017	R136a	Same locality, a foot to 2 feet lower stratigraphically. Not plotted.
77	15024	R275	Gato Ridge, Howard Canyon-Cat Canyon road, 0.1 mile north of summit.
78	15030	R279	Gato Ridge, Howard Canyon-Cat Canyon road, half a mile north of summit.
79	15031	R284	Gato Ridge, Howard Canyon-Cat Canyon road, 0.7 mile north of summit.
80	14874	R250b	Gato Ridge, cut on road to Barnsdall Oil Co. lease, 900 feet north of junction with Howard Canyon road.
81	15025	R454	Gato Ridge, 0.5 mile southeast of summit of Howard Canyon-Cat Canyon road.
82	15032	R317	Gato Ridge, 0.9 mile east-northeast of summit of Howard Canyon-Cat Canyon road.
83	15023	R259	Gato Ridge, 0.8 mile southeast of summit of Howard Canyon-Cat Canyon road.
84	15016	R81	Solomon Hills, Canada Arena, 3.3 miles northeast of Los Alamos, 450 feet south of Pinal Dome Oil Co. Wickenden No. 1 well.
85	15020	R205	Solomon Hills, 3.4 miles northeast of Los Alamos, 900 feet southeast of Pinal Dome Oil Co. Wickenden No. 1 well.
86	15027	R230	Solomon Hills, 3.3 miles northeast of Los Alamos, 300 feet northeast of Barnsdall Oil Co. Pezzoni No. 2 well.
87	15018	R189	Solomon Hills, 4.1 miles northeast of Los Alamos, 2,100 feet west-southwest of General Petroleum Corp. Wickenden No. 1 well.
88		R188	Solomon Hills, 850 feet northeast of locality 87.
89	15019	R229	Solomon Hills, 5.4 miles northeast of Los Alamos, 2,950 feet east-southeast of General Petroleum Corp. Giorgi No. 1 well.
90	15033	R418	South of Foxen Canyon, 1.2 miles south-southeast of Fremont-Foxen Monument.
91	15036	R391	South of Foxen Canyon, 2.1 miles southeast of Fremont-Foxen Monument. Phosphatic molds.
92	14963	B542	Sisquoc Ranch, 2.7 miles northeast of Fremont-Foxen Monument.
92*a*	14964	B542a	South of Sisquoc River, 25 feet stratigraphically below locality 92. Not plotted.

Fossil localities—Continued

Number used in this report	Permanent Geological Survey No.	Field No.	Description of locality
			MIOCENE AND PLIOCENE SERIES—Continued
			Sisquoc formation—Continued
			Diatomaceous strata and equivalent somewhat porcelaneous mudstone—Continued
93		B339	Purisima Hills, San Antonio Valley road, 4 miles west-northwest of Harris.
94	14958	B292	Purisima Hills, 2.2 miles southwest of Harris.
95	14869	W3	Purisima Hills, summit of Harris-Lompoc highway.
96		B185a	Purisima Hills, 0.8 mile south-southwest of Harris.
97	14950	B191a	Purisima Hills, 2.5 miles southeast of Harris.
98	14948	B60	Purisima Hills, 2.5 miles southeast of Careaga.
99		B32	Purisima Hills, 2¾ miles southwest of Los Alamos.
99*a*			Same locality, 35 feet higher stratigraphically. Not plotted.
100	14947	B34	Purisima Hills, 2.7 miles southwest of Los Alamos.
101	14967	B769	Purisima Hills, 3.6 miles southwest of Los Alamos, 150 feet west of O. C. Fields Gasoline Corp. Santa Rita No. 1 well.
102		B824	Purisima Hills, 2.6 miles south of Los Alamos.
103		B804	Purisima Hills, Drum Canyon road, 3.2 miles south of Los Alamos.
104		B800	Purisima Hills, Drum Canyon road, 3.8 miles south of Los Alamos.
105		B799	Purisima Hills, Drum Canyon road, 4.3 miles south of Los Alamos.
106		B819	Purisima Hills, Drum Canyon road, 1.6 miles south of Los Alamos.
107		B970	Purisima Hills, 1¾ miles southeast of Los Alamos.
108		B972	Purisima Hills, 2.4 miles southeast of Los Alamos.
109		B957	Purisima Hills, a mile northeast of Redrock Mountain.
111		B958	Purisima Hills, 550 feet southeast of locality 110.
112		B941	Purisima Hills, 0.7 mile southeast of Redrock Mountain.
113	14867	B940	Crest of Purisima Hills, a mile southeast of Redrock Mountain.
113*a*	14868	B940a	Crest of Purisima Hills, 200 feet southeast of locality 113. Not plotted.
113*b*	14969	B940b	600 feet N 60° W. from locality 113. Not plotted.
114		B942	Purisima Hills, 1.7 miles southeast of Redrock Mountain.
115		B924	Purisima Hills, 2.7 miles southeast of Redrock Mountain. Not plotted; immediately south of mapped area.
116		B961	Purisima Hills, a mile east-northeast of Redrock Mountain.
117	14971	B968	Purisima Hills, 1.4 miles northeast of Redrock Mountain.
118	14970	B967	Purisima Hills, 1.6 miles east-northeast of Redrock Mountain.
119		B966	Purisima Hills, 1.500 feet southeast of locality 118.
120		B975	Purisima Hills, 4 miles southeast of Los Alamos.
122	14951	B238	Purisima Hills, 4.8 miles southeast of Los Alamos, 3,000 feet northeast of Whittier Associates Barham No. 1 well.
123	14952	B239	Purisima Hills, 750 feet southwest of locality 122.
125	14956	B256	Purisima Hills, 1,600 feet southeast of locality 124.
126		B974	Purisima Hills, 1,700 feet southwest of locality 125.
127		B905	Purisima Hills, 3.6 miles east-southeast of Redrock Mountain.
128		B848a	Purisima Hills, 4.1 miles east-southeast of Redrock Mountain.
129	14953	B244a	Purisima Hills, 6 miles southeast of Los Alamos.
130	14954	B246a	Purisima Hills, 1,750 feet southeast of locality 129.
131		B247	Purisima Hills, 1,200 feet southwest of locality 130.
132	14955	B254	Purisima Hills, 2,900 feet east-southeast of locality 130.
133		B282	Purisima Hills, 3,100 feet southeast of locality 132.
			PLIOCENE SERIES
			Foxen mudstone
134	14885	W79	Casmalia Hills, 0.9 mile west-northwest of Waldorf.
135		W66	Casmalia Hills, 0.6 mile southwest of Waldorf. Not collected.
136	14882	W57	Casmalia Hills, 300 feet southeast of locality 135. Not plotted.
137		W50	Casmalia Hills, 1.1 miles south-southwest of Waldorf.
138	14889	W227	Casmalia Hills, 1.3 miles south-southeast of Waldorf.
139	14879	W40	Casmalia Hills, dump at abandoned Waldorf asphalt mine, 1.1 miles southeast of Waldorf.
140		W46	Casmalia Hills, 1.1 miles south-southwest of Waldorf.
141	15002	W29	Casmalia Hills, 700 feet east of locality 140.
142	14888	W200a	Casmalia Hills, 1.4 miles northwest of Shuman.
143	15001	W17	Casmalia Hills, 1.1 miles northwest of Shuman.
144	14876	W16	Camaslia Hills, 1.1 miles northwest of Shuman. Slide material.
145		W21a	Casmalia Hills, 0.7 mile north-northwest of Shuman, 165 feet above base of formation.
145*a*			Same locality, 30 feet higher stratigraphically. Not plotted.
145*b*			Same locality, 277 feet above base of formation. Not plotted.
145*c*			Same locality, 365 to 372 feet above base of formation. Not plotted.
146	14877	W20	Casmalia Hills, 700 feet north-northeast of locality 145.
147	14934		Casmalia Hills, railroad cut 0.8 mile northeast of Shuman.
148	14896	W377	Casmalia Hills, 0.8 mile northeast of Shuman. Between railroad and old highway.
149	14897	W404	Casmalia Hills, 1.3 miles east-southeast of Shuman.

Fossil localities—Continued

Number used in this report	Permanent Geological Survey No.	Field No.	Description of locality
			PLIOCENE SERIES—Continued
			Foxen mudstone—Continued
150	14899	W534	Casmalia Hills, 1.7 miles northwest of junction of Orcutt-Lompoc highway and road to Shell Oil Co. Careaga lease.
151		B338	Purisima Hills, San Antonio Valley road, 3.6 miles west-northwest of Harris.
152		B319	Purisima Hills, 2.6 miles southwest of Harris.
153		B317	Purisima Hills, 1,350 feet east-southeast of locality 152.
154		B312	Purisima Hills, 550 feet southeast of locality 153.
155		PH3	Purisima Hills, Orcutt-Lompoc highway, 1.6 miles south-southwest of Harris.
156		PH4+80	Purisima Hills, Orcutt-Lompoc highway, 300 feet south of locality 155.
156*a*		PH4+130	Same locality, 50 feet higher stratigraphically. Not plotted.
156*b*			Same locality, 70 feet stratigraphically above locality 156. Not plotted.
157		B4a	Purisima Hills, 2.1 miles south of Careaga.
158		B62	Purisima Hills, 2.3 miles southeast of Careaga.
159		B783	Purisima Hills, 3 miles southeast of Careaga.
160		B36	Purisima Hills, 2¾ miles southwest of Los Alamas.
161		B100	Purisima Hills, 1.6 miles southwest of Los Alamos.
162	14966	B762a	Purisima Hills, 4.6 miles south-southwest of Los Alamos, a mile west of Drum Canyon road.
			Careaga sandstone
			Cebada fine-grained member
163	14634	W44	Casmalia Hills, 0.9 mile south of Waldorf.
164	14633	W40a	Casmalia Hills, 1.1 mi. southeast of Waldorf, 150 feet southwest of locality 139 (dump of Waldorf mine). Not plotted.
165	14631	W33a	Casmalia Hills, 1.4 miles southeast of Waldorf.
166	14630	W32	Casmalia Hills, 225 feet south of locality 165. Not plotted.
167	14629	W26	Casmalia Hills, 1.7 miles northwest of Shuman.
168	14628	W25b	Casmalia Hills, 1.5 miles northwest of Shuman.
169	14627	W19	Casmalia Hills, 150 feet north of locality 146. Not plotted.
170	14608	W-83	Casmalia Hills, west side of railroad cut, 0.9 mile northeast of Shuman, bed 3 of section.
171	14647	W622	Graciosa Ridge, 600 feet west-southwest of Union Oil Co. Newlove No. 9 well.
172	14649	W660	Graciosa Ridge, 450 feet south-southwest of Union Oil Co. Graciosa No. 3 well.
173	14650	W663	Graciosa Ridge, 350 feet east-northeast of Union Oil Co. Harris No. 2 well.
174	14654	W728	Solomon Hills, 2.5 miles east of junction of Orcutt-Lompoc highway and road to Shell Oil Co. Careaga lease.
175	14652	W667	Solomon Hills, east-flank of Mount Solomon anticline, half a mile north-northeast of Mount Solomon.
176	14653	W683	Solomon Hills, west flank of Mount Solomon anticline, half a mile southeast of Mount Solomon.
177	14648	W624	Graciosa Ridge, 3.7 miles southeast of Orcutt, 1,000 feet northwest of Union Oil Co. Newlove No. 42 well.
178	14768	FP1	Fugler Point, 1.1 miles north of Garey, 4-foot fossil bed at southeast end of bluff. Not plotted.
178*a*	14769	FP2	Fugler Point, below 4-foot fossil bed, southeast of brachipod bed. May include some specimens weathered out of 4-foot bed. Not plotted.
178*b*	14770	FP3	Fugler Point, brachiopod bed. Not plotted.
178*c*	14771	FP4	Fugler Point, below brachipod bed. Not plotted.
179	14655	R1a	Solomon Hills, 4.3 miles northwest of Los Alamos, 1,400 feet northwest of Pacific Western Oil Corp. Los Alamos No. 18 well.
180	14664	R122	Solomon Hills, 4.3 miles north-northwest of Los Alamos, 2,600 feet east-northeast of Pacific Western Oil Corp. Los Alamos No. 26 well.
180*a*	14665	R123	Solomon Hills, 185 feet southeast of locality 180. Not plotted.
181	14677	R215	Solomon Hills, 4.6 miles north-northwest of Los Alamos, 3,200 feet northeast of Pacific Western Oil Corp. Los Alamos No. 26 well.
182	14671	R132	Solomon Hills, 3.6 miles north of Los Alamos.
183	14989	R137b	Solomon Hills, 0.6 miles north-northeast of summit of Howard Canyon-Cat Canyon road.
184	14669	R128	Gato Ridge, 0.4 mile northeast of summit of Howard Canyon-Cat Canyon road.
185	14672	R133	Gato Ridge, 0.3 mile east of summit of Howard Canyon-Cat canyon road.
186	14658	R85	Solomon Hills, 2.7 miles north-northeast of Los Alamos.
187	14992	R610	Solomon Hills, 4.2 miles east-northeast of Los Alamos, 1,400 feet northwest of General Petroleum Corp. Wickenden No. 2 well.
188	14660	R93	Solomon Hills, 4.9 miles east-northeast of Los Alamos, 1,600 feet east-northeast of General Petroleum Corp. Wickenden No. 1 well.
189	14659	R92	Solomon Hills, 5.1 miles east-northeast of Los Alamos, 2,350 feet east-northeast of General Petroleum Corp. Wickenden No. 1 well.
190	15037	R575	Ravine on north side of Foxen Canyon, 1,500 feet west-northwest of Fremont-Foxen Monument. Not plotted.
191	15005	R574	Foxen Canyon road, 1,700 feet west of Fremont-Foxen Monument.
192	14743	B179	Purisima Hills, 1.7 miles southeast of Harris.

Fossil localities—Continued

Number used in this report	Permanent Geological Survey No.	Field No.	Description of locality
			PLIOCENE SERIES—Continued
			Careaga sandstone—Continued
			Cebada fine-grained member—Continued
192*a*	14744	B180	Purisima Hills, 1.7 miles south-southeast of Harris, 300 feet northeast of locality 192. Not plotted.
193	14742	B174a	Purisima Hills, 2.4 miles southwest of Careaga. Not plotted. Same as locality 227a, but 10 feet lower stratigraphically.
194	14738	B166	Purisima Hills, 2.3 miles southwest of Careaga.
			Graciosa coarse-grained member
195	14635	W60a	Casmalia Hills, half a mile southwest of Waldorf.
196	14609	W83a	Casmalia Hills, west side of railroad cut, 0.9 mile northeast of Shuman, fossiliferous lens in bed 5. Not plotted; see locality 170.
196*a*	14610	W83b	Same locality, east side of railroad cut, fossiliferous lens in bed 5 of section. Not plotted.
196*b*	14611	W83c	Same locality, west side of railroad cut, bed 7 of section. Not plotted.
196*c*	14612	W83d	Same locality, west side of railroad cut, bed 9 of section. Not plotted.
197	14645	W553	Graciosa Ridge, 2.2 miles southeast of Orcutt, 650 feet west of Union Oil Co. Pinal No. 16 well.
198	14613	W567	Graciosa Ridge, 2.8 miles southeast of Orcutt, 700 feet southeast of Union Oil Co. Folsom No. 4 well.
199	14614	W568	Graciosa Ridge, 2.9 miles southeast of Orcutt, road cut, 300 feet southeast of Union Oil Co. Folsom No. 3 well.
200	14615	W570	Graciosa Ridge, 3 miles southeast of Orcutt, 350 feet west of Union Oil Co. Newlove No. 18 well.
201	14616	W598	Graciosa Ridge, 3 miles southeast of Orcutt, road cut, 200 feet south-southeast of Union Oil Co. Pinal No. 24 well.
202	14646	W600	Graciosa Ridge, 2.5 miles southeast of Orcutt, bottom of arroyo, 700 feet southwest of Union Oil Co. Squires No. 3 well.
203	14617	W601	Graciosa Ridge, 2.7 miles southeast of Orcutt, west side of canyon, 700 feet southwest of Union Oil Co. Squires No. 7 well.
204	14618	W603	Graciosa Ridge, 2.7 miles southeast of Orcutt, east side of canyon, 350 feet southwest of Union Oil Co. Squires No. 7 well.
205	14619	W606	Graciosa Ridge, 3 miles southeast of Orcutt, west side of canyon, 600 feet south-southwest of Union Oil Co. Folsom No. 7 well.
206	14620	W608	Graciosa Ridge, 3.1 miles southeast of Orcutt, east side of canyon, 1,000 feet southeast of Union Oil Co. Folson No. 7 well.
207	14621	W609	Graciosa Ridge, 3.3 miles southeast of Orcutt, abandoned road on west side of canyon, 800 feet southwest of Union Oil Co. Newlove No. 7 well.
208	14622	W611	Graciosa Ridge, 3.4 miles southeast of Orcutt, edge of slump on west side of canyon, 200 feet west-southwest of Union Oil Co. Newlove No. 30 well.
209	14651	W666	Graciosa Ridge, 2.6 miles northeast of junction of Orcutt-Lompoc highway and road to Shell Oil Co. Careaga lease, 50 feet north of road to Shell Oil Co. Careaga lease.
210		W726	Solomon Hills, Careaga ranch, 2.7 miles east-northeast of junction of Orcutt-Lompoc highway and road to Shell Oil Co. Careaga lease.
211	15040	R18	Solomon Hills, 3.5 miles northwest of Los Alamos, 2,950 feet south-southeast of Pacific Western Oil Corp. Los Alamos No. 18 well.
212	14666	R125	Solomon Hills, 4.3 miles north-northwest of Los Alamos.
213	14663	R114	Solomon Hills, 4 miles north-northwest of Los Alamos.
214	14670	R130a	Solomon Hills, 3.6 miles north of Los Alamos.
214*a*	14724	R130b	Same locality, about 20 feet lower stratigraphically. Not plotted.
215	14662	R107a	Solomon Hills, 2.6 miles north of Los Alamos, east side of canyon west of Howard Canyon.
215*a*	14723	R107b	Same locality, loose blocks lower on slope.
216	14656	R27a	Solomon Hills, 2.6 miles north-northeast of Los Alamos.
216*a*	14722	R27d, c	Same locality, loose blocks on slope.
217	14661	R101	Solomon Hills, 2.5 miles north-northeast of Los Alamos.
218	14988	R137a	Solomon Hills, 0.6 mile north-northeast of summit of Howard Canyon road. Not plotted. Same as locality 183, but from Graciosa member.
219	14668	R127	Gato Ridge, 0.3 mile northeast of summit of Howard Canyon-Cat Canyon road.
220	15004	R128a	Gato Ridge, 0.4 mile northeast of summit of Howard Canyon-Cat Canyon road. Not plotted. Same as locality 184, but from Graciosa member.
221	14657	R78	Solomon Hills, 3 miles northeast of Los Alamos.
222	15006	R512	North side of Cat Canyon, 1.6 miles northwest of summit of Howard Canyon-Cat Canyon road.
223	14990	R511	North side of Cat Canyon, 1.5 miles northeast of summit of Howard Canyon-Cat Canyon road.
224	14679	R331	Foxen Canyon, loose block along road, 0.6 mile west-northwest of Fremont-Foxen Monument.
225	14746	B201	Purisima Hills, 1.2 miles south-southwest of Harris.
226	14745	B181	Purisima Hills, 1.8 miles southeast of Harris.
227	14735	B23	Purisima Hills, 2.1 miles southwest of Careaga.
227*a*	14741	B174	Purisima Hills, 2.4 miles southwest of Careaga, 1,000 feet southwest of locality 227.

Fossil localities—Continued

Number used in this report	Permanent Geological Survey No.	Field No.	Description of locality
			PLIOCENE SERIES—Continued
			Careaga sandstone—Continued
			Graciosa coarse-grained member—Continued
228	14945	B22	Purisima Hills, 2 miles southwest of Careaga. Top of Graciosa or base of Paso Robles.
229	14734	B19	Purisima Hills, 2 miles southwest of Careaga, 2,050 feet southeast of locality 227.
230	14736	B24	Purisima Hills, 2 miles southwest of Careaga, 1,800 feet southeast of locality 229.
230*a*	14737	B24a	Same locality, 15 feet lower stratigraphically. Not plotted.
231		B53	Purisima Hills, 2 miles southeast of Careaga.
231*a*		B7a	Purisima Hills, 1.8 miles southeast of Careaga. Float near top of member.
232	14747	B241	Purisima Hills, 5.7 miles southeast of Los Alamos.
233	14748	B243	Purisima Hills, 6.2 miles southeast of Los Alamos.
234	14752	B748	Purisima Hills, 2.8 miles southeast of Harris.
234*a*	14753	B748a	Same locality, 50 feet lower stratigraphically. Not plotted.
235	14750	B743a	Purisima Hills, 3 miles north-northeast of Mission La Purisima.
235*a*	14751	B743	Same locality, about 10 feet higher stratigraphically. Not plotted.
			Undifferentiated Careaga sandstone
236	14626	W10	Casmalia Hills, abandoned quarry a mile northeast of Shuman.
237	14637	W455	Casmalia Hills, 1.8 miles west-southwest of Orcutt.
238	14636	W437	Casmalia Hills, 750 feet southeast of locality 237.
239	14638	W463	Casmalia Hills, 1.4 miles southwest of Orcutt.
240	14639	W477	Casmalia Hills, 1.5 miles southwest of Orcutt, 1,000 feet south of locality 239.
241	14640	W495	Casmalia Hills, 2.2 miles south-southwest of Orcutt, 1,300 feet west of Orcutt-Lompoc Highway.
241*a*	14641	W496	Casmalia Hills, 300 feet east of locality 241. Not plotted.
242	14642	W517	Casmalia Hills, 2.6 miles northwest of junction of Orcutt-Lompoc highway and road to Shell Oil Co. Careaga lease.
243	14643	W527	Casmalia Hills, 2.1 miles northwest of junction of Orcutt-Lompoc highway and road to Shell Oil Co. Careaga lease.
244	15057	L199	Casmalia Hills, a mile northwest of junction of Orcutt-Lompoc highway and road to Shell Oil Co. Careaga lease.
245	15056	L192	Casmalia Hills, 3.1 miles west of junction of Orcutt-Lompoc highway and road to Shell Oil Co. Careaga lease.
246	14749	B330	San Antonio Valley road, 3.1 miles west-northwest of Harris.
247	14754	B935	Crest of Purisima Hills, 0.8 mile southeast of Redrock Mountain.
			PLIOCENE AND PLEISTOCENE(?) SERIES
			Paso Robles formation
248	14884	W77	Casmalia Hills, ¾ mile west-northwest of Waldorf.
249	14883	W63	Casmalia Hills, 0.3 mile west-southwest of Waldorf.
250		W155	Casmalia Hills, 1.4 miles southeast of Waldorf.
251		W148	Casmalia Hills, 1.7 miles southeast of Waldorf.
252			Casmalia Hills, 1,000 feet south of locality 251.
253	14887	W140	Casmalia Hills, railroad cut 1.2 miles north-northeast of Shuman.
254		R5	Solomon Hills, 4.7 miles northwest of Los Alamos. Float.
255	14947	B48	Purisima Hills, 3 miles west-southwest of Los Alamos.
			PLEISTOCENE SERIES
			Orcutt sand
256	14959	B295	Purisima Hills, 1.9 miles southwest of Harris.
257	14949	B188	Purisima Hills, 1.6 miles south of Harris.
			Marine deposits on marine terraces
258	15053	Sta 13	South slope of Mount Lospe, canyon 0.6 mile southwest of Mount Lospe, altitude 880 feet. Not plotted; same locality as locality 8.
259	15055	L15	South slope of Mount Lospe, half a mile south-southwest of Mount Lospe.
260	15054	L1	South slope of Mount Lospe, 0.9 mile south-southeast of Mount Lospe.
261			South slope of western Casmalia Hills, 2.1 miles east-southeast of Lions Head, altitude 600 feet.
262	14966	W853	Canyon ½ mile southeast of Point Sal Landing, 100 feet inland, altitude 40 feet.
263	15052	W831	Rear of lowest terrace, on east side of first canyon southeast of Lions Head, 900 feet inland, altitude 115 feet.

PLATES 7–23

PLATE 7

[Figures natural size unless otherwise specified]

Figures 1, 5. *Siliqua* cf. *S. media* (Sowerby)

1. Mold of right valve. Length (practically complete) 46.5 mm., height 20.5 mm. Locality 36. U. S. Nat. Museum 560018.
5. Cast of interior of right valve. Length 49.5 mm., approximate height 23 mm. Locality 40. U. S. Nat. Museum 560019.

2. *Cryptomya* cf. *C. californica* (Conrad). Right valve of paired mold retaining some shell material. Length 25.7 mm. height 17.8 mm., diameter (both valves) 10 mm. Locality 50. U. S. Nat. Museum 560017.

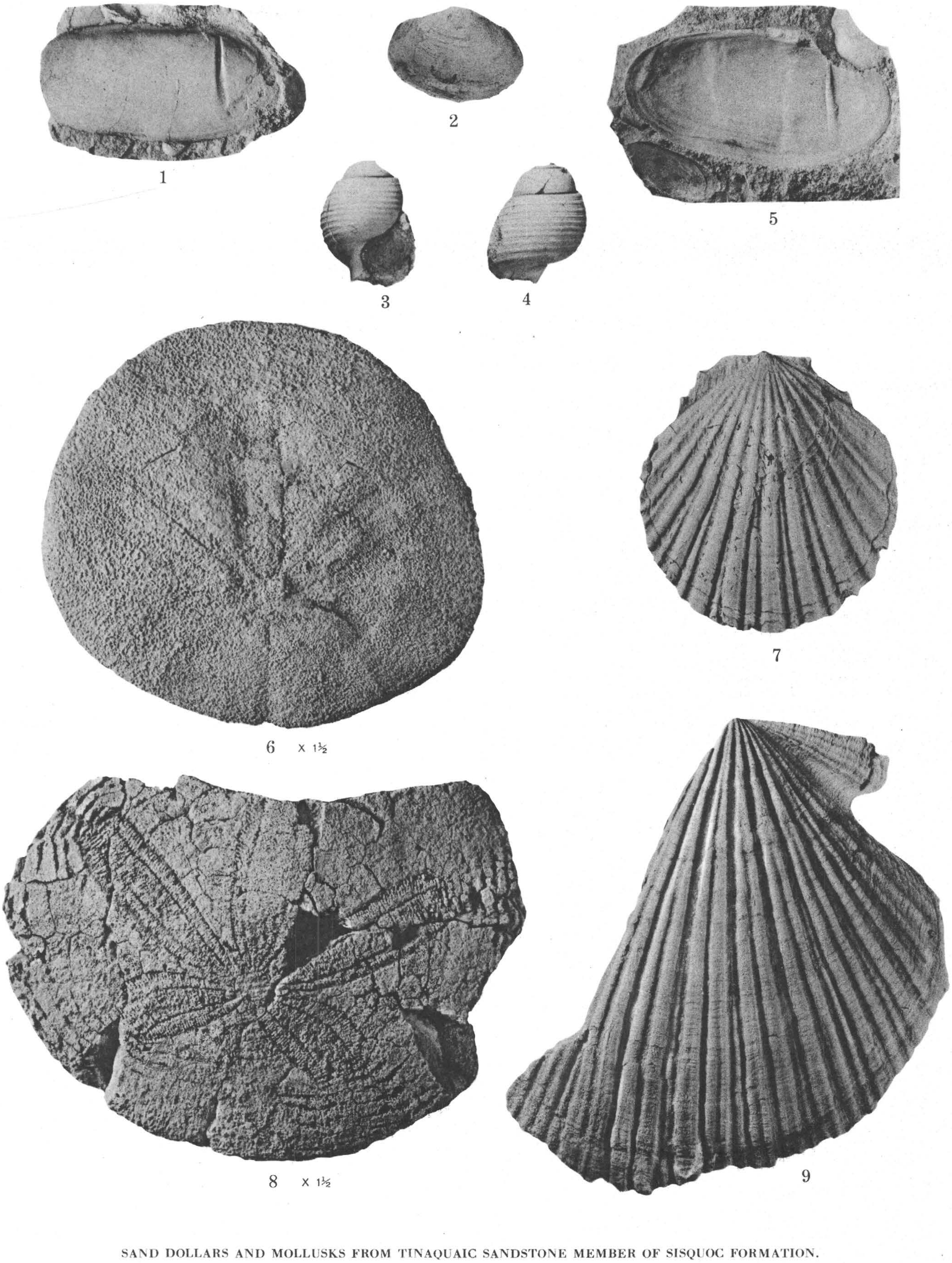
3, 4. "*Nassa*" sp. Phosphatized mold. Length (incomplete) 23.8 mm., width 18 mm. Locality 38. U. S. Nat. Museum 560014.

6, 8. *Dendraster* cf. *D. coalingaensis* Twitchell.

6. Length 50 mm., width 56.2 mm., height 6.7 mm. Locality 51. U. S. Nat. Museum 560013.
8. Length (incomplete) 51.5 mm., width (incomplete) 65 mm., approximate height 10.5 mm. Locality 43. U. S. Nat. Museum 560012.

7, 9. *Patinopecten lohri* (Hertlein).

7. Small left valve. Length 49.5 mm., height 52 mm., diameter 10.5 mm. Locality 52. U. S. Nat. Museum 560016.
9. Incomplete right valve. Length (incomplete) 81 mm., height 93.5 mm., approximate diameter 18 mm. Locality 53. U. S. Nat. Museum 560015.



SAND DOLLARS AND MOLLUSKS FROM TINAQUAIC SANDSTONE MEMBER OF SISQUOC FORMATION.

PLATE 8

[Figures natural size unless otherwise specified]

Figures 1, 2. *Yoldia gala* Woodring, n. sp.

1. Mold of left valve. Length 14.3 mm., height 7 mm., approximate diameter 2.5 mm. Locality 83. U. S. Nat. Museum 560027.
2. Type, mold of right valve. Length 25.5 mm., height 11 mm., approximate diameter 3 mm. Locality 85. U. S. Nat. Museum 560024.

3, 4, 9. *Crepidula princeps* Conrad.

3. Apical fragment showing hidden face of deck. Length (incomplete) 25.5 mm., width (incomplete) 27.8 mm., height (incomplete) 16 mm. Locality 113b. U. S. Nat. Museum 560021.

4, 9. Length (incomplete) 51.5 mm., width 34 mm., height 21 mm. Locality 56. U. S. Nat. Museum 560020.

5, 7, 8, 13. *Saccella orcutti* (Arnold). Locality 73. U. S. Nat. Museum 560023.

5. Elongate left valve. Length 11.9 mm., height 7 mm., diameter 3.2 mm.
7. Left valve of short paired specimen. Length 11 mm., height 7.5 mm., diameter (both valves) 6.8 mm.
8. Left valve of small coarsely sculptured paired specimen. Length 7.5 mm., height 4.8 mm., diameter (both valves) 3.7 mm.
13. Weakly sculptured small left valve. Length 6.5 mm., height 4.2 mm., diameter 2 mm.

6. *Pholadidea penita* (Conrad). Right valve of paired specimen. Length (almost complete) 78 mm., height 41.8 mm., diameter (both valves) 42 mm. U. S. Geol. Survey locality 4472, Pennsylvania asphalt mine. U. S. Nat. Museum 560039.

10, 11. *Macoma* n. sp.? Right (fig. 10) and left (fig. 11) valves of paired specimen. Length 73 mm., height (not quite complete) 43.5, approximate diameter (both valves) 21.5 mm. Locality 92. U. S. Nat. Museum 560038.

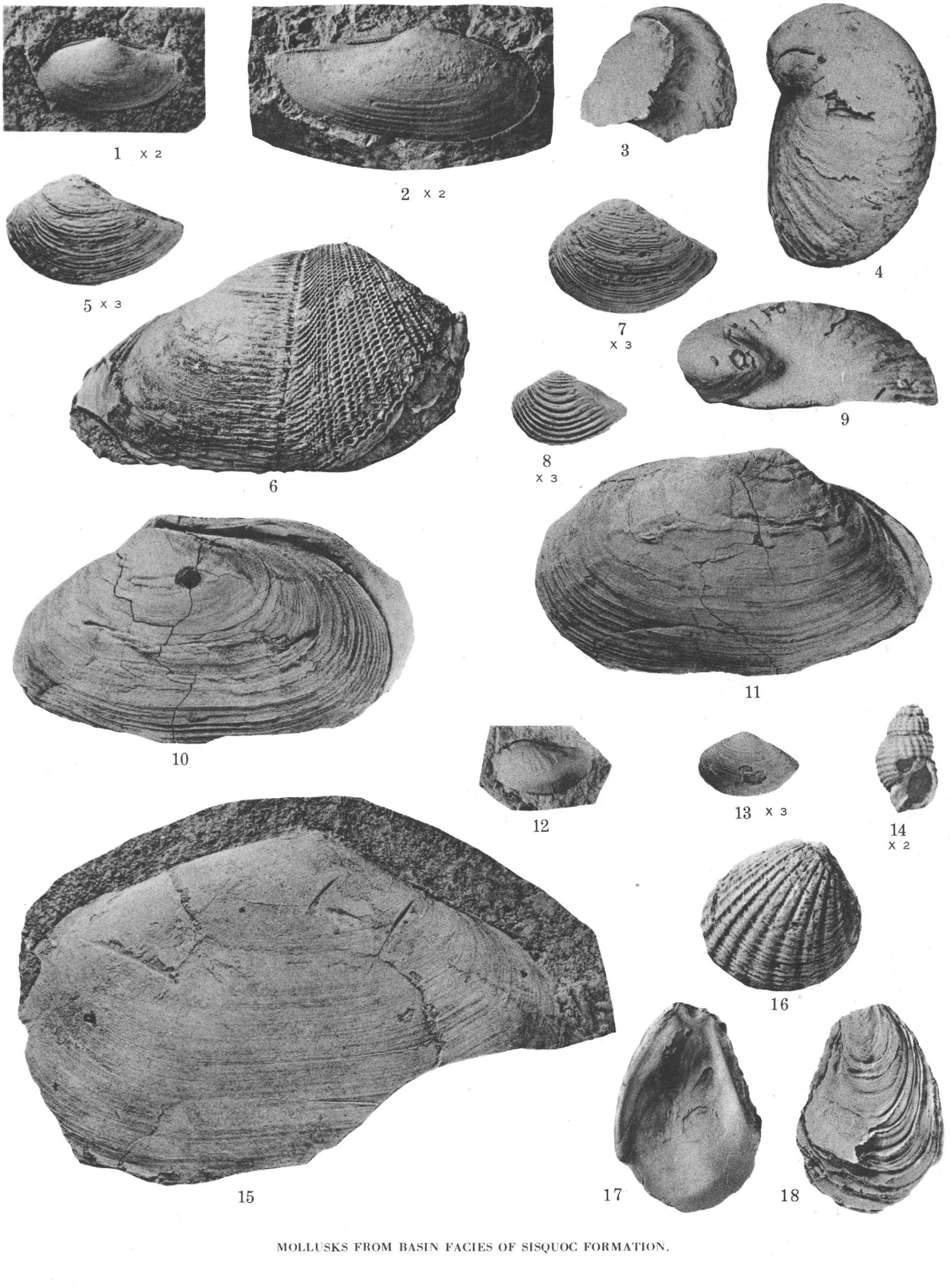
12. *Pandora* cf. *P. filosa* (Carpenter). Mold of interior of left valve. Length 19.2 mm., height 10 mm., approximate diameter 3 mm. Locality 85. U. S. Nat. Museum 560040.

14. "*Nassa*" *waldorfensis* Arnold. Length (incomplete) 10.6 mm., width 6 mm. Locality 56. U. S. Nat. Museum 560022.

15. *Tellina* cf. *T. lutea* Gray. Mold of incomplete left valve. Length (incomplete) 107 mm., height (incomplete) 63 mm. Locality 82. U. S. Nat. Museum 560037.

16. *Cyclocardia californica* (Dall). Right valve of exceptionally large paired specimen. Length 29.3 mm., height 27.7 mm., diameter (both valves) 20.5 mm. Locality 56. U. S. Nat. Museum 560036.

17, 18. *Ostrea erici* Hertlein. Small right valve. Length 28.3 mm., height 39.8 mm., diameter 5.5 mm. Locality 73a. U. S. Nat. Museum 560035.



MOLLUSKS FROM BASIN FACIES OF SISQUOC FORMATION.

PLATE 9

[Figures natural size unless otherwise specified]

Figures 1, 3, 4. *Ostrea erici* Hertlein.

1. Left valve. Length 43 mm., height 56.7 mm., diameter 19 mm. U. S. Geol. Survey locality 4472, Pennsylvania asphalt mine. U. S. Nat. Museum 560034.

3, 4. Incomplete left valve. Length 49.5 mm., height (incomplete) 55 mm., diameter 14.5 mm. Locality 73a. U. S. Nat. Museum 560033.

2, 5. *Anadara trilineata* (Conrad) of Arnold.

2. Left valve. Length 70 mm., height 50 mm., diameter 21 mm. U. S. Geol. Survey locality 4472, Pennsylvania asphalt mine. U. S. Nat. Museum 560028.

5. Short variety, right valve. Length 46 mm., height 39 mm., diameter 15.5 mm. Locality 56. U. S. Nat. Museum 560029.

6–8. *Patinopecten dilleri* (Dall), var. Locality 56.

6. Incomplete left valve. Length (incomplete) 73 mm., height (incomplete) 82.5 mm. U. S. Nat. Museum 560031.

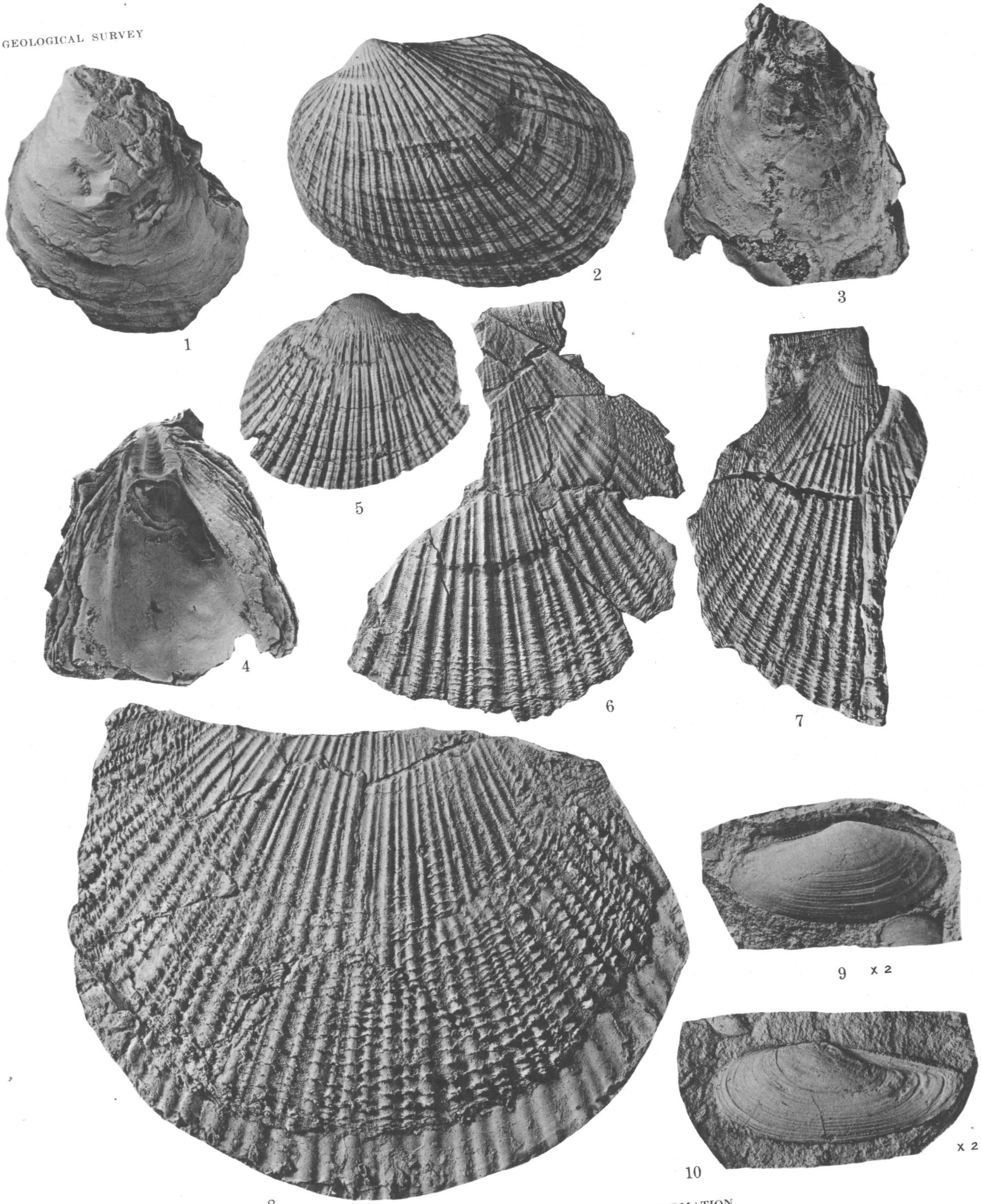
7. Incomplete left valve. Length (incomplete) 42.5 mm., height (incomplete) 78 mm. U. S. Nat. Museum 560032.

8. Rubber cast of incomplete left valve. Length (incomplete) 113 mm., height (incomplete) 84 mm. U. S. Nat. Museum 560030.

9, 10. *Yoldia gala* Woodring, n. sp.

9. Mold of right valve. Length 21.3 mm., height 10.5 mm., approximate diameter 3 mm. Locality 81. U. S. Nat. Museum 560026.

10. Rubber cast of left valve. Length 25 mm., height 10.5 mm., approximate diameter 3 mm. Locality 75. U. S. Nat. Museum 560025.



MOLLUSKS FROM BASIN FACIES OF SISQUOC FORMATION.

PLATE 10

[Figures natural size unless otherwise specified]

Figures 1. *Cryptonatica aleutica* (Dall), small var. Length (not quite complete) 33 mm., width (not quite complete) 30.5 mm. U. S. Geol. Survey locality 4473, Waldorf asphalt mine. U. S. Nat. Museum 560046.

2. *Opalia varicostata* Stearns. Length (incomplete) 29 mm., width 17 mm. Locality 139. U. S. Nat. Museum 560047.

3. *Saccella orcutti* (Arnold). Right valve. Length 13.6 mm., height 7.9 mm., diameter 3.6 mm. U. S. Geol. Survey locality 4473, Waldorf asphalt mine (type locality). U. S. Nat. Museum 560051.

4. *Crepidula princeps* Conrad. Narrow specimen. Length (not quite complete) 71.7 mm., width 46.3 mm., height 34 mm Locality 146. U. S. Nat. Museum 560045.

5, 6. *Puncturella cucullata* (Gould). Length 31.5 mm., width 25.9 mm., height 17.3 mm. U. S. Geol. Survey locality 4473, Waldorf asphalt mine. U. S. Nat. Museum 560042.

7, 8. *Cyclocardia californica* (Dall). Right valve. Length 24 mm., height 25 mm., diameter 9 mm. U. S. Geol. Survey locality 4473, Waldorf asphalt mine (type locality). U. S. Nat. Museum 560054.

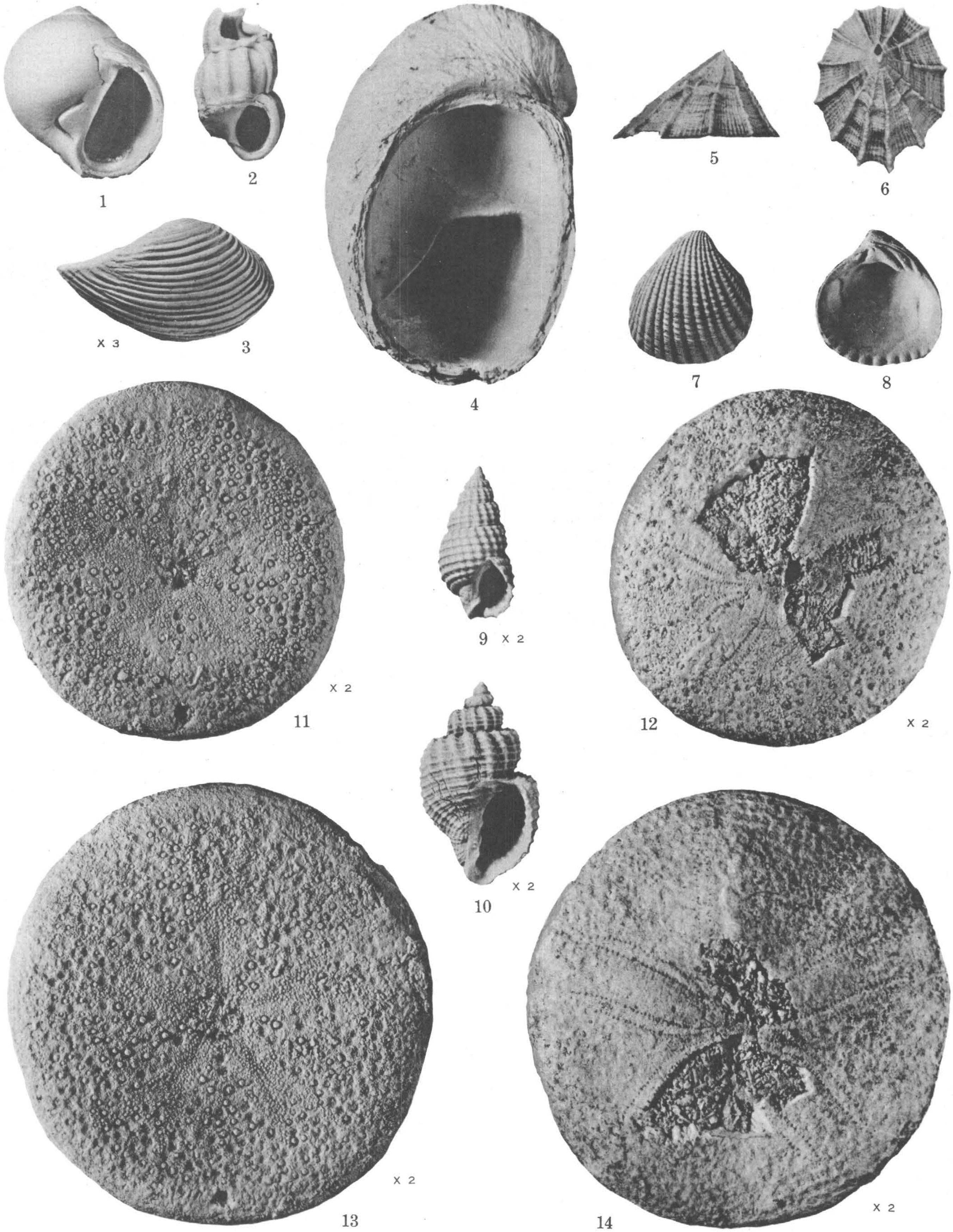
9. "*Nassa*" *waldorfensis* Arnold. Length 14.5 mm., width 7.7 mm. Locality 144. U. S. Nat. Museum 560048.

10. "*Cancellaria*" *arnoldi* (Dall). Length 19.2 mm., width 11.5 mm. U. S. Geol. Survey locality 4473, Waldorf asphalt mine. U. S. Nat. Museum 560049.

11–14. *Merriamaster* cf. *M. perrini* (Weaver). Locality 141. U. S. Nat. Museum 560041.

11, 12. Length 34.2 mm., width 32 mm., height 9 mm.

13, 14. Length 42.3 mm., width 40.3 mm., height 9.8 mm.



SAND DOLLARS AND MOLLUSKS FROM FOXEN MUDSTONE.

PLATE 11

[Figures natural size unless otherwise specified]

Figures 1, 9. *Patinopecten dilleri* (Dall). Right (fig. 1) and left (fig. 9) valves of paired specimen. Length (practically complete) 117 mm., height (practically complete) 103.5 mm., diameter (both valves) 23.5 mm. Locality L. C. 145, 1⅘ miles S. 35° E. of Casmalia, L. M. Clark collector. U. S. Nat. Museum 560053.

2, 3. *Cyclocardia californica* (Dall). Elongate left valve. Length 23.3 mm., height 23 mm., diameter 8 mm. U. S. Geol. Survey locality 4473, Waldorf asphalt mine (type locality). U. S. Nat. Museum 560054.

4. *Anadara trilineata* (Conrad) of Arnold. Left valve of paired specimen. Length 71.2 mm., height 55.5 mm., diameter (both valves) 35 mm. U. S. Geol. Survey locality 4473, Waldorf asphalt mine. U. S. Nat. Museum 560052.

5. *Crepidula princeps* Conrad. Specimen shown on pl. 10, fig. 4.

6. *Megasurcula carpenteriana tryoniana* (Gabb), strongly shouldered form. Length 44.3 mm., width 19.5 mm. U. S. Geol. Survey locality 4473, Waldorf asphalt mine. U. S. Nat. Museum 560050.

7, 8. *Bittium casmaliense* Bartsch.

7. Length (not quite complete) 13.8 mm., width 4.7 mm. Locality 144. U. S. Nat. Museum 560043.

8. Small specimen showing protoconch. Length 8.6 mm., width 3.3 mm. Locality 146. U. S. Nat. Museum 560044.

PLATE 12

[Figures natural size unless otherwise specified]

Figure 1. *Lunatia* cf. *L. lewisii* (Gould). Small specimen. Length (not quite complete) 34.5 mm., width (not quite complete) 32 mm. Locality 178a. U. S. Nat. Museum 560071.

2, 3. *Puncturella cooperi aphales* Woodring, n. var. Type. Length 5.8 mm., width 4.2 mm., height 3.8 mm. Locality 177. U. S. Nat. Museum 560060.

4. *Homalopoma* cf. *H. paucicostata* (Dall). Length 5.8 mm., width 5.8 mm. Fugler Point, Calif. Inst. Tech. locality 869. Calif. Inst. Tech. 4557.

5. *Sinum scopulosum* (Conrad). Length 23.5 mm., width 20.7 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560072.

6–8. *Vitrinella stearnsi* Bartsch, var. Length 2.3 mm., width 3.8 mm., Locality 177. U. S. Nat. Museum 560065.

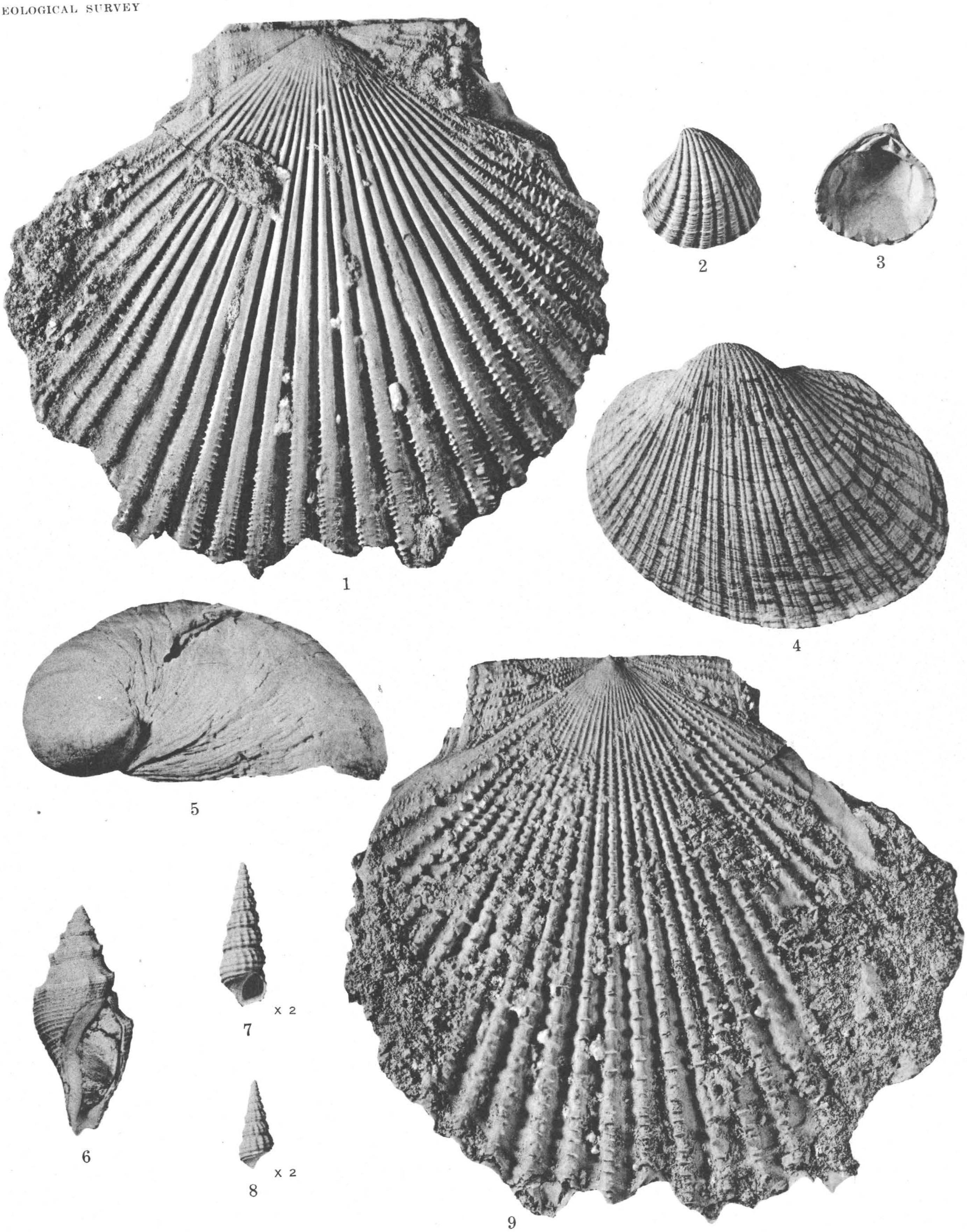
9, 10, 12, 14. *Turcica imperialis brevis* Stewart.

9, 10. Length 23.5 mm., width 20.7 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560063.

12, 14. Length (incomplete) 24.5 mm., width 24 mm. Fugler Point, Calif. Inst. Tech. locality 869. Calif. Inst. Tech. 4556.

11. *Cidarina cidaris* (A. Adams), n. var. ? Length (incomplete) 21.2 mm., width 18 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560062.

13, 15. "*Gyrineum*" *mediocre lewisii* Carson. Length (not quite complete) 136 mm., width 73 mm. An attached specimen of *Crucibulum* cf. *C. imbricatum* is visible in the aperture. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560075.



MOLLUSKS FROM FOXEN MUDSTONE.

PLATE 13

[Figures natural size unless otherwise specified]

Figures 1–4, 8, 9, 25. *Terebratalia occidentalis* (Dall). Locality 178b.

1. Narrow form with few wide ribs. Brachial valve. Length 25.7 mm., width 27.6 mm., approximate diameter 7.5 mm. U. S. Nat. Museum 560055.

2. Pedicle valve. Length (not quite complete) 25.3 mm., width 32.3 mm., approximate diameter 11.5 mm. U. S. Nat. Museum 560056.

3, 4. Brachial (fig. 3) and pedicle (fig. 4) valves of wide form. Length 21.5 mm., width 31.8 mm., diameter (both valves) 13.4 mm. U. S. Nat. Museum 560058.

8, 9. Brachial (fig. 8) and pedicle (fig. 9) valves of form with weak ribs and obscure median fold. Length (incomplete) 19.4 mm., width 23.4 mm., diameter (both valves) 10.7 mm. U. S. Nat. Museum 560059.

25. Pedicle valve. Length 30.3 mm., width 36.9 mm., diameter (both valves) 12.2 mm. U. S. Nat. Museum 560057.

5, 6, 10. *Calliostoma coalingense catoteron* Woodring, n. var. Type. Length 10.4 mm., width 13.7 mm. U. S. Geol. Survey locality 4474, railroad cut a mile north of Shuman. U. S. Nat. Museum 560061.

7, 11. *Solariella* n. sp.? Length (not quite complete) 12.9 mm., width 12.7 mm. Locality 177. U. S. Nat. Museum 560064.

12, 14, 15. *Turritella cooperi* Carpenter, strongly sculptured var.

12. Length (incomplete) 20.5 mm., width 7 mm. Locality 178a. U. S. Nat. Museum 560068.

14, 15. Locality 177. U. S. Nat. Museum 560067.

14. Length (incomplete) 23.6 mm., width 13.2 mm.

15. Length (incomplete) 23.8 mm., width 9.8 mm.

13. *Turritella gonostoma hemphilli* Applin. Length (incomplete) 50.8 mm., width 17.2 mm. Locality 178b. U. S. Nat. Museum 560069.

16. *Bittium casmaliense arnoldi* Bartsch. Length (incomplete) 12.9 mm., width 5 mm. Locality 177. U. S. Nat. Museum 560066.

17, 18. *Iselica fenestrata* (Carpenter), var. Length 4.3 mm., height 3.6 mm. Fugler Point, Calif. Inst. Tech. locality 869. Calif. Inst. Tech. 4558.

19. *Trochita radians* (Lamarck), small var. Maximum diameter 18.5 mm., height 9.3 mm. Locality 178a. U. S. Nat. Museum 560070.

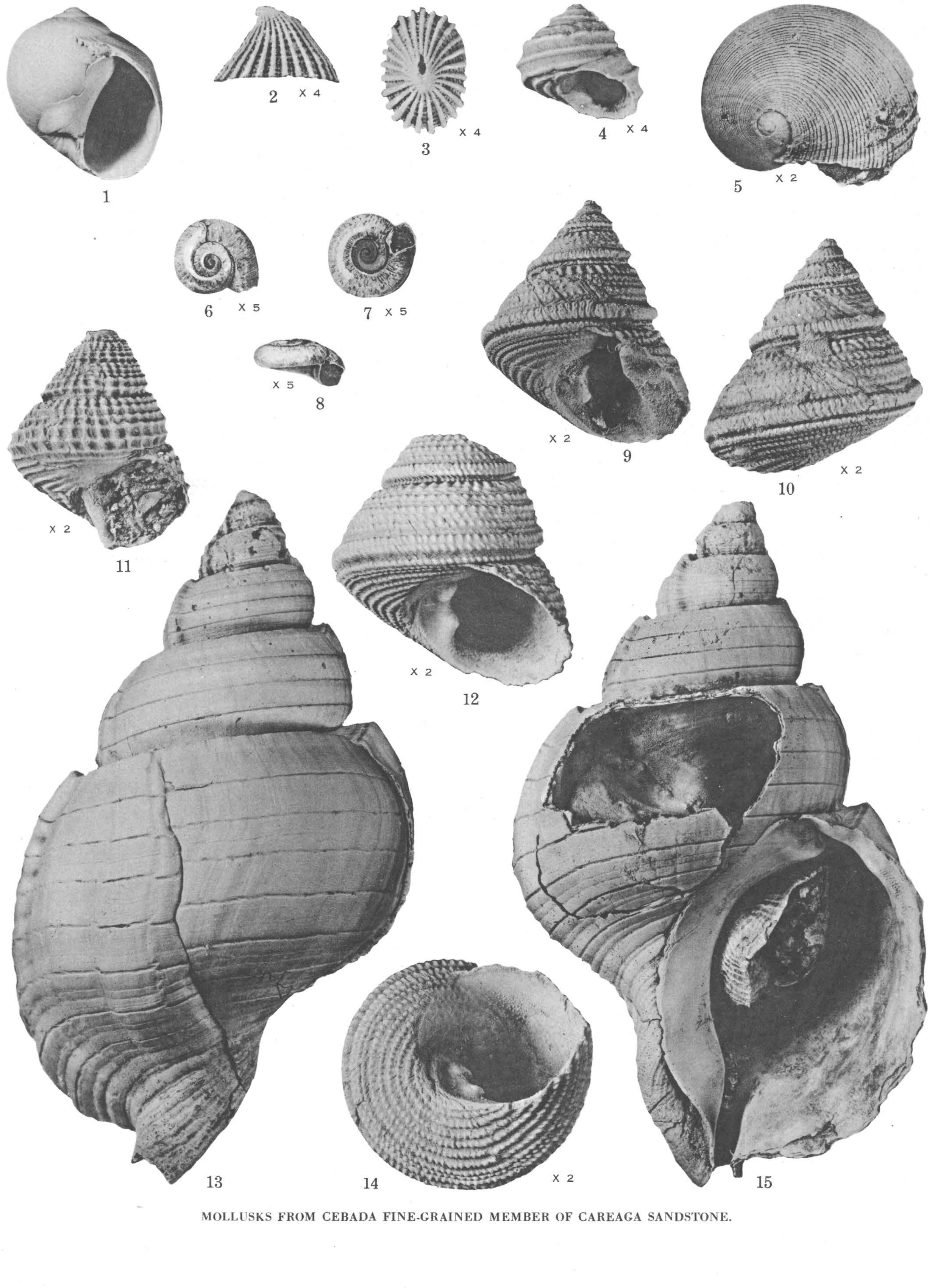
20. *Erato* cf. *E. scabriuscula* Gray. Length 10.6 mm., width 6.4 mm. Locality 177. U. S. Nat. Museum 560074.

21, 22. *Trivia* cf. *T. sanguinea* (Gray). Length 7 mm. width 5.4 mm. Locality 177. U. S. Nat. Museum 560073.

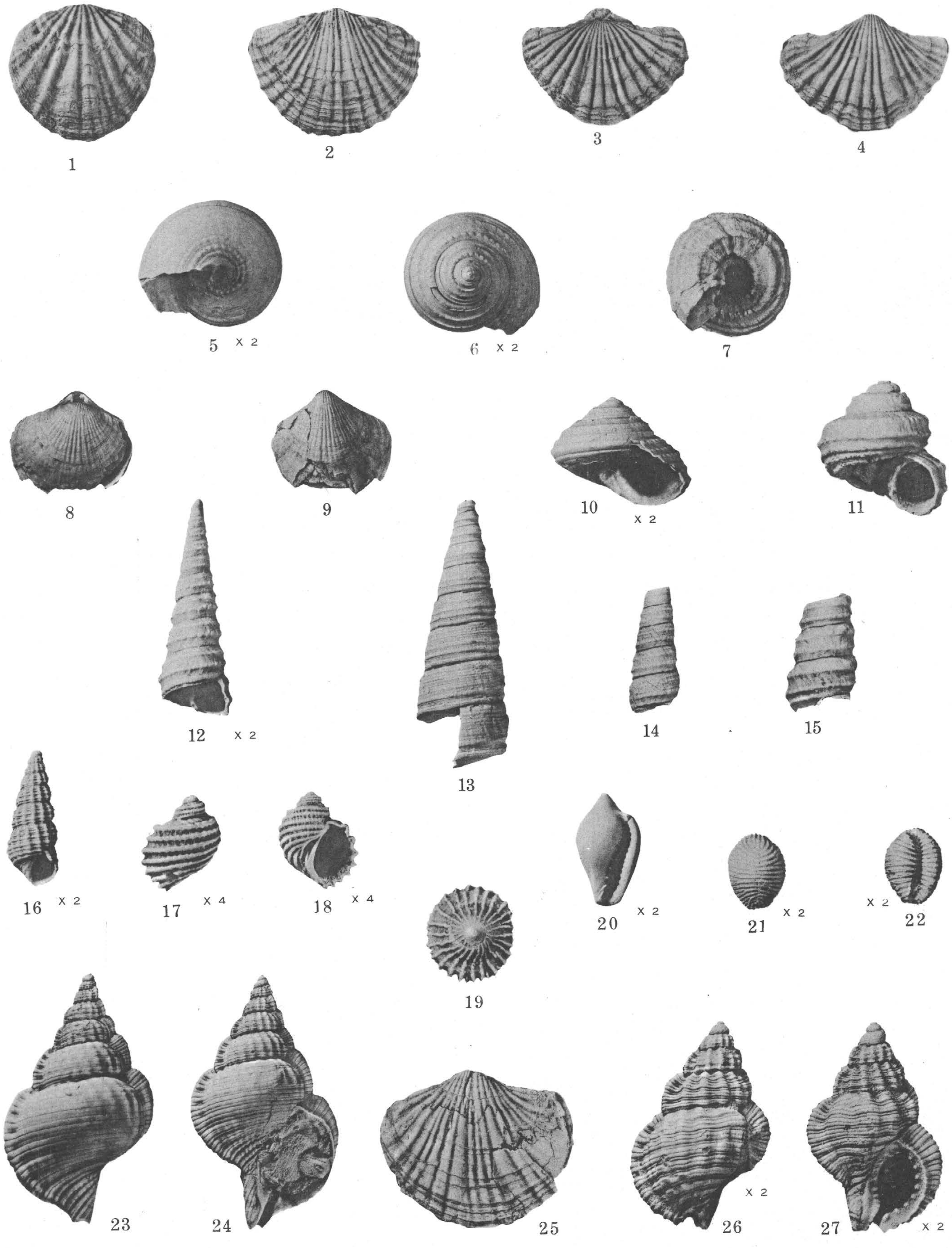
23, 24, 26, 27. "*Gyrineum*" *mediocre lewisii* Carson. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560075.

23, 24. Length 48.2 mm., width 27.3 mm.

26, 27. Length 19.5 mm., width 13.3 mm.



MOLLUSKS FROM CEBADA FINE-GRAINED MEMBER OF CAREAGA SANDSTONE.



BRACHIPODS AND MOLLUSKS FROM CEBADA FINE-GRAINED MEMBER OF CAREAGA SANDSTONE.

PLATE 14

[Figures natural size unless otherwise specified]

Figures 1, 2, 4, 5. *Psephaea oregonensis* (Dall).

1, 2. Length 64.5 mm., width 25 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560092.

4, 5. Length 68 mm., width 28 mm. Fugler Point, Calif. Inst. Tech. locality 869. Calif. Inst. Tech. 4554.

3. *Pholadidea penita* (Conrad). Left valve of paired specimen. Length 52.7 mm., height 30.7 mm., approximate diameter (both valves) 25.5 mm. Locality 177. U. S. Nat. Museum 560106.

6, 7. *Arca santamariensis* Reinhart. Posterior end (fig. 6), and right valve and upper part of left valve of small paired specimen, valves sheared. Length 28.2 mm., height 15.8 mm., approximate diameter (both valves) 17 mm. Locality 178b. U. S. Nat. Museum 560097.

8, 9. *Calicantharus portolaensis* (Arnold). Length (almost complete) 46.8 mm., width 24.5 mm. Locality 178c. U. S. Nat. Museum 560080.

10. *Calicantharus fortis* var. cf. *angulata* (Arnold). Length (incomplete) 49 mm., width 36 mm. Fugler Point. Calif. Inst. Tech. locality 869. Calif. Inst. Tech. 4453.

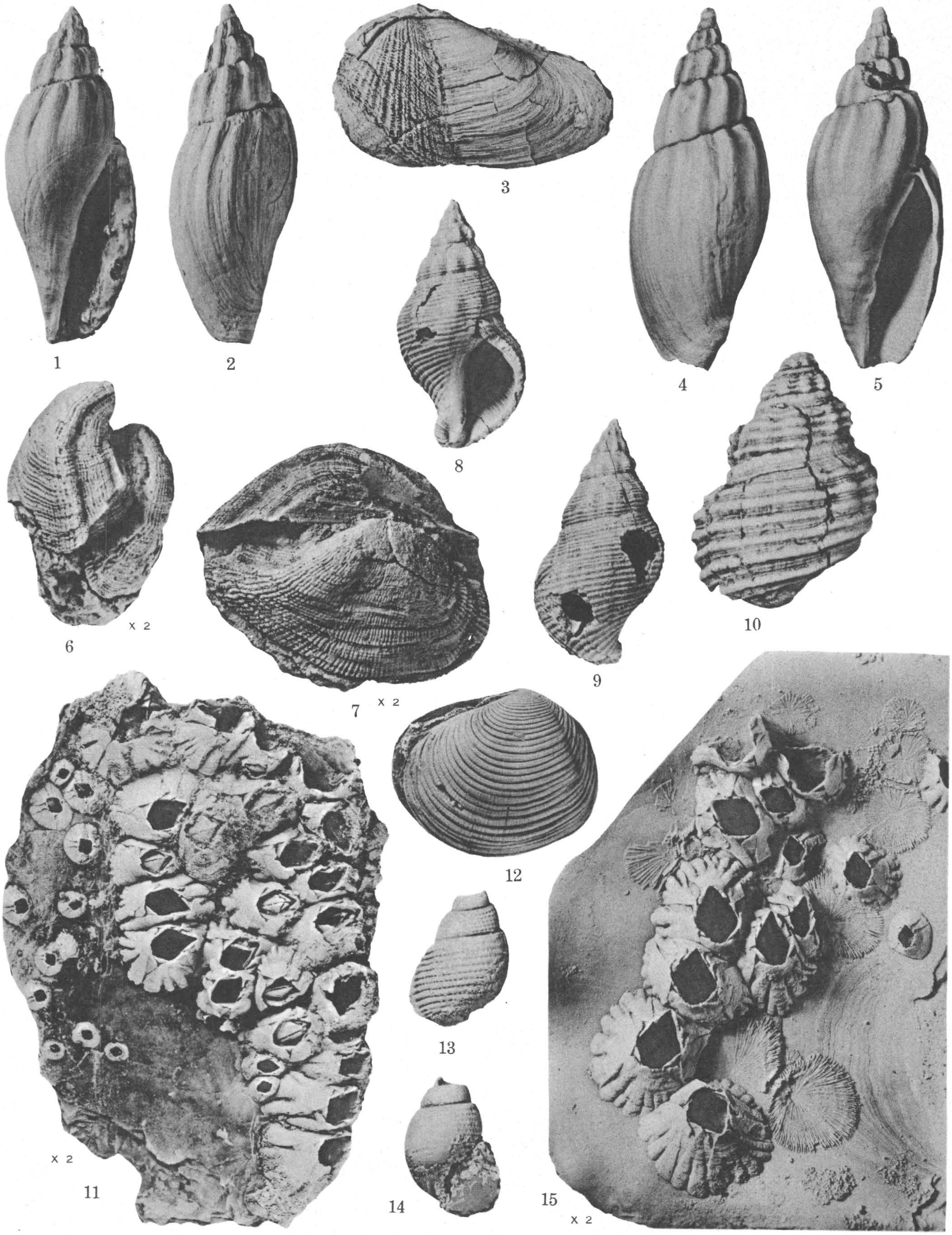
11, 15. *Balanus hesperius proinus* Woodring, n. var. Locality 236. Undifferentiated Careaga sandstone of fine-grained facies.

11. Type lot attached to oyster shell. U. S. Nat. Museum 560107.

15. Cluster attached to oyster shell. U. S. Nat. Museum 560108.

12. *Semele* cf. *S. rubropicta* Dall. Left valve of paired specimen. Length 37.2 mm., height 30.6 mm., diameter (both valves) 19.5 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560104.

13, 14. "*Nassa*" *moraniana* Martin. Mold. Length (incomplete) 26.7, width 18.5 mm. Locality 181. U. S. Nat. Museum 560076.



MOLLUSKS AND BARNACLES FROM CEBADA FINE-GRAINED MEMBER OF CAREAGA SANDSTONE AND FROM FINE-GRAINED FACIES OF UNDIFFERENTIATED CAREAGA SANDSTONE.

PLATE 15

[Figures natural size unless otherwise specified]

Figures 1, 2. *Cyclocardia californica* (Dall). Locality 170. U. S. Nat. Museum 560103.
1. Left valve. Length 22 mm., height 22.6 mm., diameter 7.8 mm.
2. Right valve, nodes subdued at early stage. Length 23 mm., height 22.3 mm., diameter 8 mm.

3, 26. *Saccella cellulita* (Dall). Left valve. Length 10.5 mm., height 7.5 mm., approximate diameter 4.2 mm. Locality 178b. U. S. Nat. Museum 560095.

4. "*Nassa*" *waldorfensis* Arnold. Length 14.1 mm., width 7.1 mm. Locality 170. U. S. Nat. Museum 560077.

5, 6. "*Nassa*" *mendica* Gould, small var. Locality 177. U. S. Nat. Museum 560078.
5. Length 11 mm., width 6.2 mm.
6. Length 6.8 mm., width 3.8 mm.

7. *Mitrella gausapata* (Gould). Length 11.8 mm., width 5.6 mm. Locality 170. U. S. Nat. Museum 560089.

8. *Olivella* cf. *O. baetica* Carpenter. Length 6.3 mm., width 2.8 mm. Locality 177. U. S. Nat. Museum 560093.

9, 11. *Jaton* cf. *J. carpenteri* (Dall). Length (incomplete) 85 mm., width 49.5 mm. Fugler Point, Calif. Inst. Tech. locality 869. Calif. Inst. Tech. 4555.

10. *Admete gracilior* (Carpenter) of Arnold. Length 9.1 mm., width 4.5 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560088.

12, 13. *Barbatia pseudoillota* Reinhart. Small right valve. Length 18.5 mm., height 13.4 mm., diameter 5.2 mm. Locality 178a. U. S. Nat. Museum 560098.

14, 15. *Calicantharus fortis* var. cf. *angulata* (Arnold). Length (not quite complete) 42.3 mm., width 24 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560079.

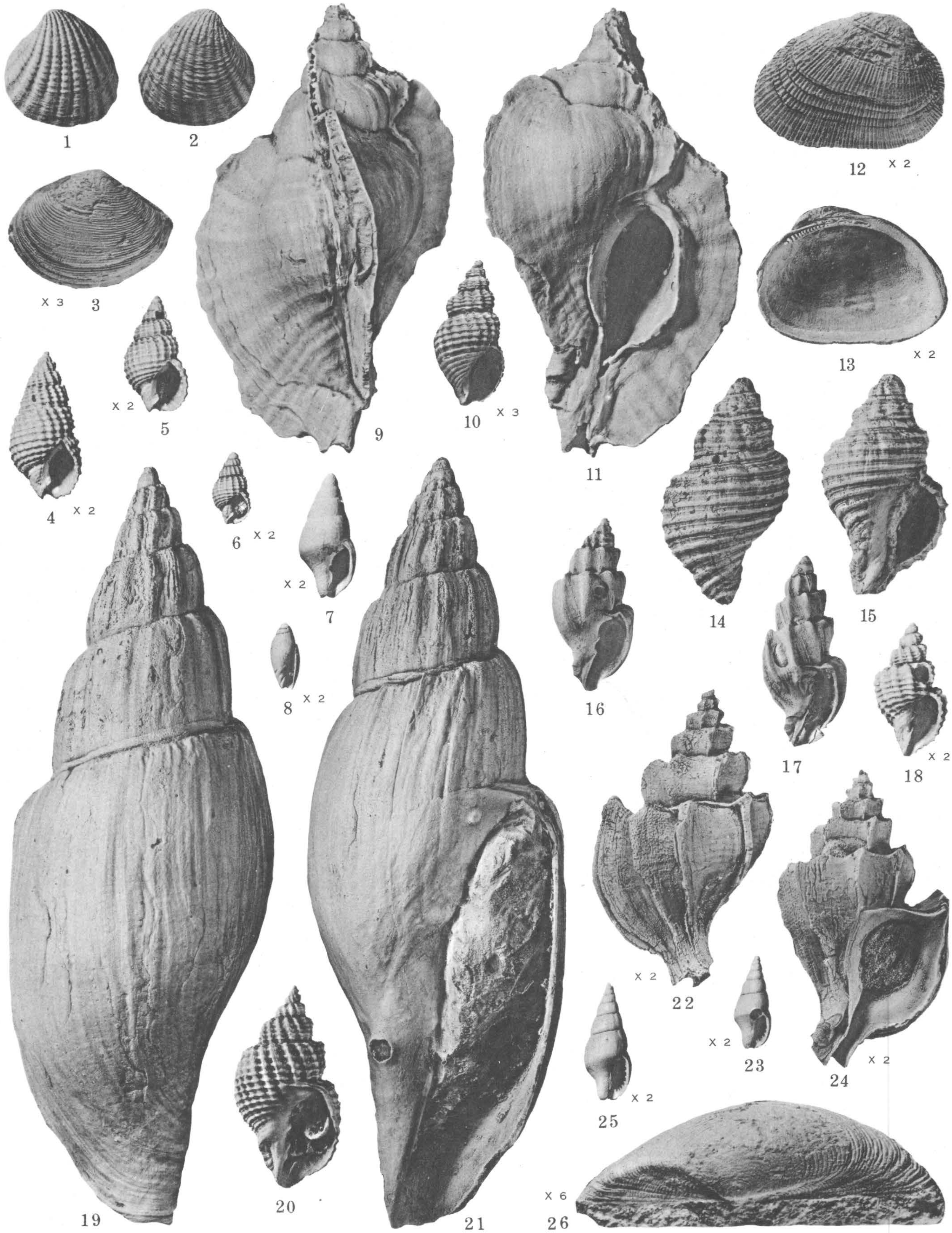
16, 17. "*Cancellaria*" *hemphilli* Dall. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560086.
16. Inflated form. Length 33.3 mm., width 16.3 mm.
17. Slender form. Length 36 mm., width 15.3 mm.

18, 20. "*Cancellaria*" *arnoldi* Dall.
18. Length 12.5 mm., width 7 mm. Locality 177. U. S. Nat. Museum 560085.
20. Exceptionally large specimen. Length 38 mm., width 21.4 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560084.

19, 21. *Psephaea oregonensis* (Dall). Length (not quite complete) 147 mm., width 47.5 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560091.

22, 24. *Boreotrophon multicostatus* (Eschscholtz), inflated var. Length 27.8 mm., width 16.3 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560081.

23, 25. *Mitrella tuberosa* (Carpenter), var. Locality 177. U. S. Nat. Museum 560090.
23. Flat-whorled form. Length 8.7 mm., width 3.6 mm.
25. Inflated-whorled form. Length 10.9 mm., width 4.7 mm.



MOLLUSKS FROM CEBADA FINE-GRAINED MEMBER OF CAREAGA SANDSTONE.

PLATE 16

[Figures natural size unless otherwise specified]

Figures 1–3, 8–12. *Balanus hesperius proinus* Woodring, n. var. Opercular valves recovered from barnacles of type lot shown on pl. 23, fig. 11. Locality 236. Undifferentiated Careaga sandstone of Cebada facies. U. S. Nat. Museum 560109.

1, 2. Tergum. Length 3.4 mm., width 2 mm.
3, 9. Tergum. Length 2.8 mm., width 1.9 mm.
8, 10. Scutum. Length 4.6 mm., width 2.5 mm.
11, 12. Scutum. Length 4.3 mm., width 2.3 mm.

4, 17. *Ostrea vespertina* Conrad. Locality 236. Undifferentiated Careaga sandstone of Cebada facies. U. S. Nat. Museum 560102.

4. Left valve. Length 67 mm., height 70 mm., diameter 17.5 mm.
17. Right valve. Length 63 mm., height 71 mm., diameter 8.5 mm.

5. "*Cancellaria*" cf. "*C.*" *tritonidea* Gabb. Length (incomplete) 32 mm., width (incomplete) 20 mm. Locality 178a. U. S. Nat. Museum 560083.

6. *Dosinia ponderosa* (Gray), var. Left valve of paired specimen. Length 78.5 mm., height 73 mm., diameter (both valves) 32.5 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560105.

7. *Crawfordina fugleri* (Arnold). Length 37.8 mm., width 20 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560087.

13, 14. *Cancellaria lipara* Woodring, n. sp. Type. Length 26.7 mm., width 18.3 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560082.

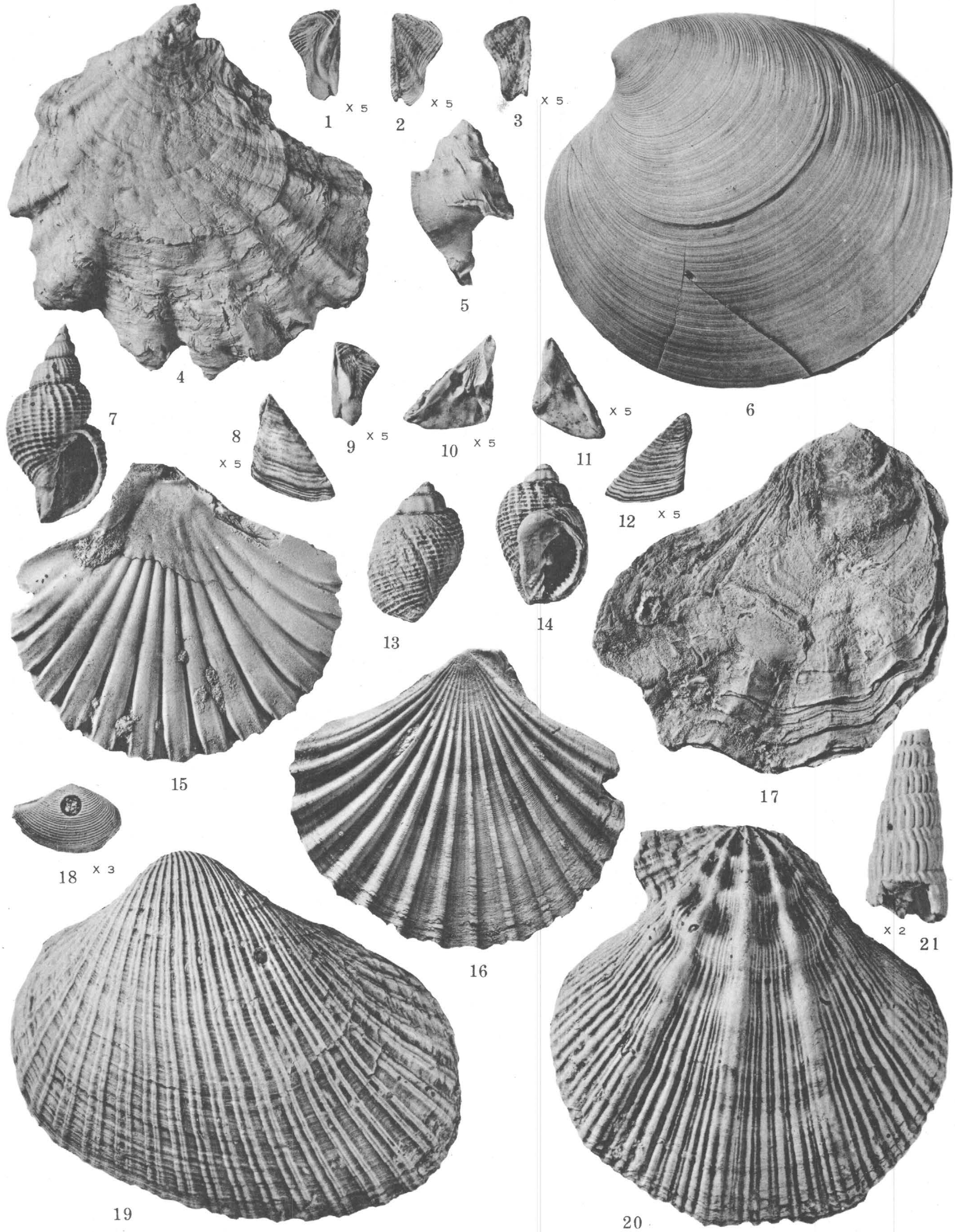
15, 16. *Pecten hemphilli* Dall. Incomplete left valve with exceptionally narrow ribs. Length 62.8 mm., height 57 mm., diameter 3.5 mm. Locality 165. U. S. Nat. Museum 560100.

18. *Saccella redondoensis* (Burch). Right valve. Length (not quite complete) 7 mm., height (not quite complete) 4.2 mm., diameter 2 mm. Locality 177. U. S. Nat. Museum 560096.

19. *Anadara trilineata* (Conrad) of Arnold. Exceptionally large left valve. Length 92.3 mm., height 68.5 mm., diameter 29.3 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560099.

20. *Chlamys parmeleei* (Dall). Large left valve, posterior ear broken. Length 75 mm., height 78 mm., approximate diameter 22.5 mm. Fugler Point, Alex Clark collector. U. S. Nat. Museum 560101.

21. *Strioterebrum martini* (English). Length (incomplete) 18.5 mm., width 8 mm. Locality 178. U. S. Nat. Museum 560094.



MOLLUSKS AND BARNACLES FROM CEBADA FINE-GRAINED MEMBER OF CAREAGA SANDSTONE AND FROM FINE-GRAINED FACIES OF UNDIFFERENTIATED CAREAGA SANDSTONE.

PLATE 17

[Figures natural size unless otherwise specified]

Figures 1, 2. "*Cancellaria*" *rapa perrini* Carson. Locality 204.

1. Slender form. Length 42.7 mm., width 22.5 mm. U. S. Nat. Museum 560124.
2. Length 39.6 mm., width 25 mm., U. S. Nat. Museum 560123.

3–6, 10. "*Drillia*" *graciosana* Arnold.

3. Slender form. Length 19.9 mm., width 8 mm. Locality 198. U. S. Nat. Museum 560132.
4. Strongly shouldered form. Length 20.4 mm., width 9 mm. Locality 198. U. S. Nat. Museum 560133.
5. Moderately inflated form. Length 24.2 mm., width 10.9 mm. Locality 207. U. S. Nat. Museum 560129.
6. Strongly inflated form. Length 24.4 mm., width 11 mm. Locality 198. U. S. Nat. Museum 560130.
10. Moderately inflated form. Length 20.8 mm., width 9.2 mm. Locality 198. U. S. Nat. Museum 560131.

7, 8. "*Nassa*" *moraniana* Martin. Locality 204. U. S. Nat. Museum 560120.

7. Length 32.5 mm., width 20.5 mm.
8. Length 25.2 mm., width 16.3 mm.

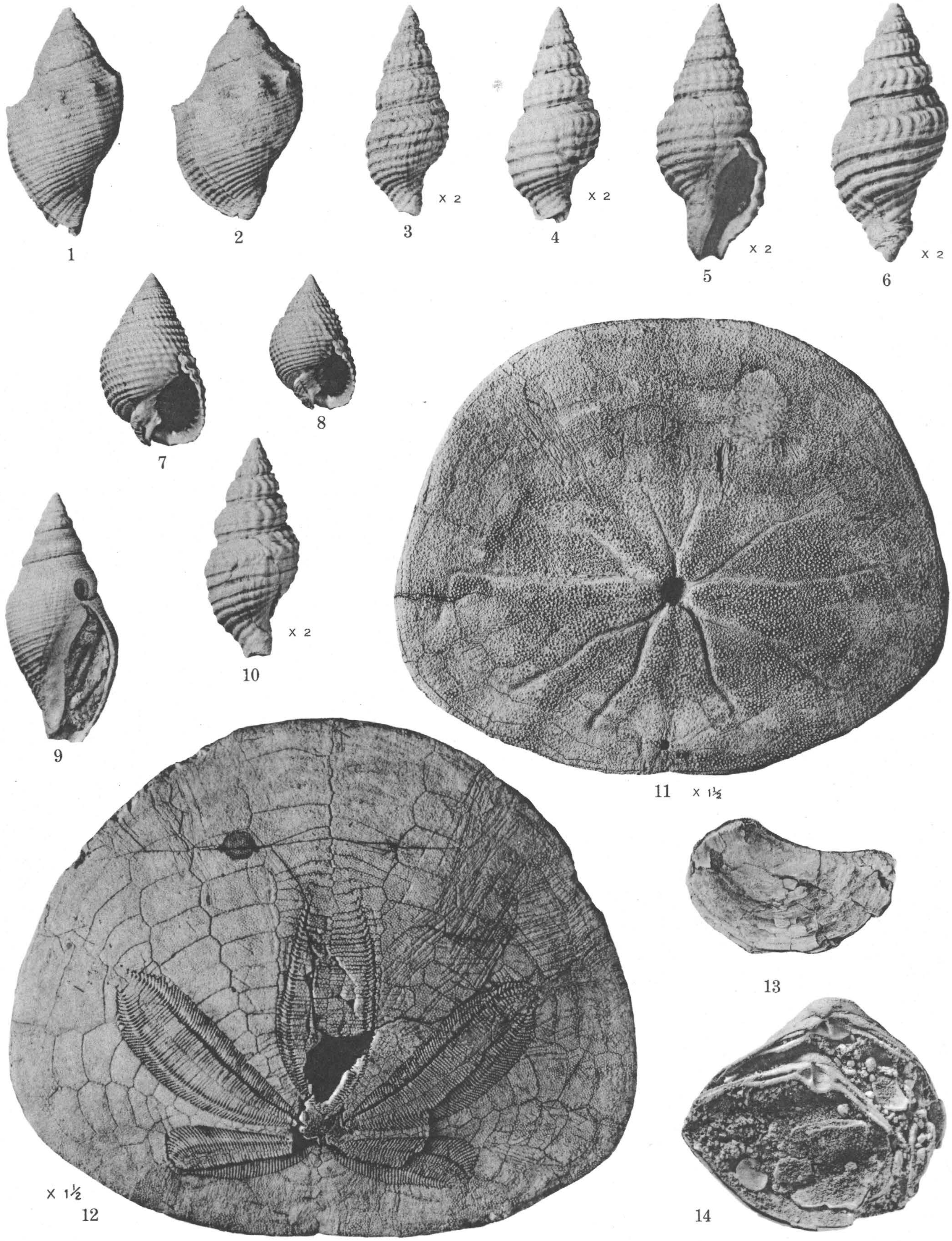
9. *Megasurcula carpenteriana* (Gabb), inflated var. Length 47.3 mm., width 21.7 mm. Locality 204. U. S. Nat. Museum 560128.

11, 12. *Dendraster ashleyi* (Arnold).

11. Length 57 mm., width 68 mm., height 9 mm. Locality 226. U. S. Nat. Museum 560112.
12. Length 66 mm., width 79 mm., height 9.2 mm. Locality 234a. U. S. Nat. Museum 560110.

13. *Pandora punctata* Conrad. Left valve. Length (practically complete) 39 mm., height 27.5 mm., approximate diameter 3.5 mm. Locality 199. U. S. Nat. Museum 560150.

14. *Pseudocardium densatum* (Conrad) of Arnold, var. cf. *gabbii* Rémond. Right valves. Length (of larger valve, incomplete) 49 mm., height 40.5 mm., diameter 15.8 mm. Locality 234. U. S. Nat. Museum 560144.



SAND DOLLARS AND MOLLUSKS FROM GRACIOSA COARSE-GRAINED MEMBER OF CAREAGA SANDSTONE.

PLATE 18

[Figures natural size unless otherwise specified. The fresh-water gastropods shown in figs. 4–11 are from the Paso Robles formation, the other fossils are from the Graciosa coarse-grained member of the Careaga sandstone]

Figure 1. *Pachydesma crassatelloides* (Conrad). Right valve of paired specimen. Length (not quite complete) 89 mm., height 66 mm., diameter (both valves) 33 mm. Locality 234. U. S. Nat. Museum 560147.

2, 3. "*Cancellaria*" *rapa perrini* Carson. Length 60 mm., width 35.5 mm. Locality 207. U. S. Nat. Museum 560122.

4, 7. *Menetus* cf. *M. cooperi* F. C. Baker. Length 1.2 mm., width 3.3 mm. Locality 253. U. S. Nat. Museum 560154.

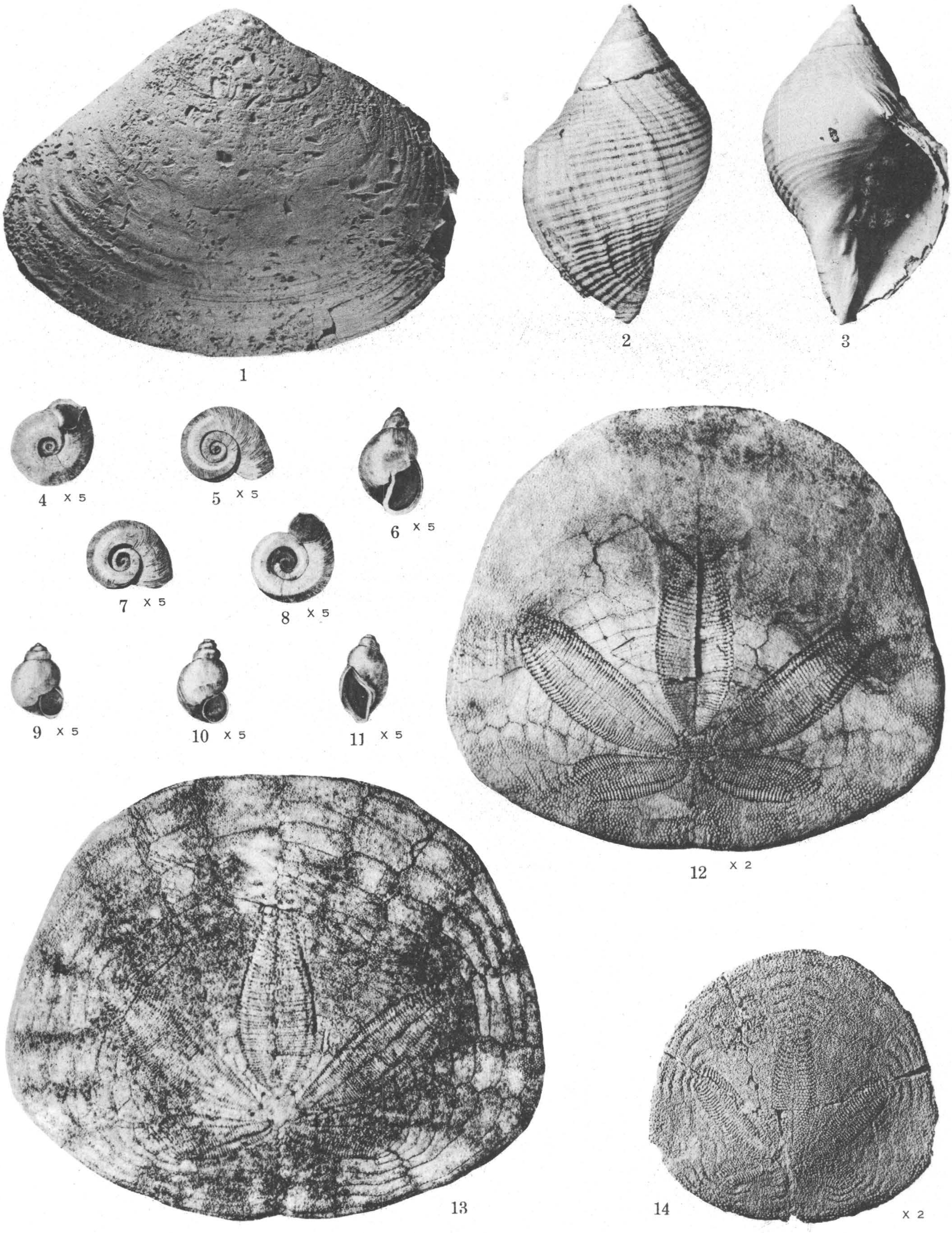
5, 8. *Gyraulus* cf. *G. vermicularis* (Gould). Length 1.5 mm., width 4.7 mm. Locality 253. U. S. Nat. Museum 560153.

6. "*Lymnaea*" *alamosensis* (Arnold). Length 4.6 mm., width 2.8 mm. Locality 253. U. S. Nat. Museum 560152.

9, 10. *Amnicola longinqua* Gould. Locality 255. U. S. Nat. Museum 560151.
- 9. Length 2.5 mm., width 1.7 mm.
- 10. Length 2.9 mm., width 1.8 mm.

11. *Physa* sp. Length 3 mm., width 1.6 mm. Locality 253. U. S. Nat. Museum 560155.

12–14. *Dendraster ashleyi* (Arnold).
- 12. Length 41.8 mm., width 48 mm., height 5.4 mm. Locality 234a. U. S. Nat. Museum 560111.
- 13. Specimen shown on pl. 17, fig. 11.
- 14. Length 25.8 mm., width 27.6 mm., height 4.3 mm. Locality 226. U. S. Nat. Museum 560113.



SAND DOLLARS AND MOLLUSKS FROM GRACIOSA COARSE-GRAINED MEMBER OF CAREAGA SANDSTONE AND MOLLUSKS FROM PASO ROBLES FORMATION.

PLATE 19

[Figures natural size unless otherwise specified]

Figure 1. *Dosinia ponderosa* (Gray), var. Right valve, worn hinge fragment. Length 78.7 mm., maximum height of hinge plate 20 mm. Locality 199. U. S. Nat. Museum 560145.

2. *Pseudocardium densatum* (Conrad) of Arnold, var. cf. *gabbii* Rémond. Specimen shown on pl. 17, fig. 14.

3, 5. *"Nassa" waldorfensis* Arnold. Large coarsely sculptured form. Locality 204. U. S. Nat. Museum 560121.
 3. Length 18.2 mm., width 8.9 mm.
 5. Length (not quite complete) 11 mm., width 6.5 mm.

4. *"Nassa" moraniana* Martin. Length 14.7 mm., width 9.6 mm. Locality 204. U. S. Nat. Museum 560120.

6. *Dendraster ashleyi* (Arnold). Length 36.7 mm., width 41.4 mm., height 5.4 mm. Locality 202. U. S. Nat. Mus. 560115.

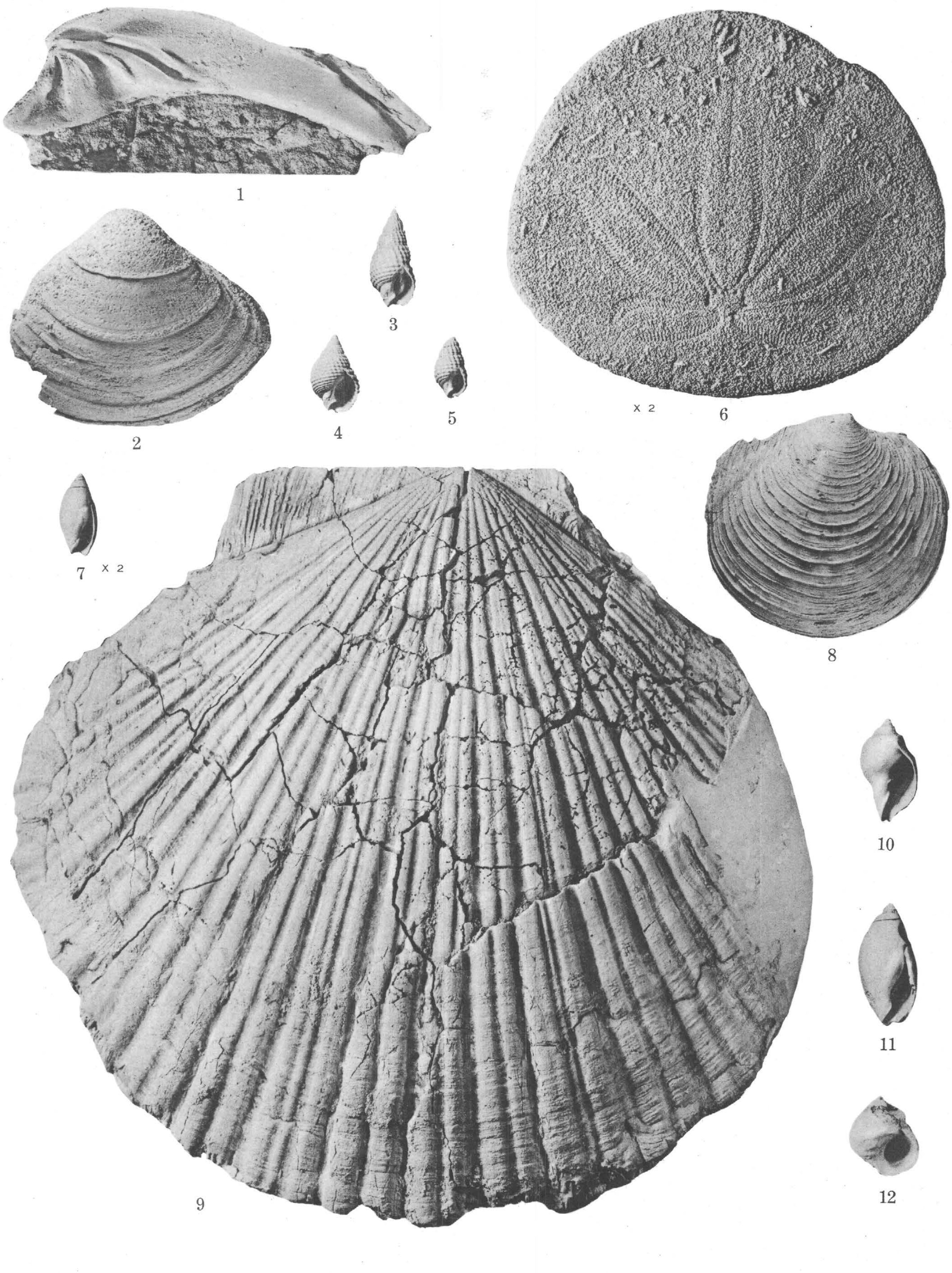
7, 11. *Olivella biplicata* (Sowerby), slender var.
 7. Length 7.8 mm., width 3.9 mm. Locality 201. U. S. Nat. Museum 560127.
 11. Length 22.8 mm., width 11.8 mm. Locality 205. U. S. Nat. Museum 560126.

8. *Lucinoma* cf. *L. annulata* (Reeve). Right valve of paired specimen. Length 47 mm., height 41.3 mm., diameter (both valves) 18.5 mm. Locality 196c. U. S. Nat. Museum 560142.

9. *Patinopecten healeyi* (Arnold). Right valve. Approximate length 152 mm., height 145 mm., approximate diameter 25 mm. U. S. Geol. Survey locality 4474, railroad cut a mile north of Shuman. U. S. Nat. Museum 560136.

10. *"Cancellaria" rapa perrini* Carson. Length 19 mm., width 11.5 mm. Locality 207. U. S. Nat. Museum 560125.

12. *Littorina* cf. *L. petricola* Dall. Length (incomplete) 15.2 mm., width 13.7 mm. Locality 205. U. S. Nat. Museum 560118.



SAND DOLLARS AND MOLLUSKS FROM GRACIOSA COARSE-GRAINED MEMBER OF CAREAGA SANDSTONE

PLATE 20

[Figures natural size unless otherwise specified]

Figures 1, 5, 6. *Dendraster ashleyi* (Arnold).

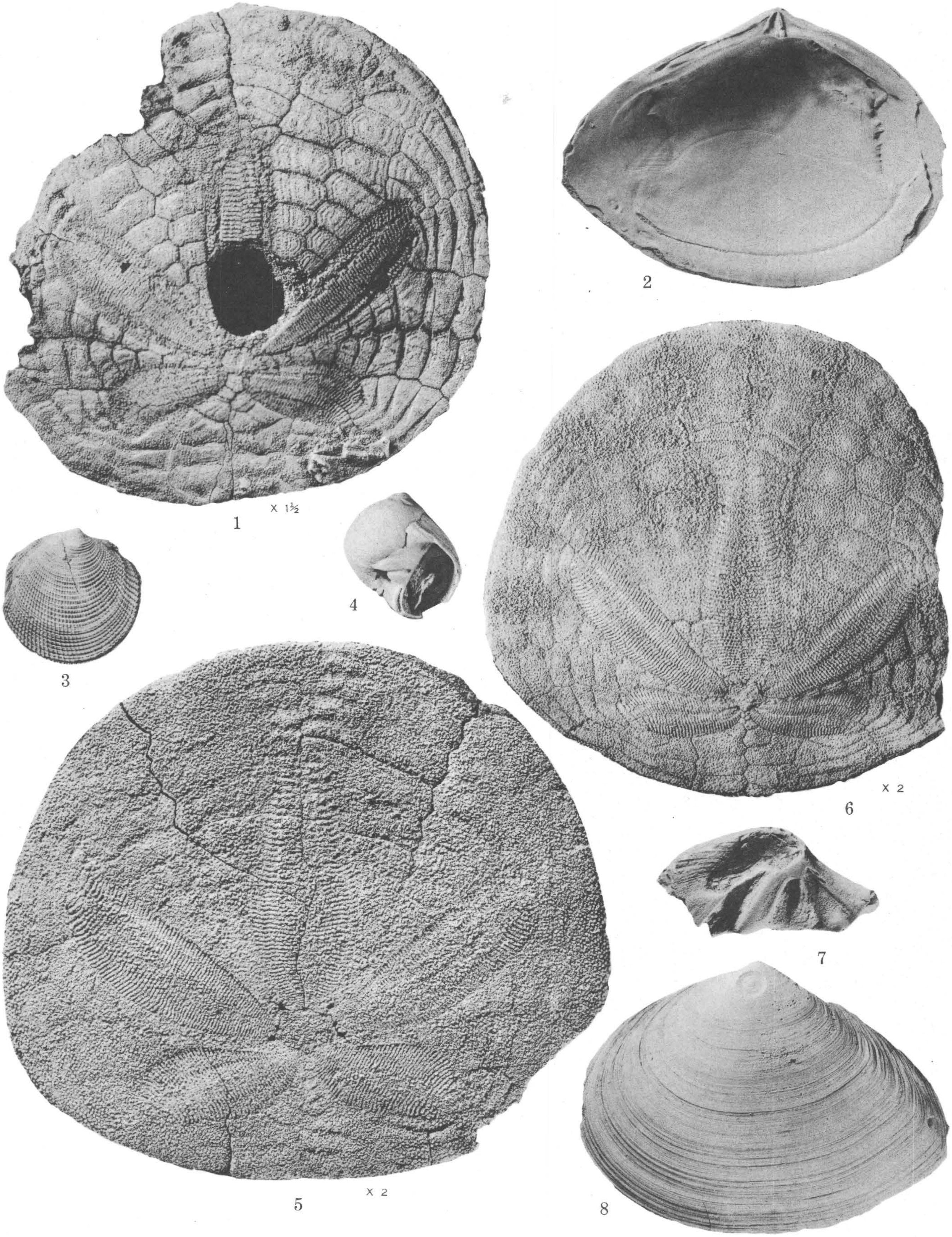
1. Moderately eccentric form. Length 62.2 mm., width (incomplete) 61 mm., height 9.5 mm. Locality 239. Undifferentiated Careaga sandstone of Graciosa facies. U. S. Nat. Museum 560117.
5. Length 50.8 mm., width 58.3 mm., height 6 mm. Locality 202. U. S. Nat. Museum 560114.
6. Narrow form. Length 44.4 mm., width (incomplete) 44.7 mm., height 6.2 mm. Locality 230. U. S. Nat. Museum 560116.

2, 8. *Macoma nasuta kelseyi* Dall. Left valve, posterior dorsal margin broken near umbo. Length 70.6 mm., height 52 mm., diameter 10 mm. Locality 199. U. S. Nat. Museum 560143.

3. *Lucinisca nuttallii antecedens* (Arnold). Right valve of paired specimen. Length 26.4 mm., height 24.7 mm., diameter (both valves) 15 mm. Locality 208. U. S. Nat. Museum 560140.

4. *Neverita reclusiana* (Deshayes). Length (not quite complete) 23.4 mm., width (not quite complete) 22.8 mm. Locality 208. U. S. Nat. Museum 560119.

7. *Dosinia ponderosa* (Gray), var. Left valve, worn hinge fragment. Length 41.5 mm., maximum height of hinge plate 19.7 mm. Locality 199. U. S. Nat. Museum 560146.



SAND DOLLARS AND MOLLUSKS FROM GRACIOSA COARSE-GRAINED MEMBER OF CAREAGA SANDSTONE AND FROM COARSE-GRAINED FACIES OF UNDIFFERENTIATED CAREAGA SANDSTONE.

PLATE 21

[Figures natural size unless otherwise specified, and fossils from Graciosa coarse-grained member unless otherwise specified]

Figure 1. *Lyropecten cerrosensis* (Gabb). Incomplete right valve. Length (incomplete) 125 mm., height (incomplete) 110 mm., approximate diameter 25 mm. Locality 178c. Cebada fine-grained member. U. S. Nat. Museum 560138.

2–4. *Protothaca staleyi* (Gabb).

2, 4. Right valve. Length 52.6 mm., height 48.7 mm., diameter 15.2 mm. Locality 234. U. S. Nat. Museum 560148.

3. Small right valve showing early sculpture. Length 12.2 mm., height 11 mm., diameter 3.9 mm. Locality 204. U. S. Nat. Museum 560149.

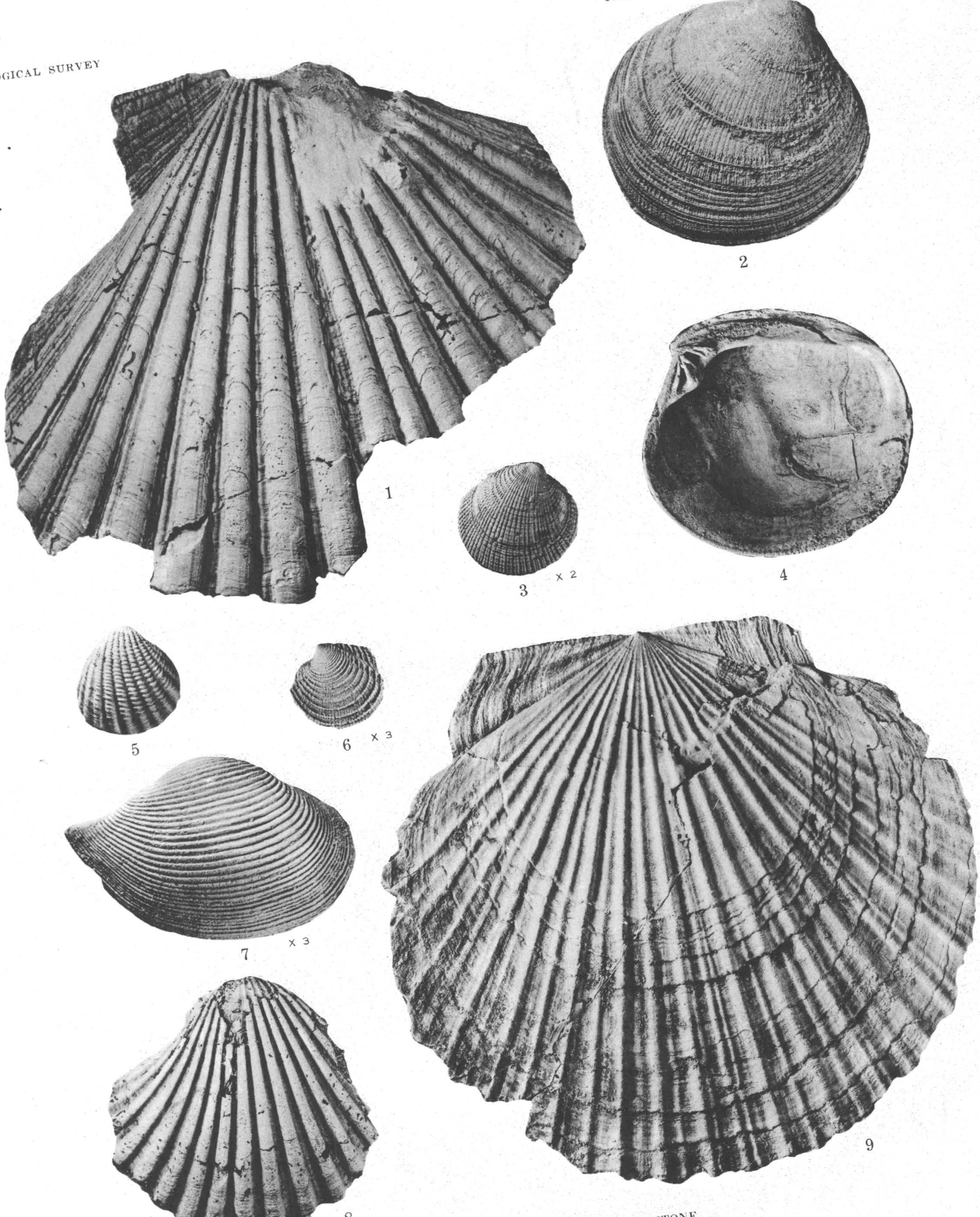
5. *Cyclocardia californica* (Dall). Right valve. Length 19.9 mm., height 21.7 mm., diameter 8.3 mm. Locality 196b. U. S. Nat. Museum 560139.

6. *Lucinisca nuttallii antecedens* (Arnold). Small left valve showing early sculpture. Length 6 mm., height 5.8 mm., diameter 1.5 mm. Locality 199. U. S. Nat. Museum 560141.

7. *Saccella taphria* (Dall). Right valve. Length 19.3 mm., height 12.9 mm., diameter 5.7 mm. Locality 199. U. S. Nat. Museum 560134.

8. *Pecten hemphilli* Dall. Incomplete right valve. Length (incomplete) 64.5 mm., height (not quite complete) 53.2 mm., approximate diameter 22.5 mm. U. S. Geol. Survey locality 4474, railroad cut a mile north of Shuman. U. S. Nat. Museum 560135.

9. *Patinopecten healeyi* (Arnold). Left valve. Length 119 mm., height 112 mm., approximate diameter 12 mm. U. S. Geol. Survey locality 4474, railroad cut a mile north of Shuman. U. S. Nat. Mus. 560137.



MOLLUSKS FROM CAREAGA SANDSTONE.

PLATE 22

Figures 1–3, 5. *Hopkinsina magnifica* Bramlette, n. sp.

1. Paratype, microspheric form. Length 1.47 mm., width 0.68 mm. North side of ravine at north edge of Peck Park, San Pedro, Los Angeles Co. (locality 20 of U. S. Geol. Survey Prof. Paper 207). Valmonte diatomite member of Monterey shale. U. S. Nat. Museum 560227.

2, 5. Holotype, megalospheric form. Length 1.52 mm., width 0.66 mm. Same locality and horizon. U. S. Nat. Museum 560226.

3. Length 2.02 mm., width 0.81 mm. Locality 16. Upper member of Monterey shale. U. S. Nat. Museum 560228.

4, 8–10. *"Ellipsoglandulina" fragilis* Bramlette, n. sp.

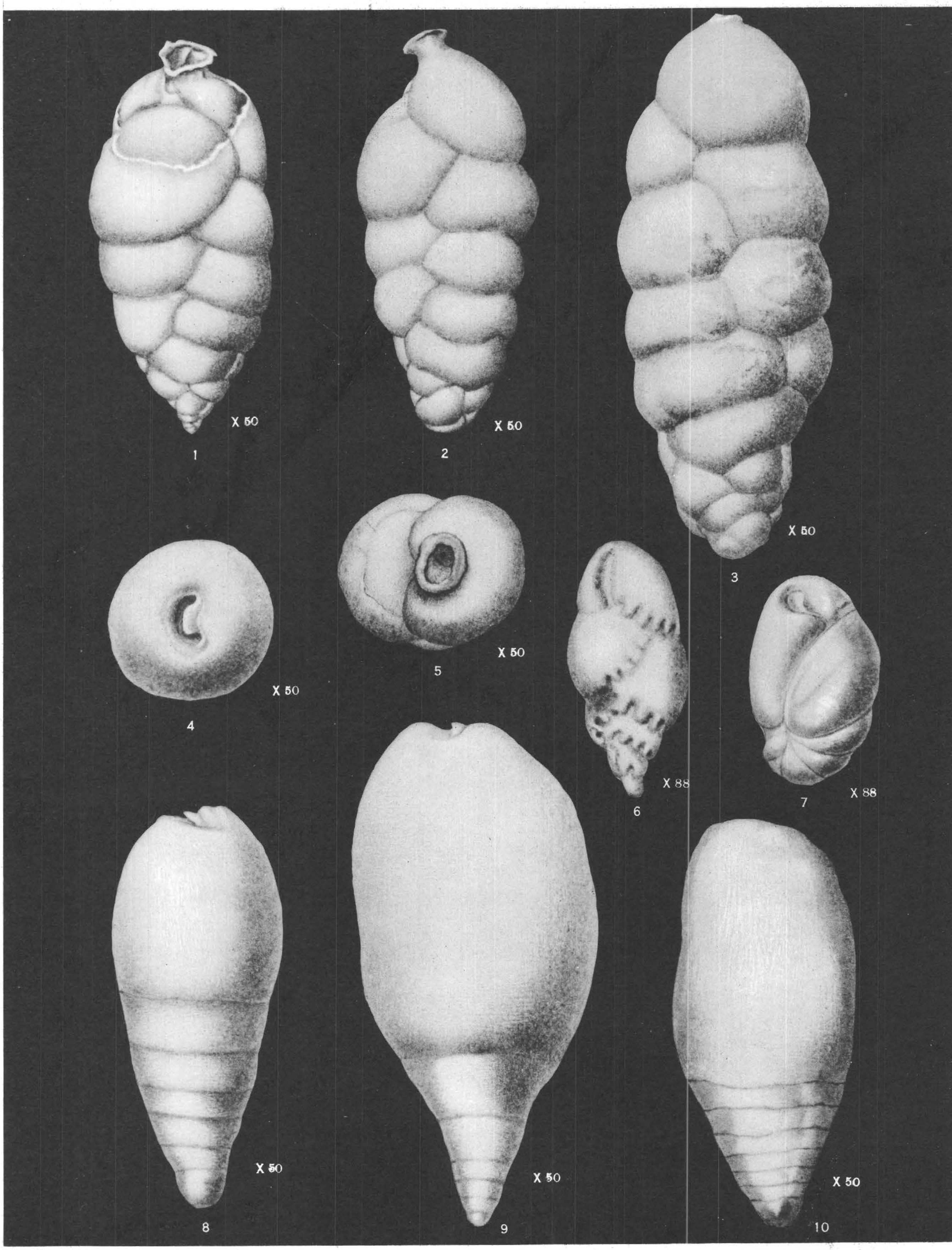
4, 8. Holotype, megalospheric form. Length 1.54 mm., diameter 0.63 mm. North slope of Santa Monica Mountains, 0.32 mile S. 17° E. from junction of Ventura Boulevard and Dixie Canyon Road (in second canyon west of that followed by Coldwater Canyon Road), Los Angeles Co. Upper member of Monterey formation (Modelo formation of some geologists). U. S. Nat. Museum 560223.

9. Paratype, microspheric form. Length 1.88 mm., diameter 0.81 mm. Same locality and horizon. U. S. Nat. Museum 560224.

10. Length 1.56 mm., diameter 0.68 mm. Locality 21. Todos Santos claystone member of Sisquoc formation. U. S. Nat. Museum 560225. Though found at locality 21 in strata mapped as Todos Santos claystone member of Sisquoc formation, this species is characteristic of upper member of Monterey shale.

6. *Virgulina (Virgulinella) pertusa* Reuss. Length 0.55 mm., width 0.26 mm. Locality 57. Sisquoc formation. U. S. Nat. Museum 560219.

7. *Cassidulinoides califonriensis* Bramlette, n. sp. Holotype. Length 0.45 mm., maximum diameter 0.25 mm. Locality 21. Todos Santos member of Sisquoc formation. U. S. Nat. Museum 560220.



FORAMINIFERA FROM UPPER MEMBER OF MONTEREY SHALE AND SISQUOC FORMATION.

PLATE 23

Figures 1–3. *Eponides* cf. *E. peruvianus* (d'Orbigny). Maximum diameter 0.36 mm., thickness 0.2 mm. Union Oil Co. well Le Roy no. 1, Santa Maria Valley field, depth 3,149 to 3,167 feet. Sisquoc formation. U. S. Nat. Museum 560215.

4, 5, 9. *Suggrunda kleinpelli* Bramlette, n. sp.

4, 9. Holotype. Length 0.4 mm., width 0.28 mm., thickness 0.2 mm. Road cut on Laureles grade, near west edge of Salinas quadrangle, 0.4 mile south of north line of Corral de Tierra grant, Monterey Co. Diatomaceous member of Monterey shale. U. S. Nat. Museum 560217.

5. Length 0.31 mm., width 0.21 mm., thickness 0.17 mm. Locality 57a. Sisquoc formation. U. S. Nat. Museum 560218.

6–8. *Eponides* cf. *E. patagonicus* (d'Orbigny). Maximum diameter 0.37 mm., thickness 0.17 mm. Locality 60. Sisquoc formation. U. S. Nat. Museum 560216.

10–15. *Pulvinulinella purisima* Bramlette, n. sp.

10–12. Maximum diameter 0.43 mm., minimum diameter 0.34 mm., thickness 0.18 mm. Locality 21. Todos Santos claystone member of Sisquoc formation. U. S. Nat. Museum 560222. Though found at locality 21 in strata mapped as Todos Santos claystone member of Sisquoc formation, this species is characteristic of upper member of Monterey shale.

13–15. Holotype. Maximum diameter 0.53 mm., minimum diameter 0.48 mm., thickness 0.16 mm. East slope of spur 0.35 mile S. 30° E. from intersection of Ventura Boulevard and Topanga Canyon Avenue, near Woodland Hills, north slope of Santa Monica Mountains, Los Angeles Co. Monterey formation (Modelo formation of some geologists). U. S. Nat. Museum 560221.

16. *Uvigerina foxenensis* Bramlette, n. sp. Holotype. Length 0.76 mm., width 0.33 mm. Locality 155. Foxen mudstone. U. S. Nat. Museum 560209.

17, 21, 22. *Bolivina obliqua* Barbat and Johnson.

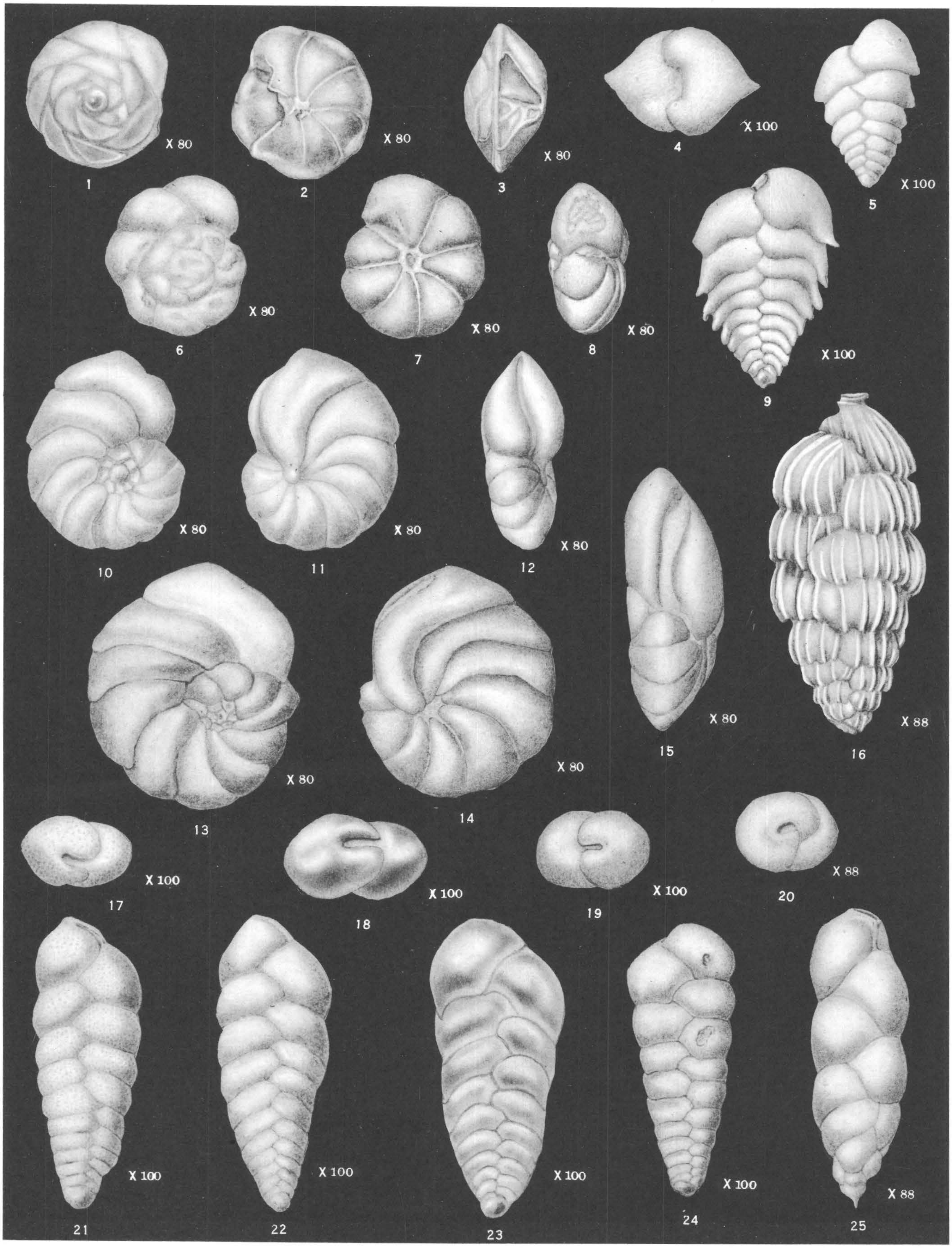
17, 21. Length 0.55 mm., width 0.21 mm., thickness 0.13 mm. Locality 156b. Foxen mudstone. U. S. Nat. Museum 560212. Perforations exaggerated on account of type of preservation.

22. Length 0.56 mm., width 0.22 mm., thickness 0.21 mm. Standard Oil Co. well Las Flores no. 1, West Cat Canyon field, depth 5,210 to 5,220 feet. Sisquoc formation. U. S. Nat. Museum 560213.

18, 23. *Bolivina obliqua* Barbat and Johnson var. Length 0.56 mm., width 0.27 mm., thickness 0.17 mm. Locality 96. Sisquoc formation. U. S. Nat. Museum 560214.

19, 24. *Bolivina foxenensis* Bramlette, n. sp. Holotype. Length 0.51 mm., width 0.2 mm., thickness 0.14 mm. Locality 156b. Foxen mudstone. U. S. Nat. Museum 560207.

20, 25. *Virgulina californiensis* var. *purisima* Bramlette, n. var. Holotype. Length 0.63 mm., width 0.2 mm. Locality 156. Foxen mudstone. U. S. Nat. Museum 560211.



FORAMINIFERA FROM SISQUOC FORMATION AND FOXEN MUDSTONE.

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