Biostratigraphy of the San Joaquin Formation in Borrow-Source Area B-17, Kettleman Hills Landfill, North Dome, Kettleman Hills, Kings County, California

By Charles L. Powell, II, Lanny H. Fisk, David F. Maloney, and David M. Haasl

Open-File Report 2010–1140

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston: Virginia 2010

For product and ordering information:
World Wide Web: *http://www.usgs.gov/pubprod*
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment:
World Wide Web: *http://www.usgs.gov*
Telephone: 1-888-ASK-USGS

Suggested citation:
Powell, C.L., II, Fisk, L.H., Maloney, D.F., and Haasl, D.M., 2010, Biostratigraphy of the San Joaquin Formation in borrow-source area B-17, Kettleman Hills landfill, North Dome, Kettleman Hills, Kings County, California: U.S. Geological Survey Open-File Report 2010-1140, 29 p. and oversized figure [*http://pubs.usgs.gov/of/2010/1140/*].

Contents

Figures

Biostratigraphy of the San Joaquin Formation in Borrow-Source Area B-17, Kettleman Hills Landfill, North Dome, Kettleman Hills, Kings County, California

By Charles L. Powell, II[1], Lanny H. Fisk[2], David F. Maloney[2], and David M. Haasl[2]

Abstract

The stratigraphic occurrences and interpreted biostratigraphy of invertebrate fossil taxa in the upper San Joaquin Formation and lower-most Tulare Formation encountered at the Chemical Waste Management Kettleman Hills waste disposal facility on the North Dome of the Kettleman Hills, Kings County, California are documented. Significant new findings include (1) a detailed biostratigraphy of the upper San Joaquin Formation; (2) the first fossil occurrence of *Modiolus neglectus*; (3) distinguishing *Ostrea sequens* from *Myrakeena veatchii* (*Ostrea vespertina* of authors) in the Central Valley of California; (4) differentiating two taxa previously attributed to *Pteropurpura festivus*; (5) finding a stratigraphic succession between *Caesia coalingensis* (lower in the section) and *Catilon iniquus* (higher in the section); and (6) recognizing Pliocene-age fossils from around Santa Barbara. In addition, the presence of the bivalves *Anodonta* and *Gonidea* in the San Joaquin Formation, both restricted to fresh water and common in the Tulare Formation, confirm periods of fresh water or very close fresh-water environments during deposition of the San Joaquin Formation.

Introduction

Development of a new site for waste deposition at the Kettleman Hills Landfill, Kings County, California (fig. 1) allowed employees from PaleoResource Consultants (Auburn, Calif.) to collect stratigraphically accurately placed fossil samples from a well-exposed section through the middle and upper part of the San Joaquin Formation and lower part of the Tulare Formation in the North Dome of the Kettleman Hills, Kings County, central California. This report documents mega-invertebrate fossil distribution (appendix 1), plots the invertebrate biostratigraphy in the section, and discusses the stratigraphic occurrences and ecologic significance of the species encountered (appendix 2), including a few new to the San Joaquin Formation. New and interesting information recognized during this study, includes (1) the first fossil occurrence of *Modiolus neglectus*; (2) distinguishing *Ostrea sequens* from *Myrakeena veatchii* (*Ostrea vespertina* of authors) in the Central Valley of California; (3) differentiating two taxa previously attributed to *Pteropurpura festivus*; (4) finding a stratigraphic succession between *Caesia coalingensis* (lower in the section) and *Catilon iniquus* (higher in the section); and (5) recognizing Pliocene age fossils from around Santa Barbara.

The Chemical Waste Management Kettleman Hills borrow-source area landfill area B-17 section is slightly less than 400 m thick and is composed of alternating sands and silt beds. The section, along with the record of fossil invertebrate occurrences, is illustrated in figure 2. The borrow-pit section is no longer exposed, having been lined to prevent leakage of waste into the local groundwater, and is in the process of being filled with waste.

[1] U.S. Geological Survey, Menlo Park, Calif.; *cpowell@usgs.gov*

[2] PaleoResource Consultants, Auburn, Calif.

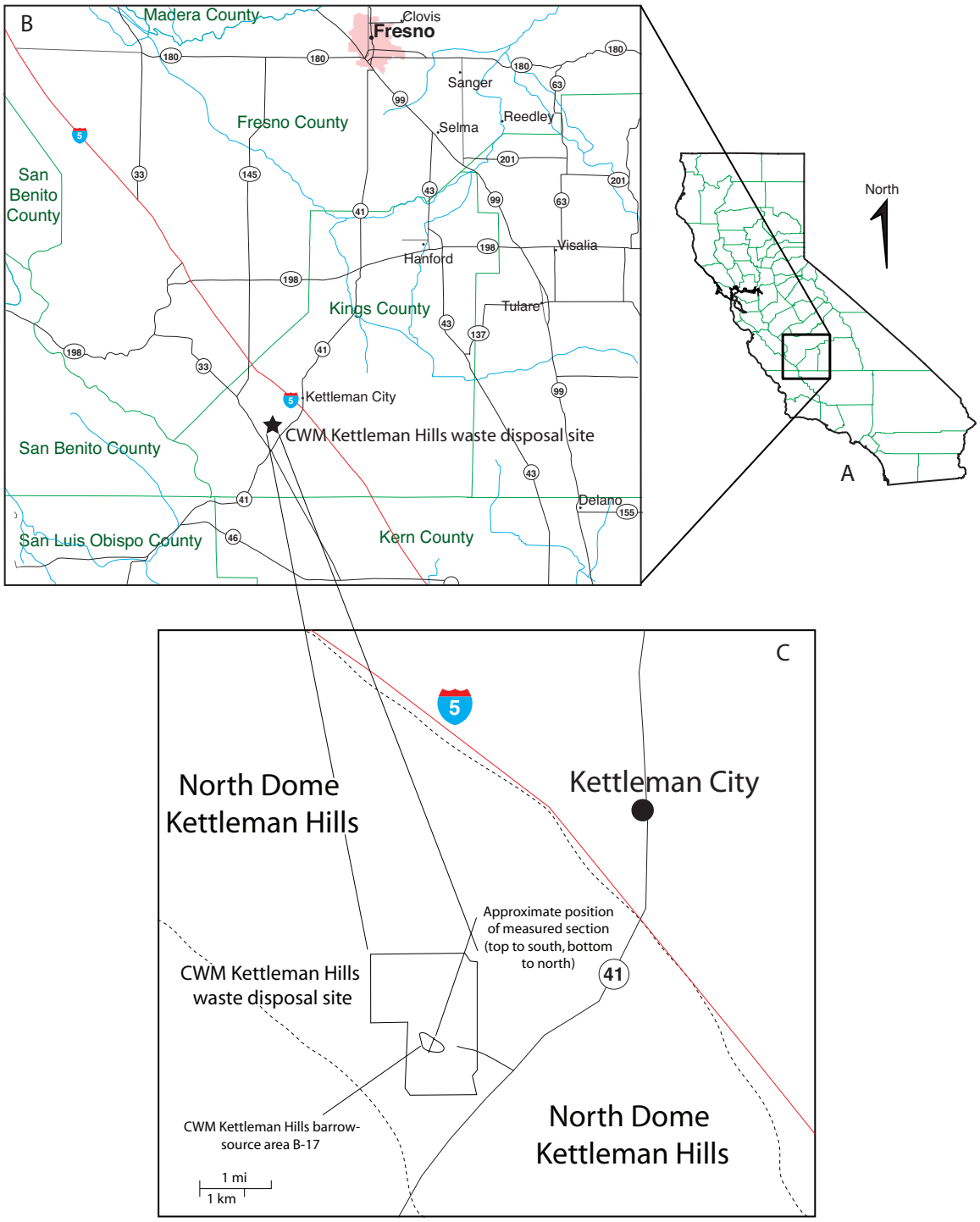

Figure 1. Location of the Chemical Waste Management (CWM) Kettleman Hills waste disposal site. *A*, Index map of California; *B*, Map of parts of Fresno, Kern, Kings, Madera, San Benito, and San Luis Obispo counties showing location of the CWM Kettleman Hills waste disposal site, interstate highways (red), California State highways (black), county boundaries (green), and rivers (blue); *C*, Details of CWM Kettleman Hills waste disposal site, with location of borrow-source area B-17 and approximate position of the measured section.

Fifty-seven samples were examined during this study. The faunal zones of Arnold (1909) and Arnold and Anderson (1909 [1910]), as modified by Woodring and others (1940 [1941]) were recognized, allowing for inclusion of these samples into a composite section for the North Dome of the Kettleman Hills and a better understanding of the biostratigraphy of the Pliocene of central California.

Age/Biostratigraphy

Based on fossil mollusks the San Joaquin Formation is Pliocene in age (Woodring and others, 1940 [1941]). Potassium/Argon dating of the San Joaquin Formation and underlying Etchegoin Formation in the Kettleman Hills yields a numerical age range for the San Joaquin between about 4.5 and 2.5 Ma (see summary in Hosford Scheirer and Magoon, 2007), or early to middle, possibly late Pliocene (using U.S. Geological Survey Fact sheet 2007-3015, and the International Stratigraphic Chart for 2004, *http://norges.uio.no/timescale/F2_chart.pdf,* accessed 2/2010). Updated International Stratigraphic Charts (*http://www.stratigraphy.org/upload/ISChart2009.pdf*, accessed 2/2010) have not been adopted by the U.S. Geological Survey, but would give an early to late Pliocene, possibly earliest Pleistocene age for the San Joaquin Formation.

The biostratigraphy used here follows that proposed by Arnold (1909 [1910]) as modified by Woodring and others (1940 [1941]). As pointed out by Stanton and Dodd (1976), the stratigraphic ranges of many prominent invertebrate taxa in central California (and elsewhere) may reflect only a small portion of each taxon's total range. The local range results from a complex interplay of (1) the total potential range; (2) the portion of the enclosing section where environmental parameters would allow the taxon to be present; (3) chance, that is to say the taxon was present among the suite of creatures in the specific location represented by the fossil locality; and (4) taphonomy, preburial, and diagenetic conditions which allow a taxon to be preserved. Documenting the stratigraphic occurrences of various taxa in a well-exposed stratigraphic section allows for the development of detailed biostratigraphy that aids in correlating and dating similar-age rocks throughout California and elsewhere in western North America.

The stratigraphic section once exposed in the Kettleman Hills Landfill borrow-source area B-17 included both the San Joaquin and Tulare formations. The occurrence of marine fossils below the top of the San Joaquin Formation indicate a shallow marine environment of mostly mud, silt, and sand with occasional conglomerates. The occurrence of fresh-water mollusks indicates the base of the Tulare Formation and the end of marine deposition in the area, although scattered occurrences of fresh-water mollusks in the San Joaquin Formation indicate that fresh-water conditions may have occurred occasionally during deposition of the San Joaquin Formation (perhaps during sea-level low stands), or that the fresh-water environment was not far away. Furthermore, the occurrence of *Anadara trilineata* into the Tulare Formation indicates a marine environment in close proximity to the fresh-water environment represented by that formation.

The stratigraphic range of extant and extinct species in the section could be due to environmental parameters favorable for their occurrence and subsequent deposition and preservation. However, the stratigraphic range of extinct species also could represent their stratigraphic ranges. Further data in well-dated sections is needed to determine accurately the stratigraphic ranges of extinct species. Figure 2 plots the stratigraphic ranges of extinct species in the CWM Kettleman Hills Landfill section. With the exception of *Pteropurpura* aff. *P. festivus*, which has yet to be adequately distinguished from the nominal species, the last occurrence of *Caesia coalingensis*, and the first occurrence *Catilon iniquus*, all these stratigraphic ranges are assumed to be due to environmental factors as they are all known to occur elsewhere in California over a broader stratigraphic interval. The stratigraphic succession of the nassariids *Caesia coalingensis* and *Catilon iniquus* appears to represent an evolutionary succession as there is no apparent significant change in environment during the interval where the change occurs. If this succession is found elsewhere in the San Joaquin Formation and (or) in other formations at about

the same time, and that time can be dated, then a detailed, well-dated biostratigraphy for this part of the California Neogene can be developed.

Acknowledgments

The authors thank Russ Graymer (USGS), Lindsey Groves (Los Angeles County Natural History Museum, Calif.) and Mary McGann (USGS) for offering helpful suggestions for improving the manuscript. Chemical Waste Management is thanked for allowing the collection of fossils from their Kettleman Hills Facility, for financial support, and for allowing publication of this report.

Patrick W. Riseley is thanked for measuring a detailed stratigraphic section of the San Joaquin Formation exposed in borrow-source area B-17 from which the generalized section in this report is derived. We also thank former PaleoResource Consultants employees Jason C. Butler, Eric S. Gore, Russ E. Hasting, Patrick W. Riseley, and Jaspal S. Saini for collecting specimens.

References

Abbott, R.T., 1974, American seashells—The marine Mollusca of the Atlantic and Pacific coasts of North America: New York, Van Nostrand Reinhold Co., 663 p.

Addicott, W.O., 1965, Some western American Cenozoic gastropods of the genus *Nassarius*: U.S. Geological Survey Professional Paper 503B, p. B1-B24.

Addicott, W.O., 1966, Late Pleistocene marine paleoecology and zoogeography in central California: U.S. Geological Survey Professional Paper 523C, p. C1-C21.

Addicott, W.O., 1970, Miocene gastropods and biostratigraphy of the Kern River area, California: U.S. Geological Survey Professional Paper 642, 174 p.

Addicott , W.O., and Vedder, J.G., 1963, Paleotemperature inferences from Miocene mollusks in the San Luis Obispo-Bakersfield area, California: U.S. Geological Survey Professional Paper 475C, p. C63-C68.

Addicott, W.O., Barron, J.A., and Miller, J.W., 1978, Marine late Neogene sequence near Santa Cruz, California, *in* Addicott, W.O., ed., Neogene biostratigraphy of selected areas in the California Coast Ranges: U.S. Geological Survey Open-File Report 78-446, p. 97-109.

Adegoke, O.S., 1969, Stratigraphy and paleontology of the marine Neogene formations of the Coalinga region, California: University of California Publications in Geological Sciences, v. 80, 241 p.

Allen, J.E., 1946, Geology of the San Juan Bautista Quadrangle, California: Berkeley, University of California, Ph.D. dissertation, 94 p.

Arnold, R.A., 1903, The paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California: California Academy of Sciences Memoir, v. 3, 420 p.

Arnold, R.A., 1906, The Tertiary and Quaternary pectens of California: U.S. Geological Survey Professional Paper 47, 264 p.

Arnold, R.A., 1907a, Geology and oil resources of the Summerland District, Santa Barbara County, California: U.S. Geological Survey Bulletin 321, 93 p.

Arnold, R.A., 1907b, New and characteristic species of fossil mollusks from the oil-bearing Tertiary formations of Santa Barbara County, California: Smithsonian Miscellaneous Collections, v. 50, p. 419-447.

Arnold, R.A., 1908, Description of new Cretaceous and Tertiary fossils from the Santa Cruz Mountains, California: U.S. National Museum Proceedings, v. 34, p. 345-390.

Arnold, R.A., 1909, Paleontology of the Coalinga District, Fresno and Kings Counties, California: U.S. Geological Survey Bulletin 396, 173 p.

Arnold, R.A., and Anderson, R., 1907, Geology and oil resources of the Santa Maria oil district, Santa Barbara County, California: U.S. Geological Survey Bulletin 322, 161 p.

Arnold, R.A., and Anderson, R., 1909 [1910], Geology and oil resources of the Coalinga District, California: U.S. Geological Survey Bulletin 398, 354 p.
Arnold, R.A., and Hannibal, H., 1913, The marine Tertiary stratigraphy of the north Pacific Coast: American Philosophical Society Proceedings, v. 3, p. 576-585.
Bernard, F.R., 1983, Catalogue of the living Bivalvia of the eastern Pacific Ocean—Bering Strait to Cape Horn: Canadian Special Publication of Fisheries and Aquatic Sciences, no. 61, 102 p.
Burch, J.Q., ed., 1944-1946, Distributional list of the west American marine Mollusca from San Diego, California to the Polar Sea: Minutes of the Conchological Club of southern California, pt. 1 (Pelecypods), nos. 33-45 (March 1944–February 1945); pt. 2, v. 1-2 (Gastropoda), nos. 46-63 (March 1945-September 1946).
Carson, C.M., 1925, Some new species from the Pliocene of southern California, with a few changes in nomenclature: Southern California Academy of Sciences Bulletin, v. 24, p. 31-35.
Clark, A., 1931, The cool-water Timms Point Pleistocene horizon at San Pedro, California: San Diego Society of Natural History Transactions, v. 7, p. 25-42.
Clark, B.L., 1915, Fauna of the San Pablo group of middle California: University of California Publications, Bulletin of the Department of Geology, v. 8, p. 385-572, pls. 42-71.
Clark, B.L., 1929, Stratigraphy and faunal horizons of the Coast Ranges of California: Privately printed, 132 p.
Coan, E.V., 1971, The Northwest American Tellinidae: The Veliger, supplement to v. 14, p. 1-63.
Coan, E.V., Scott, P.V., and Bernard, F.R., 2000, Bivalve seashells of western North America: Marine bivalves mollusks from Arctic Alaska to Baja California: Santa Barbara Museum of Natural History Monographs no. 2, Studies in Biodiversity no. 2, 764 p.
Conrad, T.A., 1857, Description of the Tertiary fossils collected on the survey [Williamson's survey], in Reports of explorations and surveys *** railroad *** from the Mississippi River to the Pacific Ocean: U.S. 33d Congress, 2d session, Senate Ex. Doc. 78 and House Ex. Doc. 91, v. 6, pt. 2, p. 69-73.
Cummings, J.C., Touring, R.M., and Brabb, E.E., 1962, Geology of the northern Santa Cruz Mountains, California, *in* Bowen, O.E., Jr., ed., Geologic guide to the gas and oil fields of northern California: California Division of Mines Bulletin, no. 181, p. 179-220.
Dall, W.H., 1917, Summary of the mollusks of the family Alectrionidae of the west coast of America. U.S. National Museum Proceedings, v. 51, p. 575-579.
DeLong, J.H., Jr., 1941, The paleontology and stratigraphy of the Pleistocene at Signal Hill, Long Beach, California: San Diego Society of Natural History Transaction, v. 9, p. 229-252.
Dibblee, T.W., Jr., 1966, Geology of the central Santa Ynez Mountains, Santa Barbara County, California: California Division of Mines and Geology Bulletin, no. 186, 99 p.
Durham, D.L., 1974, Geology of the southern Salinas Valley area, California: U.S. Geological Survey Professional Paper 819, 111 p.
Durham, D.L., and Addicott, W.O., 1965, Pancho Rico Formation, Salinas Valley, California: U.S. Geological Survey Professional Paper 525-A, p. A1-A22.
Durham, D.L., and Yerkes, R.F., 1964, Geology and oil resources of the eastern Puente Hills area, southern California: U.S. Geological Survey Professional Paper 420B, p. B1-B62.
Eaton, J.E., 1928, Division and duration of the Pleistocene in southern California: American Association of Petroleum Geologists Bulletin, v. 12, p. 111-141.
Eldridge, G.H., and Arnold, R., 1907, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U.S. Geological Survey Bulletin 309, 266 p.
Emerson, W.K., 1980, Invertebrate faunules of late Pleistocene age, with zoogeographic implications, from Turtle Bay, Baja California Sur, Mexico: The Nautilus, v. 94, p. 67-89.
English, W.A., 1914, The Fernando Group near Newhall, California: University of California Publications, Bulletin of the Department of Geology, v. 8, p. 203-218.

Erlandson, J.M., Rick, T.C., Collins, P.W., and Guthrie, D.A., 2007, Archaeological implications of a bald eagle nesting site at Ferrelo Point, San Miguel Island, California: Journal of Archaeological Science, v. 34, p. 255-271.
Fahy, N.E., 1974, Origin of Lake Merced. California: Geology, v. 27, p. 171-174.
Faustman, W.F., 1964, Paleontology of the Wildcat Group at Scotia and Centerville Beach, California: University of California Bulletin Publications in Geological Sciences, v. 41, p. 97-160.
Foster, N. R., 1991, Intertidal bivalves—A guide to the common marine bivalves of Alaska: Fairbanks, AK. University of Alaska Press, 152 p.
Gifford D.S., and Gifford, E.W., 1948, Oregonian *olivellas*: Nautilus, v. 62, p. 51-54.
Glen, W., 1959, Pliocene and lower Pleistocene of the western part of the San Francisco Peninsula: University of California Publications in Geological Sciences, v. 36, p. 147-198.
Grant, U.S., IV and Gale, H.R., 1931, Catalogue of the marine Pliocene and Pleistocene Mollusca of California and adjacent regions; with notes on their morphology, classification, and nomenclature and a special treatment of the Pectinidae and the Turridae (including a few Miocene and recent species; together with a summary of the stratigraphic relations of the formations involved: San Diego Society of Natural History Memoir no. 1, 1,036 p.
Grant, U.S., IV, and Hertlein, L.G., 1938, The west American Cenozoic Echinoidea: Publications of the University of California at Los Angeles in Mathematical and Physical Sciences, v. 2, 226 p.
Groves, L.T., 1991, Molluscan paleontology of the Pliocene-Pleistocene lower Saugus Formation, southern California: American Conchologist, v. 19, p.16-17.
Hall, C.A., 1960, Displaced Miocene molluscan provinces along the San Andreas fault, California: University of California Publications in Geological Sciences, v. 34, p. 281-308.
Hertlein, L.G., and Grant, U.S., IV, 1972, The geology and paleontology of the marine Pliocene of San Diego, California (Paleontology: Pelecypoda): San Diego Society of Natural History Memoir 2, pt. 2B: 143-409 p.
Hetherington, G.E., 1957, Geology of the south Tapo Canyon area, Santa Susana quadrangle, Ventura County, California: Los Angeles, University of California, master thesis, 93 p.
Hoots, H.W., 1930, Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California: U.S. Geological Survey Professional Paper 165C, p. 83-134.
Hosford Scheirer, A., and Magoon, L.B., 2007, Age, distribution, and stratigraphic relationship of rock units in the San Joaquin Basin Province, California, Chapter 5 *in* Petroleum systems and geologic assessment of oil and gas in the San Joaquin Basin Province, California: U.S. Geological Survey Professional Paper 1713, 107 p., *http://pubs.usgs.gov/pp/pp1713/05/.*
Howe, H.V., 1922, Faunal and stratigraphic relationships of the Empire Formation, Coos Bay, Oregon: University of California Publications, Department of Geological Sciences Bulletin, v. 14, p. 85-114.
Johnson, R.G., 1962, Mode of formation of marine fossil assemblages of the Pleistocene Millerton Formation of California: Geological Society of America Bulletin, v. 73, p. 113-130.
Jordan, E.K., 1926, Molluscan fauna of the Pleistocene of San Quintin Bay, Lower California: California Academy of Sciences Proceedings, series 4, v. 15, p. 241-254.
Kanakoff, G.P., and Emerson,W.K., 1959, Late Pleistocene invertebrates of the Newport Bay area, California: Los Angeles County Museum Contributions in Science, no. 31, 47 p.
Kennedy, G.L., 1975, Paleontologic record of areas adjacent to the Los Angeles and Long Beach Harbors, Los Angeles County, California: Allan Hancock Expedition, Marine Studies of San Pedro Bay, California, pt. 9, paleontology, p. 1-119.
Kennedy, G.L., 1978, Pleistocene paleoecology, zoogeography, and geochronology of marine invertebrate faunas of the Pacific northwest coast (San Francisco Bay to Puget Sound): Davis, University of California, Ph.D. disseratation, 824 p.

Keen, A.M., 1943, New mollusks from the Round Mountain Silt (Temblor) Miocene of California: San Diego Society of Natural History Transaction, v. 10, p. 25-60.
Kern, J.P., 1973, Early Pliocene marine climate and environment of the eastern Ventura basin southern California: University of California Publications in Geological Sciences, v. 96, 117 p.
Kern, J.P., and Wicander, E. R., 1974, Origin of a bathymetrically displaced marine invertebrate fauna in the upper part of the Capistrano Formation (lower Pliocene), southern California: Journal of Paleontology, v. 48, p. 495-505.
Kew, W.S.W., 1920, Cretaceous and Cenozoic Echinoidea of the Pacific Coast of North America: University of California Publications, Bulletin of the Department of Geology, v. 12, p. 23-236.
Kew, W.S.W., 1924, Geology and oil resources of a part of Los Angeles and Ventura Counties, California: U.S. Geological Survey Bulletin 753, 202 p.
Kohl, R.F., 1974, A new late Pleistocene fauna from Humboldt County, California: The Veliger, v. 17, p. 211-219.
Lajoie, K.R., Ponti, D J., Powell, C.L., II, Mathieson, S.A., and Sarna-Wojcicki, A.M. , 1991, Emergent marine strandlines and associated sediments, coastal California—A record of Quaternary sea-level fluctuations, vertical tectonic movements, climatic changes, and coastal processes, *in* Morrison, R.B., ed., Quaternary nonglacial geology: Conterminous U.S. The geology of North America, vol. K-2, Geological Society of America (Boulder, Colorado), p. 190-214.
Loel, W., and Corey, W.H., 1932, The Vaqueros Formation, lower Miocene of California. I. Paleontology: University of California Publications Bulletin of the Department of Geological Sciences, v. 22, p. 31-410.
MacNeil, F.S., 1965, Evolution and distribution of the genus *Mya*, and Tertiary migrations of Mollusca: U.S. Geological Survey Professional Paper 483G, p. G1-G51.
Marincovich, L.N., Jr., 1976, Late Pleistocene molluscan faunas from the upper terraces of the Palos Verdes Hills, California: Natural History Museum of Los Angeles County, Contributions in Science no. 281, 28 p.
Marincovich, L.N., Jr., 1977, Cenozoic Naticidae (Mollusca: Gastropoda) of the northeastern Pacific: American Paleontology Bulletin, v. 70, p. 165-494.
Martin, B., 1916, The Pliocene of middle and northern California: University of California Publications, Bulletin of the Department of Geology, v. 9, p. 215-259.
McLean, J.H., 1978, Marine shells of southern California: Natural History Museum of Los Angeles County, Science Series, no. 24, 94 p.
McLean, J.H., 1996, The Prosobranchia, *in* McLean, J.H. and Gosliner, T.M., The Gastropoda: Taxonomic atlas of the benthic fauna of the Santa Maria Basin and western Santa Barbara Channel, v. 9, The Mollusca, pt. 2, 228 p.
McLean, J.H., 2007, Gastropoda, Shelled Gastropods, *in* Carlton, J.T., ed., The Light and Smith Manual. Intertidal invertebrates from central California to Oregon (4th ed.): Berkeley, University of California Press, p. 713-766.
McLean, J.H., and Grosliner, T.M., 1996, The Gastropoda, *in* Taxonomic atlas of the benthic fauna of the Santa Maria Basin and western Santa Barbara Channel, v. 9, The Mollusca, pt. 2, The Gastropoda, 228 p.
Meade, R.F., 1967, Molluscan paleoecology of the Fernando Group of southern Ventura Basin: Los Angeles, University of California, Ph.D. disseration, 154 p.
Minor, S.A., Kellogg, K.S., Stanley, R.G., Stone, P., Powell, C.L., II, Gurrola, L.D., Selting, A.J., and Bradt, T.R., 2002, Preliminary geologic map of the Santa Barbara coastal plain area, Santa Barbara County, California: U.S. Geological Survey Open-File Report 02-136, scale 1:24,000, 36 p., *http://pubs.usgs.gov/of/2002/ofr-02-0136/*
Moody, C.L., 1916, Fauna of the Fernando of Los Angeles: University of California Publications, Bulletin of the Department of Geology, v. 10, p. 39-62.

Moore, E.J., 1983, Tertiary marine pelecypods of California and Baja California—Nuculidae through Malleidae: U.S. Geological Survey Professional Paper 1228A, p. A1-A108.
Moore, E.J., 1987, Tertiary marine pelecypods of California and Baja California—Plicatulidae to Ostreidae: U.S. Geological Survey Professional Paper 1228C, p. C1-C53.
Moore, E.J., 2002, Family Cardiidae, *in* Tertiary marine pelecypods of California and Baja California, Chapter F: *http://members.peak.org/~chintimp/Cardiidae.htm*, 21 p.
Nomland, J.O., 1916, Fauna from the lower Pliocene at Jacalitos Creek and Waltham Canyon, Fresno County, California: University of California Publications, Bulletin of the Department of Geology, v. 9, p. 199-214.
Nomland, J.O., 1917a, The Etchegoin of middle California: University of California Publications, Bulletin of the Department of Geology, v. 10, p. 191-254.
Nomland, J.O., 1917b, Fauna of the Santa Margarita beds in the north Coalinga region of California: University of California Publications, Bulletin of the Department of Geology, v. 10, p. 293-326.
Oakeshott, G.B., 1958, Geology of the Placerita oil field, Los Angeles County, California: California Journal of Mines and Geology, v. 46, p. 43-82.
Ogle, B.A., 1953, Geology of the Eel River Valley area, Humboldt County, California: California Division of Mines Bulletin 164, 128 p.
Oldroyd, I.S., 1924, Marine shells of Puget Sound and vicinity: Publications of the Puget Sound Biological Station of the University of Washington, v. 4, 272 p.
Oldroyd, I.S., 1925, The fossils of the lower San Pedro fauna of the Nob Hill cut, San Pedro, California: U.S. National Museum Proceedings, v. 65, art. 22, p. 1-39.
Oldroyd, I.S., and Grant, U.S., IV, 1931, A Pleistocene molluscan fauna from near Goleta, Santa Barbara County, California: The Nautilus, v. 44, p. 91-94.
Peck, J.H., 1960, Paleontology and correlation of the Ohlson Ranch Formation: University of California Publications in Geological Sciences, v. 36, p. 233-242.
Perry, F.A., 1993, Fossil invertebrates and geology of the marine cliffs at Capitola, California: Santa Cruz, Calif. Santa Cruz City Museum, p. 1-30.
Powell, C.L., II, 1998, The Purisima Formation and related rocks (upper Miocene–Pliocene), greater San Francisco Bay area, central California; review of literature and USGS collections (now housed at the Museum of Paleontology, University of California, Berkeley): U.S. Geological Survey Open-File Report 98-594, 101 p.
Powell, C.L., II, 2001, Geologic and molluscan evidence for a previously misunderstood late Pleistocene cool water, open coast terrace at Newport Bay, southern California: The Veliger, v. 44, p. 340-347.
Powell, C.L., II, 2007, Outcrops and mollusks of the "Margaritan" California provincial molluscan stage in the northern Salinas Valley, Monterey and San Benito Counties, central California: PaleoBios, v. 27, p. 86-125.
Powell, C.L., II, Allen, J.R., and Holland, P.J., 2004, Invertebrate paleontology of the Wilson Grove Formation (late Miocene to late Pliocene), Sonoma and Marin Counties, California, with some observations on its stratigraphy, thickness, and structure: U.S. Geological Survey Open-File Report 2004-1017, 106 p.
Powell, C.L., II, Barron, J.A., Sarna-Wojcicki, A.M., Clark, J.C., Perry, F.A., Brabb, E.E., and Fleck, R.J., 2007, Age, stratigraphy, and correlation of the late Neogene Purisima Formation, central California Coast Ranges: U.S. Geological Survey Professional Paper 1740, 32 p.
Powell, C.L., II, Stanton, R.J., Jr., Vendrasco, M., and Liff-Grief, P., 2009, Warm extralimital fossil mollusks used to recognize the mid-Pliocene warm event in southern California: Western Society of Malacologists Annual Report for 2008, v. 41, p. 70-91.

Powell, C.L., II, and Stevens, D., 2000, Age and paleoenvironmenal significance of mega-invertebrates from the "San Pedro" Formation in the Coyote Hills, Fullerton and Buena Park, Orange County, southern California: U.S. Geological Survey Open-File Report 00-319, 83 p.

Pressler, E.D., 1929, The Fernando Group in the Las Posas-South Mountain District, Ventura County, California: University of California Publications, Bulletin of the Department of Geological Sciences, v. 18, p. 325-345.

Rice, T., 1971, Marine shells of the Pacific northwest: Edomonds, Wash., Ellison Industries, Inc., 102 p.

Rodda, P.U., 1957, Paleontology and stratigraphy of some marine Pleistocene deposits in northwest Los Angeles Basin, California: American Association of Petroleum Geologists Bulletin, v. 41, p. 2457-2492.

Roth, B., 1979, Late Cenozoic marine invertebrates from northwest California and southwest Oregon: Berkeley, University of California, Ph.D. dissertation, 792 p.

Rowland, R.W., 1972, Paleontology and paleoecology of the San Diego Formation in northwestern Baja California: San Diego Society of Natural History Transaction, v. 17, p. 25-32.

Schoellhamer, J.E., Vedder, J.G., Yerkes, R.F., and Kinney, D.M., 1981, Geology of the northern Santa Ana Mountains: U.S. Geological Survey Professional Paper 420D, p. D1-D109.

Soot-Ryen, T., 1955, A report on the family Mytilidae (Pelecypoda): University of southern California, Allan Hancock Fondation, Allan Hancock Pacific Expeditions, v. 20, 261 p.

Soper, E.K., and Grant, U.S., IV, 1932, Geology and paleontology of a portion of Los Angeles, California: Geological Society of America Bulletin, v. 43, p. 1041-1067.

Squires, R.L., Groves, L.T., and Smith, J.T., 2006, New information on molluscan paleontology and depositional environments of the upper Pliocene Pico Formation, Valencia area, Los Angeles County, southern California: Natural History Museum of Los Angeles County, Contributions in Science, no. 511, 27 p.

Stanton, R.J., Jr., 1966, Megafauna of the upper Miocene Castaic Formation, Los Angeles County, California: Journal of Paleontology, v. 40, p. 21-40.

Stanton, R.J., Jr., and Dodd, J.R., 1976, Pliocene biostratigraphy and depositional environment of the Jacalitos Canyon area, California, *in* Fritsche, A.E., TerBest, H., Jr., and Worardt, W.W., eds., The Neogene symposium: Society of Economic Paleontologists and Mineralogists, Annual meeting, p. 85-94.

Touring, R. M., 1959, Structure and stratigraphy of the La Honda and San Gregorio Quadrangles, San Mateo County, California: Stanford, Calif., Stanford University, Ph.D. dissertation, 228 p.

Valentine, J.W., 1956, Upper Pleistocene Mollusca from Potrero Canyon, Pacific Palisades, California: San Diego Society of Natural History Transaction, v. 12, p. 181-205.

Valentine, J.W., 1958, Late Pleistocene megafauna of Cayucos, California, and its zoogeographic significance: Journal of Paleontology, v. 32, p. 687-696.

Valentine, J.W., 1960, Habitats and sources of Pleistocene mollusks at Torrey Pines Park, California: Ecology, v. 41, p. 161-165.

Valentine, J.W., 1961, Paleoecologic molluscan geography of the Californian Pleistocene: University of California Publications in Geological Sciences v. 34, p. 309-442.

Valentine, J.W., and Lipps, J.H., 1963, Late Cenozoic rocky-shore assemblages from Anacapa Island, California: Journal of Paleontology, v. 37, p. 1292-1302.

Vedder, J.G., 1972, Review of stratigraphic names and megafaunal correlation of Pliocene rocks along the southeast margin of the Los Angeles Basin, *in* Stinemeyer, E.H., ed., Pacific Coast Miocene biostratigraphy symposium: Society of Economic Paleontologists and Mineralogists, Pacific Section, 47th, Bakerfield, Calif., Proceedings, 1972, p. 158-172.

Vedder, J.G., and Norris, R.M., 1963, Geology of San Nicolas Island, California: U.S. Geological Survey Professional Paper 369, 65 p.

Waterfall, L.N., 1929, A contribution to the paleontology of the Fernando Group, Ventura Conty, California: University of California Publications, Bulletin Department Geological Science, v. 18, p. 71-92.
Weaver, C.E., 1909, Stratigraphy and paleontology of the San Pablo Formation in middle California: University of California Publications, Bulletin of the Department of Geology, v. 5, p. 243-269.
Weaver, C.E., 1949, Geology of the Coast Ranges immediately north of the San Francisco Bay region, California: Geological Society of America Memoir 35, 242 p.
Willett, G., 1937, Report on Pleistocene molluscan faunas of Capistrano Beach, Orange County, California: Southern California Academy of Sciences Bulletin, v. 36, p. 105-107.
Winterer, E.L., and Durham, D.L., 1962, Geology of southeastern Ventura Basin, Los Angeles County, California: U.S. Geological Survey Professional Paper 334H, p. H1-H366.
Woodring, W.P., 1938, Lower Pliocene mollusks and echinoids from the Los Angeles Basin, California: U.S. Geological Survey Professional Paper 190, 58 p.
Woodring, W.P., and Bramlette, M.N., 1950, Geology and paleontology of the Santa Maria District California: U.S. Geological Survey Professional Paper 222: 185 p.
Woodring, W.P., Bramlette, M.N., and Kew, W.S.W., 1946, Geology and paleontology of Palos Verdes Hills, California: U.S. Geological Survey Professional Paper 207, 145 p.
Woodring, W.P., Stewart, R., and Richards, R.W., 1940 [1941], Geology of the Kettleman Hills oil field, California: U.S. Geological Survey Professional Paper 195, 170 p.
Wright, R.H., 1972, Late Pleistocene marine fauna, Goleta, California: Journal of Paleontology, v. 46, p. 688-695.
Yancey, T.E., 1978, Stratigraphy of the Plio-Pleistocene strata in the Twelvemile Creek area, San Francisco Peninsula, California: California Academy of Sciences Proceedings, Fourth Series v. 41, p. 357-370.
Yerkes, R.F., 1972, Geology and oil resources of the western Puente Hills area, southern California: U.S. Geological Survey Professional Paper 420C, p. C1-C63.
Zinsmeister, W.J., 1970, A late Pliocene macrofossil fauna of Newport Beach, Orange County, California: Southern California Academy of Sciences Bulletin, v. 69, p. 121-125.

Appendix 1: Fossil collections/taxa collected

Arranged alphabetically and numerically by field number as marked on the sample bags. Zone determinations below are from the field geologists and do not necessarily agree with determinations in figure 2.

DFM collected by David F. Maloney.

Field no.: DFM 11-12-01-02. Borrow-source area B-17, *Acila* zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara trilineata (Conrad)

Field no.: DFM 12-12-01-01. Borrow-source area B-17, *Trachycardium* zone, San Joaquin Formation.
Mollusca:
Bivalvia:
Anadara trilineata (Conrad)
Macoma? sp.
Mytilus cf. *M. californianus* Conrad
Saxidomus cf. *S. latus* Stewart
Solen? sp.
Tellina woodringi Adegoke
Trachycardium cf. *T. quadrigenarium* (Conrad)

Gastropoda
Calliostoma cf. *C. coalingensis* Arnold
Calyptraea cf. *C. inornata* (Gabb)
Catilon cf. *C. iniquus* (Stewart)
Nassarius sp.
Naticidae, indeterminate
Neogastropoda, indeterminate

Field no.: DFM 12-12-01-03. Borrow-source area B-17, *Neverita* zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara trilineata (Conrad)
Ostrea cf. *O. sequens* Arnold
Gastropoda
Calyptraea cf. *C. inornata* (Gabb)
Naticidae, indeterminate

Field no.: DFM 18-02-08-02. Borrow-source area B-17, Tulare Formation.
Mollusca
Bivalvia
Anadara trilineata (Conrad)
Argopecten sp. [right valve ± 20 ribs, low, rounded ribs with narrow interspaces]

Field no.: DFM 18-02-08-03. Borrow-source area B-17, San Joaquin Formation.
Mollusca
Gastropoda
Forreria sp.
Glossaulax reclusiana (Deshayes)
Indeterminate gastropod (limpet)
Echinodermata
Echinoidea
Dendraster cf. *D. coalingensis* Twitchell
Arthropoda
Maxillopoda
Balanus? sp.
Malacostraca
Indeterminate taxon

Field no.: DFM 18-02-08-04. Borrow-source area B-17, San Joaquin Formation.
Mollusca
Gastropoda
Caesia coalingensis (Arnold)
Naticidae, indeterminate
Pteropurpura aff. *P. festiva* (Hinds)
Echinodermata
Echinoidea
Dendraster cf. *D. coalingensis* Twitchell

Field no.: DFM 18-12-01-01. Borrow-source area B-17, coquina layer, San Joaquin Formation.
Mollusca
Bivalvia
Anadara trilineata (Conrad)
Gonidea? sp. [note on bag "Pelecypod from Tulare Fm. SW corner of excavation"]
Macoma cf. *M. affinis* Nomland
Mya cf. *M. arenaria* Linnaeus
Solen? sp.
Gastropoda
Calyptraea cf. *C. inornata* (Gabb)

Field no.: DFM 23-01-02-01. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: Gypsum layer, *Acila* zone.
Mollusca
Bivalvia
Acila castrensis (Hinds)
Anadara trilineata (Conrad)
Macoma cf. *M. affinis* Nomland
Modiolus sp.
Zirfaea sp.
Gastropoda
Calyptraea cf. *C. inornata* (Gabb)
Catilon iniqua (Stewart)
Crepidula sp.
Arthropoda
Maxillopoda
Balanus sp.

Field no.: DFM 23-01-02-02. Borrow-source area B-17, gypsum zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara trilineata (Conrad)
Gastropoda
Calyptraea cf. *C. inornata* (Gabb)

Field no.: DFM 24-01-02-01. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: Gastropods above gypsum zone, first layer in the *Acila* zone, Kettleman Hills, CA. B-17, 1:400'. Borrow-source area B-17, *Acila* zone, San Joaquin Formation.
Mollusca
Bivalvia
Acila castrensis (Hinds)
Anadara trilineata (Conrad)
Anomia? sp.
Modiolus neglectus Soot-Ryen
Zirfaea sp.
Gastropoda
Calyptraea cf. *C. fastigiata* Gould [on *Anadara*]
Calyptraea filosa (Gabb)

Crepidula? sp.
Diodora? sp.
Nassarius? sp.
Naticidae?, indeterminate
Trochid, indeterminate
Arthropoda
Malacostraca
Balanus? sp.

Field no.: DFM 24-01-02-02. Borrow-source area B-17, gypsum zone, San Joaquin Formation.
Mollusca
Gastropoda
Cerithiopsidae?, indeterminate

Field no.: DFM 24-01-02-03. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: Lower oyster zone. Borrow-source area B-17, *Acila* zone, San Joaquin Formation.
Mollusca
Bivalvia
Ostrea sequens Arnold

Field no.: DFM 24-01-02-06. Borrow-source area B-17, *Trachycardium* zone, San Joaquin Formation.
Echinodermata
Echinoidea
Dendraster sp.

Field no.: DFM 25-01-02-01. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: Bivalves from sandy unit above gypsum zone clays. Borrow-source area B-17, gypsum zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara trilineata (Conrad)
Indeterminate bivalves

ESG collected by Eric S. Gore.
Field no.: ESG 11-12-01-01. Borrow-source area B-17, Tulare Formation.
Mollusca
Gastropoda
Minute indeterminate gastropods [internal molds]

Field no.: ESG 13-12-01-01. Southwest borrow-source area B-17, *Acila* zone, San Joaquin Formation.
Mollusca
Bivalvia
Ostrea sequens Arnold

Field no.: ESG 18-12-01-01. Southwest borrow-source area B-17, *Acila* zone, San Joaquin Formation.
Mollusca
Bivalvia
Macoma cf. *M. affinis* Nomland

Mya cf. *M. arenaria* Linnaeus

Field no.: ESG 19-12-01-01. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: Northeast section (east of evaporation pond) borrow-source area B-17 below road cut, weathering out from *Pecten* zone, San Joaquin Formation.
Mollusca
Gastropoda
Naticidae, inderminate
Pteropurpura aff. *P. festiva* (Hinds)

Field no.: ESG 20-12-01-01. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: From 6" layer in *Pecten* zone, east of evaporate pond, borrow-source area B-17, San Joaquin Formation.
Mollusca
Gastropoda
Caesia coalingensis Arnold

Field no.: ESG 20-12-01-02. East ridge of borrow-source area B-17, *Trachycardium* zone, San Joaquin Formation.
Arthropoda
Malacostraca
Indeterminate crab cheliped [identified as *Callianassa* and cf. *Loxyrhynchus* by collector]

Field no.: ESG 20-12-01-04. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: From sandy silt beds below *Trachycardium* interval on ridge, east side of borrow-source area B-17, San Joaquin Formation.
Mollusca
Bivalvia
Ostrea sequens Arnold

Field no.: ESG 20-12-01-05. Borrow-source area B-17, San Joaquin Formation.
Echinodermata
Echinoidea
Dendraster cf. *D. coalingensis* Twitchell

Field no.: ESG 20-12-01-06. From ridge on the east side of borrow-source area B-17, *Trachycardium* interval, San Joaquin Formation.
Mollusca
Bivalvia
Anadara trilineata (Conrad)
Tellinidae?, indeterminate
Gastropoda
Nassarius sp.

Field no.: ESG 20-12-01-07. From ridge on the east side of borrow-source area B-17, *Trachycardium* interval, San Joaquin Formation.
Mollusca
Bivalvia

Anadara sp.
Macoma nasuta (Conrad)
Tellina? aff. *T. oldroydi* Wiedey
Trachycardium sp.

Field no.: ESG 21-12-01-01. From ridge on the east side of borrow-source area B-17, *Trachycardium* interval, San Joaquin Formation.
Mollusca
Gastropoda
Calliostoma cf. *C. ligatum* (Gould)
Calyptraea cf. *C. fastigata* Gould
Calyptraea inornata (Gabb)
Cancellaria sp.
Nassarius sp.
Glossaulax cf. *G. reclusiana* (Deshayes)
Pteropurpura aff. *P. festiva* (Hinds)

Field no.: ESG 21-12-01-02. From ridge on the east side of borrow-source area B-17, *Trachycardium* interval, San Joaquin Formation.
Arthropoda
Maxillopoda
Balanus? sp.

Field no.: ESG 21-12-01-04. Note with specimens: *Trachycardium* zone.
Mollusca
Bivalvia
Anadara cf. *A. trilineata* (Conrad)
Gastropoda
Nassarius sp.
Naticidae, indeterminate
Neogastropoda, indeterminatec
Glossaulax cf. *G. reclusiana* (Deshayes)
Pteropurpura aff. *P. festiva* (Hinds)

Field no.: ESG 21-12-01-05. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: From 6" layer, *Pecten* zone located east of pond, borrow-source area B-17, San Joaquin Formation.
Cnidaria
Anthozoa
Indeterminate, very small cup coral
Mollusca
Bivalvia
Indeterminate fragments
Gastropoda
Naticidae, indeterminate

JCB collected by Jason C. Butler
Field no.: JCB 27-11-02-01. Northeast borrow-source area B-17, San Joaquin Formation.
Mollusca

Bivalvia
Anadara? sp. [small fragment]
Indeterminate micro bivalves or ostracodes
Gastropoda
Cerithiopsidae?, indeterminate
Naticidae, indeterminate
Neogastropoda, indeterminate

Field no.: JCB 27-11-02-02. Northeast borrow-source area B-17, San Joaquin Formation.
Mollusca
Bivalvia
Ostreidae, indeterminate

Field no.: JCB 27-11-02-03. Northeast borrow-source area B-17, San Joaquin Formation.
Mollusca
Bivalvia
Macoma cf. *M. affinis* Nomland
Mya cf. *M. arenaria* Linnaeus
Saxidomus cf. *S. latus* Stewart

Field no.: JCB 27-11-02-04. Northeast borrow-source area B-17, San Joaquin Formation.
Mollusca
Bivalvia
Ostreidae, indeterminate

Field no.: JCB 27-11-02-05. Northeast borrow-source area B-17, San Joaquin Formation.
Mollusca
Bivalvia
Modiolus cf. *M. neglectus* Soot-Ryen
Modiolus sp.

Field no.: JCB 27-11-02-06. Northeast borrow-source area B-17, San Joaquin Formation.
Mollusca
Bivalvia
Ostreidae, indeterminate

JSS collected by Jaspal S. Saini
Field no.: JSS 30-12-02-14. Borrow-source area B-17, Tulare Formation.
Mollusca
Bivalvia
Anodonta kettlemensis Arnold
Gonidea coalingensis Arnold

LHF collected by Lanny H. Fisk
Field no.: LHF 10-03-06-01. Borrow-source area B-17, San Joaquin Formation.
Mollusca
Bivalvia
Macoma cf. *M. affinis* Nomland

Field no.: LHF 16-02-07-01. Borrow-source area B-17, Tulare Formation.
Note with specimens: Collected in situ in the *Amnicola* bed at southwest side of borrow-source area B-17, Tulare Formation.
Mollusca
Bivalvia
Ostreidae, indeterminate [internal cast possibly referable to this taxon]

Field no.: LHF 18-02-08-03. Borrow-source area B-17, San Joaquin Formation.
Mollusca
Bivalvia
Indeterminate bivalve

Field no.: LHF 19-02-06-01. Borrow-source area B-17, *Trachycardium* zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara sp. [fragments]
Saxidomus latus Stewart
Tellina woodringi Adegoke
Gastropoda
Calyptraea cf. *C. fastigiata* Gould
Arthropoda
Maxillopoda
Balanus? sp.

Field no.: LHF 19-02-06-02. Borrow-source area B-17, *Trachycardium* zone, San Joaquin Formation.
Mollusca
Bivalvia
Tellina woodringi Adegoke

PWR collected by Patrick W. Riseley
Field no.: PWR 01-12-05-01. Borrow-source area B-17, *Acila* zone, San Joaquin Formation.
Echinodermata
Echinoidea
Dendraster coalingensis Twitchell [abundant]

Field no.: PWR 08-12-05-01. Borrow-source area B-17, San Joaquin Formation.
Mollusca
Gastropoda
Glossaulax cf. *G. reclusiana* (Deshayes)

Field no.: PWR 09-11-05-01 . Borrow-source area B-17, *Trachycardium* zone, San Joaquin Formation.
Mollusca
Bivalvia
Acila castrensis (Hinds)
Anadara cf. *A. trilineata* (Conrad)
Cryptomya cf. *C. californica* (Conrad)
Macoma cf. *M. affinis* Nomland
Modiolus cf. *M. neglectus* Soot-Ryen
Mytilus sp.

Solen cf. *S. rosaceus* Carpenter
Tellina woodringi Adegoke
Tellinidae, indeterminate
Gastropoda
Calyptraea cf. *C. inornata* (Gabb)
Crepidula princeps (Conrad)?
Crepidula sp.
Naticidae, indeterminate
Glossaulax reclusiana (Deshayes)
Arthropoda
Malacostraca
Indeterminate crab cheliped

Field no.: PWR 15-11-04-01. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: 88' upsection from top of *Acila* sand, San Joaquin Formation. Borrow-source area B-17, black shale bed at top of *Acila* zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara cf. *A. trilineata* (Conrad) [rare]
Modiolus cf. *M. neglectus* Soot-Ryen [articulated and common]
Note: Dark, fine grained rocks with pyrite.

Field no.: PWR 16-08-06-01. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: Sandstone in transgressive layer at base of *Trachycardium* interval. Borrow-source area B-17, base of *Trachycardium* zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara cf. *A. trilineata* (Conrad)
Ostrea cf. *O. sequens* Arnold
Gastropoda
Caesia coalingensis (Arnold)
Naticidae, indeterminate [common]
Ocenebrina cf. *O. lurida* (Middendorff)
Pteropurpura aff. *P. festiva* (Hinds)
Arthropoda
Maxillopoda
Balanus? sp.
Echinodermata
Echinoidea
Dendraster sp.

Field no.: PWR 16-09-05-01. Borrow-source area B-17, base of *Trachycardium* zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara trilineata (Conrad)
Cryptomya californica (Conrad)
Macoma cf. *M. nasuta* (Conrad)
Macoma cf. *M. affinis* Nomland

Macoma sp.
Mya cf. *M. arenaria* Linnaeus
Mytilus sp.
Ostrea cf. *O. sequens* Arnold
Ostreidae, indeterminate
Saxidomus latus Stewart
Solen cf. *S. rosaceus* Carpenter
Tellina woodringi Adegoke

Gastropoda

Calyptraea cf. *C. fastigiata* Gould
Calyptraea cf. *C. inornata* (Gabb)
Littorina? sp.
Nassarius? sp.
Naticidae, indeterminate
Turridae?, indeterminate

Arthropoda

Maxillopoda

Balanus? sp.

Field no.: PWR 18-06-06-02. Borrow-source area B-17, marl near base of the *Trachycardium* zone, San Joaquin Formation.

Mollusca

Bivalvia

Anadara? sp.
Solen? sp.
Tagelus? sp.
Tellina woodringi Adegoke
Tellinidae?, indeterminate

Gastropoda

Neogastropoda, possibly *Pteropurpurea* sp.

Arthropoda

Malacostraca

Indeterminate crab cheliped

Field no.: PWR 21-10-05-01. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: *Pecten* interval @50'-60' below *Trachycardium* marker bed. Borrow-source area B-17, *Pecten* interval, San Joaquin Formation.

Mollusca

Bivalvia

Anadara trilineata (Conrad)
Macoma cf. *M. nasuta* (Conrad)
Tellinidae?, indeterminate

Gastropoda

Crepidula sp.
Caesia cf. *C. coalingensis* (Arnold)
Glossaulax cf. *G. reclusiana* (Deshayes)

Field no.: PWR 21-11-05-01. Borrow-source area B-17, *Acila* zone, San Joaquin Formation.

Note with specimens: Interbedded green/brown shale, siltstone, and sandstone between 609.5' and 622.5' above base of *Trachycardium* zone, borrow-source area B-17, *Acila* zone, San Joaquin Formation.
Mollusca
Bivalvia
Acila castrensis (Hinds)
Anadara trilineata (Conrad)
Macoma? sp.
Modiolus cf. *M. neglectus* Soot-Ryen.
Solen? sp.
Tellinidae, indeterminate [large; possibly *Tellina woodringi* Adegoke]
Gastropoda
Calyptraea. fastigiata Gould
Calyptraea filosa (Gabb)
Catilon iniqua (Stewart)
Crepidula princeps (Conrad)
Crepidula sp. [small casts]
Naticidae, indeterminate
Glossaulax reclusiana (Deshayes)?
Arthropoda
Maxillopoda
Balanus? sp.
Malaccostraca
Indeterminate crab cheliped

Field no.: PWR 21-11-05-02. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: Pyritized fossil from 60' downsection from the top of the *Acila* zone oyster bed and upper *Pecten* bed. Borrow-source area B-17, *Acila* zone, San Joaquin Formation.
Mollusca
Bivalvia
Modiolus sp.
Indeterminate bivalve

Field no.: PWR 22-07-05-01. Borrow-source area B-17, Trachycardium zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara cf. *A. trilineata* (Conrad)
Gastropoda
Calyptraea cf. *C. inornata* (Gabb)

Field no.: PWR 23-08-06-01/PWR 21-11-05-01. Borrow-source area B-17, San Joaquin Formation.
Mollusca
Bivalvia
Acila castrensis (Hinds)
Anadara trilineata (Conrad)
Gastropoda
Astyris gauspata (Gould) [*Mitrella gouldii* of Woodring and others, 1940[1941])
Calyptraea cf. *C. fastigiata* (Gould)
Calyptraea cf. *C. inornata* (Gabb)

Field no.: PWR 27-10-05-01. Borrow-source area B-17, *Nevertia* zone, San Joaquin Formation.
Mollusca
Gastropodas
Pteropurpura festiva (Hinds)

REH collected by Russ E. Hastings
Field no.: REH 08-12-03-02. Northeast corner of borrow-source area B-17, San Joaquin Formation.
Mollusca
Bivalvia
Anodonta cf. *A. kettlemanensis* Arnold

Field no.: REH 12-12-01-02. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: Echinoids below *Neverita* zone. Borrow-source area B-17, *Neverita* zone, San Joaquin Formation.
Echinodermata
Echinoidea
Dendraster cf. *D. coalingensis* Twitchell

Field no.: REH 18-12-01-01. Borrow-source area B-17, San Joaquin Formation.
Note with specimens: "*Pecten* zone," but is it possible it came from the *Neverita* (=*Polinices*) zone? Matrix looks like Woodring and others, 1940[1941], plate 19. Borrow-source area, coquina layer, San Joaquin Formation.
Mollusca
Bivalvia
Anadara trilineata (Conrad)
Macoma cf. *M. nasuta* (Conrad) [steinkern]
Macoma? sp.
Modiolus sp.
Ostrea cf. *O. sequens* Arnold
Ostrea sp.
Solen sp.
Tellina woodringi Adegoke
Veneridae?, indeterminate [abundant fragments]
Indeterminate bivalves
Gastropoda
Caesia coalingensis (Arnold)
Callianax cf. *C. pycna* Berry
Crepidula princeps (Conrad)
Nassarius sp.
Naticidae, indeterminate [abundant]
Pteropurpura aff. *P. festiva* (Hinds)
Arthropoda
Malacostraca
Callianassa sp.
Indeterminate crab cheliped
Echinodermata
Echinoidea
Dendraster coalingensis Twitchell

Field no.: REH 20-12-01-01. East of evaporative pond in borrow-source area B-17, *Trachycardium* zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara sp.
Argopecten? sp.
Ostrea cf. *O. sequens* Arnold
Gastropoda
Glossaulax reclusiana (Deshayes)
Pteropurpura? sp.

Field no.: REH 20-12-01-02. East of evaporative pond in borrow-source area B-17, *Trachycardium* zone, San Joaquin Formation.
Mollusca
Bivalvia
Anadara trilineata (Conrad)

Field no.: REH 26-12-01-01. Borrow-source area B-17, San Joaquin Formation.
Echinodermata
Echinoidea
Dendraster sp.

Appendix 2: Notes on Taxa Encountered

Mollusca

Bivalvia

Family Nuculidae

Acila castrensis (Hinds) lives today from Punta San Pablo, Baja California, Mexico, to Cook Inlet, Alaska (Bernard, 1983; Coan and others, 2000), in water depths from 5 to 200 m (Bernard, 1983), 7 to 1,280 m (Moore, 1983, citing Woodring and others, 1940 [1941]), or 5 to 400 m (Coan and others, 2000). In the fossil record it has been reported in rocks as old as Miocene (Bernard, 1983; Moore, 1983). California fossil occurrences are in the Capistrano (Vedder,1972), Carreaga (Woodring and Bramlette, 1950), Etchegoin (Arnold, 1909; Arnold and Anderson, 1909 [1910]; Nomland, 1916), Fernando (English, 1914; Durham and Yerkes, 1964) formations, Lomita Marl (Woodring and others, 1946), Merced (Yancey, 1978), Niguel (Kern and Wicander, 1974; as Capistrano Formation; *fide* Groves, 1991), Ohlson Ranch (Peck, 1960) formations, Palos Verdes Sand (Valentine, 1961), Pico (Kew, 1924; Grant and Gale, 1931), Purisima (Powell, 1998 and citations therein), Rio Dell (Faustman, 1964; Roth, 1979), San Diego, and San Joaquin (Hertlein and Grant, 1972) formations, San Pedro Sand (Oldroyd, 1924, listed as formation; Woodring and others, 1946), Santa Barbara (Oldroyd, 1924), Saugus (= Pico) (Groves, 1991) formations, Timms Point Silt (Clark, 1931; Woodring and others, 1946), Towsley (Kern, 1973) formation, Wildcat Group (Martin, 1916; Roth, 1979), and unnamed terrace deposits in San Diego (Oldroyd, 1924).

Family Arcidae

Anadara trilineata (Conrad) (synonym *A. trilineata canalis* Conrad) was described by Conrad (1857) as having been collected by Newberry at Santa Barbara, southern California (Woodring and

others, 1940 [1941]). However, Woodring and others (1940 [1941]) indicate that according to Newberry's itinerary, he was nowhere near Santa Barbara and, therefore, most authors since Woodring and others have not reported it as occurring at or near Santa Barbara.

The Santa Barbara Formation from which it was assumed to have been collected is now considered middle Pleistocene in age (Minor and others, 2002). Addicott (1965), discussing the nassariid gastropod *Caesia grammatus* (Dall, 1917) reported this Pliocene index fossil as occurring north of Santa Barbara in Goleta; and Powell and others (2009) report possible Pliocene fossils south of Santa Barbara near Rincon Point on the Santa Barbara/Ventura County line. In addition, an unrecorded Los Angeles County Natural History Museum collection contains *A. trilineata* and was collected in Santa Barbara proper[3]. We accept that *A. trilineata* does not occur younger than Pliocene, even though it has been reported by Roth (1979) from the Scotia Bluffs Sandstone which is, in part, Pleistocene in age. Since, the occurrence of *A. trilineata* has been confirmed in modern collections north, south, and from Santa Barbara proper, we conclude that its type locality could be located at or near Santa Barbara. Elsewhere it has been reported from Kamchatka and Sakhalin Island, Russia, in the western Pacific and from British Columbia, Canada, to southern California in the eastern Pacific in Miocene to Pliocene rocks (Moore, 1983).

Family Mytilidae

Modiolus neglectus Soot-Ryen occurs from off the mouth of the Salinas River, Monterey County, central California (Soot-Ryen, 1955), south to the Outer Gorda Bank, Baja Calfiornia Sur, Mexico, in water depths from 15 to 110 m (Coan and others, 2000). Specimens examined here are all crushed to some extent, but still more closely resemble *M. neglectus* than other eastern Pacific species. *Modiolus neglectus* has not been reported previously as a fossil, and similar specimens were referred to *Volsella* cf. *V. recta* (Conrad) by Woodring and others (1940 [1941]) and to *M. rectus* (Conrad) by Adegoke (1969). Further study and better specimens are needed to confirm the identification of the San Joaquin Formation specimens.

Mytilus californianus Conrad occurs from Cook Inlet, Alaska, south to Punta Rompiente, Baja California Sur, Mexico, in water depths from the intertidal zone to 50 m (Coan and others, 2000). This species has a limited fossil record, being reported from the Merced (Arnold, 1906) and Rio Dell (Faustman, 1964) formations, the Wildcat Group (Ogle, 1953), unnamed strata on San Nicolas Island (Vedder and Norris, 1963), and at Bahía de San Quintin, Baja California, Mexico (Jordan, 1926). These and additional Pleistocene occurrences indicate a Pliocene, possibly late Pliocene to Holocene age range.

Family Ostreidae

Ostrea sequens Arnold, although considered synonymous with *Dendrostrea? vespertina* (Conrad) by most authors (see Moore, 1987), is distinguished here. Squires and others (2006) restrict *D.? vespertina* to specimens from the ancestral Golfo de California and refer similar larger oysters from the late Miocene and Pliocene of coastal central and southern California to *Myrakeena veatchii* (Gabb). Woodring and others (1940 [1941]) use the name *Ostrea vespertina* for some forms from the Kettleman Hills, but following Squires and others (2006) these are now referred to *M. veatchii*. However, central California Tertiary oysters are smaller than typical *M. veatchii* and have less defined plications. Smaller,

[3] Natural History Museum of Los Angeles County, Invertebrate Paleontology collections, field no.: PR57-1. Bottom of hill on east side of Victoria Street in 15-foot cut, Santa Barbara, Santa Barbara County, California. Collected by Peter Rhodda, 1957. Field No.: PR57-1. Unsorted sample. Sample contains the following: Mollusca, Bivalvia, *Anadara trilineata* (Conrad), *Cyclocardia* cf. *C. californica* (Dall) of Woodring and Bramlette, 1950, *Dendostrea*? aff. *D? vespertina* (Conrad), *Humilaria* sp., *Lucinoma annulatum* (Reeve), *Ostrea* sp., *Panopea abrupta* (Conrad), *Patinopecten caurinus* (Gould), *Pecten bellus* Conrad, Gastropoda, *Astraea gibberosa* (Dillwyn) [operculum], *Astyris cf. A. gausapata* (Gould), *Crepidula princeps* Conrad, *Lirobittium* sp., *Nassarius* sp., Naticidae, indeterminate, and *Callianax biplicata* (Sowerby).

smooth to moderately plicate oysters from central California are here referred to *O. sequens*. Larger, strongly plicate specimens from central California are referred to *M. veatchii*. *Ostrea atwoodii* Gabb of similar age from central California usually is larger and easily distinguished by its smooth, flat right valve and finely ribbed left valve. The later feature is not seen in any of the specimens examined from the San Joaquin Formation.

Family Unioninae

Gonidea coalingensis Arnold. The genus *Gonidea* typified by the modern *G. angulata,* occurs from southern British Columbia, Canada in the Columbia River system south in Washington, Oregon, Idaho, Nevada, and south-central California. The species lives in lakes, streams, and rivers, preferably in sites that have a constant flow of rather shallow water (typically <3 m) and well-oxygenated substrates, especially when occurring in finer sediments. *Gonidea coalingensis* has been reported most commonly from the Tulare Formation, although like *A. kettlemanensis*, the genus also has been recognized in the Etchegoin and San Joaquin Formations (Woodring and others, 1940 [1941]).

Family Anodontinae

Anodonta kettlemensis Arnold is restricted to the Pliocene to Pleistocene Tulare Formation. The genus *Anodonta* generally is found in slow moving fresh water and has been recognized from the Etchegoin, San Joaquin, and Tulare Formations in the Kettleman Hills (Woodring and others, 1940 [1941]).

Family Cardiidae

Trachycardium quadrigenarium (Conrad) is found living from middle California to Baja California Sur, Mexico, in water depths from the intertidal zone to 135 m, in sandy mud with the edges of the valves projecting above the surface (Coan and others, 2000) and in sloughs and sheltered waters of the open coast (Hertlein and Grant, 1972, p. 259). As a fossil, it has been found from the Careaga (Woodring and Bramlette, 1950) and Castaic (Stanton, 1966) formations, Etchegoin (Clark, 1915; Nomland, 1917a), Fernando (Eldridge and Arnold, 1907; Carson, 1925; Soper and Grant, 1932; Durham and Yerkes, 1964; Kennedy, 1975; also as Repetto Formation by Woodring, 1938; Oakeshott, 1958), Jacalitos (Clark, 1929), Merced (Martin, 1916), Millerton (Johnson, 1962), Monterey (Woodring and others, 1946) formations, Neroly Sandstone (Hall, 1960), Niguel (J.G. Vedder, written commun., 1978 *in* Moore, 2002), Pancho Rico (Durham and Addicott, 1965; Durham, 1974), Pico (Pressler, 1929; Waterfall, 1929; Hoots, 1930; Winterer and Durham, 1962; Meade, 1967), San Diego (Hertlein and Grant, 1972; Rowland, 1972), San Joaquin (Woodring and others, 1940 [1941]), San Pablo (Clark, 1915), San Pedro (Oldroyd, 1925), Saugus (Eaton, 1928; Pressler, 1929; Waterfall, 1929; Hetherington, 1957; Meade, 1967; Groves, 1991 [= Pico Formation]), Santa Barbara (Dibblee, 1966) formations, Cierbo Sandstone (Weaver, 1949), Santa Margarita Sandstone (Grant and Gale, 1931; Nomland, 1917b; Addicott and Vedder, 1963; Durham, 1974; Powell, 2007 and references therein), Temblor (Arnold, 1907b; Grant and Gale, 1931; Schoellhamer and others, 1981), Towsley (Winterer and Durham, 1962; Kern, 1973), and Vaqueros (Arnold and Anderson, 1907; Loel and Corey, 1932) formations, and unnamed Pleistocene strata in California (Kanakoff and Emerson, 1959; Oldroyd and Grant, 1931; Valentine, 1956, 1960) and Baja California, Mexico (Emerson, 1980; Jordan, 1926). These formations indicate a possible maximum age of Oligocene for this species.

Family Veneridae

Saxidomus latus Stewart differs from the Miocene to Holocene *S. nuttalli* Conrad, according to Stewart (*in* Woodring and others, 1940 [1941]), by having "…a wider and longer anterior end.…" In addition, specimens from the San Joaquin Formation examined here have a broader posterior end and much subdued sculpture, becoming completely obsolete from about half way up the shell to the umbo and on the anterior end, and being most prominent on the posterior end. *Saxidomus latus* also has been

reported from the San Diego Formation (Hertlein and Grant, 1972). These occurrences indicate a Pliocene age for this species.

Family Tellinidae

Macoma inquinata (Deshayes) [synonyms *M. inquinata arnheimi* Dall; *M. irus* (Hanley) of authors] occurs in the eastern Pacific from the southeastern Bering Sea south to San Pedro, southern California (Foster, 1991), in intertidal areas in bays and offshore to 48 m, below the surf line in silt (Coan, 1971). As a fossil, it has been reported from the following stratigraphic units in California: Battery (Kennedy, 1978), Etchegoin (Arnold and Anderson, 1907, 1909 [1910]; Martin, 1916; Nomland, 1916; Adegoke, 1969), Merced (Martin, 1916; Glen, 1959), Millerton (Kennedy, 1978), Moonstone Beach and Carlotta? (Roth, 1979), Ohlson Ranch (Peck, 1960), Purisima (Powell, 1998 and references therein), Rio Dell (Faustman, 1964), San Diego (Hertlein and Grant, 1972), San Pedro Sand (Arnold, 1903; 1906; Oldroyd, 1924, 1925), San Joaquin (Adegoke, 1969) formations, Santa Margarita Sandstone (Addicott and others, 1978), Timms Point Silt (Clark, 1931), and unnamed Pleistocene deposits in California (Arnold, 1903; Willett, 1937; DeLong, 1941; Addicott, 1966; Wright, 1972; Kohl, 1974; Kennedy, 1978). These fossil and modern occurrences indicate a possible late Miocene through Holocene range.

Macoma affinis Nomland has been reported from the uppermost Etchegoin (Nomland, 1917a), Pancho Rico (Durham and Addicott, 1965), and San Joaquin (Adegoke, 1969) formations in central California. These formations indicate a late Miocene to late Pliocene range for this species.

Macoma nasuta (Conrad) [synonyms *Macoma nasuta kelseyi* (Conrad)] ranges in age from Oligocene to Holocene (Grant and Gale, 1931). Modern occurrences in the eastern Pacific are along the coast from southern Baja California Sur, Mexico, north to Kodiak Island (Bernard, 1983; McLean, 1978) and Sitkalidak Island, Alaska (Foster, 1991), in water depths from the intertidal zone to 50 m (Bernard, 1983).

Tellina woodringi Adegoke (synonyms *Tellina*? cf. *T.*? *oldroydi* Wiedey *fide* Woodring and others, 1940 [1941]). Woodring and others, 1940 [1941] and Adegoke (1969) questioned if it is a true *Tellina,* but specimens examined here have lateral teeth, confirming their placement in that genus. This species has been reported only from the Etchegoin and San Joaquin formations in the Coalinga District (Adegoke, 1969), central California.

Family Solenidae

Solen rosaceus Carpenter has been reported from the Fernando (Eldridge and Arnold, 1907), Merced (Fahy, 1974), San Diego (Hertlein and Grant, 1972), and San Pedro (Arnold, 1903) formations, the Wildcat Group (Faustman, 1964), and unnamed strata in southern California (Kanakoff and Emerson, 1959), and Baja California (Jordan, 1926). These occurrences indicate a Pliocene to Holocene age range for this species. Modern occurrences are from Queen Charlotte Islands, British Columbia, Canada, to Bahía San Quintín, Baja California, Mexico, in the middle and lower intertidal zone, in sand and mud of sheltered bays, frequently in *Zostera* beds (Coan and others, 2000), although Hertlein and Grant (1972) reported it in water depths from the intertidal zone to 46 m, and Bernard (1983) noted its occurrence from the intertidal zone to 45 m. Previous specimens from the Etchegoin and San Joaquin Formations were attributed to *S. sicarius* Gould (Woodring and others, 1940 [1941]).

Family Myidae

Cryptomya californica (Conrad) (synonyms *C. ovalis* Conrad and *C. quadrata* Carpenter) is common in sand and sandy mud from the intertidal zone to 80 m (Foster, 1991) along the open coast from Prince William Sound, Gulf of Alaska (Foster, 1991) to northern Peru (McLean, 1978). Grant and Gale (1931) reported this species as a fossil from the Miocene to Pleistocene from western North America, citing references to its occurrence from Washington state south to Baja California Sur, Mexico.

Mya arenaria Linnaeus has a complicated geologic history (MacNeil, 1965). In California it has been reported as a fossil from the Cierbo Sandstone, Etchegoin, Merced, and San Joaquin formations (MacNeil, 1965). These formations indicate a late Miocene to possibly Pleistocene age (MacNeil, 1965). It then became extinct in the eastern Pacific Ocean sometime during the Pleistocene, but persisted in Japan and the north Atlantic. It was reintroduced into California in 1874 with Atlantic oysters and has successfully established itself from Icy Cape, Arctic Ocean, Alaska, south to Elkhorn Slough, Monterey County, California, with several juvenile records off San Diego, California; it also still occurs in the western Pacific and northern Atlantic (Coan and others, 2000).

Gastropoda

Family Trochidae

Calliostoma coalingensis Arnold previously has been reported from the *Siphonalia* Zone of the Etchegoin Formation and the *Acila, Pecten,* and *Trachycardium* zones of the San Joaquin Formation (Woodring and others, 1940 [1941]), as well as the Niguel (Kern and Wicander, 1974 *fide* Groves, 1991; as ?), Pancho Rico (Durham and Addicott, 1965), and Pico (Soper and Grant, 1932) formations. In addition, *C. coalingensis privum* Stewart in Woodring and others (1940 [1941]) was described from the *Patinopecten* zone of the Etchegoin Formation, and *C. coalingensis catoteron* Woodring and Bramlette was described from the Cebada Member of the Careaga Formation (Woodring and Bramlette, 1950) and also questionably (cf.) occurs in the San Diego Formation (LACM collections). These occurrences indicate a possible late Miocene to late Pliocene age range for *C. coalingensis* and its subspecies.

Calliostoma ligatum (Gould). Modern occurrences are from 60°N south to 37°N in water depths from the low intertidal zone to 64 m (CAS wet collection, 7/2007), commonly associated with *Macrocystis* (kelp) stands. It previously has been reported provisionally (cf.) from the Pliocene (Powell and Stevens, 2000) but occurs in the Pleistocene (Valentine, 1958; Valentine and Lipps, 1963; Powell, 2001) and Holocene (Erlandson and others, 2007) of central and southern California. The occurrence here supports it presence in the Pliocene of California, but the imprecise identification does not confirm it occurrence in the Pliocene.

Family Crepidulidae

Calyptraea fastigiata (Gould) is identified here as being wider than high, without radial sculpture and with a very slightly concave shell margin. *Calyptraea fastigiata* occurs from Alaska to southern California and has been dredged commonly from water depths of 18 to 140 m (10 to 75 fathoms) (Abbott, 1974), although Rice (1971) cites its occurrence from Alaska to Puget Sound, Washington, from the intertidal zone to about 100 m (300 ft). California Tertiary *Calyptraea* literature is fraught with confusion and misidentifications and, consequently, the stratigraphic range of this taxon is not known precisely. It has been reported as a fossil from the Anchor Silt (Rodda, 1957), Battery (Kennedy, 1978), Careaga (Woodring and Bramlette, 1950), Fernando (Zinsmeister, 1970), Lomita Marl and Palos Verdes Sand (Woodring and others, 1946), Pico (Winterer and Durham, 1962), Purisima (Cummings and others, 1962; and Perry, 1993) formations, San Pedro Sand (Woodring and others, 1946), Saugus (= Pico) (Groves, 1991), Sisquoc (Woodring and Bramlette, 1950) formations, Timms Point Silt (Woodring and others, 1946; Valentine, 1961), Towsley Formation (Winterer and Durham 1962), and unnamed Pleistocene deposits from Oregon to central California (Addicott, 1966; Wright, 1972; Kennedy, 1978). In addition, Arnold and Hannibal (1913) reported *C. fastigiata* Gould from the Elk River beds but their concept of this formation included the upper Pleistocene terrace material at Cape Blanco where this taxon occurs (Kennedy, 1978). These formations and its modern occurrences indicate an age range from Pliocene, possibly early Pliocene to Holocene.

Calyptraea filosa (Gabb) is characterized here by its fine, numerous radial ribs. It has been reported from the Capistrano (Kern and Wicander, 1974; =Niguel *fide* Groves, 1991), Castaic (Stanton,

1966), Etchegoin (Arnold, 1909; Arnold and Anderson, 1909 [1910]; Martin, 1916; Nomland, 1917a), Fernando (Arnold, 1903; Eldridge and Arnold, 1907; English, 1914; Soper and Grant, 1932; Yerkes, 1972), Jacalitos (Nomland, 1916), Merced (Martin, 1916; Nomland, 1917b; Yancey, 1978), Modelo (Oakeshott, 1958), Monterey (Weaver, 1909), Ohlson Ranch (Peck, 1960), Olcese Sand (Addicott, 1970), Pancho Rico (Durham and Addicott, 1965; Durham, 1974), Pico (Winterer and Durham, 1962; Meade, 1967), Purisima (Martin, 1916; Nomland, 1917a; Allen, 1946), Repetto (=lower Fernando Formation *fide* Groves, 1991), Round Mountain Silt (Keen, 1943; Addicott, 1970), San Diego (Hertlein, unpublished manuscript), San Joaquin (Woodring and others, 1940 [1941]; Stanton and Dodd, 1976), San Pablo Group (Arnold, 1906; Weaver, 1909; Clark, 1915), Santa Margarita Sandstone (Arnold, 1906; Clark, 1915; Durham, 1974), Saugus (=Pico)(Groves, 1991), Topanga Canyon (Kew, 1924; Schoellhamer and others, 1981), Towsley (Winterer and Durham, 1962; Kern, 1973), and Vaqueros (Arnold, 1909; Arnold and Anderson, 1909 [1910]; Loel and Corey, 1932) formations. If all these occurrences are assigned correctly to this taxon, then it ranges in age from late Oligocene to early Pleistocene. Further study is needed.

Calyptraea inornata (Gabb), as identified here, is higher than wide, without radial sculpture, and with a slightly convex shell margin. This species has been recorded from the Purisima and Vaqueros formations (Powell, 1998). These formations indicate a possible age range of late Oligocene to late Pliocene. However, California Tertiary *Calyptraea* are poorly defined and, consequently, the stratigraphic range of this taxon is not known precisely.

Crepidula princeps (Conrad) ranges from Alaska to Baja California, Mexico in rocks from Miocene to Pleistocene (Grant and Gale, 1931). The youngest occurrence appears to be Middle Pleistocene based on its occurrence in the Timms Point Silt (Clark, 1931), which, according to Lajoie and others (1991), is Middle Pleistocene in age. Late Pleistocene occurrences, such as at Newport Bay, Orange County, California (Kanakoff and Emerson, 1959), represent reworked specimens judging by their preservation and color.

Family Naticidae (35)

Glossaulax reclusiana (Deshayes) (synonym *Neverita recluziana alta* Dall) is fairly common in lagoons and shallow bays (not characteristic of offshore sandy bottoms) from Crescent City, California (42°N), to Mazatlan, Sinaloa, Mexico (23°N), although it is rare north of Mugu Lagoon, Ventura County, California (34°N) (Marincovich, 1977; McLean, 1978). Marincovich (1977) reported this species in rocks from the Eocene to Pleistocene from Vancouver Island, British Columbia, Canada to the Golfo de California, Mexico.

Family Muricidae (43)

Ocenebrina lurida (Middendorff) is common at low tide north of Point Conception, Santa Barbara County, California, and obtained only occasionally at subtidal depths in southern California (McLean, 1978). It ranges from Sitka, Alaska, south to Santo Tomas, Baja California Sur, Mexico (McLean, 1978). James McLean (LACM retired) is in the process of describing several new species of similar *Ocenebrina*, and the identification of the fossil specimens could change. That said, *O. lurida* has been reported from the Careaga (Woodring and Bramlette, 1950), Fernando (Arnold, 1907a; Arnold, 1907b; Arnold and Anderson, 1907; Eldridge and Arnold, 1907; Moody, 1916) Millerton (Johnson, 1962; Kennedy, 1978) formations, Palos Verdes Sand (Woodring and others, 1946), San Pedro Sand (Oldroyd, 1925), Saugus Formation (Meade, 1967; Groves, 1991 [= Pico]), and unnamed Pleistocene deposits from throughout California (Arnold, 1908; Grant and Gale, 1931; Hoots, 1930; Delong, 1941; Valentine, 1958; Vedder and Norris, 1963; Kohl, 1974; Marincovich, 1976; Kennedy, 1978). These formations indicate an age range of late Pliocene to Holocene.

Pteropurpura festiva (Hinds). According to McLean (1978) large specimens are common in muddy and rocky areas within bays, whereas smaller specimens occur on the exposed coast at low tide and in sublittoral depths on rocky bottoms from Santa Barbara, California, to Bahia Magdalena, Baja

California Sur, Mexico. In the fossil record it is found in the Niguel (Kern and Wicander, 1974; formation assignment after Groves, 1991), Pancho Rico (Durham and Addicott, 1965), and San Diego (LACM collections) formations, and in unnamed Pliocene rocks in Newport Bay, Orange County, southern California (Zinsmeister, 1970; J.D. Mount, written commun., 1979). It is also common in the Pleistocene of southern California (see Grant and Gale, 1931; Woodring and others, 1946). Closer examination is needed to see if *P. festivus* from the Pancho Rico and San Joaquin are actually this species or something similar.

Pteropurpura aff. *P. festiva* (Hinds). This is in part *Jaton* cf. *J. festvus* (Hinds) of Woodring and others (1940 [1941]) and is not *Pteropurpura festiva*. It lacks the backward rolled varices and fine brown spiral lines characteristic of *P. festiva*. This is likely a new species, but further study and better specimens are needed before it can be described.

Family Columbellidae (48)

Astyris gauspata (Gould) has been found from Bechevin Bay on the northwest side of the Alaska Peninsula, Alaska, south to Punta San Pablo, Baja California Sur, Mexico, on soft bottoms from 30 to 200 m (McLean and Gosliner, 1996) water depths. Grant and Gale (1931) report the oldest occurrence of *A. gauspata* as from the late Miocene Montesano Formation in Washington, citing Weaver, but without giving a date or reference. Discounting this occurrence, the next oldest occurrence is the late Miocene Coos Conglomerate Member of the Empire Formation in Oregon (Howe, 1922), and then the Pliocene part of the Wilson Grove Formation in central California (Powell and others, 2004), where it is common. The oldest occurrence of *Mitrella gouldii* (Carpenter), which McLean (1996) considered synomyous, is in the late Pliocene (Moody, 1916; Grant and Gale, 1931; Woodring and Bramlette, 1950; Powell and others, 2007). Together these occurrences give an age range of Miocene, probably late Miocene, through Holocene. However, because many California Columbellidae have been confused in the past, the geologic range of this species should be reviewed further.

Family Nassariidae (49)

Caesia coalingensis (Arnold), formerly assigned to the genus *Nassarius*, has been reported from the Etchegoin (unrestricted) of Arnold (1909; includes the San Joaquin Formation of later workers), Pancho Rico (Addicott, 1965), and San Joaquin (Woodring and others, 1940 [1941]) formations. These units range in age from late Miocene to late Pliocene. Further refinement of the age is not possible without detailed stratigraphic occurrences in dated sections. It is interesting that, in the Kettleman Hills Landfill section, *Caesia coalingensis* stratigraphically precedes *Carlton iniquus*, with no overlap between the two.

Catilon iniqua (Stewart), formerly in the genus *Nassarius*, is reported from the Etchegoin Formation south of Coalinga (Arnold, 1909) and from the Kettleman Hills (Woodring and others, 1940 [1941]), from the Towsley(?) Formation in Los Angeles County (Addicott, 1965), and from undetermined rocks in a core near Tipton, California (Grant and Gale, 1931), and in the Diablo Range, San Benito 15’ Quadrangle (UCMP collections cited by Addicott, 1965). Using the Etchegoin and Towsley(?) Formations occurrences, this species has a questionable age range from the late Miocene through the Pliocene.

Nassarius is used here for indeterminate taxa previously assigned to this genus (family Nassariidae). Many of the California species are now referred to the former subgenera *Hima* or *Caesia* (of Addicott, 1965) following McLean (2007). Other changes within the family are likely to occur with publication of McLean’s future review of northeastern Pacific gastropods.

Family Olivellidae (53)

Callianax pycna Berry has a modern occurrence from Seaside Rock, Clatsop County, Oregon (Gifford and Gifford, 1948), south to Morro Rock, San Luis Obispo County, California, in water depths from the intertidal zone to 27 m (Burch, 1944-46). In the fossil record, *C. pycna* has been confused with

C. biplicata (Sowerby), *C. intorta* (Carpenter), and *C. pedroana* (Conrad). Judging from published pictures and specimens examined in collections at CAS, LACM, and UCMP, *C. pycna* occurs in the Careaga Sandstone (Woodring and Bramlette, 1950), Carlotta(?), Elk River, Moonstone Beach, (Roth, 1979), and Purisima (Arnold, 1908; Martin, 1916; Allen, 1946; Touring, 1959; Cummings and others, 1962; Addicott and others, 1978; Perry, 1993) formations, and from Pleistocene terrace deposits at Año Nuevo State Reserve, central California (Addicott, 1966). These occurrences indicate a likely early Pliocene to Holocene age range for *C. pycna*.

Echinodermata

Echinoidea

Family Dendrasteridae

Dendraster coalingensis (Arnold) is known only from the Etchegoin and San Joaquin formations in central California (Kew, 1920; Grant and Hertlein, 1938), although it has provisionally (cf.) been reported from the Tinaquaic Sandstone Member of the Sisquoc Formation (Woodring and Bramlette, 1950). These formations indicate a possible late Miocene to late Pliocene age.