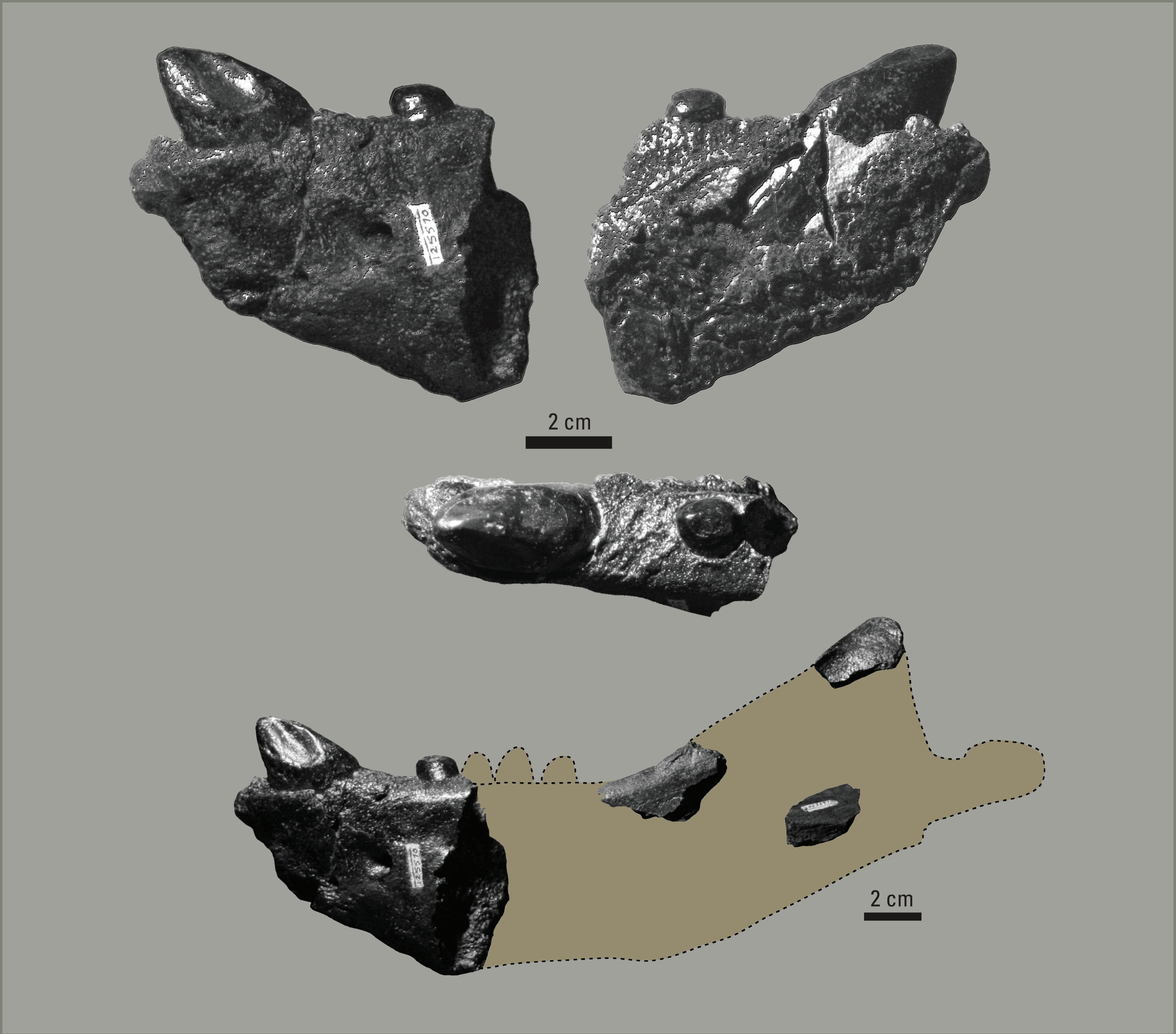
# Geology and Paleontology of the Late Miocene Wilson Grove Formation at Bloomfield Quarry, Sonoma County, California



Scientific Investigations Report 2019–5021

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

**COVER.** Photographs of fragments of a walrus (*Gomphotaria pugnax* Barnes and Raschke, 1991) mandible from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California (see plate 8 for more details). The walrus fauna at Bloomfield Quarry is the most diverse assemblage of walrus yet reported worldwide from a single locality. cm, centimeter. (Photographs by Robert Boessenecker, College of Charleston.)

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**U.S. Department of the Interior**
DAVID BERNHARDT, Secretary

**U.S. Geological Survey**
James F. Reilly II, Director

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We would like to thank Lindsey Groves (Natural History Museum of Los Angeles County) and Mary McGann (U.S. Geological Survey) for their helpful reviews. Also thanked are Christine Garcia, the late Jean DeMouthe (California Academy of Sciences), and Mark Goodwin, Patricia Holroyd, and Erica Clites (University of California Museum of Paleontology) for use of collections in their care. John K. Tucker helped find several obscure references. Janice C. Fong (University of California, Davis) and Heather B. Constable (Museum of Vertebrate Zoology, University of California, Berkeley) helped prepare tables, figures, and several of the plates. Harry Steinbeck and lessees of the Steinbeck Ranch kindly permitted sampling of the Roblar tuff on that property for age dating.

# Contents

## Plates

## Figures

## Tables

# Conversion Factors

International System of Units to U.S. customary units

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| centimeter (cm) | 0.3937 | inch (in.) |
| millimeter (mm) | 0.03937 | inch (in.) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |

# Abbreviations

| | |
|---|---|
| Ar | argon |
| $^{40}$Ar/$^{39}$Ar | argon-40/argon-39 |
| CAS | California Academy of Sciences |
| CPMS | California provincial molluscan stage |
| Fe | iron |
| LACM | Los Angeles County Museum of Natural History |
| LOWESS | locally weighted scatterplot smoothing |
| Ma | megaannum or millions of years |
| Mn | manganese |
| NCSM | North Carolina Museum of Natural History |
| PNPMS | Pacific Northwest provincial molluscan stage |
| SDNHM | San Diego Natural History Museum |
| Sr | strontium |
| $^{87}$Sr/$^{86}$Sr | strontium-87/strontium-86 |
| UCMP | University of California Museum of Paleontology |
| USGS | U.S. Geological Survey |
| USNM | National Museum of Natural History, Smithsonian Institution |

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By Charles L. Powell II,[1] Robert W. Boessenecker,[2] N. Adam Smith,[3] Robert J. Fleck,[1] Sandra J. Carlson,[4] James R. Allen,[5] Douglas J. Long,[6,7] Andrei M. Sarna-Wojcicki,[1] and Raj B. Guruswami-Naidu[8]

## Abstract

An extensive fauna of at least 77 taxa is reported from the basal Wilson Grove Formation in a small quarry just north of the town of Bloomfield, Sonoma County, California. The fauna represents intertidal to shallow subtidal water depths and water temperatures interpreted from the fauna, consistent with the latitude of the fossil locality (37° north) during the late Miocene. The fauna from Bloomfield Quarry is unusually large and diverse from such a small area. It consists of thousands of specimens of 4 brachiopod, 42 mollusk (28 bivalves and 14 gastropods), 6 arthropod (1 crab, 1 shrimp, and 4 barnacles), and 25 vertebrate (3 sharks, 1 ray, 8 bony fishes, 9 marine mammals, and 4 birds) taxa. Unusual in the fauna is the abundant and diverse brachiopod fauna, the diverse barnacle fauna, which was described previously, and the extensive and diverse vertebrate fauna. Most significant among the vertebrates is the walrus fauna, which is the most diverse assemblage of walrus yet reported worldwide from a single locality.

A single strontium (Sr) isotope age determination of about 8 million years (megaannum, Ma) from a pectinid mollusk is consistent with a new age determination of the overlying, informally named Roblar tuff as described by Sarna-Wojcicki in 1992 (6.203±0.011 Ma) and previously reported age determinations (recalculated here) from basalt (9.27±0.06 Ma) underlying these deposits. The Roblar tuff at Bloomfield Quarry can be correlated with other sites, including the Delgada Fan offshore northern California and the Coalinga anticline in California's Central Valley. These age determinations conform with the "Jacalitos" California provincial molluscan stage age, the Hemphillian North American Land Mammal age determined from the fossils, and is part of the International Tortonian Stage of the Miocene.

**Keywords:** California, Miocene, Roblar tuff, Tortonian stage, Brachiopoda, Mollusca, Arthropoda, Vertebrata, Elasmobranch, Teleost, Mammalia, Aves.

## Introduction

The Wilson Grove Formation is approximately 1,800 meters (m) thick and crops out in Sonoma County, and in a small part of Marin County, in northern California. Fossils and the informally named Roblar tuff of Sarna-Wojcicki (1992) (hereafter referred to as Roblar tuff) which occurs near the base of the formation suggest a late Neogene (late Miocene to late Pliocene) age for the formation. Several laterally varying depositional environments are represented ranging from shallower nearshore marine, which grades laterally into continental deposits of the Petaluma Formation to the east, to shelf/slope deposits (Allen, 2003; Powell and others, 2004). The Wilson Grove Formation was deposited in a basin separate from the contemporaneous (1) Purisima Formation on the San Francisco Peninsula and in Santa Cruz County and (2) Ohlson Ranch Formation in northwestern Sonoma and southern Mendocino Counties.

This paper deals with extensive fossil collections from the basal Wilson Grove Formation made in 1973 by William F. Barbat, Raj Guruswami-Naidu, Peter U. Rodda, and Barry Roth from a small quarry north of the town of Bloomfield in Sonoma County, northern California (fig. 1). The invertebrate collections are housed at the Invertebrate Zoology and Geology section of the California Academy of Sciences, whereas vertebrates are housed with the Museum of Paleontology, University of California, Berkeley. The invertebrates were reviewed previously by Powell and others (2006), who noted the unusual fauna from the quarry and abundant brachiopods. A further study of this unusual fauna (table 1) was needed and is completed here, bringing together a wide range of experts to examine specimens in their specialties.

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[1] U.S. Geological Survey.

[2] College of Charleston.

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[6] California Academy of Sciences.

[7] St. Mary's College.

[8] Occidental, California.

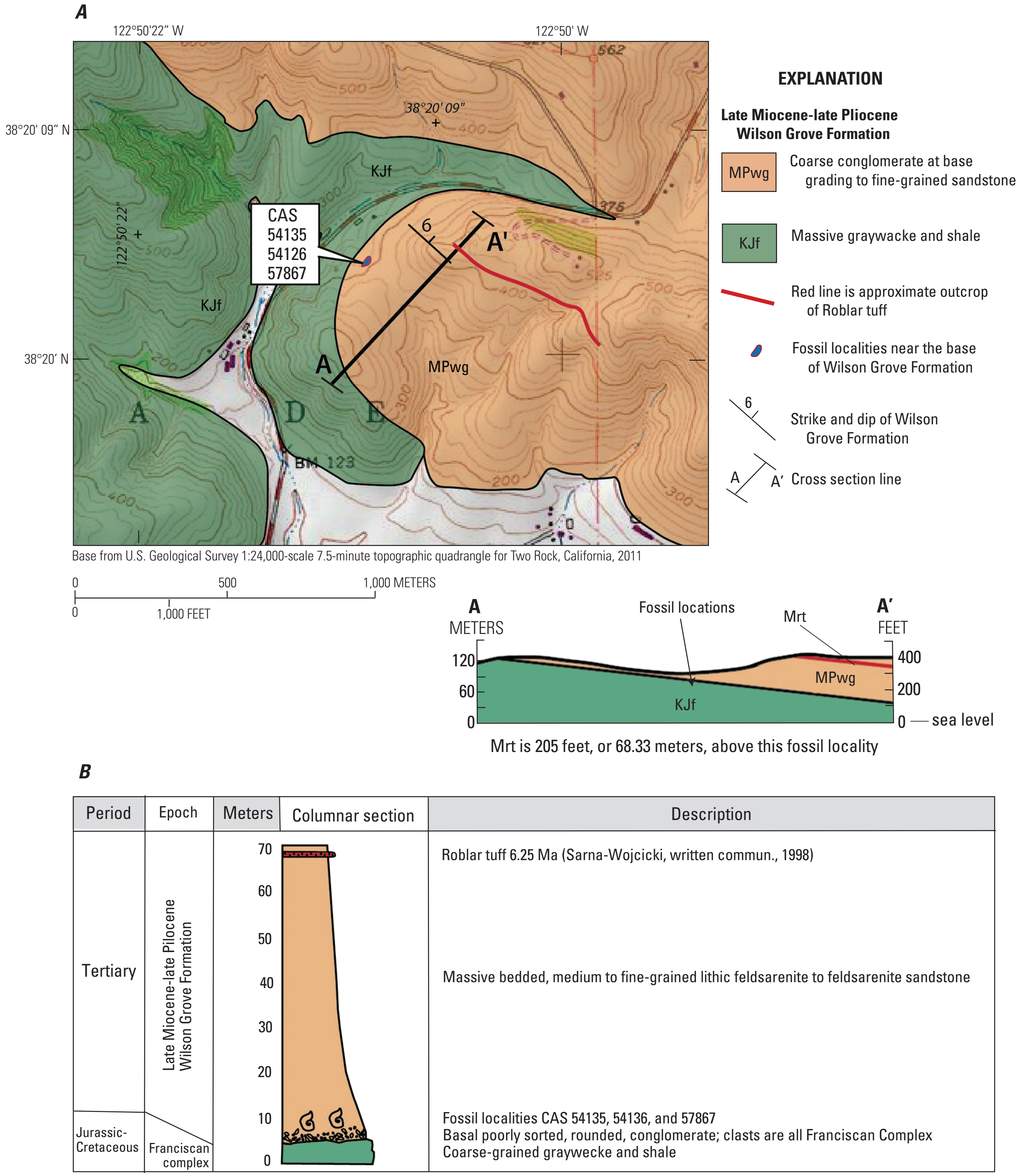

**Figure 1.** Index map (*A*) and stratigraphic column (*B*) showing the geology of Bloomfield Quarry, Sonoma County, California. California Academy of Sciences (CAS) fossil localities 54135, 54136, and 57867 are shown. Mrt, informally named Roblar tuff of Sarna-Wojcicki (1992); Ma, megaannum or millions of years ago.

**Table 1.** Faunal list (alphabetical) of late Miocene taxa recovered from the Wilson Grove Formation at Bloomfield Quarry, Sonoma County, California.

[Taxa include 4 brachiopods, 42 mollusk (28 bivalves and 14 gastropods), 6 arthropods (1 crab, 1 shrimp, and 4 barnacles), and 25 vertebrates (3 sharks, 1 ray, 8 bony fishes, 9 marine mammals, and 4 birds)]

- Brachiopoda (lamp shells)
  - Linguliformea
    - *Discinisca* cf. D. *cumingii* (Broderip, 1833)
  - Rhynchonelliformea
    - *Terebratalia* cf. T. *transversa* (Sowerby, 1846)
    - *Terebratalia* cf. T. *occidentalis obsoleta* Dall, 1891
    - *Terebratulina unguicula* Carpenter, 1864
- Mollusca
  - Bivalvia (clams)
    - *Anadara* sp. indeterminate
    - *Anomia peruviana* d'Orbigny, 1846
    - *Arca* cf. A. *santamariensis* Reinhart, 1937
    - Cardiidae indeterminate
    - *Chlamys* cf. C. *hodgei* (Hertlein, 1925)
    - *Chlamys* aff. C. *egregius* (Nomland, 1917)
    - *Chlamys* cf. C. *hastata* (Sowerby, 1842)
    - *Chlamys* sp. indeterminate
    - *Clinocardium*? sp. indeterminate
    - *Crenomytilus* cf. C. *coalingensis* (Arnold, 1909)
    - *Cryptomya californica* (Conrad, 1837)
    - *Ensis* sp. indeterminate
    - *Lucinoma annulatum* (Reeve, 1850)
    - *Macoma* aff. M. *indentata* Carpenter, 1864
    - *Macoma* sp. indeterminate
    - Mactridae indeterminate
    - *Modiolus* sp. indeterminate
    - Mytilidae indeterminate
    - *Panopea abrupta* (Conrad, 1849)
    - *Patinopecten* sp. indeterminate
    - *Pododesmus* cf. P. *macrochisma* (Deshayes, 1839)
    - *Siliqua*? sp. indeterminate
    - *Solen* sp. indeterminate
    - *Swiftopecten parmeleei* (Dall, 1898)
    - *Tellina* sp. indeterminate
    - *Teredo* sp. indeterminate
    - *Tresus pajaroanus* (Conrad, 1857)
    - *Yoldia* sp. indeterminate
  - Gastropoda (snails)
    - *Caesia grammatus* (Dall, 1917)
    - *Crepidula princeps* (Conrad, 1856)
    - *Crepidula* sp. indeterminate
    - *Desmondia* sp. indeterminate
    - *Lirabuccinum*? sp.
    - Nassariidae indeterminate
    - Naticidae indeterminate
    - Neritidae indeterminate
    - Neogastropoda indeterminate
    - *Nucella* n. sp., cf. N. *etchegoinensis* (Arnold, 1909)
    - *Nucella*? sp. indeterminate
    - *Ocenebrina*? sp. indeterminate
    - Trochidae, indeterminate
    - *Trochita* cf. T. *diabloensis* (Clark, 1915)
- Arthropoda
  - Maxillopoda (barnacles)
    - *Balanus* aff. B. *nubilus* Darwin, 1854
    - *Balanus irradians* Zullo and Guruswami-Naidu, 1982
    - *Balanus* cf. B. *irradians* Zullo and Guruswami-Naidu,1982
    - *Balanus*? sp. indeterminate
  - Malacostraca (crabs and shrimp)
    - *Callianassa*? sp. indeterminate
    - *Cancer* sp. indeterminate
- Vertebrata
  - Chondrichthyes (sharks and rays)
    - *Hexanchus griseus* (Bonnaterre, 1788)
    - *Irusus oxyrinchus* Rafinesque, 1810
    - *Cetorhinus maximus* (Guinnerus, 1765)
    - *Myliobatis californica* Gill, 1865
  - Osteichthyes (bony fish)
    - Embiotocidae, genus and species indeterminate
    - *Merluccius* sp. indeterminate
    - *Oncorhynchus* sp. indeterminate
    - *Paralichthys* sp. indeterminate
    - *Sarda* sp. indeterminate
    - *Sardinops* sp. indeterminate
    - *Sebastes* sp. indeterminate
    - *Stereolepis* sp. indeterminate
  - Mammalia (mammals)
    - Dusignathinae indeterminate (walrus)
    - *Dusignathus santacruzensis* Kellogg, 1927 (walrus)
    - *Gomphotaria pugnax* Barnes and Raschke, 1991 (walrus)
    - Cf. *Imagoteria* sp. indeterminate Mitchell, 1968
    - Mysticeti indeterminate (baleen whale)
    - Odobeninae indeterminate (walrus)
    - Odontoceti indeterminate (toothed whale)
    - Cf. *Pontolis* sp. indeterminate (walrus)
    - Sirenia indeterminate (sea cow)
  - Aves (birds)
    - Aves indeterminate
    - Mancallinae indeterminate
    - Pan-Alcidae indeterminate
    - Cf. *Uria brodkorbi* Howard, 1981

In addition, a redetermination of the age of the Roblar tuff at its type area refines its age. Using its chemical composition, the Roblar tuff is also correlated with a number of localities in the northern and central Coast Ranges and Central Valley of California (figs. 2 and 3), as well as within sediments of the eastern Pacific Ocean. Dating of units bounding the basal Wilson Grove Formation support age determinations from argon (Ar) and strontium (Sr) analysis, tuff correlations, and paleontologic methods.

## Authorship Order

The order of the authorship was determined by when each person joined the project and does not reflect the size or value of their contribution. Charles Powell wrote the introduction, previous work, geologic setting/stratigraphy/age and molluscan parts of the manuscript. The marine mammals are reported on by Robert Boessenecker. N. Adam Smith examined and reports on the bird fauna. A new age determination for the Roblar tuff was performed by Robert Fleck along with the strontium age dating. The brachiopods were examined and reported on by Sandra J. Carlson. James Allen helped with the geology/geologic setting. Fish, including sharks, were examined and reported on by Douglas Long. Andrei Sarna-Wojcicki wrote on tuff correlations among the Roblar tuff and other stratigraphically close tuffs in the Western United States. Lastly, Raj Guruswami-Naidu contributed to several discussions and helped collect the material on which this study is based. Everyone contributed to the introductory parts through their specialties.

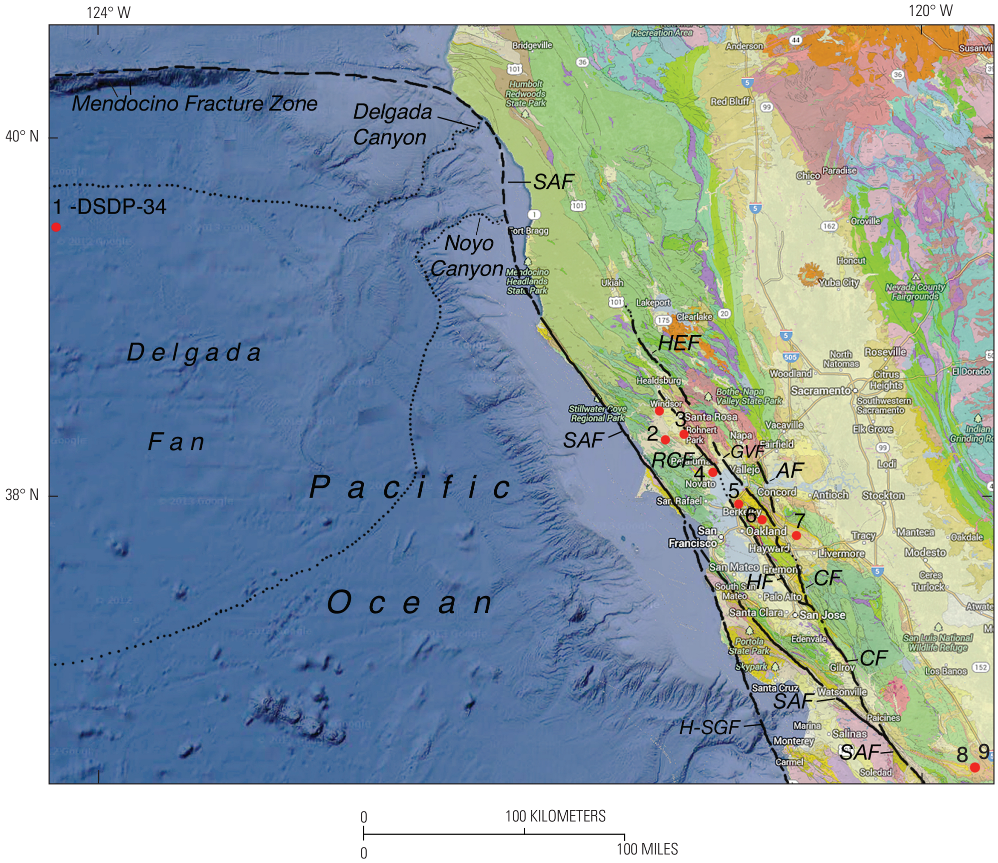

**Figure 2.** Map showing areal distribution of the informally named Roblar tuff (Sarna-Wojcicki, 1992) in northern California. Red dots are localities where the tuff has been identified. Numbers adjacent to the red circles refer to localities indicated in table 4 and figure 3. Solid black lines and dashed lines are major fault strands of the San Andreas Fault system. The Roblar tuff has been found in bottom sediments of the eastern Pacific Ocean (site 1, Deep-Sea Drilling Project hole 34 (DSDP-34), at extreme left), as well as within several fault-bounded blocks of the San Andreas Fault system (sites 2 through 8). The geometry of this distribution indicates progressive right-lateral displacement of the tuff and associated sediments by the San Andreas Fault system, and the displacement of the Delgada and Noyo Canyons from the Wilson Grove Formation (site 2), along the main trace of the San Andreas Fault Zone, between the Pacific and North American tectonic plates over the past ~6.2 million years (Sarna-Wojcicki, 1992, and Sarna-Wojcicki, written commun., 2016). The Roblar tuff is present at the Bloomfield Quarry location at and near site 2 (see table 4), the locality discussed in the present study. SAF, main trace San Andreas Fault; H-SGF, Hosgri-San Gregorio Fault; RCF, Rodgers Creek Fault; HEF, Healdsburg Fault; MF, Maacama Fault; GVF, Green Valley Fault; AF, Antioch Fault; HF, Hayward Fault; CF, Calaveras Fault. Map is modified from a part of the Interactive Geologic Map of California (California Geological Survey, 2010).

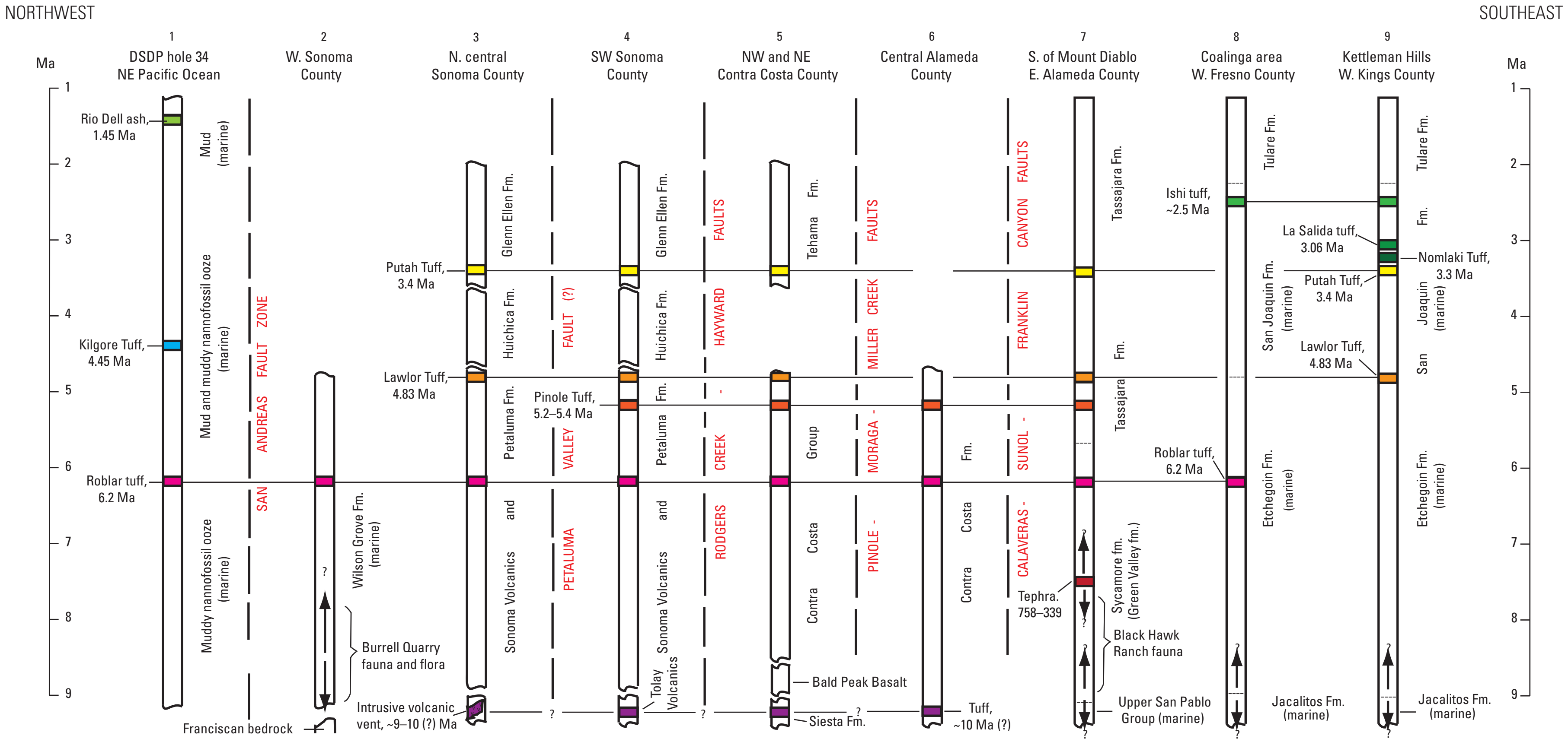

**Figure 3.** Image showing the correlation of the Roblar tuff in northwestern and central California and relations to other stratigraphic units. The stratigraphic relations of the Roblar tuff to other dated tephra layers are shown for a number of localities (1–9) at which the Roblar tuff has been identified. The localities are arranged geographically from the northwest to the southeast (from locality 1, at Deep-Sea Drilling Project (DSDP) hole 34 in the submarine Delgada Fan in the eastern Pacific Ocean, to locality 8, in the Coalinga area of western San Joaquin Valley, California) and according to age within each locality (age scale, in millions of years, on the far left). The Roblar tuff does not crop out in the Kettleman Hills, farther to the southeast (locality 9) but is presumed to be present in the subsurface there in the anticline of the Kettleman Hills, stratigraphically beneath the Lawlor Tuff. Names of faults of the San Andreas Fault system separating the localities from each other are shown in red. Names of the formations within the sections appear to the right of the stratigraphic column at each locality. Marine formations are designated as such; other formations are terrestrial or, as in the case of the Petaluma Formation, estuarine. See figure 2 for map locations of tuff localities 1 through 8. Localities at which all the units within the section are exposed are shown with solid vertical lines; localities at which the section is composite, from several sublocalities within a small area, are shown with broken vertical lines, and different parts of the composite section are separated by wavy lines. Ma, megaannum or millions of years ago; fm., formation; E., east; N., north; NE, northeast; NW, northwest; S., south; SW, southwest; W., west.

## Previous Work

A full discussion of works related to the Wilson Grove Formation can be found in Powell and others (2004) with the addition of Powell and others (2006), which discusses fossil and lithologic correlations between two wells in the Santa Rosa plain and the type Wilson Grove Formation. Works specifically mentioning Bloomfield Quarry are Zullo and Guruswami-Naidu (1982) and a section in Powell and others (2004). Zullo and Guruswami-Naidu (1982) described a barnacle fauna of five taxa from the basal conglomerate at Bloomfield Quarry. They misidentified the Roblar tuff with relation to the basal fossil beds, reporting the tuff a few meters above the base of the formation, whereas Powell and others (2004) report that the tuff lies greater than 65 m above the base of the formation. We are uncertain if the tuff reported by Zullo and Guruswami-Naidu is the Roblar tuff or another tuff and the site is no longer accessible. Powell and others (2004) reported an invertebrate fauna of 47 taxa from Bloomfield Quarry.

## Geologic Setting/Stratigraphy

The Wilson Grove Formation crops out in an inactive quarry on the east side of Bloomfield Road between Bloomfield and where the road turns sharply north-northwest at the intersection of Bloomfield Road and Canfield Road in Sonoma County (fig. 1); this quarry is referred to as the Bloomfield Quarry (Powell and others, 2004). At Bloomfield Quarry the Wilson Grove Formation overlies interbedded greywacke and shale of the Jurassic to Cretaceous Franciscan Complex mélange (Bezore and others, 2003) along an angular unconformity/nonconformity. The Wilson Grove section above the Franciscan Complex begins with a 0.3- to 0.6-m-thick basal conglomerate containing abundant sand with pebble- to cobble-size clasts of the Franciscan Complex rock and abundant disarticulated fossil shell fragments in an upward fining, gritty sandstone, which pinches out to the south. The basal conglomerate is conformably overlain by about 5 m of less fossiliferous, massive-bedded, friable to locally calcite-cemented, fine- to medium-grained, very well-sorted, sandstone. The aforementioned outcrop at the quarry is capped by about a meter of soil.

The Roblar tuff crops out on the hill to the east stratigraphically higher in the Wilson Grove Formation, overlying a thickness of at least 68 m of intervening sedimentary strata (Powell and others, 2004). This thickness varies dramatically elsewhere as elevations of the base of the Wilson Grove show at least 100 m of relief on the opposite side of the ridge from the quarry as shown by Bezore and others (2003) and Powell and others (2004). The tuff is a well-known, well-dated volcanic unit interbedded within the Wilson Grove Formation and has been used to constrain a rather precise age datum (Sarna-Wojcicki, 1992; McLaughlin and others 2012). Bedding within sedimentary rocks in the quarry outcrop is the same with respect to the bedding within the tuff outcrop. Between the Bloomfield Quarry and the Roblar tuff, outcrops are spotty consisting of typical thick, bioturbated, massively bedded to occasionally hummocky cross-stratified, medium-grained, well-sorted, subangular feldsarenite sandstone beds (Holland and Allen, 1998; Allen, 2003) with a sparse fauna mostly concentrated low in the upper unit.

## Age—Analytical Results

Argon-40/argon-39 ($^{40}Ar/^{39}Ar$) age determinations of volcanic units that stratigraphically overlie and underlie the Bloomfield Quarry stratigraphic horizon and a single successful Sr dating analysis from an indeterminate pectinid (Mollusca: Bivalvia) shell from the basal conglomerate support the less precise results from mollusk age ranges. At Roblar Road, less than 4 kilometers (km) southeast of the quarry, the base of the Wilson Grove Formation rests on Miocene basalt (Bezore and others, 2003), which forms a wedge whose thickness increases locally eastward between the sediments and the underlying Franciscan Complex. The basalt is about 100–110 m below the Roblar tuff, and the two volcanic units provide very good age control for the Wilson Grove Formation at this location. Wagner and others (2011) report an age of 9.27±0.06 Ma (recalculated to new constants) for outcrops of the basalt on the south side of Roblar Road (table 2, sample TW-5C-B), establishing a maximum age for the base of the Wilson Grove Formation in these exposures. Table 2 also shows similar ages for two basalts (088-27A and B) 18–20 km to the southeast near Petaluma, California, that occupy identical stratigraphic positions, resting on Franciscan Complex and underlying the Wilson Grove Formation (Bezore and others, 2002; Wagner and others, 2002).

A sample of the Roblar tuff (088-27D) was collected from the Steinbeck Ranch on the north side of Roblar Road, about 1.5 km northeast of the basalt TW-5C-B and about 2.5 km east of Bloomfield Quarry. The tuff sample is a pumice-clast-bearing, water-lain tuff with white pumice clasts as great as 10 centimeters (cm) in diameter in a clastic matrix of mixed volcanic and detrital components. The pumice clasts were separated from the matrix, and all matrix was removed from each clast with a small grinding tool. Pumice clasts were then brushed free of remaining loose grains, crushed, and plagioclase was separated by heavy-liquid techniques. All adhering glass was removed with dilute hydrofluoric acid. Plagioclase from this sample of Roblar tuff was analyzed by the $^{40}Ar/^{39}Ar$ incremental-heating technique. Based on a monitor age of 28.198 million years (megaannum, Ma) for Fish Canyon Tuff sanidine (Kuiper and others, 2008), an age of 6.203±0.011 Ma was obtained combining the results of two separate, incremental-heating experiments (table 2) (monitor age refers to the age of the mineral standard or “monitor” to which the unknown sample is referenced in $^{40}$Ar/$^{39}$Ar dating to calculate an age). This represents a redetermination of the age of the Roblar tuff at the area of its original designation (Sarna-Wojcicki, 1992) and is considered the most reliable.

The temporal variation of strontium-87/strontium-86 ($^{87}$Sr/$^{86}$Sr) in seawater can be used to constrain the age of deposition of a variety of Sr-bearing materials (Peterman and others, 1970; Burke and others, 1982; Veizer, 1989; McArthur and others, 2001). Two fragments of an indeterminate pectinid (Mollusca: Bivalvia) from California Academy of Sciences (CAS) locality 54135 were analyzed for Sr chronology using the dissolution methods of Bailey and others (2000). Results of inductively coupled plasma mass-spectrometry analyses of the shell material show that one sample exhibited diagenetic patterns indicating chemical exchange in an open system, incorporating large amounts of both iron (Fe) and manganese (Mn) and exhibiting a lower than expected Sr concentration (table 3). Mn and Fe commonly increase during alteration and exchange, whereas Sr may decrease (Brand and Veizer, 1980). Denison and others (1994) showed that limestone samples with the lowest Fe and Mn and the highest Sr/Mn ratios were the most likely to retain the original strontium isotope ratio of the seawater (Jones and others, 1994, McArthur and others, 2000). For quarry sample CAS 54135-1 both the Sr/Mn and Sr/Fe molar ratios shown in table 3 are well below those of the EN-1 modern shell standard and consistent with postdepositional alteration. Sample CAS 54135-2 also shows lower Sr and somewhat elevated Mn (table 3). However, its Fe values are less than the EN-1 values and its molar Sr/Fe value is similar to EN-1. In view of its inconclusive compositional ratios, CAS 54135-2 must be considered suspect, but seawater Sr age information was calculated for

**Table 2.** Age of Miocene volcanic rocks near Bloomfield Quarry, Sonoma County, California.

[Ma, megaannum or millions of years ago; GM, groundmass separate; Plag, plagioclase; NAD27, North American Datum of 1927; σ, standard deviation; MSWD, mean-square weighted deviation]

| Sample number | Material | Latitude (North) NAD27 | Longitude (West) NAD27 | Type of data analysis[1] | Indicated age (Ma) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Age[2] | ±1σ | MSWD[3] |
| 088-27A | GM | 38.22374 | 122.61463 | Recoil model | 9.928 | 0.041 | 3.80 |
| 088-27B | GM | 38.22011 | 122.64305 | Recoil model | 9.786 | 0.049 | 2.99 |
| 088-27D Run 1 | Plag | 38.32766 | 122.79960 | Plateau | 6.215 | 0.014 | 1.70 |
| 088-27D Run 2 | Plag | 38.32766 | 122.79960 | Recoil model | 6.192 | 0.013 | 0.34 |
| TW-5C-B | GM | 38.31509 | 122.80510 | Plateau | 9.268 | 0.058 | 1.5 |

[1] A "plateau" age is the weighted mean age of contiguous, concordant age steps representing at least 50 percent of the potassium-derived. Argon-39 ($^{39}$Ar) released in an incremental-heating experiment (Fleck and others, 1977). A "recoil model" age is calculated as the integrated age of contiguous age steps and fractions of steps in a central fraction of the age spectrum (Fleck and others, 2014).

[2] All ages are calculated to a monitor age equivalent to an age of 28.198 Ma for Fish Canyon Tuff sanidine.

[3] Mean-square weighted deviation, a measure of goodness of fit, comparing the observed scatter to that expected from calculated analytical errors (McIntyre and others, 1966).

**Table 3.** Chemical and isotopic data for samples from Bloomfield Quarry, Sonoma County, California.

[CAS, California Academy of Sciences. Samples 54134-1 and 54134-2 are *Chlamys* (Mollusca: Bivalvia) fragments from CAS locality 54135. Sr, strontium; Ca, calcium, Mn, manganese; Fe, iron; Rb, rubidium; $^{87}$Sr/$^{86}$Sr, strontium-87/strontium-86; ppm, parts per million; %, percent; σ, standard deviation; Ma, megaannum or millions of years ago; --, no data]

| CAS sample no. | Sr (ppm) | Ca (%) | Mn (ppm) | Fe (ppm) | Rb (ppm) | Molar Sr/Ca ×1,000 | Molar Sr/Mn | Molar Sr/Fe | $^{87}$Sr/$^{86}$Sr | ±2σ | Age (Ma) | ±2σ (Ma) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 54135-1 | 736.5 | 37.35 | 709.0 | 6,197 | 4.05 | 0.90 | 0.65 | 0.08 | 0.708761 | 0.000019 | Too altered | |
| 54135-2 | 817.1 | 36.12 | 49.3 | 1,335 | 0.05 | 1.03 | 10.39 | 0.39 | 0.708933 | 0.000019 | 7.92 | 0.46 |
| Standards | | | | | | | | | | | | |
| EN-1 | 1,201 | 4.717 | 0.45 | 1,628 | 0.044 | 1.58 | 1,672.22 | 0.47 | 0.709173 | 0.000014 | -- | -- |
| SRM987 | -- | -- | -- | -- | -- | -- | -- | -- | 0.710243 | 0.000018 | -- | -- |

this sample (table 3). An age and uncertainty were assigned using the look-up table for conversion of $^{87}Sr/^{86}Sr$ in minerals, LOWESS version 3, the best-fit to the Sr seawater variation curve of McArthur and others, 2001 (also see Howarth and McArthur, 1997). The age of 7.92±0.46 Ma obtained from these data is consistent with age constraints provided by the $^{40}Ar/^{39}Ar$ ages of bracketing volcanic units but would benefit from Sr testing of less altered samples from the quarry.

## Tuff Correlations

Within the Wilson Grove Formation, the Roblar tuff is continuously exposed to the east-southeast of Bloomfield Quarry for about 6.5 km and discontinuously exposed to the northwest for about 9.5 km to near Jonive School (Travis, 1952). The tuff dips at a low angle (3–5°), generally toward the northeast, and is broadly exposed in the hilltops and hillsides within a 2- to 3 km-wide belt between these localities. The Roblar tuff is also exposed in a small area near Trenton, on the south side of Mark West Creek, where it is present on the north side of a fault that has uplifted the lower part of the Wilson Grove Formation and the Franciscan bedrock and juxtaposed it with the upper part of the Wilson Grove Formation, lying to the southwest of the fault.

Multiple chemical analyses of volcanic glass obtained from the Roblar tuff have been made using several different analytical techniques—energy-dispersive X-ray fluorescence, electron-microprobe analysis, and instrumental nuclear activation analysis (Sarna-Wojcicki, 1971, 1976; and unpublished data in the data repository of the Tephrochronology Project, U.S. Geological Survey, Menlo Park, CA 94025). These analyses make it possible to derive a unique chemical signature (a chemical “fingerprint”) for this tephra layer, which allows us to distinguish this tephra layer from others, to correlate it between outcrops that are not continuously exposed, and to correlate it to other exposures within a much broader region (Sarna-Wojcicki, 1971, 1976, 2000). Chemical analysis of the volcanic glass indicates that a ~15-m-thick volcanic breccia that lies near the base of the Wilson Grove Formation to the north of Mark West Creek, and outcrops at the extreme northwest part of this formation, is the same as the Roblar tuff, contrary to Travis’ (1952) inference that these two deposits were of different origin. However, Travis (1952) was correct in assuming that the source of the Roblar tuff was situated to the northeast of the Wilson Grove Formation, as the tuff thickens and coarsens in that direction. Pumice clasts as large as 10 cm in diameter are present in the tuff breccia situated on the north side of Mark West Creek. This suggests that the source was probably close, most likely within the older part of the Sonoma Volcanics to the east. The actual source vent has not been determined and may be buried by younger deposits beneath the Santa Rosa Plain to the east of the coarse breccia on the northside of Mark West Creek.

Using its chemical composition, the Roblar tuff in the Wilson Grove Formation has now been correlated with a number of localities in the northern and central Coast Ranges of California, as well as within sediments of the eastern Pacific Ocean (fig. 2; table 4). Specifically (proceeding from the northwest to the southeast), the tephra is present in sediments of the Delgada Fan offshore of northern California, where it was encountered in Deep-Sea Drilling Program (DSDP) hole 34 with the base of the ash at 118.90 m beneath the sediment/water interface.

The Delgada Fan was fed through two deep-ocean canyons, the Noyo and Delgada Canyons, and the heads of these canyons abut the San Andreas Fault Zone that lies just to the east. Sarna-Wojcicki (1992) proposed that the Delgada Canyon and fan were juxtaposed opposite the present area of the Wilson Grove Formation at the time of the eruption of the Roblar tuff, that the Roblar tuff was transported across the San Andreas Fault by streams and ocean currents into the Delgada Canyon shortly after the eruption, and that the area to the west of the Wilson Grove Formation (the Pacific Plate) was offset by right lateral movement on the fault to the northwest, a distance of about 230 km, from the Wilson Grove Formation on the east, which is situated on the North American Plate (fig. 2).

The Roblar tuff is also present to the east of the Wilson Grove Formation, at several sites within the Sonoma Volcanics near Santa Rosa, and to the southeast near Cannon Road and Sears Point, Sonoma County, within the Petaluma Formation. Farther to the southeast, across the Rodgers Creek-Hayward Fault Zone, the Roblar tuff is present within the Contra Costa Group near the town of San Pablo, stratigraphically below the ~5.4–5.2 Ma Pinole Tuff. Farther to the southeast, southeast of the town of Lafayette, the Roblar tuff has been identified near the top of the Contra Costa Group. To the east and southeast of the latter locality, the Roblar tuff has been identified at several sites within the informal Green Valley formation of Conduit (1938) (also sometimes called the Sycamore Canyon formation of Graymer and others (2002), Tedford and others, 2004, and Sarna-Wojcicki and others (2011); Sycamore Canyon Formation has previous been use in Puente Hills, Los Angeles Basin California), where it is present below the Pinole Tuff, and the latter, in turn, below the Lawlor Tuff (4.83 Ma; Sarna-Wojcicki and others, 2011). The Roblar tuff is also present about 200 km farther to the southeast, in the marine Etchegoin Formation within the Coalinga Anticline, just east of the town of Coalinga in the San Joaquin Valley (fig. 3; table 4).

## Biostratigraphy

Molluscan biostratigraphy supports the age for the Wilson Grove Formation at Bloomfield Quarry determined above but does not help refine it further. Four extinct molluscan species reported by Zullo and Guruswami-Naidu (1982) from

**Table 4.** Electron-microprobe analyses of volcanic glass shards of the Roblar tephra (tuff and ash) and of an older rhyolitic pumice from a vent near the town of Roblar, Sonoma County, California, inferred to have been the source vent of the Roblar tephra (Travis, 1952).

[Chemical data and argon/argon (Ar/Ar) ages indicate that the two units are not the same. Values given for each sample are in oxide weight percent recalculated to a fluid-free basis, and are the means of between ~15 and 20 analyzed shards per sample. Chemical abbreviations: $SiO_2$, silicon dioxide; $Al_2O_3$, aluminum oxide; $Fe_2O_3$, ferric oxide; MgO, magnesium oxide; MnO, manganese oxide; CaO, calcium oxide; $TiO_2$, titanium dioxide; $Na_2O$, sodium oxide; $K_2O$, potassium oxide. Total, R, total recalculated to 100 percent to correct for a variable deficit from 100 percent due mostly to the presence of water of hydration in the glasses. Total O, original total on analysis. Values for iron were originally calculated as FeO, then recalculated to $Fe_2O_3$ before normalization to 100 percent. Results of replicate analysis of three standards used in analysis (grand means) are given below to provide an approximation of replication on analysis. Samples analyzed by Charles E. Meyer, James Walker, and Elmira Wan, U.S. Geological Survey (USGS), Menlo Park, California, 1986–1998. σ, standard deviation; fm., formation; DSDP, Deep Sea Drilling Project; NA, not applicable]

| Roblar tephra locality | Number of samples and standard deviation (1σ) | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | MnO | CaO | $TiO_2$ | $Na_2O$ | $K_2O$ | Total O | Total R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Northeast Pacific Ocean, DSDP-34-8-6 (Delgada Fan) | 1 sample | 75.04 | 13.61 | 1.49 | 0.07 | 0.03 | 0.60 | 0.14 | 4.45 | 4.57 | 93.07 | 100.00 |
| 2. Wilson Grove Fm. (includes Bloomfield Quarry locality) | Mean of 9 samples | 75.03 | 13.62 | 1.48 | 0.06 | 0.03 | 0.58 | 0.13 | 4.44 | 4.62 | 92.69 | 100.00 |
| | Standard deviation | 0.18 | 0.19 | 0.03 | 0.01 | 0.01 | 0.02 | 0.02 | 0.11 | 0.16 | 0.32 | 0.00 |
| 3. Southeast of Roblar (Wilson Grove Fm. (?)) | Mean of 2 samples | 75.52 | 13.44 | 1.46 | 0.07 | 0.02 | 0.59 | 0.13 | 3.90 | 4.88 | 92.74 | 99.99 |
| 4. Northwest Sonoma Volcanics (including Petaluma Fm. (?)) | Mean of 8 samples | 75.44 | 13.51 | 1.45 | 0.07 | 0.03 | 0.60 | 0.12 | 4.14 | 4.66 | 94.47 | 100.00 |
| | Standard deviation | 0.34 | 0.21 | 0.09 | 0.01 | 0.01 | 0.03 | 0.01 | 0.29 | 0.19 | 0.96 | 0.01 |
| 5. Southwest Sonoma Volcanics (Petaluma Fm.) | Mean of 5 samples | 75.62 | 13.76 | 1.51 | 0.07 | 0.03 | 0.59 | 0.11 | 4.49 | 3.83 | 93.22 | 100.00 |
| | Standard deviation | 0.38 | 0.08 | 0.04 | 0.00 | 0.01 | 0.02 | 0.01 | 0.20 | 0.63 | 1.33 | 0.01 |
| 6. Berkeley Hills block (Contra Costa Group) | Mean of 4 samples | 75.62 | 13.74 | 1.47 | 0.06 | 0.03 | 0.57 | 0.11 | 3.64 | 4.59 | 92.61 | 100.00 |
| | Standard deviation | 0.83 | 0.21 | 0.03 | 0.02 | 0.01 | 0.04 | 0.02 | 0.53 | 0.89 | 2.63 | 0.00 |
| 7. Block 5 of Mount Diablo (Green Valley or Sycamore fm.) | Mean of 4 samples | 75.46 | 13.48 | 1.48 | 0.07 | 0.02 | 0.58 | 0.11 | 3.93 | 4.88 | 91.43 | 100.00 |
| | Standard deviation | 0.19 | 0.13 | 0.03 | 0.01 | 0.00 | 0.02 | 0.01 | 0.35 | 0.39 | 0.71 | 0.01 |
| 8. Coalinga Anticline (Etchegoin Fm.) | 1 sample | 75.89 | 13.59 | 1.51 | 0.06 | 0.01 | 0.58 | 0.11 | 5.01 | 3.25 | 92.85 | 100.01 |
| Roblar tephra, average composition | | | | | | | | | | | | |
| | Grand mean, 35 samples | 75.41 | 13.59 | 1.47 | 0.07 | 0.03 | 0.58 | 0.12 | 4.20 | 4.52 | 93.09 | 100.00 |
| | Standard deviation | 0.43 | 0.19 | 0.05 | 0.01 | 0.01 | 0.03 | 0.01 | 0.41 | 0.54 | 1.42 | 0.01 |
| Reference standards used in analysis and replication (values on analysis; not normalized to 100 percent) | | | | | | | | | | | | |
| USGS obsidian glass standard RLS 132, a homogenous glass from near Puebla, Mexico | Grand mean, 94 samples | 75.42 | 75.42 | 2.115[1] | 0.06 | 0.150 | 0.11 | 0.19 | 4.578 | 4.39 | 98.56 | NA |
| | Standard deviation | 0.69 | 0.15 | 0.038 | 0.02 | 0.01 | 0.02 | 0.02 | 0.516 | 0.12 | 0.71 | NA |
| USGS glass standard GSC, a synthetic glass standard made for the USGS by Corning Glass Co. (Myers and others, 1976) | Grand mean, 77 samples | 61.99 | 14.22 | 6.276 | 3.85 | 0.027 | 5.0 | 0.01 | 4.028 | 3.59 | 98.978 | NA |
| | Standard deviation | 0.31 | 0.31 | 0.169 | 0.12 | 0.007 | 0.1 | 0.01 | 0.119 | 0.09 | 0.41 | NA |
| USGS mineral standard, andesine plagioclase $An_{40}$ | Grand mean, 60 samples | 57.91 | 27.35 | 0.029 | 0 | 0.008 | 8.36 | 0.01 | 6.88 | 0.02 | 100.57 | NA |
| | Standard deviation | 0.51 | 0.31 | 0.009 | 0 | 0.005 | 0.09 | 0.01 | 0.368 | 0.01 | 0.78 | NA |

[1] Iron in standard RLS 132 is reported as FeO.

the basal unit [*Arca santamariensis* (provisionally identified), *Crenomytilus coalingensis* (provisionally identified), *Swiftopecten parmeleei*, and *Tresus pajaroanus*], two from the upper sand unit (*Tresus pajaroanus* and *Crepidula princeps*) and an additional gastropod and bivalve from the quarry in collections at the CAS [*Caesia grammatus* (provisionally identified) and *Chlamys hodgei* (provisionally identified)] are also extinct. Most of these taxa have overlapping teil zones within the "Jacalitos" California provincial molluscan stage (CPMS); however, *Caesia grammatus* (provisionally identified) has previously been restricted to the Pliocene (uppermost "Etchegoin" and "San Joaquin" CPMSs), although it is not confidently identified so it is not used to determine the age of the unit or to have it stratigraphic distribution modified.

# Age Summary

The data presented above indicate that the lower part (below the Roblar tuff) of the Wilson Grove Formation is late Miocene in age, between <9.27±0.06 Ma and >6.203±0.011 Ma, whereas in its upper part (above the Roblar tuff) an age range between 6.203±0.011 Ma to possibly as young as >2.6 Ma (late Pliocene; Powell and others, 2004) is determined. This age range includes the "Jacalitos" CPMS for the lower unit to possibly the "San Joaquin" CPMS for the upper unit and overall overlaps the upper part of the Tortonian and lower part of the Messinian to the Piacenzian stages of the International Chronostratigraphic Chart (International Commission on Stratigraphy, 2012).

# Paleontology

The fauna from the Bloomfield Quarry exposures of the Wilson Grove Formation consists of 77 taxa—4 brachiopods, 42 mollusks (28 bivalves and 14 gastropods), 6 arthropods (1 crab, 1 shrimp, and 4 barnacles), and 25 vertebrates (3 sharks, 1 ray, 8 bony fishes, 9 marine mammals, and 4 birds) (table 1; see the appendix for taxonomic notes). Not documented during this study are a few bryozoans, fragmentary fish bones, and other possible biologic remains in the CAS and the University of California Museum of Paleontology (UCMP) collections, most of which are not well enough preserved for more precise identification.

The paleoenvironmental interpretation of the brachiopods is a shallow subtidal to rocky intertidal environment, with some, but relatively little, transport of individuals away from their in-life position to the site of deposition, very similar to that described for mollusks, below. This interpretation is supported by several lines of evidence. The depth and habitat ranges for extant representatives of these species, and closely related congeners, is shallow subtidal to intertidal; all require a hard substrate (rocky substrate or shells of other organisms) for attachment by a pedicle and live gregariously in crowded conditions of relatively high abundance. Extant articulated brachiopod valves from dead individuals that remain on the substrate will begin to degrade after only a few weeks of exposure from decay of organic material surrounding the "fibers" making up the mineralized secondary shell (Kowalewski and LaBarbera, 2004). The nature of the preservation of individual valves, and relative proportions of still-articulated individuals and disarticulated valves, indicates relatively rapid burial shortly after death, with little prolonged exposure on the seafloor. Rapid deposition is also indicated by the three-dimensional orientation of disarticulated valves within the sandstone matrix—either as unoriented individual dorsal valves of inarticulated brachiopods floating in matrix or as clumped or imbricated dorsal or ventral valves of articulated brachiopods; relatively strong, bidirectional forces generated near wave base could result in a deposit of this type.

Mollusks and the geologic setting indicate a paleoenvironment similar to that described above for the Brachiopoda. Mollusks collected from the basal conglomerate were analyzed by Barry Roth (*in* Zullo and Guruswami-Naidu, 1982) and interpreted as representing a rocky intertidal or shallow subtidal environment exposed to moderate to heavy surf. A rocky substrate with adjacent sandy areas is indicated by the mollusks identified here supplementing the environmental interpretation of Roth (*in* Zullo and Guruswami-Naidu, 1982) cited above. In addition, the stratigraphic position of the underlying Franciscan Complex basement indicates very shallow water depths in agreement with Zullo and Guruswami-Naidu (1982). Using extant mollusks ($n$=14), the overlapping latitudinal ranges show that the bivalve genera *Anadara* and *Arca* today occur only south of the current latitude of the fossil locality today, whereas the others are consistent with that latitude. However, both genera are known from further north than Sonoma County during the Miocene, so the faunal composition is consistent with the latitude of the fossil locality in the Miocene.

The ichthyofauna is indicative of the relatively recent northeastern Pacific assemblages that originated in the late Miocene with the evolution of a temperate upwelling regime (Long, 1994; Hobson 2006), and each of the family and genera of bony fishes collected at this site, as well as those sharks and ray identified to the species level, are still found in California marine waters. The most important aspect of the teleost fauna is that many represent early records, or even ancestral forms, of later species found in California waters today. These fossil teleosts are taxa that today are found in nearshore habitats, such as kelp beds, seagrass meadows, sand flats, and muddy bottoms (Allen and Pondella, 2006). Most of these species are coastal, or have ranges that extend into littoral waters, but due to the wide latitudinal and bathymetric distributions of some species, they are not especially indicative of a more precise paleoecology of the locality. Several species, such as the shark *Isurus oxyrinchus* and the bonito *Sarda* sp. tend to be associated with warmer temperate waters, but often extend into cool-temperate waters when waters are seasonally warm or during warmer El Niño events. This indicates that the local marine climate of this depositional environment was slightly warmer than the adjacent coast today or that these specimens were deposited during periods of seasonal or abnormal warm-water intrusion (Long, 1992, 1993b).

Barnes (1976 [1977]) reported the first marine mammals from the Wilson Grove Formation, including the lipotid dolphin *Parapontoporia sternbergi* and the balaenid right whale *Balaenula* sp. However, these specimens have not yet been described. To that list can be added *Dusignathus santacruzensis*, *Gomphotaria pugnax*, cf. *Pontolis*, an unidentified odobenine walrus, and an unidentified sirenian. The marine mammal assemblage from Bloomfield Quarry represents the most diverse walrus assemblage yet reported in the world. It includes three dusignathine walruses and an indeterminate odobenine walrus. The cetacean fossils are less diagnostic and only indicate the presence of unidentified odontocetes and mysticetes; more diagnostic cetacean material including skulls, jaws, and petrosals are known from other localities in the Wilson Grove Formation that are not yet described, including a pygmy mysticete a few kilometers to the east (Allen and Holland, 1999; Powell and others, 2004). Notably lacking from the marine mammal assemblage are otariid fur seals, which are known from other late Miocene strata such as the Purisima Formation in central California (Repenning and Tedford, 1977), as well as localities stratigraphically higher in the Wilson Grove Formation. Again, these other specimens from the Wilson Grove Formation have yet to be described. The pinniped assemblage is similar to that of the basal Purisima Formation near Santa Cruz, where *Gomphotaria* and *Dusignathus* are preserved alongside odobenine walruses and otariid fur seals. However, no other strata from the eastern North Pacific preserve even two of these three dusignathine taxa together.

Bird remains have not been reported previously from the Wilson Grove Formation, and a minimum of only two species can be attributed to the avifauna from Bloomfield Quarry based on the material presently available. However, conclusions regarding the composition of the Wilson Grove Formation avifauna are necessarily preliminary because the quantity of fossil remains ($n$=6 specimens) is very limited. Nonetheless, the species represented by the material described herein (Mancallinae indeterminate and cf. *Uria brodkorbi*) are consistent with that documented for other Miocene marine avifaunas from the eastern Pacific Ocean basin (Warheit, 1992, 2002). *Uria* and Mancallinae co-occur in the middle-late Miocene “Monterey” Formation of Orange County, California (Howard, 1966, 1978) and the late Miocene to early Pliocene San Mateo Member of the Capistrano Formation of San Diego County, California. However, Mancallinae remains have not been reported from the type locality of *Uria brodkorbi*, the late Miocene to early Pliocene diatomite deposits of the Sisquoc Formation in Santa Barbara, County, California (Howard, 1981).

Nearly every deposit that has produced pan-alcid remains has been interpreted as the result of moderate to shallow depth deposition of sediments associated with cold-water upwelling (Deméré, 1983; Olson and Rasmussen, 2001; Smith, 2011; Smith and Clarke, 2011; Smith, 2013a,b). This interpretation is in agreement with the intertidal to shallow subtidal water depths indicated by the molluscan fauna and the relatively shallow (that is, <10 m) depositional setting proposed by Roth *in* Zullo and Guruswami-Naidu (1982).

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# Appendix—Taxonomic Notes

**Institutional abbreviations**—CAS, California Academy of Sciences; NCSM, North Carolina Museum of Natural Sciences; LACM, Natural History Museum of Los Angeles County; SDNHM, San Diego Natural History Museum; UCMP, University of California Museum of Paleontology; USNM, National Museum of Natural History, Smithsonian Institution.

## Invertebrates

Taxa are arranged taxonomically following the Treatise on Invertebrate Paleontology for the higher classification of invertebrates and following Bouchet and others (2010) for the bivalve mollusks and Bouchet and Rocroi (2005) for the gastropods. Discussed below are only specimens that can be confidently identified, and (or) aid in age and environmental interpretation. Other specimens are found in collections but due to poor preservation are not identifiable, or in the instance of Bryozoa, are not identified because of lack of expertise.

### Brachiopods by Sandra J. Carlson

Phylum Brachiopoda Duméril, 1806
Subphylum Linguliformea Williams and others, 1996
Class Lingulata Gorjansky and Popov, 1985
Order Lingulida Waagen, 1885 [see Waagen, 1882–1885]
Superfamily Discinoidea Gray, 1840
Family Discinidae Gray, 1840
Genus *Discinisca* Dall, 1871
*Discinisca* cf. *D. cumingii* (Broderip, 1833)
Plate 1, figure 1

Abundant (>25 specimens), moderately well to poorly preserved inarticulated brachiopod dorsal valves, the best preserved of which are assigned to *Discinisca* cf. *D. cumingii*, occur at CAS locality 54136. They can reach large (>20 millimeters, mm) size, and are gently conical and roughly circular to oval in outline with irregular, moderate concentric ribs around an eccentrically placed umbo. Faint to moderate radial ribs are visible mainly over the outer (older) regions of the dorsal valve surface, at some distance from the umbo. Nodes form in a vaguely reticulate pattern where the radial and concentric ribs cross. No ventral valves, which would retain the characteristic slit-like pedicle opening, were observed. Reported by Broderip (1835, p. 203) to range in the Holocene from Cabo San Lucas (Baja California Sur, Mexico) to Panama, and extending as far south as Chile along the Pacific coast of Central and South America, “attached to the lower side of stones in sandy mud at low water, and in some instances at a depth of from six to eight fathoms” (Cuming). Extant congeners (*D. sparselineata*; Kato, 1996) in Japan live in the middle intertidal zone “attached beneath boulders that were deeply buried in coarse sand,” protected from many biotic and abiotic threats. Warm and very shallow water (<60 feet depth) habitat was likely for *D. cumingii*; lower depth range unknown. More details on the occurrence of this genus and species in California can be found in Hertlein and Grant (1944), as well as Adegoke (1969).

These brachiopods have chitinophosphatic valves and fossilize with a distinctive golden brown to black color and a lustrous sheen, preserving fine details of the exterior ornament; no color bands can be observed. The radial and concentric ornament together distinguish this species from others in the genus. Dorsal valves vary considerably in conical height and in location of the umbo, from central to marginal; ornament is also variable in appearance among individuals. Dorsal valve interiors are largely filled with well-cemented fine sandstone, making it impossible to see anatomical features on most valve interiors. Valve interiors were exposed in approximately six individuals, but unfortunately no adductor muscle scars were visible; no median septum was present either, clearly distinguishing these valves from West African *Discina*.

In fist-sized samples of sandstone from CAS locality 54135, *Discinisca* valves can be seen floating in the rock matrix, unoriented and dispersed from one another, which suggests that the dorsal valves were removed by physical (wave?) force from the ventral valves that remained attached by the pedicle to the underside of rocks, and were then deposited very rapidly. Specimens are rarely deformed, but may be chipped along the commissural margin.

Subphylum Rhynchonelliformea Williams and others, 1996
Class Rhynchonellata Williams and others, 1996
Order Terebratulida Waagen, 1883 [see Waagen, 1882–1885]
Suborder Terebratulidina Waagen, 1883 [see Waagen, 1882–1885]
Family Cancellothyrididae Thomson, 1926
Genus *Terebratulina* d’Orbigny, 1847
*Terebratulina* cf. *T. unguicula* (Carpenter, 1864)
Plate 1, figures 2, 3, 4

Ten partial and single elongate valves with fine radial sculpture collected from CAS locality 54135 are identified as *Terebratulina* cf. *T. unguicula*, based on distinctive features of the dorsal cardinalia, but all are missing the short loops supporting the lophophore that characterize terebratulidines. Some of the fragments are too incomplete to warrant definitive identification, but can be clearly distinguished from *Terebratalia* by their smaller size, thinner valves, and very delicate radial ribs (costellae). Bloomfield Quarry specimens are similar in size to *T. unguicula*, but the specimen figured in plate 1 is wider than long, whereas *T. unguicula* is more often longer than wide, as is the case for several of the less complete, unfigured specimens. Several of the smaller valves (5 mm) are flatter and nearly equal in length and width, which is more similar to *T. kiiensis* Dall and Pilsbry, 1891. The full range of variability in valve proportions cannot be determined from the small sample size here.

*Terebratulina unguicula* is the more common Miocene species of *Terebratulina* from western North America and has a modern range from the Pribilof Islands in the Bering Sea, off Alaska, south to Cabo San Lucas, Baja California Sur, Mexico (Dall, 1920), from 10 to 850 m (Hochberg, 1996). Hertlein and Grant (1944) report it as a fossil from the Miocene of Oregon to the middle Pleistocene Lomita Marl (then considered late Pliocene) of southern California.

Suborder Terebratellidina Muir-Wood, 1955
Superfamily Laqueoidea Thomson, 1927
Family Terebrataliidae Richardson, 1975
Genus *Terebratalia* Beecher, 1893
Type species—*Terebratalia transversa* (Sowerby, 1846), by original designation by Beecher, 1893

This genus is highly variable in many external morphological features, in both extant and extinct forms (Schumann, 1991). Distinctions among named species are not clear in practice, and specimens can vary by “insensible gradations” from one species to another (Hertlein and Grant, 1944; p. 119). Valve shape varies from weakly to strongly biconvex, from longer than wide to wider than long, from unisulcate to rectimarginate to uniplicate, and from strongly ribbed to smooth, with concentric growth lines that range from faint to broad and rugose. Extant *T. transversa* attach to a hard substrate by a pedicle, do not move once they settle and metamorphose on that substrate, and live in gregarious clusters, which can cause crowding and disrupt the bilateral symmetry of the valves in unpredictable ways.

*Terebratalia occidentalis* (uniplicate, with dorsal fold) outnumbers *T. transversa* (unisulcate, with dorsal sulcus) by approximately 5 to 1 among Bloomfield Quarry specimens. Dorsal valves of *Terebratalia* outnumber ventral valves in these collections by roughly 4 to 1. Ventral valves exhibit large to very large pedicle foramina and broad palintropes. Many of the valves, dorsal and ventral, preserve natural irregularities in shape due to crowding in life; many (particularly those from CAS locality 54135), but not all, also exhibit post-depositional crushing fractures and early diagenetic bending of shells, due to decay of the large amount of organic material contained within the fabric of the valves shortly after death. *Terebratalia* valves interlock in articulation in life (Jaanusson, 1971; Carlson, 1989) but are not uncommonly separated after death; the relatively large number of articulated specimens indicates that these individuals were buried shortly after death and, if transported, were not moved far from their life position and were probably moved while the animal was still alive, causing their death, or immediately after death. A few sedimentary blocks from Bloomfield Quarry contain abundant brachiopods, as a coquina of disarticulated valves; they most likely were transported at least some distance before deposition. Most valves, originally low magnesium calcite, from CAS localities 54135 and 54136 are medium to dark gray in color, similar to the fine sandstone matrix in which they are preserved, but some from the basal conglomerate at CAS locality 54135 are a creamy white color and hardly look fossilized. Brachiopods are far less commonly preserved in Tertiary sedimentary rocks than are mollusks; the relative abundance of brachiopods in Bloomfield Quarry indicates that they were deposited close to their hard-substrate habitat in life. *Terebratalia* ranges stratigraphically from Eocene to Holocene and occurs today along western North America and Japan, from high intertidal to generally less than 200 m depth.

*Terebratalia* cf. *T. transversa* (Sowerby, 1846)
Plate 1, figures 8, 10

One articulated specimen, abundant (>25) single and partial valves are in collections from CAS locality 54135, and an additional three articulated specimens, five single valves and four internal molds (steinkerns) are present from CAS locality 54136. Many specimens are deformed, either before and/or after deposition, but all are easily recognized as *Terebratalia* and a small percentage (<20 percent) are identifiable as *Terebratalia* cf. *T. transversa*. *Terebratalia transversa* is distinguished from *T. occidentalis* by the presence of a weak dorsal sulcus and ventral fold (Hertlein and Grant, 1944). Although this species is locally common today in patches along the west coast of North America, it is not the most abundant morphology among Bloomfield Quarry *Terebratalia*.

*Terebratalia transversa* [syn. *T. caurina* Gould, 1850; *T. transversa* v. *rubescens* Dall, 1910; *T. hemphilli* Dall, 1902; *fide* Hochberg, 1996] has a fossil record from the Miocene and Pleistocene from Alaska to California (Hertlein and Grant, 1944). It is reported living from Kodiak Island, Gulf of Alaska south to off Ensenada, Baja California, Mexico (Burch, 1942), from the intertidal zone to 1,800 m in the south (Hochberg, 1996).

*Terebratalia* cf. *T. occidentalis* Dall, 1891
Plate 1, figures 5, 6, 7, 9

At least 10 articulated specimens and abundant (>100) single and partial valves from CAS localities 54135 and 54136 resemble (cf.) *T. occidentalis obsoleta* as illustrated by Hertlein and Grant (1944, plate 12, figs. 9–11), most closely the variant named as a distinct species, *T. arnoldi*, by Hertlein and Grant (1944, p. 119). *Terebratalia occidentalis* is characterized primarily by a dorsal fold and ventral sulcus, which are commonly weakly developed, but frequently rather sharply demarcated from the rest of the valve. Valve length and width are often nearly equal, but individuals can be considerably wider than long; biconvexity varies but is often relatively strong. Radial ribs are commonly present and broad, but weakly developed, occasionally bifurcate, and occasionally absent entirely; they may be present only on the posterior region of the shell or only the anterior region. More typical *T. occidentalis* obsoleta has a nearly smooth shell with strongly developed fold and sulcus, but the abundant specimens collected at Bloomfield Quarry show considerable variation in the development of the fold and sulcus, of radial ribs, and in overall shell shape.

*Terebratalia occidentalis* [syn. *Waldheimia kennedyi* Dall, 1874; *T. occidentalis obsoleta* Dall, 1891; *T. arnoldi* Hertlein and Grant, 1944; *Miogryphus wiletti* Hertlein and Grant, 1944; *fide* Hochberg, 1996] has been reported in the Miocene from Clallum Bay, Clallum County, Washington, south to Los Angeles County, southern California, from the Pliocene from Los Angeles County, southern California, and is reported living from Monterey, Monterey County, California, south to Cabo San Lucas, Baja California Sur, Mexico, and out to Isla Cedros, Baja California Sur, Mexico, at water depths to 50 to 250 m (Hochberg, 1996). Hertlein and Grant (1944) report *T. occidentalis* obsoleta from the late Miocene to Pliocene from Oregon to southern California and *T. occidentalis* from the Oligocene of Washington to the Pliocene of southern California with many occurrences in between. Together these occurrences indicate an Oligocene to Pliocene age range for *T. occidentalis*.

## Mollusks by Charles L. Powell II

Phylum Mollusca Linnaeus, 1758
Class Bivalvia Linnaeus, 1758 (Taxonomy follows Bouchet and others, 2010)
Family Nuculidae Gray, 1824
*Yoldia* sp. indeterminate
Plate 2, figures 1, 4, 5, 6

Two internal molds from CAS locality 54135 resemble the genus *Yoldia*, but the outline is poorly defined and the shell lacks detail so further identification is not possible.

Family Mytilinae Rafinesque, 1815
*Crenomytilus* cf. *C. coalingensis* (Arnold, 1909 [1910])
Plate 2, figure 16

One moderately well preserved valve from CAS locality 54135 is referred to *Crenomytilus* cf. *C. coalingensis* based on size and shape. The characteristic fine transverse rows of pustules on the exterior of the anterior ventral end are not preserved, making the identification provisional. *Crenomytilus coalingensis* is reported in Moore (1983) from the Castaic, Etchegoin, Fernando, Merced, Niguel, Pancho Rico, San Joaquin, and Towsley Formations, indicating an age range from the "Jacalitos" to "San Joaquin" CPMS. In addition, Powell (2007) provisionally reported it from the late Miocene "Margaritan" CPMS.

*Mytilus* sp. indeterminate

Several large shell fragments resembling the genus *Mytilus* are present in large conglomeratic clasts from CAS locality 54134, and fragments of indeterminate *Mytilus* shells are present from CAS locality 54135. In addition, numerous partial specimens of an indeterminate *Mytilus* are also present. Unfortunately, none are well enough preserved to identify beyond *Mytilus* sp.

*Modiolus* sp. indeterminate

One internal mold fragment and one articulated internal mold missing its umbonal end from CAS locality 54136 are assigned to the genus *Modiolus* based on their size and shape. Unfortunately, they are not well enough preserved to identify to species. The genus *Modiolus* is widespread in the eastern Pacific Ocean and not ecologically or chronostratigraphically significant here.

Indeterminate Mytilidae

A single fragment of a valve from CAS locality 54136 is assigned to an indeterminate Mytilidae, based on its sculpture and internal pearly luster similar to that seen in *Geukensia demissum* (Dillwyn, 1817). Because *G. demissum* was introduced to the eastern Pacific Ocean from the Atlantic Ocean during the past century, the Bloomfield Quarry specimen cannot be attributed to that species and remains unidentified.

Family Arcidae Lamarck, 1809
*Anadara* sp. indeterminate

Several shell fragments from CAS locality 54135 resemble the genus *Anadara* and are identified as indeterminate species within that genus.

*Arca* cf. *A. santamariensis* Reinhart, 1937
Plate 2, figures 2, 3

Four incomplete specimens and three internal molds from CAS locality 54135 are referred to *Arca santamariensis* based on their sculpture and irregular shell outline. The best-preserved specimen is easily identified as this species but is much larger than previously reported for this species, in excess of 50 mm and still appears slightly incomplete, whereas the type is only 26 mm long. These specimens are therefore provisionally identified. *Arca santamariensis* has previously been reported from the Niguel Formation (originally referred to Capistrano Formation, *fide* Groves, 1991) in Orange County (Vedder *in* Kern and Wicander, 1974) and Cebada Member of the Careaga Sandstone in the Santa Margarita District (Woodring in Woodring and Bramlette, 1950 [1951]), both of Pliocene age. Therefore, its occurrence in the lower Wilson Grove Formation at Bloomfield Quarry extends its stratigraphic range to the late Miocene.

Family Anomiidae Rafinesque, 1815
*Pododesmus* cf. *P. macrochisma* (Deshayes, 1839)
Plate 2, figures 7, 15

Three incomplete valves and two fragments from CAS locality 54136 are provisionally (cf.) assigned to *Pododesmus macrochisma* (Deshayes, 1839) based on their shape and sculpture. *Pododesmus macrochisma* has a modern range from Wainright, Chukchi Sea, Alaska, south to Bahia Magdalena, Baja California Sur, and near Guaymas, Sonora, Mexico, from the intertidal zone to 90 m attached to a hard substrate (Coan and others, 2000). Moore (1987) reports *P. macrochisma* as occurring in formation from the "Margaritan" CPMS to late Pleistocene.

### *Anomia peruviana* d'Orbigny, 1846

In addition, a single specimen from CAS locality 54135 resembles *Anomia peruviana* and is assigned to that species. *Anomia peruviana* as a modern occurrence from Monterey, central California south through the Gulf of California, Mexico, to Paita, Peru, at intertidal water depths to 120 m (Coan and others, 2000). This species has been reported from the late Miocene (C. Powell, oral commun. in Moore, 1987) to Holocene (Coan and others, 2000). The previous Miocene occurrence is from proto-Gulf California deposits in south-central California. The occurrence here is the first from the Miocene of coastal California.

### Family Pectininae Rafinesque, 1815

At least three species of *Chlamys* are present from CAS locality 54135. These three taxa are distinguished by the structure and number of radial ribs, shell microsculpture, and the auricles. In addition, indeterminate *Patinopecten* and *Swiftopecten parmeleei* occur at the Bloomfield Quarry.

### *Chlamys hodgei* (Hertlein, 1925)
Plate 2, figure 11

The first, *Chlamys hodgei* (Hertlein, 1925), is best represented at Bloomfield Quarry by a small right valve, higher than long and equilateral with about 17 major radial ribs and an apical angle of about 95°. These features and the riblets on either side of the major ribs, fine sharp imbricated spines, and very finely pitted surface serve to identify this species. *Chlamys hodgei* occurs in the "Margaritan" and "Jacalitos" CPMS in California and Oregon indicating a middle late to late Miocene age range for this species (Addicott, 1981).

### *Chlamys* n. sp., aff. *C. egregius* (Nomland, 1917)
Plate 2, figure 12

*Chlamys* n. sp., aff. *C. egregius*, the second species, is also small, with about 25 wide radial ribs on the right valve and narrow, shallow radial grooves which are about a quarter of the width of the ribs. This number includes 2 to 3 riblets on the anterior and posterior shell margins. What we presume is the left valve (plate 2, fig. 13) has 20 round-topped radial ribs with radial grooves slightly narrower than the radial ribs. The ribs are not medially sulcate and are unornamented except for very small nodes scattered across the shell—ribs and interspaces on both valves. This last feature serves to refer these two valves to the same species. The posterior auricle on the right valve is large and inclined slightly towards the posterior and is unornamented. Four major and possibly two minor ctenidia are present below the posterior auricle. The anterior auricle is small, inclined towards the posterior and is ornamented by at least four radial ribs with wide interspaces. The left valve (plate 2, fig. 13) is ornamented by about 21 unornamented rounded radial ribs with interspaces from about 1/3 to 2/3 the width of the ribs and steep sides. Its anterior auricle is mostly missing but appears to have at least one rounded radial rib. The posterior auricle has five, and part of a sixth rounded near its base, radial ribs after half the width of the interspaces; the anterior auricle is mostly missing but does show one faint radial rib. The posterior auricle has five and part of a sixth round-topped, kinked, radial ribs with interspaces about twice their width.

As the name implies this form is closest to *Chlamys egregius* and may be this species although there are significant differences between the type specimen and our specimens. However, *C. egregius* is a rare species and the extent of its variability is unknown. *Chlamys egregius* was described as having a smaller umbonal angle of about 70°, whereas our specimens has an angle of about 87°, also the ribs are wider and interspaces narrower on the right valve of the Bloomfield Quarry species.

### *Chlamys* cf. *C. hastata* (Sowerby, 1842)
Plate 2, figure 14

The third species, *Chlamys* cf. *C. hastata* is large, with undivided ribs and small, weak, slightly intertwining cords between the ribs. The ribs, about 20 on the illustrated right valve, are high in the center with slight shelves to either side and have small rough scales down the center. The auricle on the right valve has 3–4 fine radial ribs with wide interspaces and the end of the auricle is vertical. The byssal notch is wide and well indented. This specimen is provisionally referred to *C. hastata* and is similar to the form previously identified as *C. hastata hericeus* (Gould, 1850) in the form and sculpture on the ribs but is provisionally identified because of its worn condition. *Chlamys* hastata and *C. hastata hericeus* [synonymized by Coan and others (2000)] as reported by Moore (1984) occurs in the late Miocene to Holocene. Modern occurrences (Coan and others, 2000) are from the Kenai Peninsula, Alaska, south to San Diego, California, at water depths from the intertidal zone to 160 m.

### *Patinopecten* sp. indeterminate

Several shell fragments are identified as *Patinopecten* sp. indeterminate based on the shell shape and broad, medially sulcate, flat topped ribs that are broader than the interspaces. Unfortunately, they are incomplete and do not allow for precise identification.

### *Swiftopecten parmeleei* (Dall, 1898)
Plate 2, figures 8, 9

Specimens identified as well-worn *Swiftopecten parmeleei* (Dall, 1898) are represented at Bloomfield Quarry by two well-preserved specimens from CAS locality 54135 and a partial internal mold. These specimens are remarkably similar to *Chlamys* ("*Chlamys*") *coatsi* MacNeil (1967) from the Pleistocene of Alaska differing in the tops of the major ribs being smooth and in having microsculpture over the valves especially on the margins. As compiled by Moore (1984), *S. parmeleei* has also been reported from the Careaga Sandstone and Castaic, Etchegoin, Fernando, Niguel (as Capistrano), Pico, Purisima, San Diego, and San Joaquin Formations, as well as the Wildcat Group. These formations indicate the species ranges from "Jacalitos" to "San Joaquin" CPMS in age, or late Miocene through Pliocene.

### Family Lucinidae Fleming, 1828
### *Lucinoma annulatum Reeve*, 1850

Three articulated specimens and a few fragments are assigned to *Lucinoma annulatum* based on their size, shape, and strong comarginal sculpture. There has been much confusion in the early literature between *L. annulatum* and *L. acutilineata* (Conrad, 1849) (Moore, 1963 [1964]; Powell, 1998). Post-Moore (1963]) literature indicates that *L. acutilineata* occurs questionably from the Juanian Pacific Northwest provincial molluscan stage (PNPMS; upper Oligocene and lower Miocene) and Pillarian PNPMS (lower Miocene) to Newportian PNPMS (lower and middle Miocene) (Moore and Addicott, 1987), whereas *L. annulatum* (Reeve, 1850) ranges in rocks from Moclipsian PNPMS (most of the Pliocene) to Holocene in the Pacific Northwest (Addicott, 1976a). However, Roth (1979) believes the range of *L. annulatum* extended back to the Wishkahan PNPMS (early late Miocene), but this record has not been published. To add to the confusion, *L. annulatum* has been reported in rocks as old as Eocene in the Russian Federation (Kafanov and Ogasawara, 2003). In California *L. annulatum* is reported in rocks from the "Margaritan" CPMS (Powell, 2007; late middle to middle late Miocene) to middle Pleistocene (Clark, 1931). Modern occurrences of *L. annulatum* in the eastern Pacific are from Prince William Sound, Alaska, south to Guaymas, Sonora, Mexico, including the Gulf of California as far south as Isla Monserrate, at water depths between the intertidal zone and 665 m in sand (Coan and others, 2000).

### Family Veneridae Rafinesque, 1815
### *Leukoma* sp. indeterminate

A single shell fragment from CAS locality 54135 with moderately strong radial and comarginal sculpture resembles the genus *Leukoma* and is questionably assigned to that genus. In the eastern Pacific the genus *Leukoma* is wide-ranging and not ecologically significant because of its wide latitudinal and depth ranges.

### Family Cardiidae Lamarck, 1809
### Cardiidae, indeterminate
Plate 3, figure 6

All specimens of Cardiidae from Bloomfield Quarry are referred to as indeterminate Cardiidae. Seven specimens from CAS locality 54135, both casts and molds, resemble the genus *Clinocardium*, but lack sufficient detail to identify them confidently to that genus. In addition, three internal molds from CAS locality 54136 are identified as indeterminate Cardiidae based on their size and shape. No sculpture is preserved and the outline of the shells is incomplete, so further identification is impossible.

### Family Mactridae Lamarck, 1809
### Mactridae, indeterminate

One internal mold from CAS locality 54135 resembles the family Mactridae in shape and size, but does not allow for a confident identification.

### Family Tellinidae Blainville, 1814
### *Macoma* aff. *M. indentata indentata* Carpenter, 1864
Plate 3, figure 1

A single specimen from CAS locality 54135 is identified as *Macoma* aff. *M. indentata s.s.* based on its size, shape and bent posterior end. However, the Bloomfield Quarry specimen is shorter, higher, and the posterior dorsal margin is inclined more than the nominal species. In addition, two specimens from the same collection are referred to indeterminate *Macoma* (plate 3, figs. 2, 3) lacking distinguishing features or shape because of poor preservation.

### *Tellina*? sp. indeterminate

Several large elongate tellinids are provisionally identified as *Tellina*? based on their size and shape alone as the lateral hinge teeth are not visible. They somewhat resemble *Tellina emacerata* Conrad (1849) in shell outline but not exactly and were broken through the umbo during preservation making precise identification impossible.

### Family Myidae Lamarck, 1809
### *Cryptomya californica* (Conrad, 1837)

Abundant *Cryptomya californica* are in collections from CAS localities 54135 and 54136 as internal molds and fewer specimens with shells of one or both valves still preserved. *Cryptomya californica* [synonyms *C. ovalis* Conrad (1857) and *C. quadrata* Arnold (1909 [1910])] commonly lives in sand and sandy mud from the intertidal zone to 80 m (Foster, 1991) along the open coast from Montagu Island, Alaska south to Bayovar, Peru, in the eastern Pacific (Coan and others, 2000). This species is always associated with larger burrowing invertebrates including the shrimp *Callianassa* and *Upogebia* and the spoon worm *Urechis* (Annelida: Echiura) (Coan and others, 2000). Grant and Gale (1931) reported this species as a fossil from the Miocene to Pleistocene from western North America, citing occurrences from Washington south to Baja California Sur, Mexico. Based on the formations reported by Grant and Gale (1931), this species likely ranges from the "Margaritan" CPMS to Holocene. The "Margaritan" CPMS occurrence was confirmed by Powell (2007).

### Family Teredinidae Rafinesque, 1815
### *Teredo*(?) sp. indeterminate

A single specimen from CAS locality 54135 resembles *Teredo* bored wood. No shell is present so further identification is impossible.

### Family Hiatellidae Gray, 1824
### *Panopea* sp. indeterminate

A single valve and fragment of a second valve from CAS locality 54135 are assigned to indeterminate *Panopea* based on their size shape and comarginal sculpture. Recently, Vadopaias and others (2010) separated the two species synonymized by Moore (1963 [1964]), giving distinguishing characters for each. They referred fossil specimens mostly to *P. abrupta* (Conrad, 1849) and modern specimens to *P. generosa* Gould (1850). *Panopea* resembling these two species are common in the Neogene of California from the early Miocene (Addicott, 1976a), possibly middle Oligocene (Hickman, 1969), to Holocene and no attempt has been made here or elsewhere to differentiate these two species in the fossil record. It is assumed that *P. generosa* is not restricted to the Holocene, but its stratigraphic range remains unknown.

### *Tresus pajaroanus* (Conrad, 1857)
Plate 3, figures 5, 7

Abundant internal molds of *Tresus pajaroanus* (Conrad, 1857), some with original shell, occur at CAS localities 54135 and 54136. Some of the specimens are crushed or partially crushed but almost all are articulated and show the distinctive outline of this species allowing identification to species. Interestingly, most of the specimens are small for this species and are rarely in excess of 100 mm maximum length. *Tresus pajaroanus* occurs from Washington to southern California in rocks of late Miocene age, judging by its occurrences in Grant and Gale (1931), to middle Pleistocene (Powell, 1998).

### Family Solenidae Lamarck, 1809
### *Solen sp.* indeterminate

Six incomplete valves resembling the genus Solen are present from CAS locality 54135. Unfortunately, they are not well enough preserved to assign to species.

### Family Pharidae H. Adams and A. Adams, 1856
### *Ensis sp.* indeterminate
Plate 3, figure 4

A few bivalve cast fragments from CAS locality 54135 have an internal buttress that appears to run from the dorsal to ventral surface. These specimens are identified as an indeterminate species of *Ensis*.

### Class Gastropoda Cuvier, 1795
### Family Trochidae Rafinesque, 1815
### Trochidae indeterminate

A single internal mold from CAS locality 54136 consisting of the ultimate and most of the penultimate whorl is identified as an indeterminate Trochidae.

### Family Fissurellidae Fleming, 1822
### Fissurellidae indeterminate

Two incomplete specimens from CAS locality 54135 are assigned to the indeterminate Fissurellidae on the basis of the shell form. The distinction between the genera *Diodora* and *Fissurella* is based on the callus inside the apex, which is squared posteriorly in *Diodora*. This feature cannot be observed in the Bloomfield specimens so both genera are discussed here. The larger specimen is incomplete, about 29.6 mm wide and 35.2 mm high, showing fine, low, thread-like straight primary radial ribs with three very low rounded secondary radial ribs, whereas the smaller is 19.0 mm high and 15.7 mm wide and shows primary radial ribs crossed by secondary circular ribs and three tertiary radial ribs between the primary ribs.

Neogene *Fissurella* and *Diodora* are unusual as fossils in California with only eight species reported—*Diodora arnoldi* McLean (1966) [as *Fissuridae murina* Carpenter, ms., *fide* Arnold, 1907)], *Diodora aspera* (Rathke, 1833), *Diodora cayenensis* (Lamarck, 1822), *Diodora* (*Diodora*) n. sp. of Addicott (1970), *Diodora*? n. sp. of Addicott (1970), *Diodora subelliptica* (Nomland, 1916), *Diodora unica* (Nomland, 1917), and *Fissurella rixfordi* Hertlein (1928). Arnold (1907) reported *Diodora arnoldi* (as *Fissuridae murina*) from the Repetto Formation in Los Angeles; however, Woodring (1938) rejected it as a doubtful Repetto fossil. *Diodora aspera*, reported from the Pliocene to Holocene, is easily identified by its larger, higher shell and different sculpture with primary, tertiary, and secondary radial ribs. The Atlantic *Diodora cayenensis* (Lamarck, 1822) is reported from the late Miocene “Imperial” Formation in south-central California (Schremp, 1981). It is easily distinguished from the present specimens by its sculpture. The early Miocene *Diodora* (*D.*) n. sp. of Addicott (1970) is easily distinguished by having abundant equally spaced, fine radial ribs as in *Fissurella rixfordi* Hertlein, 1928. *Diodora*? n. sp. of Addicott (1970) (lower Miocene) is remarkably similar to the Bloomfield Quarry specimen although less than half the length. It also differs in only having a single secondary riblet between the primary radial ribs. *Diodora subelliptica* Nomland reported from the Jacalitos Formation and *D. unica* (Nomland) from the upper Etchegoin Formation (Nomland, 1917) both differ having a higher apex and numerous, generally uniform, radial ribs with narrow interspaces. In addition, there is a single poorly preserved fissurellid limpet from the middle Miocene Topanga Formation in Los Angeles County (LACM invertebrate paleontology collections) that is easily distinguished in lacking the circular ribs. These specimens likely represent a new species but they are not described until more complete specimens can be obtained.

### Family Neritidae Rafinesque, 1815
### Neritidae indeterminate

A single partially crushed, internal mold from CAS locality 54135 is identified as an indeterminate Neritidae similar to *Nerita* based on its shape and a few patches of spiral sculpture that are preserved on the specimen. These spiral ribs consist of a larger broad, flat-topped rib that in some cases appears medially sulcate separated by a rib about half the width of the larger ribs and separated from one another by a shallow trough about the width of the smaller ribs. The only *Nerita* reported from the Neogene of coastal California is *N. joaquinensis* Addicott (1970) from the middle Miocene Round Mountain Silt in Kern County, California (Addicott, 1970; Vermeij and others, 2009). Other Neritidae genera occur in the Late Cretaceous and Paleogene of California and Baja California, Mexico (Woods and Saul, 1986; Squires, 1992; Squires, 1993; Squires and Saul, 1993; questionably by Squires and Goedert, 1996; Squires and Saul, 2002), but they are not similar to the single incomplete Bloomfield Quarry specimen.

### Family Calyptraeidae Lamarck, 1809

California Neogene Calyptraeidae are divided into two genera *Calyptraea* and *Trochita*, which are in need of revision. After a review of the literature and some museum specimens, they can be divided into six basic groups. The two genera that have similar shells were originally divided with *Calyptraea* having no or fine radial sculpture, whereas *Trochita* has medium to coarse sculpture. Because radial sculpture is variable within a species, the genera are divided as follows here—(1) species that are smooth and lack radial sculpture are identified as *Calyptraea*, whereas (2) species with radial sculpture are referred to the genus *Trochita*. The genus *Trochita* (as here defined) includes nine species in the Neogene of California—*T. coreyi* Addicott (1970), *T. costellata* (Conrad, 1857), *T. costella panzana* (Loel and Corey, 1932), *T. diabloensis* Clark (1915), *T. diegoana* (Conrad, 1855), *T. inornata* (Gabb, 1869), *T. martini* Clark (1915), *T. radians* (Lamarck, 1815) of authors, not of Lamarck, 1815, and *T. spirata* (Forbes, 1852). These *Trochita* are further divided into five groups.

*Trochita* group 1 consists of *Trochita coreyi* and *T. filosa* (Gabb, 1869) that are easily distinguished from other members of the genus in California by their fine, numerous radial ribs. They can be distinguished from one another in that *T. coreyi* is generally higher than wide with shouldered whorl profile, whereas *T. filosa* is generally wider than high with a smooth profile. In addition, *T. coreyi* is generally larger than *T. filosa*. Trochita group 1 species would previously have been attributed to *Calyptraea*.

Woodring (1957), following Grant and Gale (1931), suggested that all heavy-ribbed Miocene forms be synonymized under *T. trochiformis* Born (1778). However, there are differences among several of the California fossil taxa that will be outlined below and that allow for further differentiation. From photographs in the literature four coarser ribbed *Trochita* forms are recognized here in California. *Trochita* group 2 are small specimens (<20 mm diameter), generally wider than high, with smooth whorl profiles, and slightly curved radial sculpture narrower than the interspaces (Arnold, 1908; English, 1914; Moody, 1916; Woodring and Bramlette, 1950, plate 13, fig. 19; Zinsmeister, 1970; *T. radians* of authors), which appears to be restricted to the Pliocene. *Trochita* group 3 are larger specimens (>20 mm diameter) that resemble modern specimens of *T. spirata* and (or) *T. trochiformis* and are generally wider than high, with slightly oblique radial ribs that are wider than the interspaces, and with a smooth to slightly shouldered whorl profile (Clark, 1915, plate 70m, fig. 8, *Calyptraea martini*; Loel and Corey, 1932, plate 63, fig. 11, *C. costellata*). This group is restricted to the Miocene. *Trochita* group 4 are larger specimens, with a generally smooth whorl profile and broad flat-topped spiral ribs and narrow sharp interspaces (Clark, 1915, plate 70, fig. 9, *T. diabloensis*), also restricted to the Miocene. Lastly is *Trochita* group 5 that consists of *T. costellata panzana* (Loel and Corey 1932, plate 63, fig. 10), which is much higher than wide with a strongly shouldered profile. This species appears to be restricted to its type locality and could be a local ecological variant.

Specimens from group 2 in California are referred to an undescribed *Trochita*. Several authors refer these specimens to *Trochita radians*; however, *T. radians* is a Caribbean and northern South American species that ranges in age from the Miocene to Pleistocene (Fossilworks, 2011) and is not found along the west coast of North America. Specimens referred to this species by west coast authors (Martin, 1916; Clark, 1918; Woodring and Bramlette, 1950) are in error. They were referred to *T. trochiformis* by Grant and Gale (1931) and Woodring (1957), but the authors do not agree with this synonymy and considers this taxon to be undescribed.

Group 3 includes the modern *T. spirata* and *T. trochiformis*, which Keen (1971) separates based on size, color, sculpture, and distribution, but as fossils they are indistinguishable. *Trochita spirata* has a modern range from Mazatlán, Mexico, south to the Gulf of Tehuantepec, Mexico, and *T. trochiformis* occurs from Manta, Ecuador, south to Valparaiso, Chile. Fossil specimens are often poorly preserved and are not referable to either species with any degree of confidence. Also, the name *T. trochiformis* has been used for Neogene fossils in southern and central California by Grant and Gale (1931) and followed by later authors, although this does not make sense biogeographically as *T. trochiformis* occurs further from southern California than does *T. spirata*. The California Neogene specimens need a new name but that must await further research.

### *Trochita* cf. *T. diabloensis* (Clark, 1915)
Plate 3, figure 11

About 20 incomplete specimens and latex casts from CAS locality 54315, and a few from CAS locality 54316, are identified as *Trochita* cf. *T. diabloensis*. The best-preserved specimen is about 7 cm in diameter and ornamented by broadly round, straight, radial ribs, with narrow interspaces. In addition, many specimens show moderately thick rounded radial ribs more prominent in the lower part of the shell and separated by a narrow, broadly rounded interspace. The ribs are curved toward the leading margin of the shell. The umbo appears significantly eccentric. *Trochita diabloensis* has been only been reported previously from the lower San Pablo Group around Mount Diablo in Contra Costa County (Clark 1915), which is likely referable to the "Margaritan" CPMS. Better preserved specimens may show these specimens to be a new species.

### *Crepidula princeps* Conrad, 1855
Plate 3, figure 8

Abundant internal molds from CAS locality 53135 and a single fragment with some original shell near the umbonal region from CAS locality 53136 are identified as *Crepidula princeps* based on its size and shape. *Crepidula princeps* ranges from Alaska to Baja California, Mexico, in rocks from Miocene to middle Pleistocene (Grant and Gale, 1931; Powell and others, 2010). The youngest occurrence is well dated, but early occurrences of *C. princeps* are poorly dated because this species is easily confused with *C. praerupta* (Conrad, 1849) and can only be distinguished when the internal shelf is exposed. Addicott (1970) reports early Miocene occurrences from the Vaqueros Formation in the Santa Cruz Mountains citing Arnold (1908) and from the Caliente Range citing oral communication (1963) with Jack G. Vedder. He also reports it from the Jewett Sand in the Kern River area also citing an early Miocene age. Recently (Hosford Scheirer and Magoon, 2007) cite the age of the Jewett Sand as 25 to 21 Ma or late Oligocene to early Miocene. Therefore, an early Miocene to middle Pleistocene age range for *C. princeps* seems reasonable.

### *Crepidula sp*. indeterminate

Ten small internal molds from CAS locality 54136 are referred to indeterminate *Crepidula*. They could represent immature *C. princeps* or another species, but their preservation does not allow for identification beyond the genus level.

### Family Naticidae Guilding, 1834
Naticidae, indeterminate

Eight internal molds from CAS locality 54136 are identified as indeterminate Naticidae based on their size and shape. In addition, numerous specimens from CAS locality 54135 and two minute specimens with original shells are similarly identified. A more detailed determination is fruitless as the specimens lack distinguishing features.

### Family Nassariidae Iredale, 1916
*Desmondia* sp. indeterminate

Most specimens from Bloomfield Quarry are too poorly preserved for precise identification and are here referred to an indeterminate Nassariidae. However, a few better-preserved specimens are discussed below. Specifically, two small internal molds and one incomplete specimen from CAS locality 54135 resemble the genus *Desmondia* based on their shape and strong radial sculpture but the whorls are more stepped than *D. perpinguis* (Hinds, 1844 [1845]) and are identified as indeterminate *Desmondia* sp.

### *Caesia* cf. *C. grammatus* Dall, 1917

One crushed and incomplete specimen and a partial cast from CAS locality 54135 strongly resembles small *Caesia grammatus* and are provisionally identified (cf.) as that species based on their shape and strong concentric sculpture. According to Addicott (1965) *Caesia grammatus* is restricted to Pliocene age deposits (see also Powell and others, 2010, p. 23). The occurrence of this species in the late Miocene would represent a chronostratigraphic range extension, however the provisional identification prevents the extension.

### Family Muricidae Rafinesque, 1815
*Ocinebrina*? sp. indeterminate

Three small shell fragments from CAS locality 54135 show coarse, radial sculpture on what appears to be a fusiform shell. The radial sculpture and shell form resembles that seen on the genus *Ocinebrina* in the eastern Pacific. These specimens are not complete enough to identify properly and are here assigned questionably to the genus *Ocinebrina*.

### *Nucella* n. sp. aff. *N. etchegoinensis* (Arnold, 1909 [1910])
Plate 3, figures 9, 10

Abundant entire whole and partial specimens of small juveniles to larger adult shells previously attributed to *Nucella* n. sp.? aff. *N. lamellosa* (Gmelin, 1791) (Powell and others, 2004) are present from CAS locality 54135, and six immature specimens are present from CAS locality 54136. These specimens are here referred to N. n. sp., aff. *N. etchegoinensis* and are being described separately by the senior author and Barry Roth. The best preserved of these specimens resemble *N. etchegoinensis*, ribbed variety, illustrated by Woodring and others (1940, plate 36, figs. 1, 7), but have a maximum height (37 mm), at best only about half the height of Woodring's illustrated species (plate 36, figs. 1, 7; 73 and 83 mm, respectively). In addition, the Bloomfield Quarry specimens have three to five subdued denticles along the inside of the outer lip, along with a broadly flattened and flaring outer lip. These features are not present in *N. etchegoinensis* and only the first is very rarely observed in *N. lamellosa* which are more pronounced in the Bloomfield Quarry specimens than in any form of *N. lamellosa* observed.

Grant and Gale (1931) synonymized *N. etchegoinensis* under *N. lamellosa*, because the latter species shows remarkably modern variability (see Kincade, 1957); however, none of the specimens illustrated by Kincade (1957) or in any other publication illustrates modern *Nucella* that compare favorably with *N. etchegoinensis* or the Bloomfield Quarry specimens. *Nucella* appears to be over-synonymized in the California Tertiary. In particular *N. etchegoinensis* and the Bloomfield Quarry species have no modern equivalent. *Nucella etchegoinensis* has been reported previously from the Etchegoin-San Joaquin Formations (Arnold, 1909; Pack and English, 1914; Woodring and others 1940) and Pancho Rico Formation (Durham and Addicott, 1965) in central California and the Empire Formation (restricted) at Cape Blanco, Oregon (Addicott, 1980, 1983), indicating a possible late Miocene ("Jacalitos" CPMS) to Pliocene ("San Joaquin" CPMS) age range. *Nucella lamellosa* excluding *N. etchegoinensis* has been reported from late Miocene to Pliocene Purisima Formation (Arnold, 1908; Martin, 1916; Allen, 1945; Glen, 1959; Touring, 1959; Cummings and others, 1962; Perry, 1993), Pliocene Foxen Mudstone, both members of the Careaga Sandstone (Woodring and others, 1943; Woodring and Bramlette, 1950), "Santa Margarita Sandstone" (Clark, 1981) [although this unit is considered late Miocene elsewhere, mollusks reported from the collection containing *N. lamellosa* in Clark (1981) also contain *Patinopecten healeyi* (Arnold, 1909), which is restricted to the Pliocene], middle Pliocene to early Pleistocene San Diego Formation (Vendrasco and others, 2012), and coastal Pleistocene terraces and basin deposits (Arnold, 1903; Woodring and others, 1946; Valentine, 1958; Campbell and Valentine, 1979; Valentine, 1980) in California. These occurrences suggest an age range of possibly late Miocene ("Jacalitos" or "Etchegoin" CPMS) to Holocene. The older late Miocene age may be supported by Addicott (1976b), who reported the lowest stratigraphic occurrence of *N. lamellosa* in the Wishkahan Pacific Northwest provincial molluscan stage (PNPMS; late Miocene); however, the Wishkahan PNPMS may be of limited stratigraphic use (Armentrout, 1981; Prothero and others, 2001). California Tertiary *Nucella* are in need of review, but that is beyond the scope of this paper.

*Nucella* sp. indeterminate

A number of immature, poorly preserved *Nucella* from CAS locality 54135 are not identifiable to species.

Family Buccinidae Rafinesque, 1815
*Lirabuccinum portolaensis* (Arnold, 1908)?

Abundant poorly preserved and commonly crushed specimens of a moderate sized neogastropod are questionably attributed to *Lirabuccinum portolaensis* (Arnold, 1908) based on their size, shape, and spiral sculpture. From occurrences reported in the literature (Arnold, 1908; Martin, 1916; Allen, 1945, Adegoke, 1969; Addicott and others, 1978; Perry, 1993), Powell (1998) suggested a late Miocene to late Pliocene stratigraphic range for *L. portolaensis*, although Powell and others (2004) further suggested that most, if not all, of its occurrences appear to be restricted to the Pliocene part of their respective formations. The Bloomfield Quarry deposits are definitely late Miocene but the specimens examined do not allow for a confident identification, so the Powell and others (2004) hypothesis is neither confirmed nor refuted.

## Arthropods

Phylum Arthropoda Latreille, 1829
Class Maxillopoda Dahl, 1956 (Barnacles)
Family Balanidae Leach, 1817

Barnacles from Bloomfield Quarry were described and discussed in detail by Zullo and Guruswami-Naidu (1982) and no new information is provided here. They recognized five species of which *Balanus irradians* and *Notomegabalanus*? *insperatus* were described as new. Also identified are *B.* aff. *B. nubilus* Darwin (1854*)*, *B*. cf. *B. irradians* Zullo and Guruswami-Naidu (1982), and an indeterminate *Balanus*.

Class Malacostraca Latreille, 1802
Family Callianassidae Dana, 1852
*Callianassa*? sp. indeterminate

A single cheliped, questionably (?) assigned to the genus *Callianassa* based on its size and shape, is present from CAS locality 54135. *Callianassa* are common intertidal and subtidal burrowers along the California coast. They have a fossil record in the western Pacific going back to at least the Late Cretaceous (Vega and others, 1995; Hyzny and others, 2013).

*Cancer* sp. indeterminate

The genus *Cancer* is well represented in the fossil record of California (Nations, 1975) from the late Miocene to Pleistocene and it is still common today off the California coast. The specimens identified here are indeterminate chelipeds provisionally referred to genus.

## Vertebrates

Phylum Chordata Bateson, 1885

## Fishes by Douglas J. Long

Class Chondrichthyes Huxley, 1880
Superorder Galeomorphii Compagno, 1973
Order Hexanchiformes Compagno, 1973
Family Hexanchidae Gray, 1851
Genus *Hexanchus* Rafinesque, 1810
*Hexanchus griseus* (Bonnaterre, 1788)
Plate 4, figures 1, 2

**Referred Specimens—**Specimens referred to this species include UCMP 125599, a complete upper anterior tooth;

UCMP 125600, a complete lower right lateral tooth; UCMP 125601, an isolated anterior cusp broken from an upper tooth; and UCMP 125602, an isolated anterior cusp broken from a lower lateral tooth.

**Remarks**—The extant sixgill shark *Hexanchus griseus*, and its Neogene synonym *H. gigas*, is known from the Miocene through late Pleistocene of western North America, as well as additional localities scattered worldwide (Welton, 1979; Long, 1993a, 1994; Cappetta, 2012). It currently has a worldwide distribution around oceanic islands and along continental shelves and slopes from the tropics to subpolar zones, including western North America, but most common in water below 200 m; in cool-temperate areas this species can be found nearshore and in water shallower than 60 m and often have both diel and seasonal migrations between deep and shallow water (Andrews and others, 2009; Ebert and Compagno, 2013).

Order Lamnifornes Berg, 1958
Family Lamnidae Müller and Henle, 1838
Genus *Isurus Rafinesque*, 1810
*Isurus oxyrinchus* Rafinesque, 1810
Plate 4, figure 3

**Referred Specimens**—UCMP 125605, a complete lateral tooth clearly identifiable as the extant mako shark *Isurus oxyrinchus*.

**Remarks**—This species occurs in late Miocene to late Pleistocene localities in the western United States and Mexico, as well as in various localities throughout eastern North America, South America, Europe, and Asia but may also occur earlier in the Miocene, although there is confusion among a number of various Paleogene and Neogene species that may not all be valid (Boessenecker, 2011; Fitch, 1964, 1967, 1968; Long, 1993a, 1994; Cappetta, 2012). Currently, *I. oxyrinchus* is also found worldwide from tropical to cool-temperate waters, including coastal areas above the continental shelf, and into pelagic areas over deep ocean basins; in California it is more common in warmer areas south of Point Conception, Santa Barbara County, but will move seasonally north as southern waters warm and extend northward (Compagno, 2001; Ebert, 2003).

Family Cetorhinidae Gill, 1862
*Cetorhinus maximus* (Gunnerus, 1765)

**Referred Specimens**—Broken and incomplete gill rakers, UCMP 125603; and UCMP125604; which contain the articulating base of the raker that is used to identify the species as the extant *Cetorhinus maximus* (Welton, 2013a,b, 2015).

**Remarks**—This species is known from the late Miocene through the Pleistocene of the West Coast of the United States and has been found in late Miocene to late Pleistocene localities worldwide including eastern North America, Europe, South America, and Japan (Boessenecker, 2011; Cappetta, 2012; Long, 1993a,b, 1994; Welton, 2013a,b). Basking sharks are filter feeders that live along subpolar to warm-temperate coasts above the continental shelf where it feeds on zooplankton and can sometimes be found very close to the shore, often occurring just beyond the surf zone and into enclosed bays (Ebert, 2003). Along the west coast of North America, this species is found from Alaska south to the Baja Peninsula and the Gulf of California, Mexico (Baldwin, 1961; Sandoval-Castillo and others 2008), with an apparent absence in the equatorial tropics and subtropics, and then ranges in the southern hemisphere from Ecuador to southern Chile (Hernández and others, 2010).

Superorder Batoidea Compagno, 1973
Order Myliobatiformes Compagno, 1973
Family Myliobatidae Bonaparte, 1838
Genus *Myliobatis* Cuvier, 1816
*Myliobatis californica* Gill, 1865

**Referred Specimens**—UCMP 125606, UCMP 128199, UCMP 128200, UCMP 128201, each a single medial tooth plate; UCMP 128202, UCMP 128203, UCMP128204, UCMP 128205, each a lateral tooth plate.

**Remarks**—These tooth plates are identifiable to the extant bat stingray *Myliobatis californica*, an epibenthic coastal species of stingray that ranges from the coast of Oregon south through the Gulf of California, Mexico, inhabiting bays, estuaries, and coastal areas above 50 m depth (Ebert, 2003). The fossil record of this species on the west coast of North America ranges from the late Pleistocene (Fitch, 1964, 1967, 1970; Long 1993b), the late Pliocene (Fitch and Reimer, 1967) and into the late Miocene (D.J. Long, unpublished data), so these specimens are well within the paleochronological range of the species.

Class Osteichthyes Huxley, 1880
Subclass Actinopterygii Klein, 1885
Subdivision Teleostei Müller, 1846
Order Salmoniformes Bleeker, 1859
Genus *Oncorhynchus* Suckley, 1861
*Oncorhynchus* sp. indeterminate

**Referred Specimens**—UCMP 125609, a fragmented thoracic vertebra showing the fine bony lattice-like organization around the external radial edge of the vertebra seen in the modern salmonid genus *Oncorhynchus*.

**Remarks**—This fragmented vertebra, although it may not be identifiable to any particular salmon species, is important in being a relatively early record of *Oncorhynchus* in West Coast marine localities. Other than the large salmon *Oncorhynchus rostratus*, which is relatively abundant in late Miocene and early Pliocene deposits (Sankey and others, 2016), fossil salmonids are surprisingly uncommon in late Cenozoic marine deposits of the Western United States. By the late Miocene-early Pliocene, the different extant species of Pacific salmon had already evolved (Smith, 1992; Stearley, 1992; Montgomery, 2000). However, only one late Pleistocene salmon, *Oncorhynchus tshawytscha*, has been collected from a late Pleistocene marine locality in the northern California Crannell Junction site near Arcata (Fitch, 1970).

### Superorder Clupeomorpha Greenwood and others, 1966
### Order Clupeiformes Bleeker, 1859
### Family Clupeidae Cuvier, 1817
### Genus *Sardinops* Hubbs, 1929
### *Sardinops* sp. indeterminate

**Referred Specimens**—UCMP 125622 and UCMP125623, both single isolated thoracic vertebrae.

**Remarks**—*Sardinops* has several species in the eastern Pacific, including the extant *Sardinops caeruleus* found along the west coast of North America (Whitehead, 1985) and is also known from the late Pleistocene of California (Long, 1993b). Fitch (1970) found no *Sardinops otoliths* in any early Pleistocene or late Pliocene deposits in California, but these fish shed scales throughout their lifetime that can accumulate in abundance in marine sediments (Baumgartner and others, 1992). Grant and Bowen (1998) show that *Sardinops*, as a world-wide genus, has been in existence for at least 20 million years, and although other clupeoid fishes are well known from Miocene deposits in California (Fierstine and others, 2012), none have been assigned to *Sardinops*. These fossils appear to be the earliest record of *Sardinops* in the late Neogene of the west coast of the North America; however, due to the fragmentary nature of these specimens, and to the lack of comparative material from any other late Miocene and Pliocene species, the identification herein remains only as *Sardinops* sp.

### Superorder Paracanthopterygii Greenwood and others, 1966
### Order Gadiformes Goodrich, 1909
### Family Merlucciidae Gill, 1884
### Genus *Merluccius* Rafinesque, 1810
### *Merluccius* sp. indeterminate

**Referred Specimens**—UCMP 125638, several damaged isolated vertebrae; UCMP 287609 and UCMP 287610, each a slightly damaged thoracic vertebrae embedded in a sandstone block; all specimens identifiable as the hake *Merluccius*.

**Remarks**—The extant *Merluccius productus* is known from the late Pleistocene into the late Pliocene from numerous localities on the west coast of North America, (Fitch and Reimer, 1967; Fitch, 1969; Fitch and Lavenberg, 1971; Long, 1993b; Welton, 2015). Although the genus *Merluccius* is known from fossils dating back to the Oligocene in Europe and central Asia, and genetic divergence scenarios also support this time frame (Campbell, 1929; Roldan and others, 1999; Quinteiro and others, 2000), no pre-Pliocene fossils of *Merluccius* are yet conclusively identified from western North America, so these specimens may be the earliest record for the genus in this region. A somewhat enigmatic early Pliocene species *Promerluccius venturaensis* David (1956) is known from a single scale (Fierstine and others, 2012), so there cannot be any equitable taxonomic comparisons between our fossil *Merluccius* vertebrae and *M. venturaensis*. Until more complete and more extensive osteological material can be collected from this site and critically examined, these specimens will only be referred to as *Merluccius* sp. The extant *Merluccius productus* is usually a shoaling species in deeper waters (45–1,000 m) of the Continental Shelf from southern Baja California north to Alaska, but they are sometimes known to move into nearshore and occasionally even estuarine waters (Cohen and others, 1990).

### Superorder Acanthopterygii Greenwood and others, 1966
### Order Scorpaeniformes Greenwood and others, 1966
### Family Sebastidae Kaup, 1873
### Genus *Sebastes* Cuvier, 1829
### *Sebastes* sp. indeterminate

**Referred Specimens**—UCMP 125632, UCMP 125633, UCMP 125634, UCMP 125635, UCMP125636, and UCMP 125637, each a single isolated vertebra.

**Remarks**—These specimens are from the genus *Sebastes*, a diverse, common and widespread genus of scorpionfishes along the western coast of North America consisting of more than 60 species (Love and others, 2002). Although different living species can be distinguished by their skull morphology (Miller and Lea, 1972) and otoliths (Lowry, 2011), there is very little consistent variation in the vertebrae between species to make a confident identification to anything more than the generic level.

The genus *Sebastes* dates back to at least the late Miocene, being represented by several ancestral taxa (see review in Fierstine and others, 2012), and species diversity in *Sebastes* is high by the Pleistocene, with many extant species represented (Fitch 1964; 1967, 1970; Fitch and Lavenberg, 1971; Long, 1993b; Welton, 2015).

### Order Perciformes Bleeker, 1859
### Family Polyprionidae Oken, 1817
### Genus *Stereolepis* Ayres, 1859
### *Stereolepis* sp. indeterminate
### Plate 4, figure 4

**Referred Specimens**—UCMP 125612, incomplete anterior vertebra; UCMP 125613, broken but mostly complete caudal vertebra.

**Remarks**—These two specimens represent the largest of the teleost fossils recorded from the Wilson Grove Formation, and are attributable to the wreckfish genus *Stereolepis*; however, these vertebrae are not necessarily diagnostic for the present-day species. The extant Black Sea Bass, *Stereolepis gigas*, has not yet been recorded from the fossil record in California (Fitch and Lavenberg, 1971; Fierstine and others 2012), although the large, dense bones should promote both preservation and discovery. Based on genetic phylogenies, the genus *Stereolepis* is thought to have originated in the Miocene (Near and others, 2013), and further genetic data shows the extant species was present in the waters of California and western Mexico since the late Pleistocene (Gaffney and others, 2007). These bones indicate that the genus was present in California since the late Miocene. *Stereolepis gigas* is a characteristic top-level predator in shallow coastal kelp forests from central California through to the Gulf of California, Mexico (House and others, 2016).

### Family Embiotocidae Agassiz, 1853
### Embiotocidae indeterminate

**Referred Specimens**—UCMP 125617, lower lateral pharyngeal plate missing teeth; UCMP 125618, upper medial pharyngeal plate missing teeth.

**Remarks**—These two pharyngeal plates are of the same general morphology seen in the extant surfperches, but in comparison to all recent genera from the western coast of North America, they show minor differences and cannot be positively identifiable to any one genus and are considered Embiotocidae indeterminate. However, one specimen (UCMP 125618), a lower pharyngeal plate missing the teeth most resembles the extant genus *Damalichthys*, and another (UCMP 125618) an upper pharyngeal plate missing the teeth, is similar to the extant genus *Embiotoca*. Both of these fossils are incomplete, and it could be that some key osteological characters may have been lost from post-depositional erosion. Fitch (1969) had difficulty identifying surfperches based on their skeletal remains and left most identified as "embiotocids," although several extant taxa including *Embiotoca* and *Damalichthys* have been identified from their otoliths in late Pliocene and Pleistocene deposits (Fitch and Lavenberg, 1971, 1975; Fierstine and others 2012). Genetic data from Bernardi and Bucciarelli (1999) and Near and others (2013) suggest that surfperches rapidly radiated into many genera at the end of the Miocene and in the early Pliocene, so the fossils above would indicate representative ancestral forms rather than extant species. The Embiotocidae are abundant shallow-water fishes of kelp beds, seagrass meadows, and rocky intertidal habitats along the coasts and in the estuaries of western North America (Allen and Pondella, 2006).

### Family Scombridae Cuvier, 1817
### Genus *Sarda* Cuvier, 1829
### *Sarda* sp. indeterminate

**Referred Specimens**—UCMP 125615, a single isolated vertebra, and locality UCMP 287611, a relatively complete vertebrae embedded in a block of sandstone; both specimens are attributable to the bonito *Sarda*.

**Remarks—**The extant *Sarda chiliensis* ranges in coastal and epipelagic offshore waters from southern Baja California well into southern Alaska but is more common in its northern range in warm-water years (Collette and Nauen, 1983). Although genetic and biogeographic evidence suggests this species has been present along the west coast of North America in the late Neogene (Vinas and others, 2010), it has no Pleistocene record, but *Sarda*, either as *Sarda* sp. or as the extinct *S. stockii*, is known from the middle to late Miocene in California (Fierstine and others, 2012). These specimens, although representing an important late Neogene record for the genus, are not associated with enough additional skeletal material to make a comparison between the extant *S. chiliensis* (Cuvier, 1832 [see Cuvier and Valenciennes, 1828–1849]) or the fossil *S. stockii* David (1943).

### Order Pleuronectiformes
### Family Paralichthyidae Regan, 1910
### Genus *Paralichthys* Girard, 1858
### *Paralichthys* sp. indeterminate

**Referred Specimens**—UCMP 125614, a partially complete vertebrae missing haemel and neural spines.

**Remarks**—This large vertebra shows characteristics consistent with the large halibut *Paralichthys*. The extant California halibut *P. californicus* is known from the Pleistocene (Fitch, 1970; Long, 1993b) and the late Pliocene (Fitch and Reimer, 1967). Vertebrae of a late Miocene specimen from the Purisima Formation was identified as *Paralichthys* sp. (Boessenecker, 2011), and otoliths from *Paralichthys* sp. have been recovered from an unnamed Miocene locality near Bakersfield (Fitch and Lavenberg, 1971); these material have not been compared to the extinct *Paralichthys antiquus* (Jordan, 1924) from middle to late Miocene Monterey Formation deposits in central California (Fierstein and others, 2012). Therefore, this isolated vertebra cannot be confidently identified to either the extant *P. californicus* or the extinct *P. antiquus* and will be left as *Paralichthys* sp.

Modern-day *P. californicus* is found along the west coast of North America from northern California down through the Pacific coast of Baja California, Mexico, in shallow estuaries and along soft sand and silt substrates above the continental shelf (Allen, 1990).

## Marine Mammals by Robert W. Boessenecker

### Class Mammalia Linnaeus, 1758
### Order Carnivora Bowdich, 1821
### Family Odobenidae Allen, 1880
### Odobenidae indeterminate
### Plate 5, figures 6–13

**Referred Specimens**—UCMP 125574, partial right innominate; UCMP 125576, left third metatarsal; UCMP 125579, distal phalanx fragment.

**Description—***Innominate*—UCMP 125575 includes the ischium and pubis, and the posterior part of the acetabulum, but is lacking the ilium (plate 5, figs. 12 and 13). The innominate is robust with a widely divergent ischium and pubis. Although incomplete, the obturator foramen is anteroposteriorly elongate and oval in shape. Near the posterior end of the preserved part of the ischium, the ischium is dorsally thickened where the broadly rounded dorsal spine of the ischium occurs. The pubis is straight and posteriorly directed. The part of the innominate adjacent to the acetabulum is robust and thickened; the acetabulum is deeply concave with a raised peripheral rim of bone.

*Metatarsal*—A single large and robust left metatarsal III is preserved (plate 5, figs. 8–11). The shaft is relatively long (113 mm total length). The proximal end is dorsoventrally expanded (39.9 mm greatest proximal width) and transversely compressed (21.86 mm least proximal width), and slight tubercles are developed at the proximal ventral and dorsal extremities. On the lateral surface of the proximal side, there are two oval to quadrate-shaped articular facets for the metatarsal IV, with a shallow concavity between. On the medial side there are two articular facets for the metatarsal II—a small facet dorsally and an elongate oval-shaped facet ventrally; again, a small concave surface extends between these facets. The ventral metatarsal II articulation facet is proximally continuous with the ectocuneiform facet, and forms a distinct convex tubercle in dorsal aspect. A plantar tuberosity occurs ventral to this facet. The shaft of the metatarsal III is circular in cross section. The distal end is slightly transversely wider than the shaft, and the trochlea is dorsoventrally convex. Ventrally, the trochlea exhibits a median ridge with two small fossae on either side, and small tubercles occur along the lateral and medial sides at the position of the distal trochlea.

*Phalanx*—A single distal fragment of a large phalanx is preserved (plate 5, figs. 6 and 7). The shaft appears to have been relatively wide, and the distal end is rectangular with a flat (not saddle-shaped) distal trochlea.

**Remarks**—These specimens can be differentiated from the contemporary otariid *Thalassoleon* in their larger size and more robust morphology, and are referred to the Odobenidae. However, they cannot be identified below the level of Odobenidae, either because they are elements that are not diagnostic at the subfamilial level (metatarsal) or because they are too incomplete (innominate) for detailed comparisons. The innominate can be compared with *Dusignathus seftoni* Deméré (1994b) (SDNHM 77891), cf. *Pontolis magnus* (USNM 335571), *Valenictus chulavistensis* Deméré (1994b) (SDNHM 83719), and *Odobenus rosmarus* (Linnaeus, 1758). UCMP 125575 differs from *Odobenus* in lacking small dorsal and ventrally projecting spines at the anterior end of the obturator foramen, and is generally less robust than innominata of *Odobenus* and *Valenictus*. It further differs from *Valenictus* in not being pachyosteosclerotic, not having a slit-shaped obturator foramen, lacking a posteriorly expanding pubis, and lacking a tubercle along the ventral margin just anterior to the pubis. This specimen compares reasonably well with *Dusignathus seftoni*, but has a slightly more robust ischium. UCMP 125572 is nearly identical to the innominate of cf. *Pontolis magnus* (True, 1905) (USNM 335571), although it is much smaller in size. It is not possible to make comparisons with *Gomphotaria*, as the innominata of *Gomphotaria* are unknown. The metatarsal is tentatively referred to the Dusignathinae based on its longer and slenderer shaft relative to the odobenines *Odobenus* and *Valenictus*; well-preserved metatarsals are not yet known for *Dusignathus* or *Gomphotaria*, and cf. *Pontolis magnus* (USNM 335571) preserves only metatarsal II, IV, and V. This specimen has a shorter shaft than the metatarsal III of the basal odobenid *Proneotherium* (Deméré and Berta, 2001), which also has a less robust proximal end than UCMP 125576. It further differs from *Valenictus* in lacking a distally thickening shaft, and lacking a sharp tuberosity at the distal end of the ventral metatarsal II facet. UCMP 125576 further differs from *Odobenus* in having a smooth proximal shaft that lacks a sharp ridge along the ventromedial and ventrolateral edges of the shaft. The wide and distally tapering distal end of UCMP 125579 is similar to phalanges of *Gomphotaria* and *Valenictus*.

### Genus *Imagotaria* Mitchell, 1968
### cf. *Imagotaria*
Plate 5, figures 1–3

**Referred Specimens**—UCMP 125572, isolated left radius.

**Description—***Radius*—This specimen is relatively small (184 mm total length), and has completely fused distal and proximal epiphyses (plate 5, figs. 1–3). The diaphysis of the radius is transversely flattened, and the proximal end is robust, transversely flared (54 mm greatest diameter), and anteriorly extended. The proximal humeral articular surface is sinuous and concave, and the head sits atop a transversely and anteroposteriorly narrow neck (37.4 mm least width). A small, convex radial tuberosity is located on the medial side of the neck. Along the anterior margin of the diaphysis, a slight ‘corner’ occurs midway at the pronator teres process. Distal to the pronator teres process, the radius is greatly expanded anteroposteriorly (70 mm greatest distal width). The medial surface of the diaphysis is slightly concave, and the lateral surface is gently convex. A well-developed flange-like radial process occurs on the anterodistal margin; distal to the radial process is a distally extending projection with a small convexity for the supinator longus, and a small trench between it and the radial process. The distal end bears a concave articular surface for the scapholunar; this facet is oval-shaped and smooth, and curves anterodistally. The styloid process occurs as a small arcuate ridge along the anterior margin of the scapholunar facet.

**Remarks—**The distally expanded and projecting radial process identifies this specimen as an odobenid radius (Deméré, 1994a). UCMP 125572 differs from radii of odobenine (for example, *Aivukus*, *Odobenus*, *Pliopedia*, *Valenictus*) walruses in its generally smaller size, more strongly anteriorly bowed shaft, and greater anteroposterior expansion of the distal half of the element. The robust proportions are similar with dusignathine radii, such as a referred forelimb of *Dusignathus santacruzensis* (LACM 3011, referred by Repenning and Tedford, 1977), an isolated radius of *Dusignathus seftoni* (SDNHM 92134), and the holotype radius of *Gomphotaria pugnax* Barnes and Raschke (1991) (LACM 121508); however, UCMP 125572 differs in being transversely narrow as opposed to the inflated radii of dusignathines (Mitchell, 1962; Repenning and Tedford, 1977; Barnes and Raschke, 1991), as well as being substantially smaller. A radius is unknown for *Pontolis* magnus, but would have certainly been much larger as *Pontolis* is even more gigantic than *Gomphotaria* (Deméré, 1994a). This specimen instead compares best with the radius of *Imagotaria downsi* (Repenning and Tedford, 1977, plates 11, 13) and *Titanotaria* *orangensis* (Magallanes and others, 2018, figs. 12d,e); these taxa share with UCMP 125572 a similarly expanded distal half but is relatively transversely narrow in comparison to dusignathines. However, because UCMP 125572 is somewhat smaller and even more transversely flattened than *Imagotaria downsi*, and far smaller than *Titanotaria orangensis*, this specimen is more conservatively identified as cf. *Imagotaria*.

*Imagotaria downsi* Mitchell (1968) has been previously reported from the late Miocene Monterey, Santa Margarita, and Sisquoc formations of California (10–7 Ma; Mitchell, 1968; Barnes, 1971; Barnes and others, 1985; Repenning and Tedford, 1977). Geochronologically younger but undescribed occurrences of *Imagotaria* include a new species from the upper Miocene Empire Formation of Oregon (8.7–6.5 Ma; Deméré, 1994a; Prothero and others, 2001) and several isolated postcanine teeth (UCMP 138156, 219435, and 219683) of cf. *Imagotaria* from the basal bonebed of the Purisima Formation near Santa Cruz, California (6.9–5.6 Ma; Boessenecker, 2013, appendix). This record of cf. *Imagotaria* further supports Messinian survival of the stem odobenid *Imagotaria*.

### Subfamily Dusignathinae Mitchell, 1968
### Genus *Dusignathus* Kellogg, 1927
### *Dusignathus santacruzensis* Kellogg, 1927
Plate 6, figures 1–5; plate 7, figures 1–3

**Referred Specimens**—UCMP 125571, fragment of right maxilla with c1; UCMP 125569, left mandible lacking teeth.

**Description—***Maxilla and Upper Dentition*—UCMP 125571 is a fragment of the right maxilla with the c1 preserved from a relatively small individual, possibly representing a neonate or juvenile (plate 6, figs. 1–6). The lateral side of the maxilla is relatively flat and smooth. On the posterodorsal margin, the anterior part of the infraorbital foramen is preserved as a small arc-shaped excavation. The medial and dorsal surfaces are broken, including the anterodorsal wall of the c1 alveolus. The c1 is preserved *in situ* within a cavernous alveolus, and the c1 does not contact the sides of the alveolus, similar to extant juvenile pinnipeds. The canine is circular in cross section, relatively straight and slightly curving, and there is a small enamel crown with a posterior crista. The c1 crown apex does not reach the ventral margin of the maxilla. The pulp cavity of the c1 is open and large (but filled with matrix) and encircled by a thin cylindrical wall of dentine. Empty circular p1 and p2 alveoli are present on the ventral margin; the maxilla is broken at the level of the partially preserved p3 alveolus. The p2 and p3 alveoli extended far dorsally and are exposed dorsomedially and medial to the c1. Premolar alveoli are all cylindrical, indicating that the p1–3 had robust, cylindrical roots.

*Mandible*—This relatively small mandible (UCMP 125569) lacks teeth and is otherwise well preserved, except for slight damage to the coronoid process (plate 7). The horizontal ramus is tabular, with nearly parallel dorsal and ventral margins. The symphyseal surface is elongate and oval-shaped in medial aspect, and bears a slightly rugose surface texture. The bone surface of the anterior end of the mandible and mandibular terminus is smooth. The symphyseal part of the mandible is slightly upturned, and the i2, i3, and c1 alveoli are positioned at the anterodorsal tip. In dorsal aspect, the symphyseal part of the mandible is transversely very narrow; the toothrow and horizontal ramus are widely divergent from the midline (approximately 15–20° between the toothrow and sagittal plane). A poorly developed genial tuberosity is present at the posteroventral termination of the mandibular symphysis. The ventral margin of the mandible is sinuous due to the well-developed flange-like digastric insertion. The angular process is positioned on the ventral side of the ascending ramus; it is anteroposteriorly short, and developed into a robust medial shelf. A shallow masseteric fossa occurs on the lateral surface of the ascending ramus; medially, a posterodorsally opening mandibular foramen is present. The coronoid process is low and posterodorsally directed, and although broken, the posterior margin of the coronoid process appears to have been straight and vertical. The mandibular condyle is cylindrical and horizontally oriented.

*Lower Dentition*—Although no teeth are preserved in this specimen, the alveoli are well-preserved and indicate the position and root morphology of the dentition (plate 7, fig. 2). The i2 alveolus is small and oval in shape, and positioned adjacent to the symphyseal surface. A much larger i3 alveolus is circular and positioned posteromedial to the i2 alveolus. The c1 alveolus is large, oval shaped, and positioned posteriorly to the i3 alveolus. Most of the postcanine alveoli are all oval in shape, with the exception of the circular p1 alveolus; it is also separated from the c1 by a slight diastema. The postcanine toothrow only includes four alveoli; there is a large diastema between the third and fourth alveolus; this alveolus is wide enough to have included an additional fifth alveolus, and this is interpreted to be a pathologically closed p4 alveolus. The alveolus posterior to this and separated from the third alveolus is interpreted to be the m1, and the other three alveoli as the p1–3. The p2 alveolus is larger and oval in shape, and is separated from the p1 and p3 by small diastemata. The p3 alveolus is larger and also oval in shape, whereas the m1 alveolus is small and circular. The p2 and p3 alveoli are proportionally wide relative to the width of the ramus that there are triangular notches in the dorsal margin where mandibular bone was resorbed from around the roots of these teeth. All alveoli are single-rooted.

**Remarks—**These specimens compare best with *Dusignathus santacruzensis*. The sinuous ventral margin of the mandible indicates that this specimen is a dusignathine (Deméré 1994a). UCMP 125569 differs from *Gomphotaria pugnax* in having a relatively smaller diameter canine, a sinuous lower border of the mandible (*Gomphotaria* is the only dusignathine that lacks this feature), and in its smaller size. It differs from *Pontolis magnus* in its substantially smaller size, single-rooted m1 alveolus, proportionally more elongate mandibular symphysis, anteroposteriorly shorter coronoid process, and a less well-developed digastric process.

UCMP 125569 also can be excluded from *Dusignathus seftoni* in its smaller size, lacking a fused mandibular symphysis, and having a linear postcanine toothrow (not arcuate as in *D. seftoni*). With some minor differences, this specimen compares best with the holotype mandible (UCMP 27121) of *Dusignathus santacruzensis* Kellogg (1927) and can be confidently referred to *Dusignathus santacruzensis*. Both of these specimens are relatively small in comparison to adult specimens of *Dusignathus*. The maxilla fragment is extremely small, and the canine is clearly interrupted and incompletely formed; it is likely that these are from a young juvenile or neonate. Because of the extremely small size of the upper canine in UCMP 125571, it is likely deciduous. The small size of the mandible and small diameter canine in comparison with the probable female holotype specimen (UCMP 27121) indicate that the mandible (UCMP 125569) likely represents a juvenile female. UCMP 125569 differs from the holotype of *D. santacruzensis* described from the Purisima Formation in Santa Cruz, Santa Cruz County, in possessing large incisor alveoli positioned anterior to the c1 alveolus, which according to Deméré (1994b), lacks lower incisors or alveoli. Like the holotype of *D. santacruzensis*, the incisor alveoli of UCMP 125569 are not positioned medial to the c1. However, in the holotype specimen the part of the mandible anterior to the c1 is broken and completely missing, thus illuminating the possibility that the holotype specimen possessed lower incisors prior to damage incurred during collection. Fossils of *Dusignathus santacruzensis* have been reported from the Purisima Formation of central California (Kellogg, 1927; Repenning and Tedford, 1977) and from the Almejas Formation of Baja California, Mexico (Repenning and Tedford, 1977). Additional specimens (UCMP 83370; Repenning and Tedford, 1977, p. 44, 47, plate 15, fig. 22) that were referred to *D. santacruzensis* by Repenning and Tedford (1977) from the Santa Margarita Sandstone at Point Reyes, Marin County, California, (same as Drakes Bay Formation of Galloway, 1977; Repenning and Tedford, 1977, p. 44 and 47, plate 15, fig. 22) are currently being reevaluated, and may represent a separate odobenid taxon (Boessenecker, 2007). Additionally, a partial odobenid forelimb (LACM 3011) described by Mitchell (1962) from the Purisima Formation also probably belongs to *D. santacruzensis* (Repenning and Tedford, 1977; Boessenecker, 2007). A second, geologically younger species, *Dusignathus seftoni*, was described by Deméré (1994b) from the San Diego Formation of southern California. A preliminary study by Boessenecker (2007) reported a partial forelimb of *Dusignathus* from the late Miocene St. George Formation near Crescent City, Del Norte County, California. In addition, *Dusignathus santacruzensis* is now described from the Wilson Grove Formation. This occurrence is unsurprising as all these formations (Purisima, St. George, and Wilson Grove Formations) are roughly the same age (equivalent with the Messinian Stage of international usage). Furthermore, owing for 130 km post-late Miocene San Andreas Fault offset, these occurrences suggest that *Dusignathus santacruzensis* inhabited 1,450 km of the Pacific shoreline of North America during the latest Miocene.

### Genus *Gomphotaria* Barnes and Raschke, 1991
### *Gomphotaria pugnax* Barnes and Raschke, 1991
Plate 8, figures 1–4

**Referred Specimens**—UCMP 125570, a fragment of the anterior part of a large left mandible including the c1 and probable p2.

**Description—***Mandible*—The anterior part of a mandible is preserved, and is broken at the p3 alveolus (plate 8). It includes the i3 alveolus, the c1, the p1 alveolus (filled with bone), p2, and part of the p3 alveolus. The symphyseal surface is completely preserved, is oval in shape, and has a very rugose surface texture. There is missing bone on the symphyseal surface medial to the canine; a thin layer of matrix sits on this exposed medial surface of the canine where the bone would have been, and only a wafer-thin septum of bone could have been present between the canines. Although very fragmentary, the ramus appears to be posterolaterally oriented, but at a very low angle. The ramus is very wide and robust transversely. On the lateral surface, there are mental foramina below the c1 and p1 alveoli. Another large foramen is present along the anteroventral margin, separated medially from the symphyseal surface by a thin septum of bone.

*Dentition*—Only one incisor alveolus is present, and it is small, shallow (about 6 mm deep), and positioned anteromedial to the c1. It is unclear if this is the i2 or i3. The c1 is very large, robust, and parasagittally oriented. The apex of the crown is extremely worn into three wear facets (anterolateral, medial, and posterior). The canine is oval-shaped in cross section, and exhibits longitudinal striations. The canine is not curved laterally, and is slightly curved dorsally. There is a large diastema between the c1 and the anteriormost alveolus, and in between is a circular patch of bone with a slightly more cancellous texture. In modern pinnipeds (most often otariids), postcanine teeth are occasionally lost during life, and are filled in with cancellous bone, leaving a similar texture as in this specimen. Thus, this former alveolus is interpreted to be the p1. The p2 is still present in its alveolus, and is simple, peg-like, and appears to have a single, cylindrical root. The crown is completely abraded away, and the crown morphology is indiscernible. The tooth is oval in cross section, and is closely appressed with the p1 and p2 alveoli. The root of the p2 is visible anteriorly from the p3 alveolus where part of the interalveolar septum is missing. It is not clear if this was taphonomic, or if the teeth were so closely appressed that the interalveolar septum was remodeled away, as occurs in some extant pinnipeds. Only the anterior part of the p3 alveolus is preserved.

**Remarks**—This specimen shares several features in common with the holotype of *Gomphotaria pugnax* (LACM 121508), including a very large and procumbent c1 with longitudinal striations, a single-rooted p2, extreme wear of the dentition, and rugose surface texture of the mandibular terminus. As the mandible is well preserved and unabraded, the extreme tooth wear most likely occurred during life and is not a taphonomic feature. This specimen shares the most features in common with *G. pugnax* and is assigned to that species. *Dusignathus santacruzensis* also exhibits procumbent lower canines, but these are less robust and tusk-like and lack the longitudinal striations that characterize this specimen; the postcanine teeth of *Dusignathus santacruzensis* also only exhibit anterior and posterior wear facets. A recently collected mandible of *D. seftoni* (SDNHM 90507) exhibits highly worn tusk-like lower canines, but these are less procumbent, and the dentaries of *D. seftoni* are fused at the symphysis, unlike this specimen. Lastly, *Pontolis magnus* differs from this specimen in lacking procumbent lower incisors, lacking extreme wear on the postcanine teeth, and having a bilobate p2 root.

UCMP 125570 differs from the holotype of *Gomphotaria pugnax* in its narrower canine, smaller size, and more extreme wear of the canine. The extreme dental wear and rugose bone surface both suggest that this individual was mature, and the relatively smaller size and proportionally smaller canine suggest this may be a female; the holotype skeleton of *G. pugnax* (LACM 121508) has a baculum and is thus demonstrably a male (Barnes and Raschke, 1991). *Gomphotaria* has previously been described from the late Miocene to early Pliocene Capistrano Formation (Barnes and Raschke, 1991; Deméré, 1994b) and listed from the late Miocene to late Pliocene Purisima Formation (Deméré and others, 2003); the new specimen from the Purisima Formation has yet to be described. An apparently new plesiomorphic species of *Gomphotaria* from the late Miocene to early Pliocene Towsley Formation (Berkoff and Barnes, 1998) also awaits description. The Wilson Grove Formation specimen is the first specimen of *Gomphotaria* to be described from outside the Capistrano Formation, and extends the range of this taxon approximately 850 km north (adjusted for San Andreas Fault offset).

### cf. *Pontolis*

Plate 9, figures 1–3

**Referred Specimens**—UCMP 81134, a large femur missing the head.

**Description—***Femur*—The femur is very large, and relatively elongate (238.3 mm total length from condyle to greater trochanter; plate 9). The greater trochanter is partially preserved, and laterally convex. The lesser trochanter is small and convex, and situated below the preserved neck of the femur. The shaft of the femur broadens distally towards the large, convex, distal condyles (113.6 mm distal transverse width). A deep intercondylar furrow is present between the condyles. In anterior aspect, the distal margin of the femur is inclined so that the medial condyle is positioned slightly further distal than the lateral condyle. The anterior surface of the shaft is transversely convex, and distally a large, rectangular and slightly damaged patellar trochlea occurs.

**Remarks—**This specimen is most similar to femora of dusignathine odobenids, and can be directly compared with the dusignathines *Dusignathus seftoni*, *Gomphotaria pugnax*, and *Pontolis magnus*, the stem odobenid *Imagotaria*, Pliocene odobenines including *Ontocetus emmonsi* and *Valenictus chulavistensis*, and the extant walrus *Odobenus rosmarus*. *Pontolis* is represented by a partial skeleton of a gigantic individual (National Museum of Natural History, Smithsonian Institution, USNM, 335571, identified here as cf. *Pontolis magnus*) from the late Miocene Empire Formation in Oregon (Deméré, 1994a), the holotype specimen of which was collected from the same locality (Deméré, 1994a). Additional topotypic material of *Pontolis magnus* exists in the Douglas Emlong collection and awaits description. The Wilson Grove Formation specimen, UCMP 81134, differs from all known odobenids with the exception of cf. *Pontolis magnus* (USNM 335571) in possessing a relatively elongate femoral shaft and distal end that is not widely flared; all other odobenids exhibit relatively short femora with widely flaring distal ends. *Dusignathus seftoni* (SDNHM 77891) is similar in overall size but differs from UCMP 81134 in having a narrower shaft with an abruptly widening distal end; *Imagotaria downsi* (USNM 23870) differs from UCMP 81134 in being proportionally wider, and UCMP 81134 further differs from the toothless odobenine *Valenictus chulavistensis* in lacking an osteosclerotic femoral histology, and lacking an extremely inflated distal end. *Gomphotaria pugnax* exhibits an extremely robust and wide shaft, and is nearly twice as wide relative to UCMP 81134. Although slightly less robust and transversely narrower, UCMP 81134 is most similar to USNM 335571 (cf. *Pontolis magnus*) and is therefore tentatively assigned to the genus *Pontolis*.

### Subfamily Odobeninae Mitchell, 1968

### Odobeninae indeterminate

Plate 5, figures 4–5

**Referred Specimens**—UCMP 125575, first left metacarpal.

**Description—***Metacarpal*—This specimen is a small (63.9 mm total length) and robust left metacarpal I lacking the proximal epiphysis (plate 5, figs. 4 and 5). It is proximally swollen and thick (16.34 mm proximal width) and tapers distally. It is slightly laterally curved.

**Remarks—**UCMP 125575 is similar to the metacarpal I of the odobenine walruses *Aivukus*, *Pliopedia*, *Valenictus*, and *Odobenus* in being proximally swollen. A single specimen of *Valenictus chulavistensis* with articulated forelimbs (SDNHM 83719) also possesses a similarly bowed and proximally inflated proximal manual phalanx on the first digit, although it is straight in *Odobenus rosmarus*. This specimen represents a first metacarpal as it possesses a convex distal trochlea, unlike the saddle-shaped trochlea in the proximal phalanx of SDNHM 83719. It differs from the metacarpal I of *Imagotaria* and *Dusignathus* in lacking a straight, narrow shaft. UCMP

125575 differs from *Pliopedia* in having a more swollen shaft, but shares the lateral curvature. This specimen shares a swollen shaft with *Aivukus*, *Valenictus*, and *Odobenus* and differs from *Aivukus* in having a more laterally curved shaft; it is most similar to *Odobenus* and *Valenictus*, and is referred to the Odobeninae.

### Order Cetacea Brisson, 1762
### Suborder Odontoceti Flower, 1869
### Odontoceti indeterminate
Plate 10, figures 1–6

**Referred Specimens**—UCMP 125585, tooth; 125586, atlas; UCMP 125587-8, vertebrae.

**Description and Remarks**—The isolated tooth is very small, with a conical crown, and a cylindrical root (plate 10, figs. 1–3). The tooth is posteriorly curved. The partial atlas and vertebrae are of typical odontocete morphology (plate 10, figs. 4–6). Because teeth and vertebrae are generally not diagnostic for cetaceans (Barnes, 1976 [1977]), it is not possible to further identify these specimens.

### Suborder Mysticeti Flower, 1864
### Family Balaenopteridae Gray, 1864
### Balaenopteridae indeterminate
Plate 11, figures 1–6, 9–10

**Referred Specimens**—UCMP 125833, a fragmentary left mandible including the anterior part and a fragment of the posterior part of the mandible.

**Description and Remarks**—UCMP 125833 consists of two fragments of a poorly preserved left mandible (plate 11, figs. 1–4). The posterior fragment preserves a part of the mandible near the coronoid process, but anterior to the mandibular foramen opening and the coronoid process. The mandibular foramen is large in cross section. Posteriorly, the mandible fragment is transversely narrow, and planar medially and slightly convex laterally. Dorsally, there is a very high precoronoid crest that becomes gradually higher posteriorly. Anteriorly, the medial and lateral surfaces are much more convex. The anterior part of a mandible is very transversely thin, although this may be due in part to diagenetic compaction as it exhibits obvious crushing. The anterior tip is missing and damaged. The anterior mandible transversely tapers anteriorly, and is bowed slightly laterally. The lateral surface is gently convex, and the medial surface is nearly flat. No ligamental groove on the anteromedial surface is preserved.

Although very fragmentary, some comparisons can be made of this specimen. UCMP 125833 is most similar to balaenopterid mysticetes in its morphology, and differs from eschrichtiids (gray whales) in having such a high anterior coronoid crest and having less convex medial and lateral surfaces anterior. UCMP 125833 differs from balaenids (right whales) in lacking a sharp ventral crest, and in having a well-developed, sharp anterior coronoid crest, and in being transversely narrow anteriorly. Additionally, UCMP 125833 is not an archaic mysticete, as the only known archaic mysticetes from the late Miocene of the eastern North Pacific are the herpetocetine cetotheriids such as *Nannocetus* and *Herpetocetus*, which have dentaries that are substantially smaller than the Wilson Grove Formation specimen (Boessenecker, 2011). This specimen, however, differs from all extant balaenopterids (*Balaenoptera* spp. and *Megaptera novaeangliae*) in having a mandible that is far more transversely narrow anterior and posterior, and has a much higher anterior coronoid crest. The coronoid crest of UCMP 125833 is similar to that of the extinct balaenopterid *Parabalaenoptera baulinensis* (Zeigler and others, 1997), which has an unusually tall and elongate crest on the dorsal surface of the mandible, which increases in height posteriorly, and has a posterior mandible that is unusually transversely narrow for a balaenopterid. *Parabalaenoptera* was first described from the contemporaneous Santa Cruz Mudstone near Bolinas in Marin County, California. However, because this specimen is so incomplete, it is not possible to assign this specimen to a genus. In addition, a partial cervical vertebra (UCMP uncatalogued), two well-preserved vertebral epiphyses (UCMP 125597 and 125598), and a phalanx (UCMP 125596) representing indeterminate large mysticetes (plate 11, figs. 5, 6, 9, and 10) were collected from Bloomfield Quarry, which may also belong to a balaenopterid. However, postcranial elements are generally not diagnostic among cetaceans (Barnes, 1976 [1977]).

### Family Cetotheriidae Brandt, 1872
### Subfamily Herpetocetinae Whitmore and Barnes, 2008
### Herpetocetinae indeterminate
Plate 11, figures 7–8

**Referred Specimens**—UCMP uncatalogued, a partial supraorbital process of the frontal bone.

**Description and Remarks**—This specimen is the anterior half of a small supraorbital process of the frontal, and the anteromedial and posterior parts are broken away (plate 11, figs. 7 and 8). Dorsally, it is relatively flat, and the antorbital process is slightly knoblike. The lateral margin of the supraorbital process continues posteromedially, and forms the anterior part of the laterally concave orbital margin. The dorsal surface slopes evenly laterally. Ventrally, there is a broadly convex ridge anteriorly. Posterior to this is a gentle concave surface that forms the dorsal roof of the orbit, and would have been medially confluent with the optic canal. This small supraorbital process is very similar to that of the herpetocetine mysticetes *Herpetocetus* and *Piscobalaena* (Bouetel and Muizon, 2006; Whitmore and Barnes, 2008); unfortunately, the Tortonian herpetocetine *Nannocetus* is not known from a complete frontal, and comparison is not possible. However, due to its similarity with *Herpetocetus*, this specimen is referred to the Herpetocetinae.

Order Sirenia Illiger, 1811
Family Dugongidae Gray, 1821
Subfamily Hydrodamalinae Palmer, 1895
Hydrodamalinae indeterminate
Plate 12, figures 1–6

**Referred Specimens**—UCMP 125594 and 125595, rib fragments.

**Description and Remarks**—These fragmentary ribs (plate 12) are robust and composed of dense bone, and almost completely lack a medullary cavity (plate 12, figs. 1–3). UCMP 125594 and 125595 are oval in cross section, and relatively more inflated than cetacean ribs. These rib fragments are pachyosteosclerotic, a condition that characterizes sirenians (manatees and sea cows). Only two taxa of sea cows are known from the late Miocene of the eastern North Pacific, the hydrodamalines *Dusisiren* spp. and *Hydrodamalis cuestae* (Domning 1978; Domning and Deméré 1984). *Dusisiren* is relatively smaller than the gigantic *Hydrodamalis* (Domning 1978), and these ribs are so small that they could be from a juvenile of either taxon, and thus can only be identified to the Hydrodamalinae.

### Discussion

Barnes (1976 [1977]) reported the first marine mammals from the Wilson Grove Formation, including the lipotid dolphin *Parapontoporia sternbergi* and the balaenid right whale *Balaenula* sp. However, these specimens have not yet been described. To that list can be added cf. *Imagotaria*, *Dusignathus santacruzensis*, cf. *Dusignathus*, *Gomphotaria pugnax*, an indeterminate odobenine walrus, an indeterminate odontocete, an indeterminate balaenopterid whale, an indeterminate herpetocetine whale, and an indeterminate hydrodamaline sirenian. The marine mammal assemblage from Bloomfield Quarry represents the most diverse walrus assemblage yet reported worldwide. It includes a stem odobenid (cf. *Imagotaria*), three dusignathine walruses (*Dusignathus santacruzensis*, *Gomphotaria pugnax*, and cf. *Pontolis*), and an indeterminate odobenine walrus. The cetacean fossils are less diagnostic, and only indicate the presence of indeterminate odontocetes and mysticetes; more diagnostic cetacean material awaiting formal description includes skulls, mandibles, and petrosals from other localities in the Wilson Grove Formation, including a dwarf mysticete cranium (likely a herpetocetine) a few kilometers to the east (Allen and others, 1999; Powell and others, 2004, fig. 9), a skull of the extinct right whale *Balaenula*, and a mandible of the lipotid “river dolphin” *Parapontoporia* (Barnes, 1976 [1977]). Notably lacking from the marine mammal assemblage are otariid fur seals. Otariids are known from other late Miocene strata such as the Purisima Formation in central California (Repenning and Tedford, 1977), as well as localities stratigraphically higher in the Wilson Grove Formation. Again, these other specimens from the Wilson Grove Formation have yet to be described.

The pinniped assemblage is otherwise similar to that of the basal Purisima Formation near Santa Cruz, where *Imagotaria*, *Gomphotaria* and *Dusignathus* are preserved, alongside odobenine walruses and otariid fur seals (Mitchell, 1962; Boessenecker, 2013, appendix). Furthermore, *Pontolis* and *Imagotaria* are already known to co-occur within the Empire Formation of Oregon (Deméré, 1994a) and the Monterey Formation of Orange County (Barnes and others, 1985) and both *Pontolis* and *Gomphotaria* have been reported from the Capistrano Formation (Mitchell, 1968; Barnes and Raschke, 1991). Other multispecies walrus assemblages include the uppermost Miocene Almejas Formation of Baja California, Mexico (*Aivukus cedrosensis* and *Dusignathus santacruzensis*; Repenning and Tedford, 1977) and the Pliocene San Diego Formation of southern California (*Dusignathus seftoni*, *Valenictus chulavistensis*, and Odobeninae indeterminate; Deméré, 1994b; Boessenecker, 2013, p. 904). With five identified odobenids, the Wilson Grove Formation represents an unusually diverse assemblage of walruses.

## Birds by N. Adam Smith

**Materials and Methods—**In the avian anatomical descriptions, the English equivalents of the Latin osteological nomenclature summarized by Baumel and Witmer (1993) are used. The terminology of Howard (1929) is followed for features not treated by Baumel and Witmer (1993). With the exception of the terms anterior and posterior substituted for cranial and caudal, respectively, the terms used for the anatomical orientation of a bird are those used by Clark (1993). Measurements follow those of von den Driesch (1976). All measurements were taken using digital calipers and rounded to the nearest tenth of a millimeter. Comparisons with extinct taxa were made through direct observation of type and referred specimens. Extant comparative skeletal material is listed below.

**Extant Comparative Skeletal Material**—*Aethia cristatella* Crested Auklet (NCSM 17749 and USNM 223707, 488675, 498282, 561934, 61094); *Alca torda* Razorbill Auk (NCSM 20058, 20502 and USNM 18062, 347946, 501644, 502378, 502382, 502387, 502388, 502389, 502549, 555666, 555668); *Alle alle* Dovekie (NCSM 18374 and USNM 344740, 344748, 499471, 560929); *Brachyramphus perdix* Long-billed Murrelet (USNM 582506, 599498); *Cepphus columba* Pigeon Guillemot (NCSM 18094, 18095, 18096, 18097 and USNM 610936); *Fratercula arctica* Atlantic Puffin (USNM 18055, 18057, 18058, 224189, 621331); *Pinguinus impennis* Great Auk (USNM 346387 (composite), 557975 (composite), 623465 (composite); *Uria aalge* Common Murre (NCSM 17822, 18116, 18117, 18118, 18234); *Uria lomvia* Thick-billed Murre (NCSM 18114, 19414 and USNM 344435, 561265); *Synthliboramphus hypoleucus* Xantus’ Murrelet (USNM 19387, 291879, 345427, 345428, 500652).

### Class Aves Linnaeus, 1758
### Aves indeterminate

**Referred Specimens**—UCMP 128208, distal end of right tibiotarsus (plate 13, figs. 1 and 2).

**Description**—Morphology and position of ossified supratendinal bridge and medial epicondylar depression of UCMP 128208 consistent with that of Pan-Alcidae.

**Remarks**—No apomorphies are preserved that would allow for precise referral of this specimen within Aves.

### Order Charadriiformes Huxley, 1867
### Clade Pan-Alcidae Smith, 2011
### Pan-Alcidae indeterminate
### Plate 13, figures 3–6

**Referred Specimens**—UCMP 128209, proximal part of right ulnar shaft fragment (plate 13, figs. 3 and 4); UCMP 128210, two fragments of left humeral shaft (plate 13, figs. 5 and 6).

**Description**—The dorsoventral compression of these fragments of pectoral limb shaft supports referral to Pan-Alcidae. A distinct groove, possibly the m. brachialis fossa, is visible along the anterior margin of UCMP 128209 (plate 13, figs. 3 and 4). However, no feather papillae are visible on the preserved part of shaft.

A part of the deltopectoral crest is preserved along the dorsal margin of the two humeral shaft fragments (UCMP 128210; plate 13, figs. 5 and 6). Based on the size and cross-sectional profile, these specimens likely represent the mid-shaft of the humerus. Distal extension of the deltopectoral crest past the mid-shaft is an apomorphy of Mancallinae and these specimens likely represent that taxon.

**Remarks—**No additional apomorphies or diagnostic characteristics are preserved that would allow for more precise referral of these three specimens.

### Clade Mancallinae Brodkorb, 1967
### Mancallinae indeterminate
### Plate 14

**Referred Specimens**—UCMP 128207, right coracoid (plate 14).

**Description—**UCMP 128207 is missing a fragment of bone along the lateral margin of the sternal end where the lateral process would likely have been, but is otherwise complete (plate 14). The shaft of the coracoid omal to the procoracoid process is relatively straight as in Fraterculinae (that is, *Aethia*, *Ptychoramphus*, *Cerorhinca*, *and Fratercula*) and other Mancallinae (that is, the clade comprising *Mancalla+Miomancalla*), rather than curved as in Alcinae (that is, *Alca*, *Pinguinus*, *Uria*, *Alle*, *Miocepphus*, *Cepphus*, *Brachyramphus*, and *Synthliboramphus*; fig. 4). As in all known Mancallinae, the procoracoid process is triangular and lacks an nervus supracoracoideus foramen. The procoracoid process of *Cerorhinca*, and *Fratercula* (that is, Fraterculini) is fenestrated and the procoracoid process of *Aethia* and *Ptychoramphus* (that is, Aethiini; fig. 4) is rectangular (Smith, 2013b). The furcular facet is rounded rather than oval as in *Mancalla californiensis* Lucas (1901), and the supracoracoideus scar is less distinct than in *Mancalla californiensis*. As in all other Mancallinae, the sternal facet is angled ~135° in sternal view. This angle is more acute in all other Pan-Alcidae (Smith, 2011).

**Remarks**—Mancallinae coracoids are known only for *Mancalla vegrandis* Smith (2011), *Mancalla californiensis* Lucas (1901), and *Mancalla cedrosensis* Howard 1971 (Smith, 2011). Although UCMP 128207 can be differentiated from the only coracoid referred to *Mancalla californiensis* (LACM 15410), there are no morphological characters that differentiate this specimen from the holotype coracoids of *Mancalla cedrosensis* or *Mancalla vegrandis*. However, the greatest length of UCMP 128207 (62.7 mm) is considerably greater (~27 percent) than that of *Mancalla cedrosensis* (45.6 mm) and *Mancalla vegrandis* (45.8 mm). This large difference in size is outside the range of intraspecific variation calculated for extant Alcidae (Smith and Clarke, 2011) and suggests that this coracoid is not referable to either of those species. Among *Mancalla*, only *M. cedrosensis* is known from the Miocene (that is, all other *Mancalla* species are Pliocene or younger), suggesting that UCMP 128207 may be representative of the relatively large, Miocene Mancallinae species, *Miomancalla wetmorei* (Howard 1976) or *M. howardae* Smith (2011), for which coracoids are not presently known.

### Tribe Alcini Storer, 1960
### Genus *Uria* Pontoppidan, 1763
### cf. *Uria brodkorbi* Howard, 1981
### Plate 15

**Referred Specimens**—UCMP 128206, proximal end of right humerus (plate 15).

**Description—**UCMP 128206 is broken distal to the junction of the bicipital crest with the humeral shaft (plate 15). The preserved part of shaft displays the dorsoventral compression characteristic of all Pan-Alcidae. The medial projection and roundness of the humeral head and the strong anteroventral curvature of the deltopectoral crest agree with that of previously documented *Uria* species. Although damaged, the posterior margin of the humeral head appears to be triangular like that of *Uria* rather than rounded as in Mancallinae and many other species of Alcinae (for example, *Alca torda*, *Synthliboramphus hypoleucus*, *Brachyramphus perdix*). As in all crown clade Alcidae, the head of the humerus is inline with the humeral shaft rather than anteriorly rotated as in Mancallinae (Smith, 2011). The junction between the bicipital crest and the humeral shaft is not notched as in *Cepphus* and *Miocepphus*, and the angle between the bicipital crest and the humeral shaft is not perpendicular as in *Pinguinus*, *Alle*, and Fraterculini. The musculus supracoracoideus scar on the posterior side of the humerus does not broaden proximally as in Fraterculini, *Cepphus*, and *Miomancalla*. As in all Pan-Alcidae, the primary pneumotricipital fossa is not deeply pneumatized (that is, pneumatic foramen absent). The depth of the primary pneumotricipital fossa (that is, ventral fossa) is consistent with that of *Uria* (that is, deeper than that of *Pinguinus*, *Alca*, *Cerorhinca*, and Mancallinae). As in all Alcinae, the secondary pneumotricipital fossa (that is, dorsal fossa) is not pneumatized (Smith, 2011). Fine-scale morphological details of the ventral tubercle are not discernible owing to weathering. The dorsolateral orientation and width of the capital groove are consistent with that of *Uria*, and the passage of nervus coracobrachialis on the anterior humeral surface appears to be in a sulcus like that of *Uria* rather than an enclosed bony canal as in *Alca* (Smith and Clarke, 2011).

**Remarks**—Other Alcinae known from the Miocene of the Pacific Ocean basin are limited to *Uria brodkorbi* Howard (1981), *U. paleohesperis* Howard (1982), and *Cepphus olsoni* Howard (1982) (Olson, 1985). UCMP 128206 is not referable to *Cepphus* (see description above), and *Uria paleohesperis* is likely a junior synonym of *U. brodkorbi* (Smith and Clarke, 2011). A poorly preserved specimen (proximal end of humerus; LACM 52018) from the Miocene “Monterey” Formation (not equivalent to the type Monterey Formation in Monterey County) of Orange County, California, was tentatively referred to *Uria* by Howard (1978). Additional *Uria* remains have not been reported from that location (N.A. Smith, unpublished data, 2018). *Uria brodkorbi* is known from a single well-preserved associated partial skeleton (UF/PB 7960 A and B) from the late Miocene to early Pliocene Sisquoc Formation of Santa Barbara County, California (Howard, 1981). The age of *Uria brodkorbi* is consistent with the late Miocene (>6.25 Ma) age assigned to the basal unit of the Wilson Grove Formation (Sarna-Wojcicki, 1992; Powell and others, 2004). The greatest width of the proximal humerus of *Uria brodkorbi* (18.2 mm) is also consistent with that dimension in UCMP 128206 (19.0 mm). Although UCMP 128206 does not preserve sufficient morphological detail to be unambiguously referred to *Uria brodkorbi*, the possibility that this specimen represents that species should be considered on recovery of additional remains of this taxon from the Wilson Grove Formation.

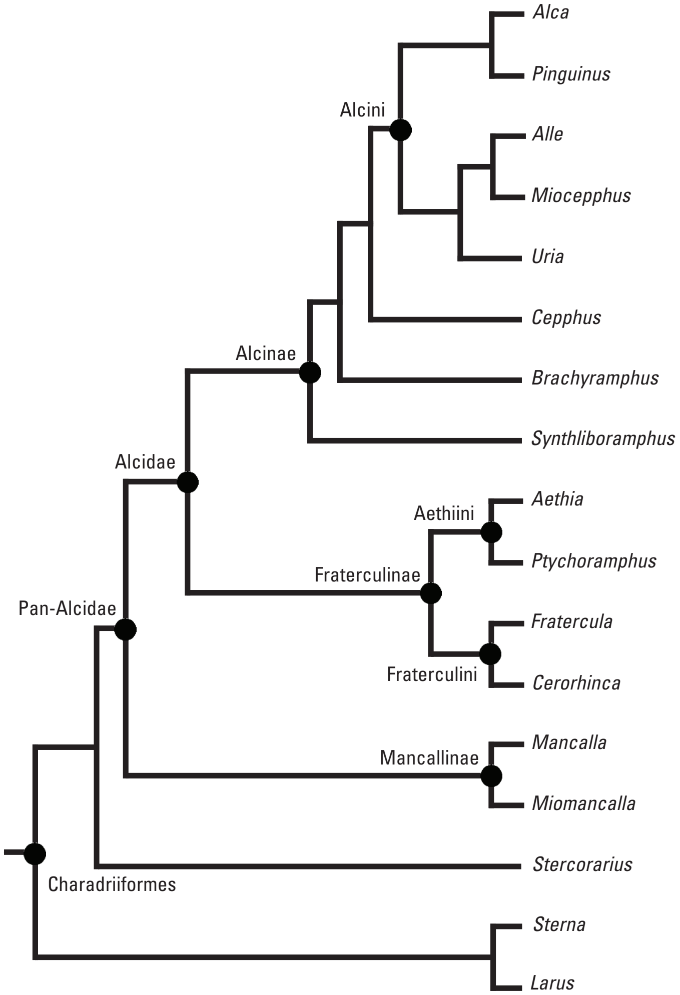


**Figure 4.** Cladogram depicting pan-alcid relations (topology based on Smith, 2011, fig. 15; Smith and Clarke, 2011, fig. 6).

# Plates 1–15

[Institutional abbreviations—CAS, California Academy of Sciences; NCSM, North Carolina Museum of Natural Sciences; LACM, Natural History Museum of Los Angeles County; SDNHM, San Diego Natural History Museum; UCMP, University of California Museum of Paleontology; USNM, National Museum of Natural History, Smithsonian Institution]

# Plate 1

Selected brachiopod fossils from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. mm, millimeter. (Photographs by Sandy Carlson, University of California, Davis, and Christine Garcia, California Academy of Sciences.)

**Figures**

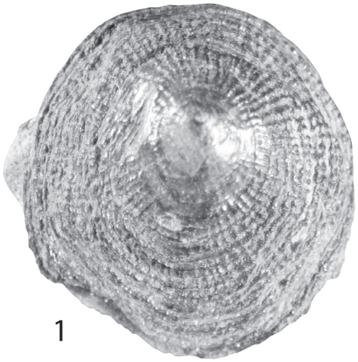
**1.** *Discinisca* cf. *D. cumingii* (Broderip, 1833). Dorsal valve exterior. CAS locality 54136. CAS hypotype 78201. Maximum length 21 mm, maximum width 20 mm. Vaguely reticulate ornament visible.

**2–4.** *Terebratulina* cf. *T. unguicula* (Carpenter, 1864). Dorsal valve. CAS locality 54135. CAS hypotype 78202. Maximum length 12 mm, maximum width 15 mm. 2, Interior; 3, exterior with delicate radial ribbing; 4, posterior view of cardinal process and broken cardinalia.

**5–6.** *Terebratalia* cf. *T. occidentalis* Dall (1891). Articulated specimen. CAS locality 54136. CAS hypotype 78204. Maximum length 27 mm, maximum width 24 mm, maximum depth 16 mm. 5, Lateral view, ventral valve on left; 6, ventral valve exterior.

**7, 9.** *Terebratalia* cf. *T. occidentalis* Dall (1891). Articulated specimen. CAS locality 54135. CAS hypotype 78205. Maximum length 25 mm, maximum width 22 mm, maximum depth 14 mm. 7, Dorsal view, dorsal valve exterior with broad and weakly developed radial ornament; 9, anterior commissure view, ventral valve below, with ventral sulcus clearly demarcated.

**8, 10.** *Terebratalia* cf. *T. transversa* (Sowerby, 1846). CAS locality 54135. 8, CAS hypotype 78206, dorsal valve interior, maximum length 22 mm, maximum width 34 mm, wide cardinal process and low median septum visible. 10, CAS hypotype 78207, ventral valve interior, maximum length 22 mm, maximum width 27 mm. Large pedicle foramen and broad palintrope clearly visible, as is valve asymmetry most likely due to crowding of individuals attached to hard substrate.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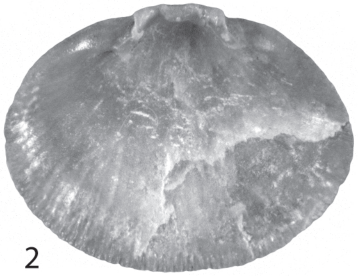
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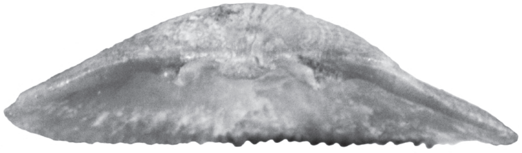
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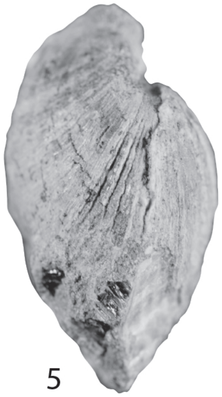
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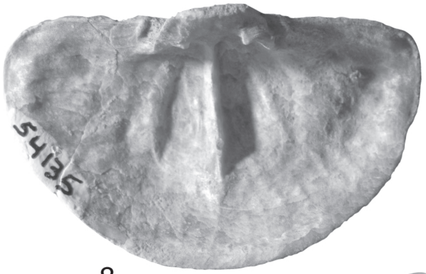

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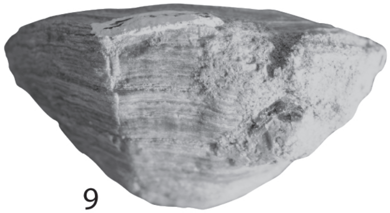
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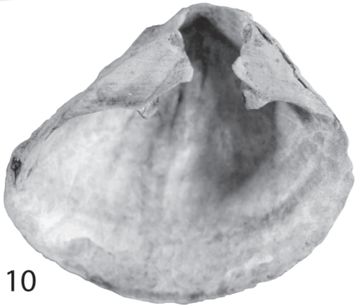
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Plate 1

# Plate 2

Selected mollusk fossils from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. mm, millimeter. (U.S. Geological Survey photographs by Charles Powell II.)

**Figures**

**1, 4–6.** *Yoldia* sp. indeterminate. CAS locality 54135. 1, 5, CAS hypotype 78401. Length 22.4 mm, height 11.9 mm. 4, 6, CAS hypotype 78402. Length 20.6 mm, height 10.5 mm.

**2, 3.** *Arca santamariensis* Reinhart (1937). CAS locality 54135. 2, CAS hypotype 78403. Length 55.4 mm, height 32.6 mm. 3, CAS hypotype 78404. Length 45.6 mm, height 30.4 mm.

**7, 15.** *Pododesmus* cf. *P. macrochisma* (Deshayes, 1839). CAS locality 54135. 7, CAS hypotype 78426. Length 56.2 mm, height 55.8 mm. 15, CAS hypotype 78429. Length 24.8 mm, width 17.1 mm.

**8, 9.** *Swiftopecten parmeleei* (Dall, 1898). CAS locality 54135. 8, CAS hypotype 78405. Length 38.2 mm, height 43.1 mm. 9, CAS hypotype 78406. Length 27.2 mm, height 33.5 mm.

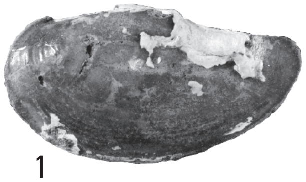
**10.** *Anomia peruviana* d'Orbigny (1846). CAS locality 54135. CAS hypotype 78427. Length 29.4 mm, height 30.9 mm.

**11.** *Chlamys hodgei* (Hertlein, 1925). CAS locality 54135. CAS hypotype 78428. Length 64.2 mm, height 66.0 mm.

**12, 13.** *Chlamys* aff. *C. egregius* (Nomland, 1917). CAS locality 54135. 12, Right valve. CAS hypotype 78407. Length 29.2 mm, height 32.3 mm. 13, Left valve. CAS hypotype 78408. Length 24.5 mm, height 32.5 mm.

**14.** *Chlamys* cf. *C. hastata* (Sowerby, 1842). Right valve. CAS locality 54136. CAS hypotype 78409. Length 67.3 mm, height 75.4 mm.

**16.** *Crenomytilus* cf. *C. coalingensis* (Arnold, 1909). CAS locality 54135. CAS hypotype 78410. Length 189 mm, height 109 mm.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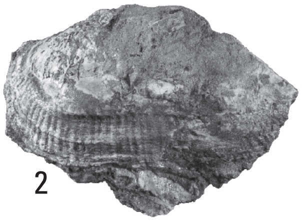
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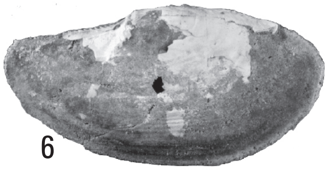
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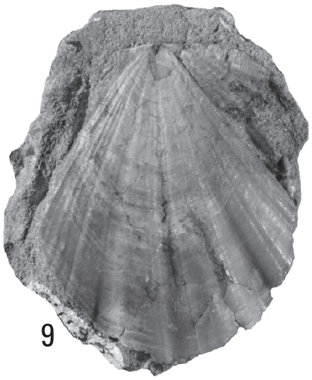
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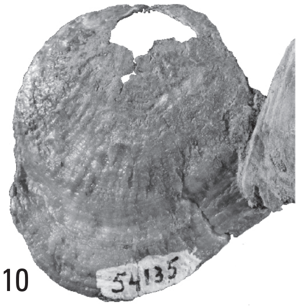

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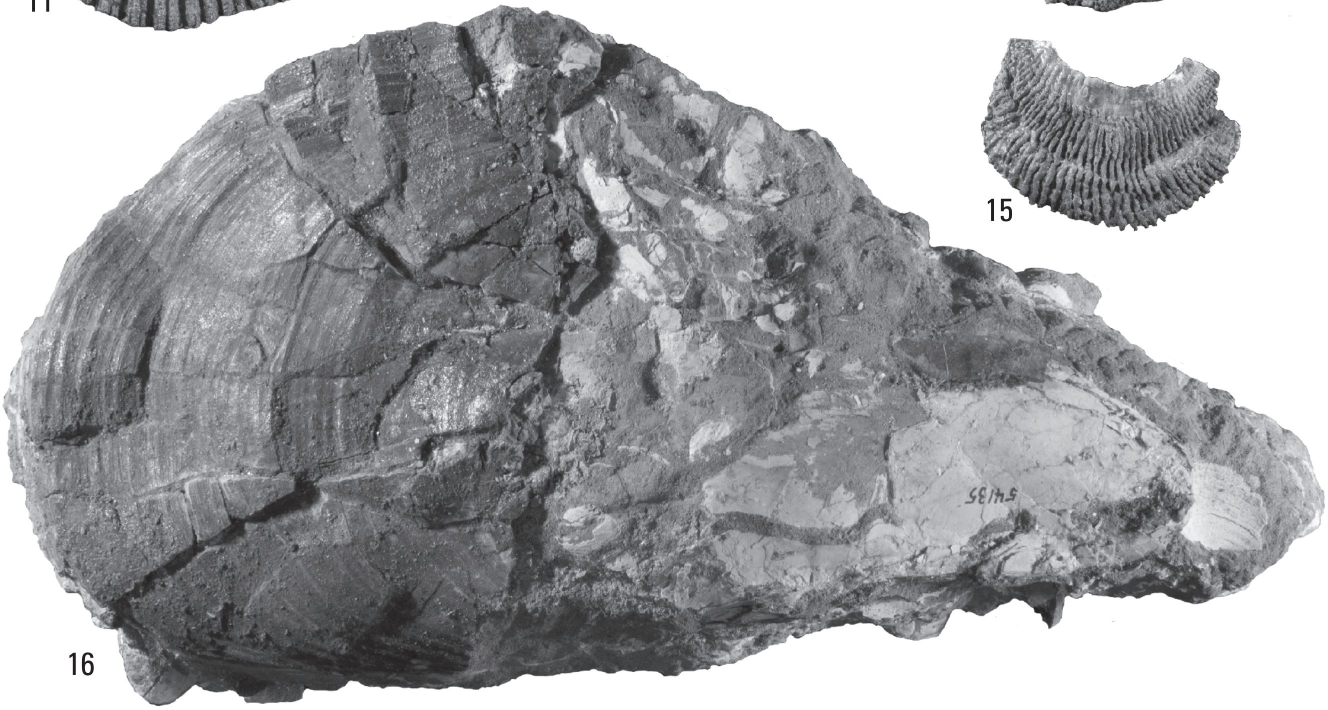
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# Plate 3

Selected mollusk fossils from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. mm, millimeter. (U.S. Geological Survey photographs by Charles Powell II.)

**Figures**

**1.** *Macoma* aff. *M. indentata s.s.* Carpenter (1864). Left valve. CAS locality 54135, CAS hypotype 78411. Length 42.5 mm, height 32.7 mm.

**2, 3.** *Macoma* sp. indeterminate. CAS locality 54135, CAS hypotype 78412. Length 38.2 mm, height 32.9 mm. 2, Left valve; 3, right valve.

**4.** *Ensis* sp. indeterminate. CAS locality 54135. Incomplete pair of valves. CAS hypotype 78413. Lower, right valve: height 17.9 mm, width 41.2 mm.

**5, 7.** *Tresus pajaroanus* (Conrad, 1857). CAS locality 54136. CAS hypotype 78414, Length 64.6 mm, height 47.6 mm. 5, Left valve. 7, Right valve.

**6.** Cardiidae indeterminate. Right valve. CAS locality 54135. CAS hypotype 78415. Length 53.4 mm, height 52.8 mm.

**8.** *Crepidula princeps* (Conrad, 1856 [1857]). Apical view, internal mold. CAS locality 54135. CAS hypotype 78416. Height 63.0, width 65.9.

**9, 10.** *Nucella* n. sp. CAS locality 54136. CAS hypotype 73156. Height 33.4 mm, width 19.5 mm. 9, Adapertural view; 10, apertural view.

**11.** *Trochita* cf. *T. diabloensis* (Clark, 1915). Apical view, latex cast. CAS locality 54135. CAS hypotype 78417, Height 46 mm, greatest width 47.9 mm.

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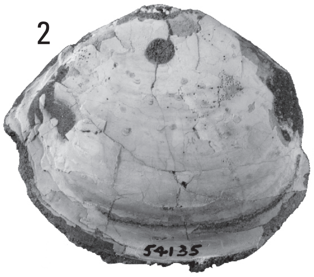

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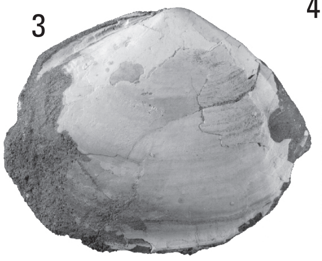

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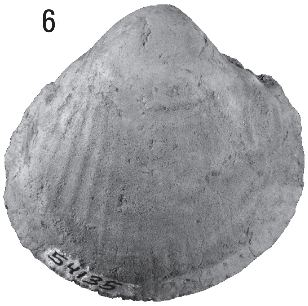

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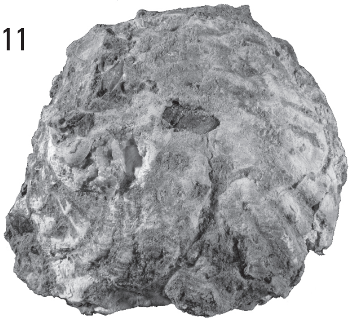

# Plate 4

Selected fish fossils from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. mm, millimeter. (Photographs by Douglas Long, Saint Mary's College.)

**Figures**

**1.** *Hexanchus griseus* (Bonnaterre, 1788) upper anterior tooth. UCMP 125599.

**2.** *Hexanchus griseus* (Bonnaterre, 1788) lower lateral tooth. UCMP 1256000.

**3.** *Isurus oxyrinchus* Rafinesque (1810) lateral tooth. UCMP 125605.

**4.** *Stereolepis* sp. indeterminate. Vertebra anterior and lateral views of vertebra. UCMP 125612.

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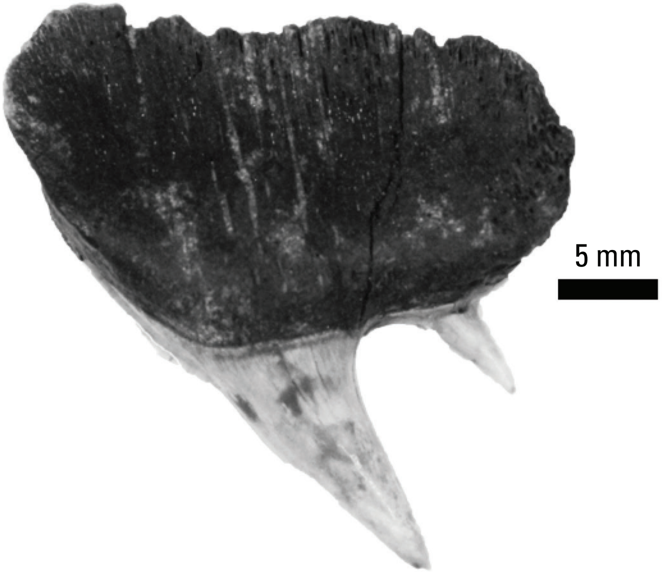

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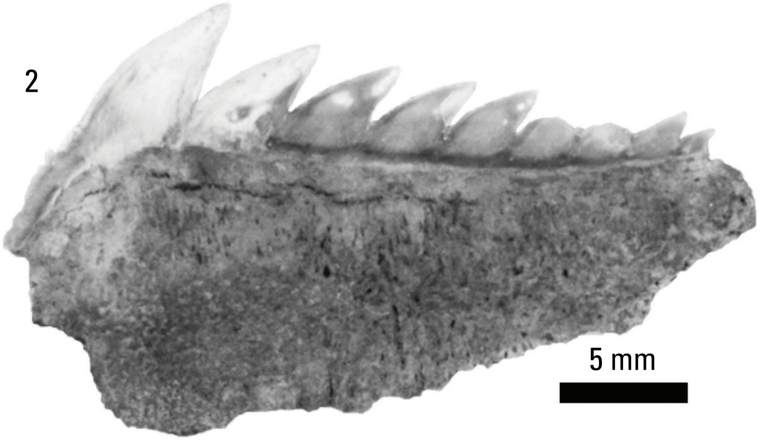

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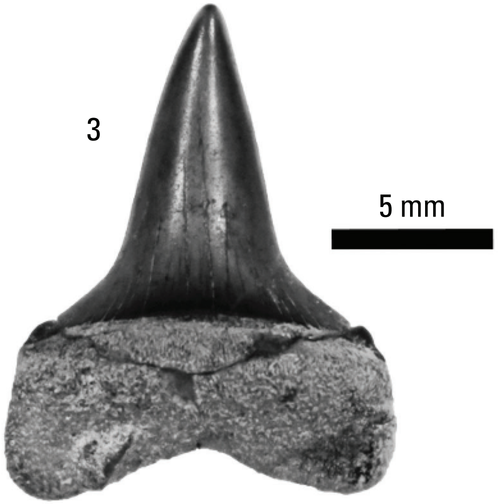

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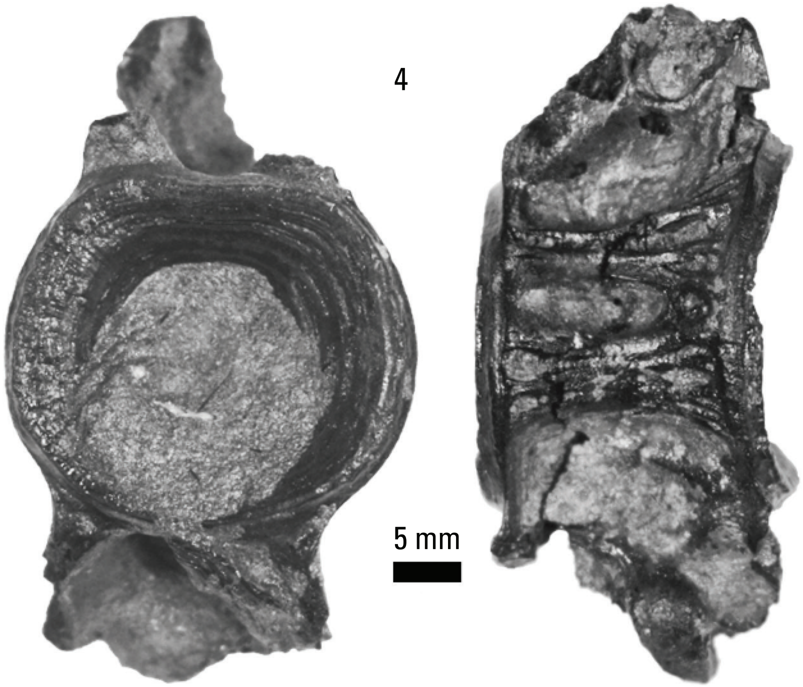

Plate 4

# Plate 5

Walrus (Odobenidae) postcrania from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. cm, centimeter. (Photographs by Robert Boessenecker, College of Charleston.)

**Figures**

**1–3.** *Imagotaria* sp. indeterminate. Left radius. UCMP 125572. 1, Lateral view; 2, anterior view; 3, medial view.

**4, 5.** Odobeninae indeterminate. Left metacarpal 1. UCMP 125575. 4, Dorsal view; 5, ventral view.

**6, 7.** Odobenidae indeterminate. Distal phalanx. UCMP 125579. 6, Dorsal view; 7, ventral view.

**8–11.** Odobenidae indeterminate. Left third metatarsal. UCMP 125576. 8, Ventral view; 9, medial view; 10, dorsal view; 11, lateral view.

**12, 13.** Odobenidae indeterminate. Right innominate. UCMP 125574. 12, Medial view; 13, lateral view.

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# Plate 6

Walrus (Odobenidae) teeth from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. cm, centimeter. (Photographs by Robert Boessenecker, College of Charleston.)

| | | |
|---|---|---|
| **Figures** | **1–3.** | *Dusignathus santacruzensis* Kellogg (1927). Partial right maxilla. UCMP 125571. *1*, Lateral view; *2,* medial view; *3,* ventral view. |
| | **4–5.** | *Dusignathus santacruzensis* Kellogg (1927). Canine tooth. UCMP 125571. 4, Labial view; *5,* lingual view; *6,* mesial view. |

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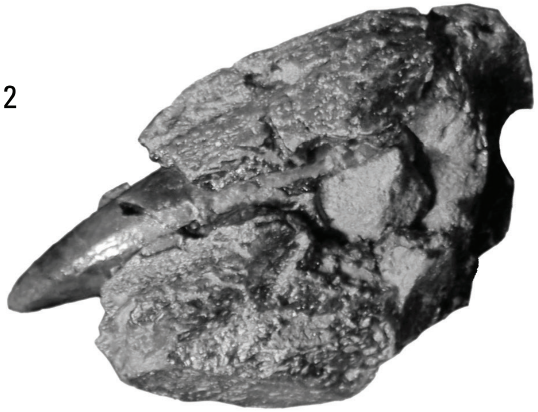

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# Plate 7

Walrus (Odobenidae) mandible from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. cm, centimeter. (Photographs by Robert Boessenecker, College of Charleston.)

| | | |
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| **Figures** | **1–3.** | *Dusignathus santacruzensis* Kellogg (1927). Left mandible. UCMP 125567. 1, Lateral view; 2, dorsal view; 3, medial view. |

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# Plate 8

Walrus (Odobenidae) mandible from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. cm, centimeter. (Photographs by Robert Boessenecker, College of Charleston.)

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| **Figures** | **1–4.** | *Gomphotaria pugnax* Barnes and Raschke (1991). Partial left mandible. UCMP 125570. 1, Lateral view; 2, medial view; 3, dorsal view; 4, lateral view, with other fragments. |

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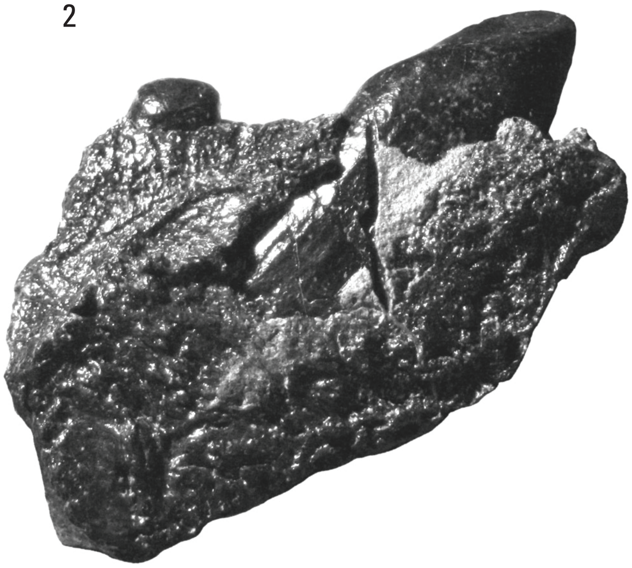

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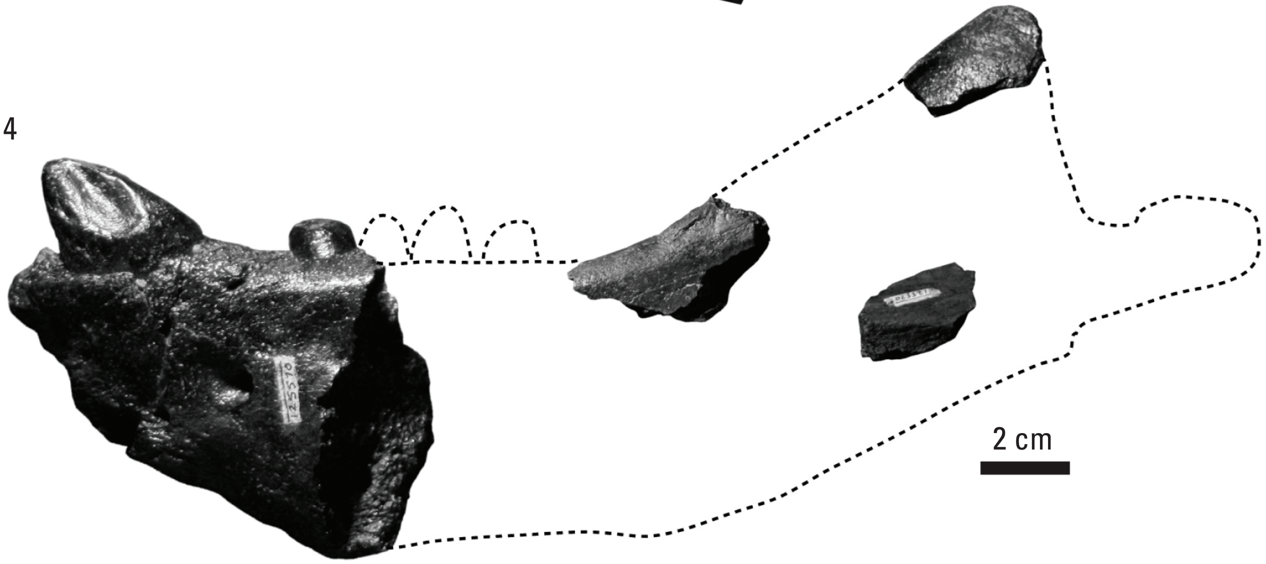

# Plate 9

Walrus (Odobenidae) femur from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. cm, centimeter. (Photographs by Robert Boessenecker, College of Charleston.)

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| **Figures** | **1–3.** | Cf. *Pontolis* sp. indeterminate. Right femur. UCMP 137438. 1, Anterior view; 2, lateral view; 3, posterior view. |

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**Plate 9**

# Plate 10

Dolphin (Odontoceti) teeth and bones from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. cm, centimeter. (Photographs by Robert Boessenecker, College of Charleston.)

**Figures** **1–3.** Odontoceti indeterminate. Tooth. UCMP 125585. 1, Mesial or distal view; 2, lingual view; 3, occlusal view.

**4.** Odontoceti indeterminate. Lumbar vertebra. UCMP 125587. Anterior view.

**5–6.** Odontoceti indeterminate. Atlas vertebra. UCMP 125586. 5, Posterior view; 6, anterior view.

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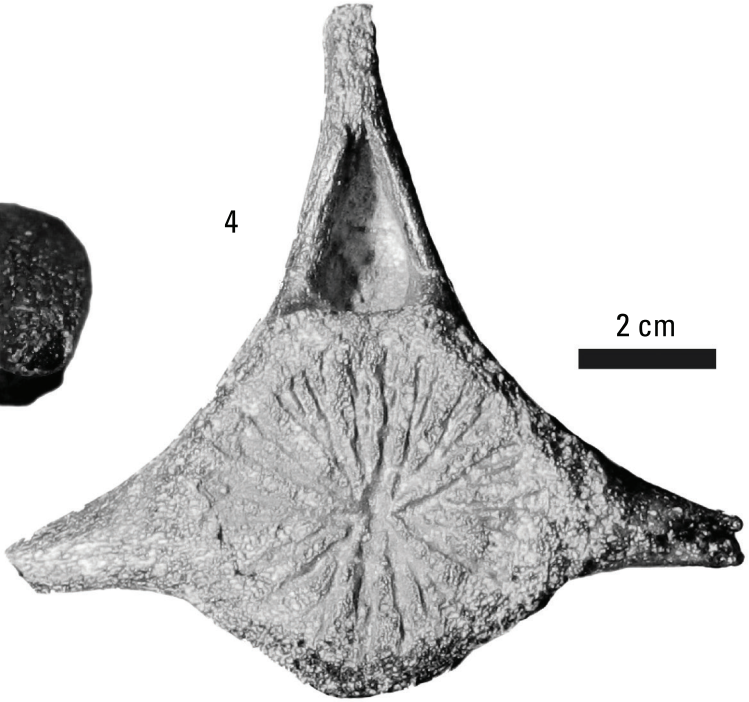

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# Plate 11

Baleen whale (Mysticeti) bones from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. cm, centimeter. (Photographs by Robert Boessenecker, College of Charleston.)

| **Figures** | | |
|---|---|---|
| | **1–4.** | Balaenopteridae indeterminate. UCMP 125833. Partial left dentary. 1, Dorsal view; *2,* lateral view; *3*, *4*, cross section. |
| | **5.** | Mysticeti indeterminate. Phalanx. UCMP 125596. Cervical vertebra. UCMP uncatalogued. |
| | **6.** | Mysticeti indeterminate. Cervical vertebra. UCMP uncatalogued. |
| | **7, 8.** | Herpetocetinae indeterminate. *1*, *2,* Frontal bone. UCMP uncatalogued. |
| | **9.** | Mysticeti indeterminate. Isolated vertebral epiphysis. UCMP 125597. |
| | **10.** | Mysticeti indeterminate. Isolated vertebral epiphysis. UCMP 125598. |

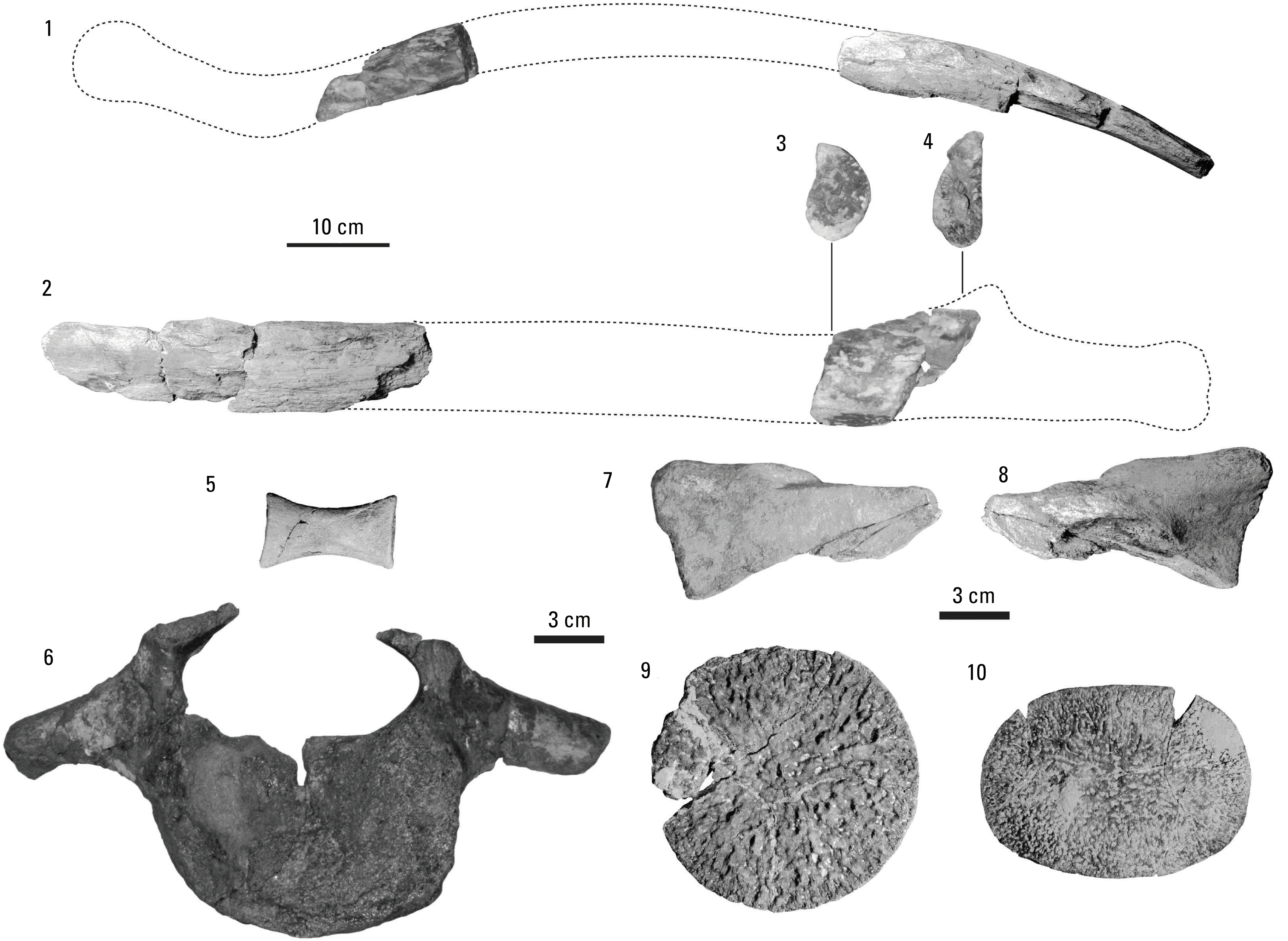


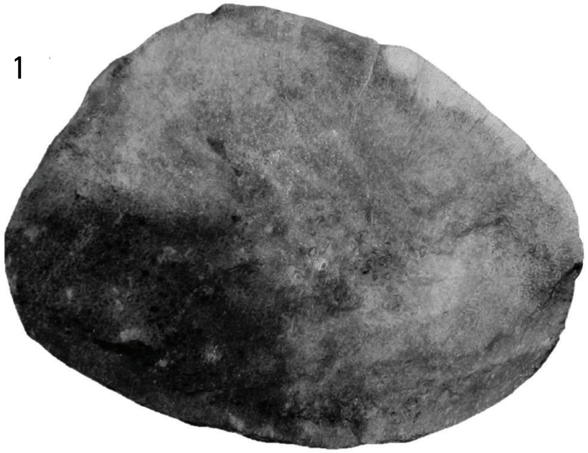
**Plate 11**

# Plate 12

Sea cow (Hydrodamalinae) rib fragments from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. cm, centimeter. (Photographs by Robert Boessenecker, College of Charleston.)

| **Figures** | | |
|---|---|---|
| | **1, 4.** | Hydrodamalinae indeterminate. Rib fragment. UCMP 125594. 1, Cross section; 4, external view. |
| | **5, 6, 2, 3.** | Hydrodamalinae indeterminate. Rib fragment. UCMP 125595. 5, 6, External views; 2, 3, cross-sectional views. |

1



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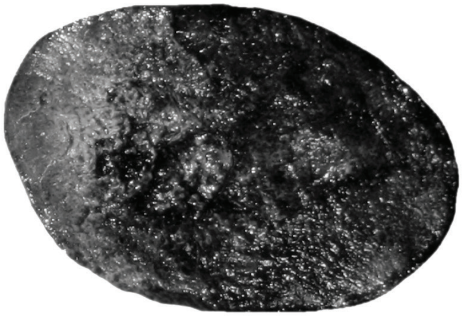

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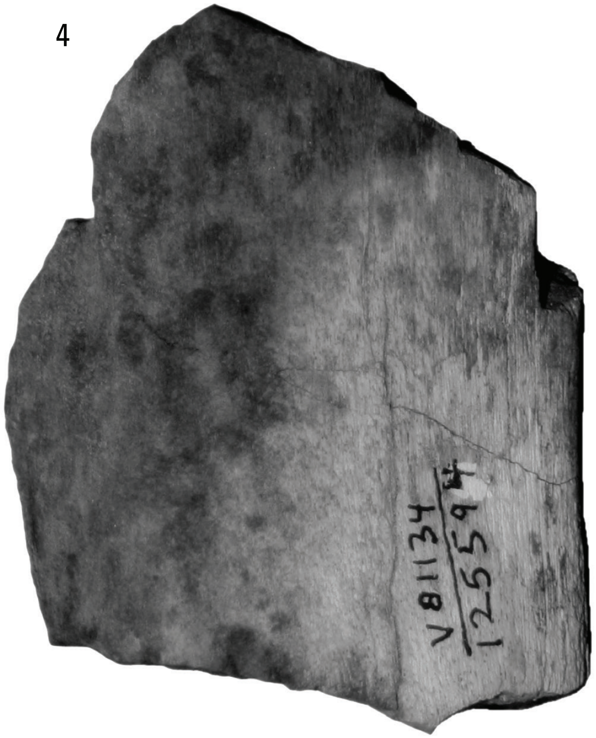


5

6

4 cm

Plate 12

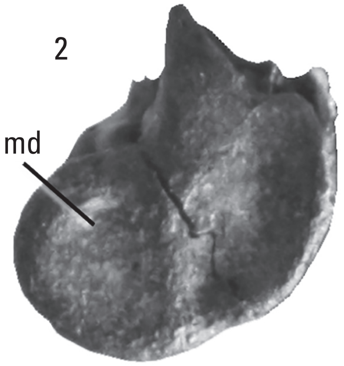
# Plate 13

Fragmented avian fossils from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. dc, deltopectoral crest; bs, musculus brachialis scar; md, medial epicondylar depression; sb, supratindinal bridge; cm, centimeter. (Photographs by N. Adam Smith, Campbell Geology Museum, Clemson University.)

| | | |
|---|---|---|
| **Figures** | **1, 2.** | Aves indeterminate. Distal end of tibiotarsus. UCMP 128208. 1, anterior view; 2, medial view. |
| | **3, 4.** | Pan-Alcidae indeterminate. Ulnar shaft. UCMP 128209. 3, Anterior view; 4, ventral view. |
| | **5, 6.** | Pan-Alcidae indeterminate. Humeral shafts. UCMP 128210. 5, Dorsal view; 6, ventral view. |

1

2



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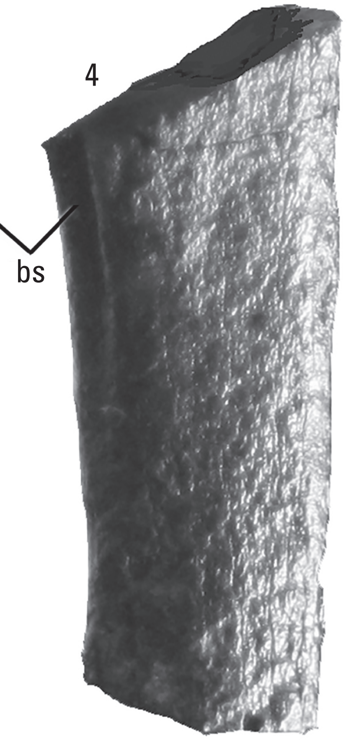
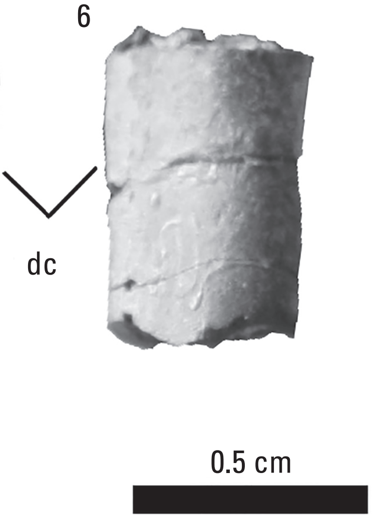


5

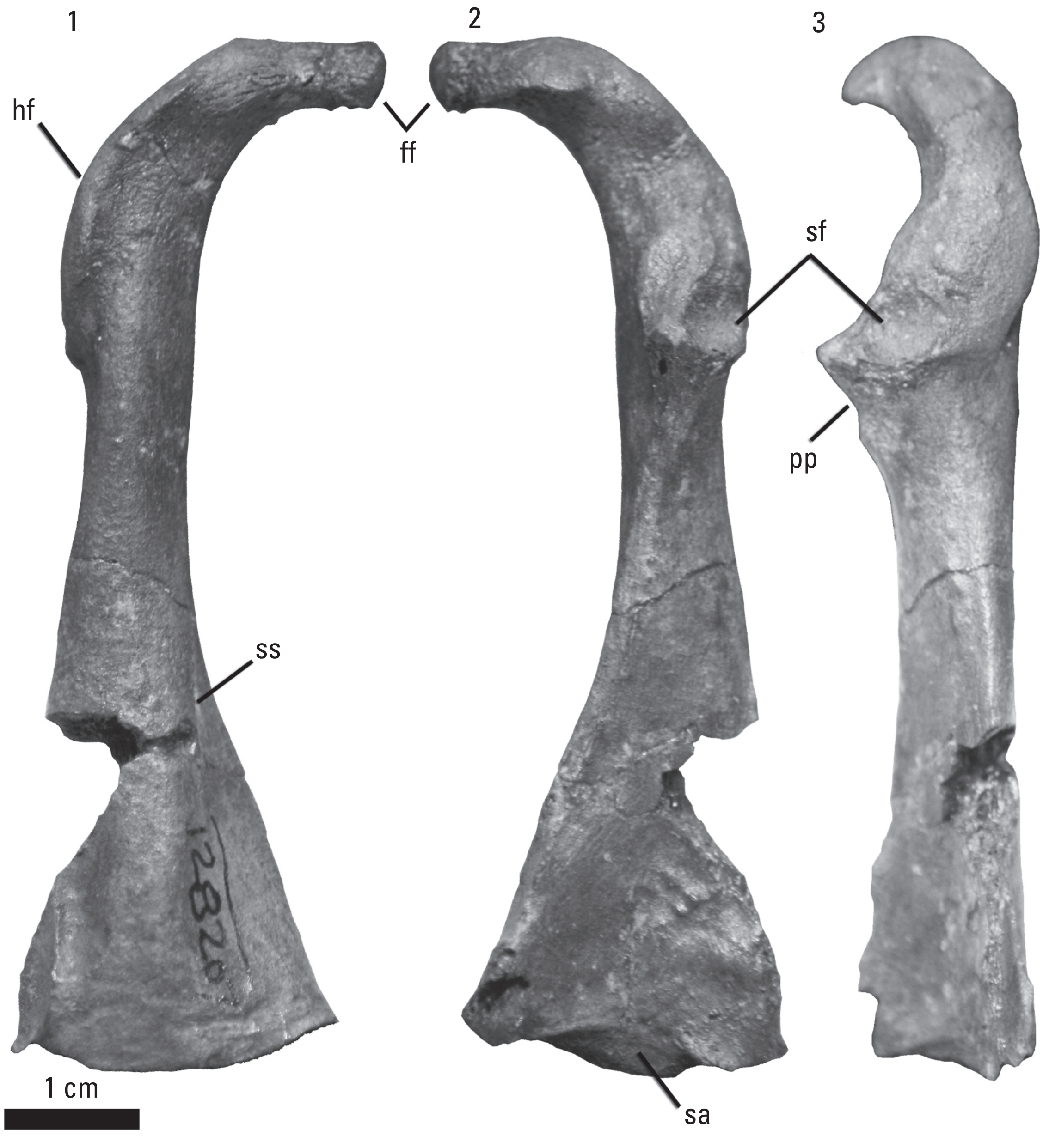
6



# Plate 14

Flightless auk (Mancallinae) fossil from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. hf, humeral facet; ff, furcular facet; pp, procoracoid process; sa, sternal articulation; sf, scapular facet; ss, musculus supracoracoideus scar; cm, centimeter. (Photographs by N. Adam Smith, Campbell Geology Museum, Clemson University.)

| | | |
|---|---|---|
| **Figures** | **1–3.** | Mancallinae indeterminate. Right coracoid. UCMP 128207. 1, Ventral view; 2, dorsal view; 3, lateral view. |

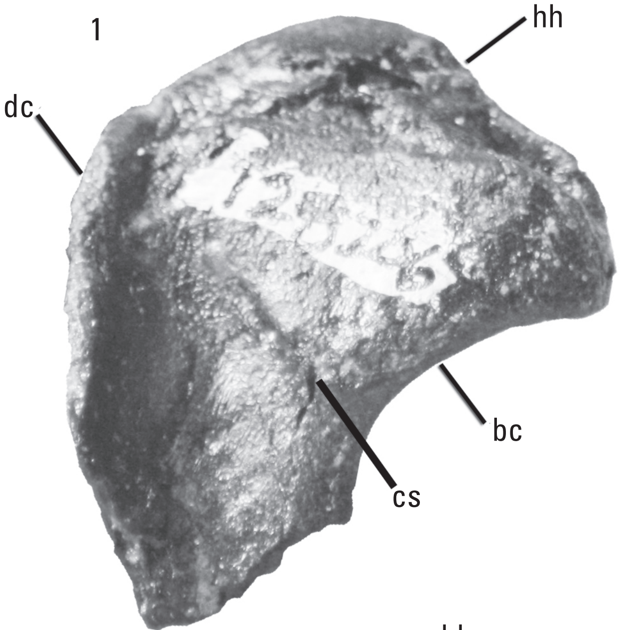

1
2
3
hf
ff
sf
pp
ss
12820
1 cm
sa

# Plate 15

Auk (cf. *Uria brodkorbi* Howard, 1981) fossil from the basal Wilson Grove Formation exposed in Bloomfield Quarry, just north of the town of Bloomfield in Sonoma County, California. bc, bicipital crest; cg, capital groove; cs, coracobrachialis sulcus; dc, deltopectoral crest; hh, humeral head; pf1, primary pneumotricipital fossa; pf2, secondary pneumotricipital fossa; sc, musculus supracoracoideus scar; vt, ventral tubercle; cm, centimeter. (Photographs by N. Adam Smith, Campbell Geology Museum, Clemson University.)

| **Figures** | **1, 2.** | Cf. *Uria brodkorbi* Howard, 1981. Proximal end of right humerus. UCMP 128206. 1, Anterior view; 2, posterior view. |
|---|---|---|

1



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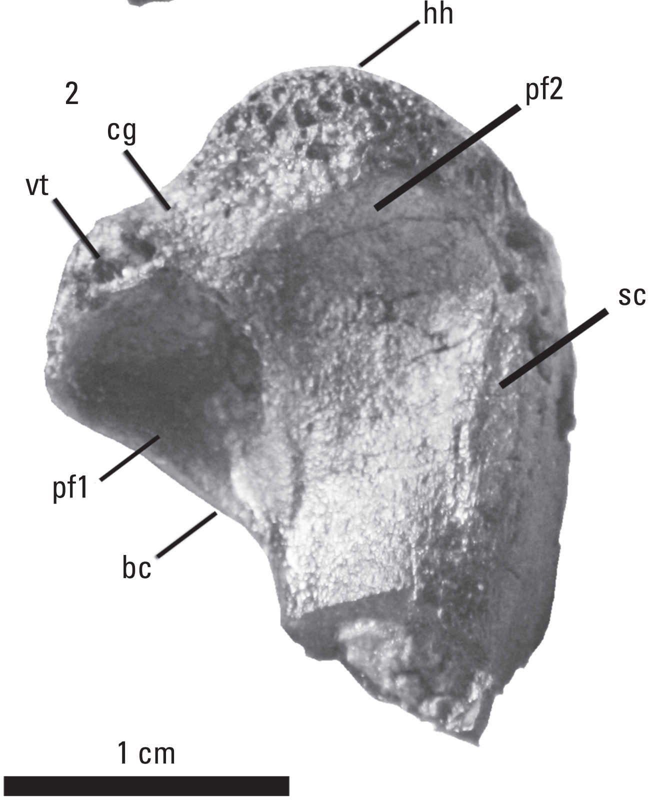

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