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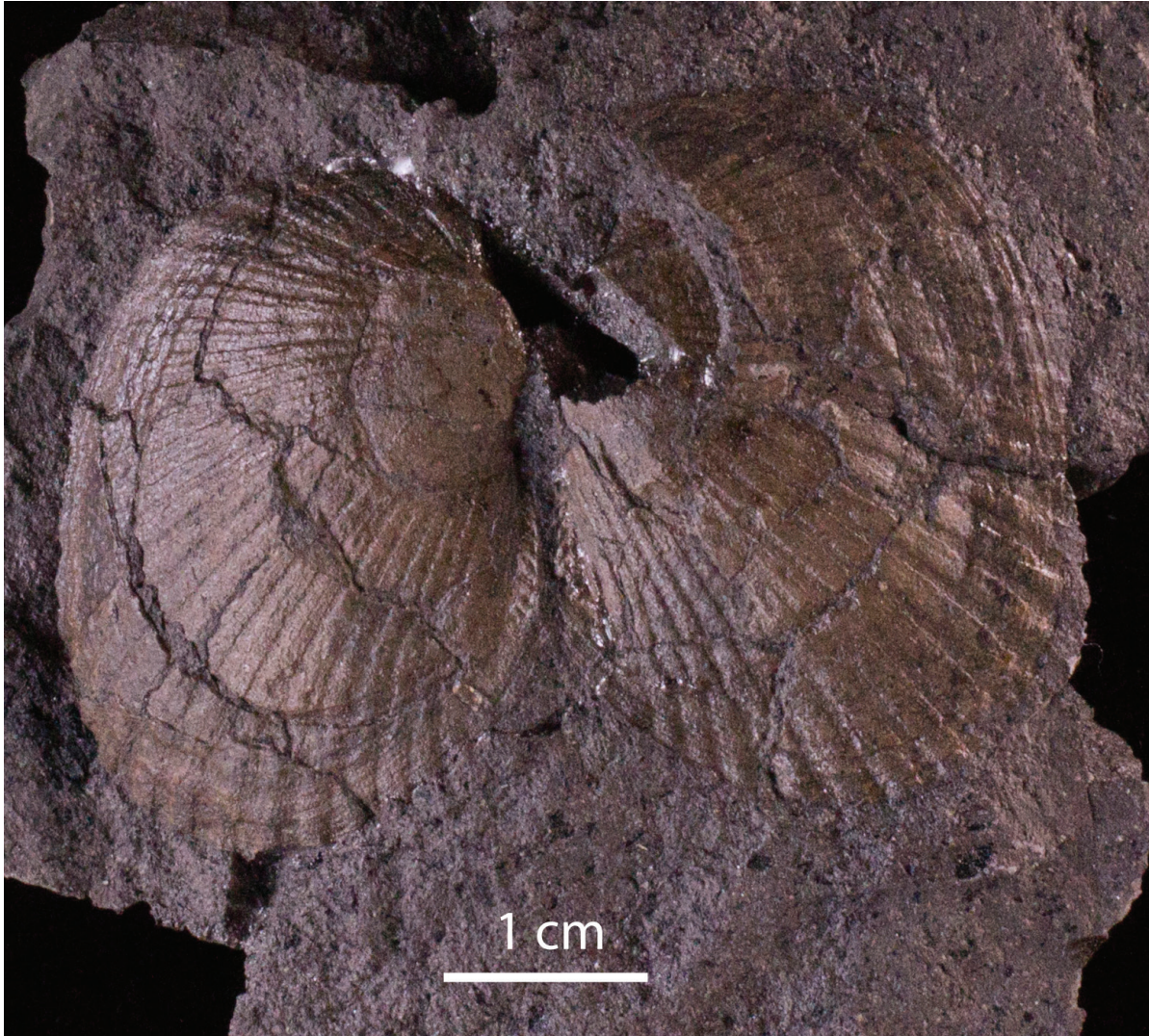
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# *PaleoBios*

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**CHARLES L. POWELL, II, ERICA C. CLITES & ASHLEY W. POUST (2019).  
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**Cover:** Valves of the hypotype specimen, cf. *Anadara osmonti* (UCMP 412699), from the Tsm Caldecott Tunnel fauna.

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# Miocene marine macropaleontology of the fourth bore Caldecott Tunnel excavation, Berkeley Hills, Oakland, California, USA

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Excavation of the new fourth bore of the Caldecott Tunnel in the Berkeley Hills, Oakland, California reveals two faunas attributed to an unnamed glauconitic mudstone (=Sobrante Formation and mapped as Tsm) and the Claremont chert (both of Graymer 2000). The fossil assemblage from the unnamed glauconitic mudstone, referred to here as the Tsm Caldecott Tunnel fauna, consists of 32 taxa: one bryozoan, 22 Mollusca (16 Bivalvia, five Gastropoda and one Scaphopoda), two Arthropoda (one Decapoda and one Maxillopoda), two Echinodermata (one Crinoidae and one Echinoidea), and five Chordata. Mollusks indicate a middle Miocene age based on the co-occurrence of the provisionally identified bivalves *Acila empirensis*, *Anadara osmonti*, *Yoldia submontereyensis*, *Y. supramontereyensis* and the gastropod genera *Bruclarkia* and *Trophoscyon*. This fauna was likely deposited at water depths between 350 and 400 m. Although several taxa from shallower depths are present, these are assumed to have washed in from shallower depths. Only one taxon was found that typically occurs in deeper water. The fauna lived in a methane-rich environment based on the occurrence of vesicomid bivalves and on a vesicomid/lucinid bivalve association shown elsewhere to be associated with cold seep environments. Vertebrates include great numbers of small, pelagic fish and the piscivorous sharks and marine mammals which likely took advantage of them for food. The Tsm Caldecott Tunnel fauna represents the second fauna from a methane-rich environment from the greater San Francisco Bay area and the first attributed to a methane seep environment. In addition, this fauna contains the first reported Cenozoic crinoid from California and the new species *Dentalium (Fissidentalium?) mcganna* (Mollusca: Scaphopoda) is described. The fauna from the Claremont chert includes two bivalve mollusks, one scaphopod, one barnacle and three vertebrates. These taxa are all represented by single specimens. They represent a marine environment likely at continental shelf or slope water depths. The occurrence of the shark *Carcharhinus obscurus* may indicate water temperatures warmer than off the central California coast today.

**Keywords:** paleontology, Mollusca, crinoid, Cetacea, methane seep

## INTRODUCTION

Excavation of the fourth bore of the Caldecott Tunnel (=Broadway Tunnel of Page 1950), Oakland, western Berkeley Hills, California (Fig. 1) has yielded megafossils attributed to both the unnamed glauconitic mudstone (mapped as Tsm by Graymer 2000) (=Sobrante Formation) and Claremont chert (also of Graymer 2000). Specimens are rare and were collected from talus piles moved outside of the tunnel because examination and collection of potentially fossil-bearing rocks inside the tunnel was not allowed due to safety concerns. These

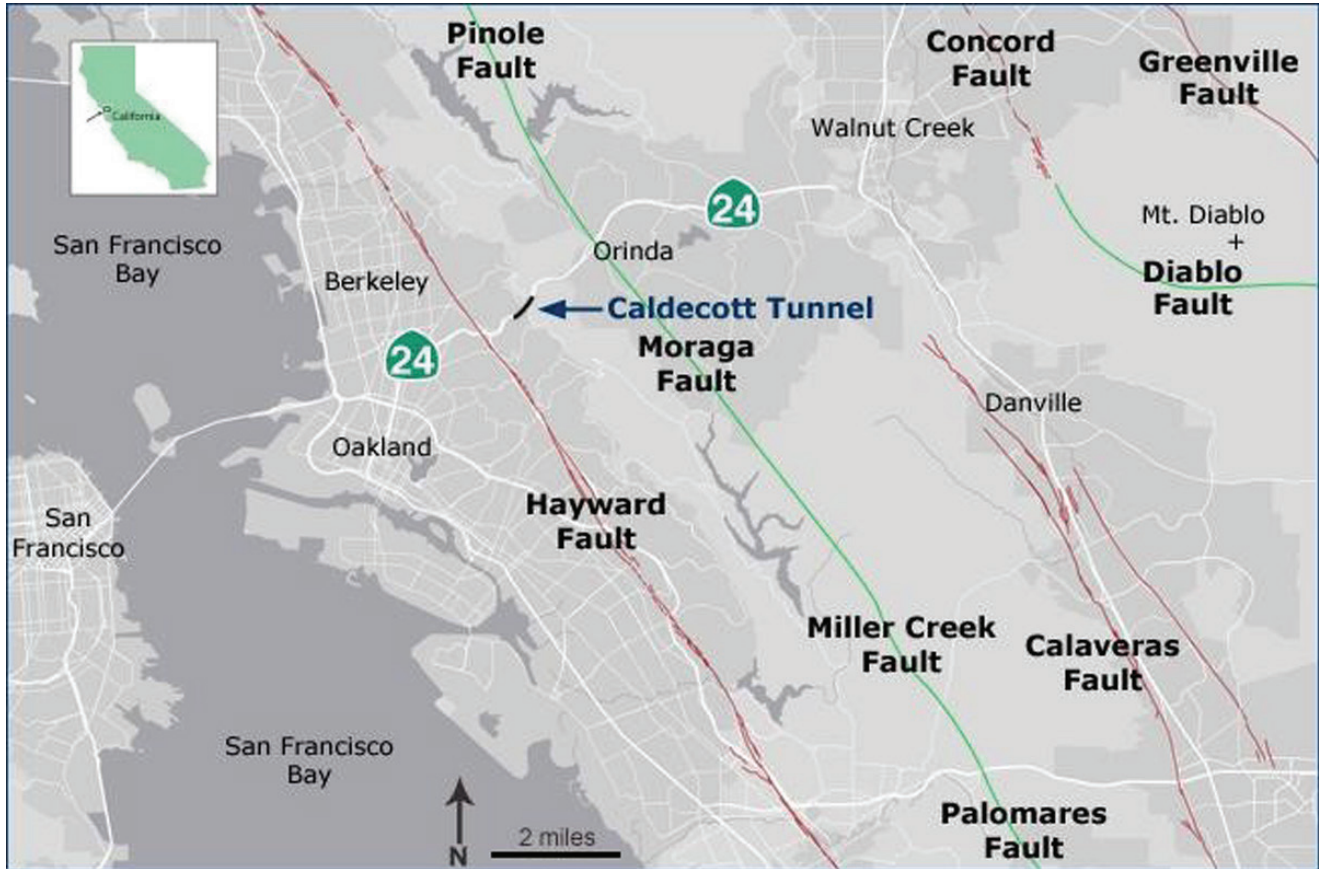
concerns relate to the four California Department of Transportation (Caltrans) workers who died in two cave-ins during construction of boreholes 1 and 2 in the 1930s, due to cutting through fractured and unstable rocks in the tunnels. Although the stratigraphic units these specimens are attributed to were not recorded from inside the tunnel, we know their provenance with a high degree of certainty based on how far the excavator was through the Berkeley Hills and more importantly the lithology associated with the fossils. Medium to fine, light-colored sandstone is attributed to the Claremont chert, while fine to very fine, dark sandstone is attributed to the unnamed glauconitic mudstone. Here we

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**Figure 1.** Index map showing location of the Caldecott Tunnel in the central San Francisco Bay area. Fossils were collected from tunnel talus drilled from the west end of the new, fourth bore along California Highway 24, western Berkeley Hills, California. Major faults of the East Bay (Alameda and Contra Costa counties) are labeled with strike-slip faults in red and thrust faults in green. Map modified from <http://www.ucmp.berkeley.edu/exhibits/caltrans/fourthbore2.php>. Insert shows location of the Berkeley Hills, California.

refer specimens attributed to the Claremont chert as the Claremont Caldecott Tunnel fauna and those attributed to the unnamed glauconitic mudstone to as the Tsm Caldecott Tunnel fauna.

#### GEOLOGIC SETTING

In the East Bay (Alameda and Contra Costa counties) of central California the juxtaposition of Cenozoic fault-bounded rock bodies does not allow for precise lithologic correlations across the area. These groups of rock have been subdivided into blocks or assemblages which have stratigraphic sequences significantly different from those in surrounding rock bodies. This juxtaposition of fault-bounded rocks was first recognized by Jones and Curtis (1991). They were refined by Graymer et al. (1994, 1996), and Graymer (2000) for Alameda and Contra Costa counties, and later supported by McDougall and Block (2014). Rocks in the Berkeley Hills and at the Caldecott Tunnel are referred to Assemblage or Block 1 of Graymer et al.

(1994, 1996) and Graymer (2000).

The geological setting of the Caldecott Tunnel is shown in Fig. 2 with exposures attributed to the unnamed glauconitic mudstone (Tsm=Sobrante Formation), Claremont chert of Graymer (2000) and Orinda Formation going upsection from west to east. Fossils reported here are from the Tsm and the Claremont chert.

Rocks from the Tsm unit are possibly Oligocene(?) and Miocene in age according to Graymer et al. (1994, 1996) and Graymer (2000), and in the Berkeley Hills were formally referred to the Sobrante Formation (Radbruch 1964; <http://www.ucmp.berkeley.edu/exhibits/caltrans/fourthbore2.php>). This unit is equivalent to the Sobrante Formation in other fault blocks (Graymer et al. 1994, 1996). The only paleontological work directly attributed to this fault block is that of McDougall and Block (2014). They report microfossils from Tsm ranging in age from late Oligocene to middle Miocene; however, they considered that their samples may represent more than

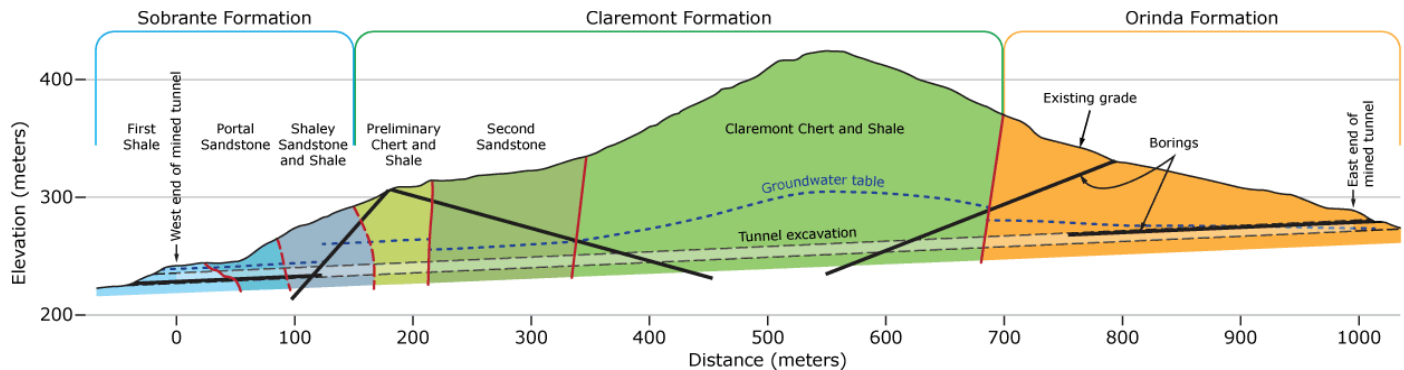


Figure 2. Geologic cross section along the alignment of the Fourth Bore looking north. The solid red lines indicate inactive faults along the contacts between different rock units. The dashed red lines indicate the approximate position of contacts or gradational contacts. Based on Figure 3.1, Caldecott Improvement Project: Geotechnical Baseline Report, prepared by Jacobs Associates, June 2009, from <http://www.ucmp.berkeley.edu/exhibits/caltrans/fourthbore2.php>. Sobrante Formation of Caltrans is unnamed glauconitic mudstone (Tsm) in this report.

one geologic unit. Zemorrian to late Saucesian through Relizian (early to middle Miocene) California benthic foraminiferal Stage assemblages were located in the same area within Block 1 and were assumed to represent the age of the unit.

The only rocks chronostratigraphically equivalent and representing a similar environment with Tsm are exposures referred to the “Temblor” Formation at the construction site for a new dam at Calaveras Reservoir in Alameda and Santa Clara counties. The use of the name Temblor is incorrect in the San Francisco Bay area as these rocks cannot be lithologically correlated with the type Temblor Formation in southern San Luis Obispo County, which is mostly older (Addicott 1973; late Oligocene to middle Miocene). However, these new exposures while lithologically dissimilar to the Tsm unit represent a marine, continental shelf or upper slope environment, possibly with an associated methane rich environment (C.P. personal observation, 2016–17). Other exposures attributed to the Sobrante Formation represent a shallow marine environment.

Lawson (1914) noted that the Sobrante Formation in other fault blocks in the East Bay (Alameda and Contra Costa counties) is, in part, chronostratigraphically equivalent to Tsm and therefore discussed here. The Sobrante Formation was described for exposures along Sobrante Ridge in Contra Costa County which he described as up to 400 ft (120 m) thick and “Somewhat variable in character, but prevailing fine-grained and light-colored, though it shows local ferruginous staining. Some beds are gritty and some flaggy,” and made it the basal formation in the Monterey Group. Clark (1918) restricted the Sobrante Formation to the upper 80 to 100

ft (20–30 m) of Lawson’s Sobrante Sandstone, or beds containing the *Arca* [now *Anadara*] *montereyana* zone, and reassigned it to the lower (and unconformable) part of the original unit to the Oligocene San Lorenzo Formation. The formation was further restricted by Lutz (1951) followed by Hall (1958). Lutz (1951) formally assigned the Sobrante Ridge as the type locality and re-described the Sobrante Formation following Clark (1918) measuring its thickness as about 150 ft (45 m) at the type section. Hall (1958) further restricted the type locality as “along Bear Creek Road summit between Oursan Ridge and Lawson Hill in Contra Costa County” and cited the thickness at about 200 ft (60 m), also removing it from the Monterey Group.

The Claremont Shale was described by Lawson (1914) as part of his Monterey Group consisting of “...in part soft and distinctly shaly or chalky and in places contains a large admixture of fine detrital material, but in the Berkeley Hills it is notably cherty, consisting of beds of hard flinty chert alternating at regular interval with partings of shale,” and having a thickness of between 250 and 1,000 ft (75–300 m). It was named for exposures in Claremont Creek in the Concord quadrangle. Hall (1958) removed it from the Monterey Group which he (and we) consider an inappropriate use of the name. Exposures in the Berkeley Hills (assemblage or block 1) are more chert than shale, therefore Graymer (2000) referred them to his informal Claremont chert.

#### PREVIOUS PALEONTOLOGIC STUDIES

Aside from newspaper and web reports, the only paleontologic publication on the fourth bore of the Caldecott Tunnel is on turtle eggshell fragments from the Orinda

Formation (Poust 2017). During the construction of the third bore, Page (1950) reported marine *Arca* Linnaeus (1758) (likely *Anadara* Gray, 1847) shells identified by Frank Tolman collected from the “Shale, Sandy Shale, and Shaly Sandstone (Miocene)” unit, the Tsm unit of Graymer (2000) in this report. Additional fossils have been reported from the non-marine formations of the tunnel; these are not discussed here and will be published separately.

The Sobrante Formation has an extensive paleontologic pedigree including Lawson (1914), Clark (1918), Bramlette (1946), Lutz (1951), Weaver (1953), Robinson (1956), Hall (1958), Rensberger (1969) and as previously mentioned McDougall and Block (2014). In the early part of the 20th century Lawson (1914) listed a fauna of 46 taxa consisting of one coral, 43 mollusks, one arthropod and one vertebrate from his Sobrante Formation. From the data presented it is impossible to tell which taxa were collected from the Sobrante Formation (of Clark, 1918) or those that should be referred to the underlying Oligocene San Ramon Formation of Clark (1918) (see discussion under Geologic Setting above). Also, by modern standards, the names used by Lawson are a mixture of outdated Oligocene to Holocene taxonomic names. Therefore, Lawson’s (1914) work does not add any details to the paleontology of the Sobrante Formation. Clark (1918) removed the San Ramon Sandstone (= *Agasoma gravidum* fauna) from the Sobrante Sandstone of Lawson (1914) on the basis of an unconformity in the rocks previously referred to the Sobrante Formation restricting the Sobrante Formation to the upper part of Lawson’s (1914) Sobrante Sandstone (= *Arca montereyana* fauna). The most important species from the Sobrante Formation according to Clark (1918) include the bivalves *Anadara montereyana* (Osmond, 1905) (as *Arca montereyana*), *Crassostrea?* sp. (as *Ostrea* n. sp. aff. *O. titan* Conrad, 1853), *Chione* cf. *Ch. temblorensis* (Anderson, 1905), *Katherinella angustifrons* (? as *Marcia oregonensis* Weaver, 1912), *Pacipecten andersoni* (as *Pecten andersoni* Arnold, 1906), *Pandora scapha* Gabb, 1866, *Pseudocardium densata* (as *Mulinia densata* Conrad, 1856), *Mactromeris catiliformis* (as *Spisula catiliformis* Conrad, 1867), *Vertipecten?* sp. (as *Pecten* cf. *Pe. nevadensis* Conrad, 1855), *Macoma arctata* (as *Tellina arctata* Conrad, 1849), *Mactromeris albaria selbyensis* (as *Spisula selbyensis* Packard, 1916), *Thracia trapezoides* Conrad, 1849, and the gastropods *Bruclarkia barkeriana* (?) (as *Agasoma barkernianum* Cooper, 1894; *Br. barkeriana* is a lower Miocene species according to Vendetti [2009]), *Crepidula princeps* Conrad, 1855, *Neverita reclusiana* (Deshayes, 1839) (?) (as *Natica reclusiana*

Petit; Deshayes cited the author as Petit for this species in error), and *Trophosycon kerniana* (Cooper, 1894) (as *Fusinus stanfordensis* Arnold, 1908). Bramlette (1946) mentions silicified diatoms and foraminifers from chert and cherty-shale in Claremont Canyon, Alameda County. These specimens were illustrated (Bramlette 1946, pl. 8, f. C, D; pl. 9, f. B, C) but no further discussion is presented.

In the latter part of the 20th century Lutz (1951) refined the Sobrante Sandstone designating a type section along Bear Creek Road in the Pacheco Syncline, not along Sobrante Ridge as implied but not designated by Lawson (1914). He reported a fauna of 33 molluscan taxa including 24 bivalves and nine gastropods. Weaver (1953) also discussed exposures in the Pacheco Syncline reporting a fauna of 20 molluscan taxa, 14 bivalves and six gastropods, plus one arthropod. Later Hall (1958) reported eight foraminifers and two mollusks from the Pleasanton Quadrangle near the Calaveras Reservoir, Alameda and Santa Clara counties. Robinson (1956) discussed the Sobrante Formation in the Hayward 15’ Quadrangle south of the Berkeley Hills reporting a molluscan fauna identified by Wendell P. Woodring and Ellen J. Trumbull (later E. J. Moore) (written communication, August 31, 1951) composed of the gastropods *Boreotrophon?* sp., *Br. barkeriana*, naticid indeterminate (as *Neverita?* sp.), *Nucella* sp., *Ocenebrina?* sp. (as *Tritonalia?* sp.), the bivalves *Anadara osmonti* (Dall, 1909), *Anadara* spp., *Axinopsis?* sp., *Compsomyax?* sp., *Lucinoma* cf. *L. acutilineata* (Conrad, 1849) (possibly one of our indeterminate Lucinids), *Patinopecten* cf. *Pa. propatulus* (Conrad, 1849), *Nemocardium* cf. *N. centifilosum* (Carpenter, 1864) (as *Pratulium?* cf. *Pr. centifilosum*), *Simomactra* cf. *S. falcata* (Gould, 1850) (as *Spisula* cf. *Sp. falcata*), *Yoldia?* sp. and the scaphopod *Dentalium* sp.; also reported is the benthic foraminiferal genus *Amphistegina* d’Orbigny, 1826. Of all the mollusk faunas reported from the Sobrante Sandstone the one by Robinson (1956) appears most similar having more taxa in common with the Tsm Caldecott Tunnel fauna. In the Pleasanton Quadrangle east-southeast of the Caldecott Tunnel Hall (1958) reports the bivalve *Patinopecten haywardensis* Lutz, 1951 and indeterminate specimens of the bivalves *Lima Bruguière, 1797* and *Mytilus*. None of these taxa are independently age diagnostic and all are environmentally wide ranging indicate a marine environment presumed as shelf or upper slope water depths (0–500 m). Lastly, at least two cetaceans, remains of a shark and a sirenian were collected in 1939 by H.F. Goeriz. From this collection a nearly complete skull was prepared and later described by Rensberger (1969) as a new genus and species of porpoise, *Kampholophos*

*serrulus*. Although these specimens were collected as float in Alameda Creek near Sunol, Alameda County, biostratigraphic relationships indicate that they came from nearby exposures attributed to the Claremont Shale. In addition to the vertebrates, Rensberger (1969) also reported the gastropod genus *Thais* (now *Nucella*) from beds stratigraphically underlying the vertebrates. We have been unable to locate Rensberger's (1969) *Nucella*.

The only paper dealing with the Claremont chert in the vicinity of the Caldecott Tunnel is McDougall and Block (2014). They reported that the Claremont chert samples were either barren or not age diagnostic, with the exception of sample USGS Mf806. USGS Mf806 contains *Siphogenerina hughesi* (Cushman 1925), which restricts that sample to the early Relizian California benthic foraminiferal Stage (middle Miocene).

#### MATERIALS AND METHODS

Samples were collected in conjunction with the paleontological mitigation plan prepared by James R. Allen for the California Division of Transportation's Caldecott 4th bore project. The specimens examined here were collected by various paleontological monitors from talus piles moved outside of the 4th bore of the Caldecott Tunnel for monitors safety. After collection the specimens were deposited at UCMP where they were integrated into the museum collections. One of us (CP) was asked to examine specimens early on by James Allen, who recognized them as Vesicomids and that these faunas might be from a cold seep environment.

Detailed descriptions of the Caldecott Tunnel collections are presented in Appendix 1.

**Institutional abbreviations**—UCMP, University of California, Berkeley, Museum of Paleontology; IP, invertebrate paleontology; V, vertebrate paleontology.

#### THE Tsm CALDECOTT TUNNEL FAUNA

The Tsm Caldecott Tunnel fauna consists of 32 taxa, one Bryozoan, 22 mollusks (16 Bivalvia, five Gastropoda and one Scaphopoda), two Arthropoda (one Decapoda and one Maxillopoda), two Echinodermata (one Crinoidae and one Echinoidea), and five Chordata (Appendix 2). Various trace fossils, microfossils, and plant fossils were also recovered but are not discussed here. Though most of the fauna is represented by one or two specimens, there are at least 18 specimens of *Dentalium*, 40 *Acila*, 59 *Yoldia* and 75 *Anadara*.

#### SYSTEMATIC PALEONTOLOGY

BRYOZOA EHRENBERG, 1831  
GYMNOLAEMATA ALLMAN, 1856  
CHEILOSTOMATA(?) BUSK, 1852

FIG. 3

UCMP 412845 is a bryozoan that was tentatively identified as belonging to the order Cheilostomata by Mark A. Wilson (personal communication, 8/15/2016). Further identification is not possible without thin-sectioning. Cheilostomata is a marine order and ranges in age from Late Jurassic to Holocene.

MOLLUSCA LINNAEUS, 1758  
BIVALVIA LINNAEUS, 1758  
SOLEMYIDA DALL, 1889  
SOLEMYIDAE J.E. GRAY, 1840  
ACHARAX DALL, 1908  
ACHARAX JOHNSONI DALL, 1891

FIG. 4

The single, double-valved specimen, UCMP 410421, compares well with *Acharax johnsoni*. This specimen has numerous, shallow, radial ribs and interspaces, which occur from the anterior end past the middle of the shell, characteristics shared by *Ach. johnsoni*. The poor preservation and single specimen make precise identification impossible. Fossil *Ach. johnsoni* are rare in the eastern Pacific occurring only in the Pliocene (Woodring 1938; Roth, 1979) from northern and southern California, while in the western Pacific it has been reported from the Eocene to Pliocene (O'Hara and Nemoto 1988, Nobuhara and Tanaka 1993, Kafanov and Ogasawara 2003, 2004). Coan et al. (2000) list the modern range of *Ach. johnsoni* as from Sitka, Alaska, south through to the Isla de Afuera, Peru in water depths from 400 to 4,100 m.

The family Solemyidae favors reduced oxygen and high organic content environments, and harbors chemototrophic bacteria in their gill filaments to obtain nutrition. In the northeastern Pacific they are typically found in basins on the continental shelf and nearshore where there is an accumulation of plant debris (Coan et al. 2000). It is represented by two genera off the coast of California and the northeast Pacific, *Acharax* and *Solemya*, with three modern species and three fossil species. Modern species include *Solemya* (*So.*) *reidi* Bernard, 1980 which occurs from Vancouver Island, British Columbia, Canada, south to San Diego, California at water depths between 40 and 600 m (Coan et al. 2000), *So.* (*Petrasma*) *valvulus* (Carpenter, 1864) which occurs from Monterey Bay, California south to Jalisco, Mexico, including the



**Figure 3.** Cheilostomata? bryozoan. Tsm Caldecott Tunnel fauna. Hypotype from UCMP locality IP13003, UCMP 412845.



**Figure 4.** *Acharax* cf. *Ach. johnsoni*. Tsm Caldecott Tunnel fauna. Hypotype from UCMP locality IP13003, UCMP 410421.

Golfo de California at water depths between the intertidal zone and 360 m, and *Ach. johnsoni* occurring from Sitka, Alaska through the Golfo de California south to off Lima, Peru at water depths between 100 and 5,379 m (Coan and Valentich-Scott 2012). In addition to the modern species there are three fossil species in the Pacific northwest: *Ach. dalli* (Clark, 1925) from the lower Miocene of Washington (Addicott 1976), *Ach. ventricosa* (Conrad 1849) from the middle Miocene to lower Pleistocene of Washington south to northern California (Moore 1963, Addicott 1976), and *Ach. willapaensis* (Weaver, 1942) that occurs from the upper Eocene to lower Miocene of Washington (Weaver 1942).

NUCULIDA DALL, 1889  
 NUCULIDAE J.E. GRAY, 1824  
 ACILA H. & A. ADAMS, 1858

FIG. 5

Figure 5 illustrates what appears to be a juvenile specimen of *Acila*. Although parts of the specimen are



**Figure 5.** *Acila* cf. *Aci. empirensis* Howe, left valve. Tsm Caldecott Tunnel fauna. Hypotype from UCMP locality IP13003, UCMP 410923.



covered by sediment, its valve shape is unlike that of a mature *Acila*. Still, the size and sculpture match well with *Acil. empirensis* Howe, 1922 and it is provisionally (cf.) identified as that species. Neontologists have synonymized *Acil. empirensis* under *Acil. castrensis* (Bernard 1983, Valentich-Scott 1998, Coan et al. 2000), however molluscan paleontologists have kept the two species separate (Roth 1979, Moore 1983). Here we follow the paleontologists view until a detailed study of modern and fossil specimens can be performed. *Acila empirensis* has only been reported from the Wildcat Group in California (Ogle 1953) although both Faustman (1964) and Roth (1979) dispute this, citing *Acila* from the Wildcat Group as *Acil. castrensis*. However, *Acil. empirensis* has been found throughout the Pacific northwest. In Alaska it occurs in the middle Miocene Bear Lake Formation (Marincovich and Powell 1989, Detterman et al. 1996), the middle Miocene Tachilni Formation (Marincovich and Powell 1989, Detterman et al. 1996) and the Pliocene Milky River Formation (Blodgett et al. 2008). In Canada it is known from the Miocene to possibly Pliocene Skonun Formation (White et al. 1994). In Washington State it is known from the Montesano Formation (Schenck 1936) and the Empire Formation of Oregon (Howe 1922, Schenck 1936). The above occurrences indicate a middle Miocene to early Pliocene age for *Acil. empirensis*.

YOLDIIDAE HABE, 1977

YOLDIA MÖLLER, 1842

FIGS. 6, 7

Specimens are here referred to three taxa of the Yoldiidae. The largest specimens have a centrally-placed umbo and strong co-marginal sculpture, characters shared with the taxon *Yoldia* cf. *Y. submontereyensis* Arnold, 1908 (Figs. 6, 7). *Yoldia submontereyensis* has been previously

reported from the upper part of the Temblor Formation (Loel and Corey 1932) and unnamed Miocene sandstone near Stanford University of Dibblee (1966). The second is typically smaller with the umbo placed slightly anterior of the middle of the shell, a more inflated anterior-dorsal margin, coarser co-marginal sculpture, and a truncated and inclined posterior end. Specimens with these characters are here identified as *Yoldia* cf. *Y. supramontereyensis* Arnold, 1908 (Fig. 8). This species occurs in California from the Hambre Sandstone (Hall 1958), "Monterey" Formation (Lutz 1951, Addicott et al. 1978), Oursan and San Ramon sandstones (Weaver 1953), Sobrante Sandstone (Lutz 1951), Temblor Formation (Stewart 1946), and unnamed sandstone near Stanford University of Dibblee (1966). The last species is only represented by a single partially covered specimen that cannot be identified to either genus or species with confidence and is referred here to *Yoldia?* sp. indeterminate (Fig. 9). It is easily distinguished from the previous two species by its much finer and more numerous co-marginal sculpture.

ARCOIDA STOLICZKA, 1871

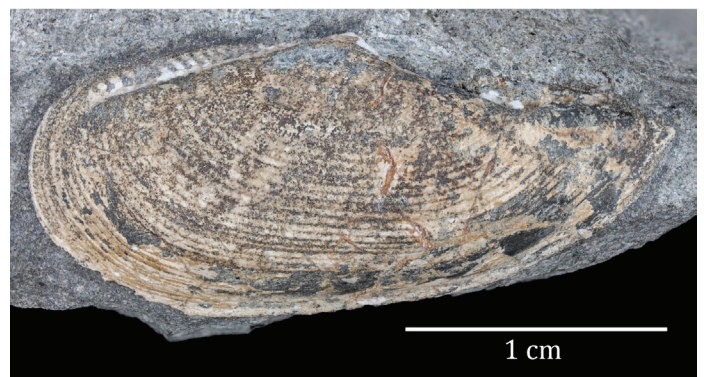
ARCIDAE DE LAMARCK, 1809

ANADARA GRAY, 1847

Neogene West American *Anadara* are differentiated based on the shape of the shell and the number of radial ribs, which sometimes show a medial sulcation. The best preserved Caldecott Tunnel specimens have around 31 radial ribs that are mostly not medially sulcate, although a few ribs appear to be slightly sulcate. This matches best with *An. osmonti* (Dall, 1909) (Fig. 10), which according to Reinhart (1943) has between 28 and 31 radial ribs that appear to not be bifurcated but on well preserved portions of shell are shown to be weakly bifurcated. Therefore, the Tsm Caldecott Tunnel fauna specimens are



**Figure 6.** *Yoldia* cf. *Y. submontereyensis* from the Tsm Caldecott Tunnel fauna, left valve. Hypotype from UCMP locality IP13008, UCMP 218804.



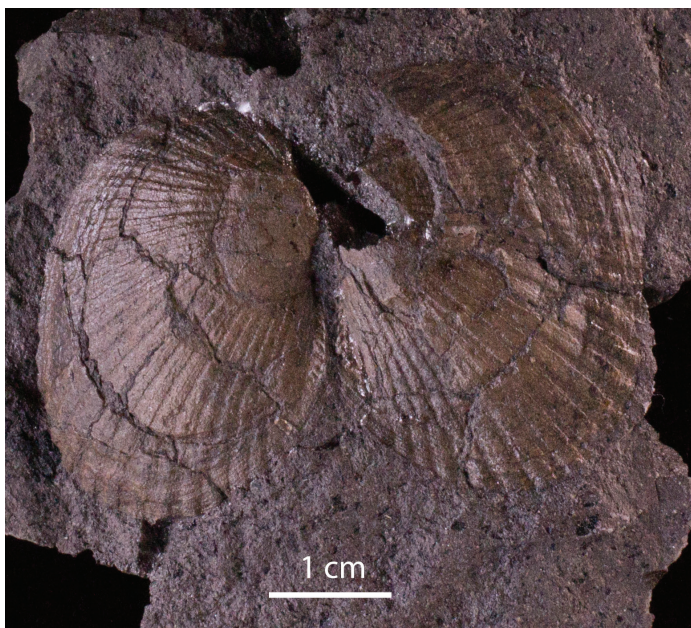
**Figure 7.** *Yoldia* cf. *Y. submontereyensis* from the Tsm Caldecott Tunnel fauna, right valve. Hypotype from UCMP locality IP13008, UCMP 218771.



**Figure 8.** *Yoldia* cf. *Y. supramonterensis* from the Tsm Caldecott Tunnel fauna, left valve. Hypotype from UCMP locality IP13003, UCMP 218714.



**Figure 9.** *Yoldia?* sp. indeterminate from the Tsm Caldecott Tunnel fauna, right valve. Hypotype from UCMP locality IP13003, UCMP 218702.



**Figure 10.** Valves of *Anadara* cf. *An. osmonti* from the Tsm Caldecott Tunnel fauna. Hypotype from UCMP locality IP13003, UCMP 412699.



**Figure 11.** Indeterminate *Lima?* from the Tsm Caldecott Tunnel fauna, right valve. Hypotype from UCMP locality IP13001, UCMP 412479.

provisionally referred to this species. *Anadara osmonti*, according to Moore (1983), occurs possibly from Alaska to southern California and from formations that appear to be restricted to the middle Miocene.

LIMOIDA WALLER, 1978  
LIMIDAE RAFINESQUE, 1815  
LIMA BRUGUIÉRE, 1797

FIG. 11

A single cast in sediment that measures about 8 mm high is questionably referred to the genus *Lima* based on its overall shape and broad, square radial ribs which curve toward the posterior end. The mold recovered is small with 13 broad, ribs slightly curving to the posterior

end, that are square-sided with interspaces that are slightly less wide than the corresponding rib. The overall shape and sculpture is indicative of the genus *Lima*, which is known in California from only two species: *Lima* cf. *Li. caribaea* (d'Orbigny, 1853) from the late Miocene part of the "Imperial" Formation north of Palm Springs, Riverside County (Powell 1986) and *Li. vedderi* Moore, 1977, which occurs in the Monterey Formation (Moore 1977), the Santa Margarita Sandstone (Addicott et al. 1978), and unnamed Miocene strata on San Clemente Island, Los Angeles County, southern California (Moore 1977). It is easily distinguished from both these species by lacking sculpture on the ribs and its small size. *Miodontiscus prolongatus* Carpenter, 1864 (Carditidae de Lamarck,

1809) somewhat resembles the cast, however; the shell shape is slightly different and *Mi. prograongatus* does not have as many ribs as the Caldecott Tunnel specimen.

MYTILOIDA DE FÉRUSSAC, 1822  
MYTILIDAE RAFINESQUE, 1815  
*CRENELLA* BROWN, 1827

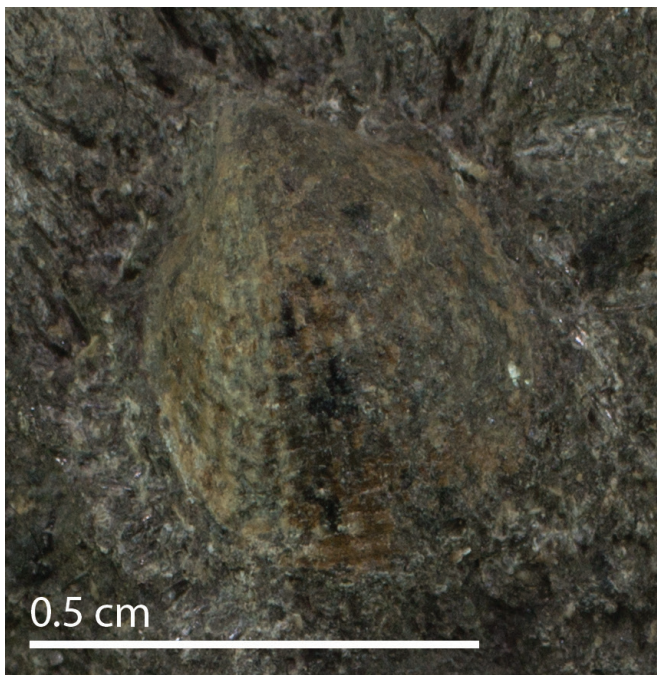
FIG. 12

A single small cast is questionably identified as the genus *Crenella* based on its shape, size, and radial sculpture indicative of the genus. No extinct species of this genus have been reported from California and the oldest recorded fossil occurrence of the modern species is from the Pliocene (Moore 1983). This specimen likely represents a new species but without better specimens it does not warrant naming at this time.

PROPEAMUSSIIDAE ABBOTT, 1954

FIG. 13

Two partial, mostly decorticated, possibly right, valves of an indeterminate Propeamussiidae are represented in the Tsm Caldecott Tunnel fauna. On first glance they appear to have interior radial ribs as in the genus *Propeamussium*; however, they do not originate at the umbo and therefore are interpreted as cracks formed in the shell during or after deposition. The family is distributed



**Figure 12.** Indeterminate *Crenella*? from the Tsm Caldecott Tunnel fauna, right valve(?). Hypotype from UCMP locality IP13003, UCMP 218709.

worldwide and according to Waller (1971) occurs in water depths from 275 to 2,740 m. It ranges in age from the Jurassic to Holocene (Moore 1984).

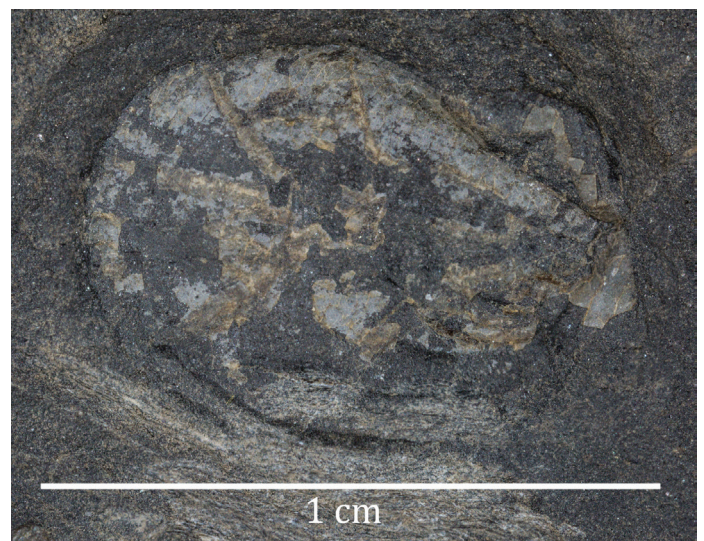
VENEROIDA H. & A. ADAMS, 1856  
LUCINIDAE FLEMING, 1828

We identify specimens attributable to two lucinid taxa in the Tsm Caldecott Tunnel fauna. The first, represented by specimen, UCMP 218741, has a diamond shape outline and sculpture most similar to *Lucinoma* but may represent a new genus (Fig. 13) with a well-defined posterior sulcus instead of weak to sometimes nearly absent sulcus as in *L. acutilineata*, *L. annulata*, and *L. hannibali* (Clark, 1925). The second lucinid-type specimens may also represent another new genus that is similar in outline to the genus *Tehamatea* (Myrteinae Chavan, 1969) (Fig. 14) but sculptured like the previous undetermined taxon with fine co-marginal lirae.

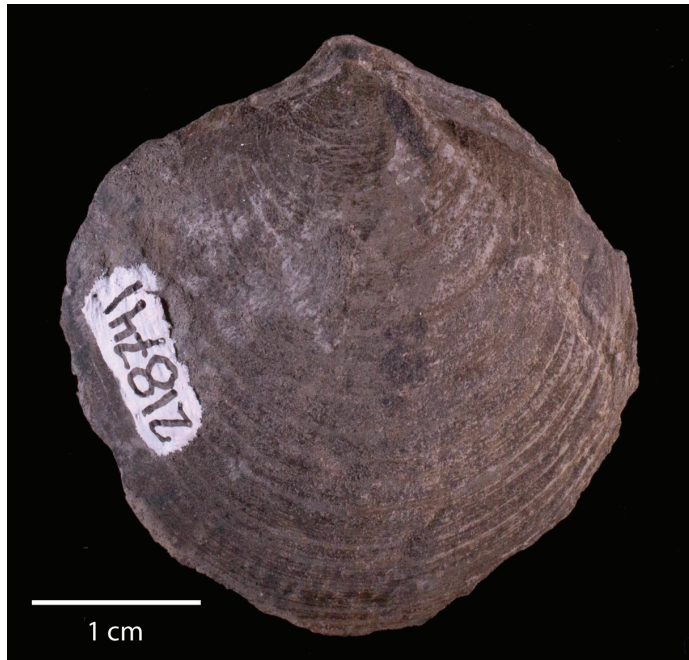
CODAKIINAE KOROBOKOV, 1954

FIG. 14

UCMP 218741 is a single specimen that may represent a new genus and species within the subfamily Codaikiinae. The combination of its diamond-shaped outline with slightly inflated valve, and a strong posterior radial sulcus that extends to the posterior ventral margin serve to separate this species from West Coast species of *Lucinoma*, although these features could be an artifact of preservation. Sculpture consists of numerous, slightly



**Figure 13.** Indeterminate Propeamussiidae from the Tsm Caldecott Tunnel fauna, possibly right valve. Hypotype from UCMP locality IP13004, UCMP 412704.



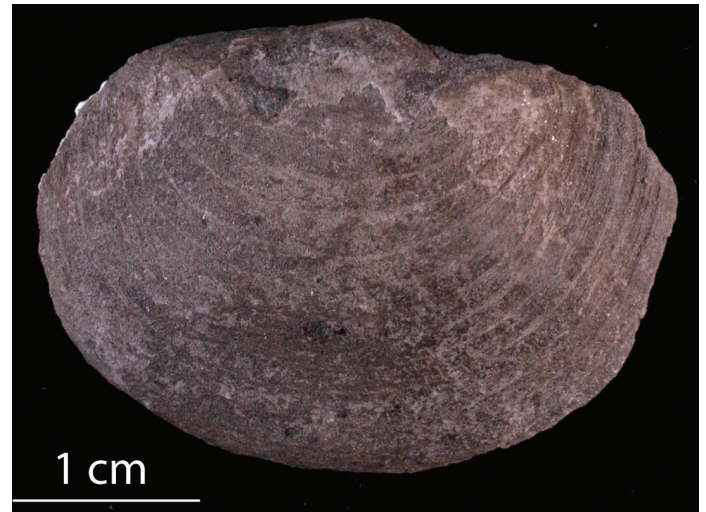
**Figure 14.** aff. *Lucinoma?* n. sp. from the Tsm Caldecott Tunnel fauna, left valve. Hypotype from UCMP locality IP13005, UCMP 218741.

irregularly-spaced, co-marginal lamellae, with wide to moderate interspaces. The lunule, ligament, and escutcheon were not observed. This species appears most similar to the western Atlantic species *L. atlantis* (McLean, 1936), *L. "atlantis"* of Taylor and Glover (2017, figs. 39–43) and *L. sp.* of Taylor and Glover (2017, fig. 51–52) differing from them in being taller than wide and in having a pointed ventral margin. This species is also somewhat similar to *Scabrilucina* (Taylor and Glover 2013), a modern genus from the southwest Pacific but lacks an anterior sulcus and the ventral margin is angular not rounded. It is here referred to aff. *Lucinoma* until additional specimens can be found and described in detail.

MYRTEINAE CHAVAN, 1969(?)

FIG. 15

The second lucinid in the Tsm Caldecott Tunnel fauna is similar to the previous one in having widely-spaced co-marginal lamellae, but differs in its low, broad umbo, wide, oval shape, and weak anterior dorsal sulcus. This lucinid is very similar in shape to genus *Tehamatea* recently described by Kiel (2013). However, *Tehamatea* has a more prominent umbo and co-marginal lamellae only on its early shell after which the sculpture becomes irregular co-marginal growth lines. Also *Tehamatea* is only known from the Late Jurassic to Early Cretaceous of central California (Kiel 2013). Interestingly, *Tehamatea*



**Figure 15.** aff. *Tehamatea* n. sp., from the Tsm Caldecott Tunnel fauna, right valve. Hypotype from UCMP locality IP13001, UCMP 410562.

is also found in ancient methane seeps. We assign this species to aff. *Tehamatea* until additional specimens can be found and studied in depth.

CARDITOIDA DE LAMARCK, 1809

CARDITIDAE FLEMING, 1828

FIG. 16

One indeterminate *Cyclocardia* has been recovered from the Caldecott Tunnel. It shows the exterior of a right(?) valve that has been crushed but appears to show greater than 16 broadly rounded radial ribs with slightly narrower shallow interspaces and appears to be crossed by fine co-marginal growth lines. This specimen is about 8.7 mm long and 7.5 mm high.

Only two *Cyclocardia* have been reported from the Miocene of California, *Cy. monilicosta* (Gabb, 1861) [= *Cy. occidentalis* (Conrad, 1855)] and *Cy. californica* (Dall, 1903). According to its original description *Cy. monilicosta* was described from the Santa Barbara area and questionably referred to the Miocene. The Santa Barbara Formation, from which *Cy. monilicosta* was likely collected, is middle Pleistocene in age (Minor et al. 2002, 2009), although in the past the Santa Barbara Formation has been referred to rocks of Miocene to Pleistocene age (Gabb 1861, Arnold and Arnold 1902, Moore 1983). Powell et al. (2010, p. 23, footnote) noted a single collection of Pliocene age from the Santa Barbara area and Minor et al. (2002, 2009) reported two geologic units of questionable Pliocene age in the sea cliffs below More Mesa just south of UC Santa Barbara at Goleta, so Pliocene but no Miocene geologic units occur in the area. Although it is uncertain which



**Figure 16.** *Cyclocardia* sp. Indeterminate from the Tsm Caldecott Tunnel fauna, right valve(?). Hypotype from UCMP locality IP13001, UCMP 410563.

geologic unit *Cy. monilicosta* was described from, it was most likely the Santa Barbara Formation where it occurs abundantly. Given this there is no data supporting a Miocene age for *Cy. monilicosta*, which is abundant in other Pliocene and Pleistocene formations in California (Moore 1992).

The other reported California Miocene *Cyclocardia*, *Cy. californica* has been reported from the late Miocene to Pleistocene of central and southern California (Moore 1992). In the Pacific northwest (Oregon and Washington) *Cy. hannibali* (Clark, 1925) and *Cy. subtenta* (Conrad, 1849) have been reported from the Miocene (Addicott 1976, Moore 1976). Also, Allison and Marincovich (1981) provisionally (cf.) reported five western Pacific *Cyclocardia* from the late Oligocene to early Miocene Narrow Cape Formation on Sitkinak Island, Alaska. Unfortunately, the Caldecott Tunnel specimen is not well enough preserved for a detailed comparison with any of the Miocene western North American *Cyclocardia*.

#### VENEROIDA GRAY, 1854

#### TELLINIDAE DE BLAINVILLE, 1814

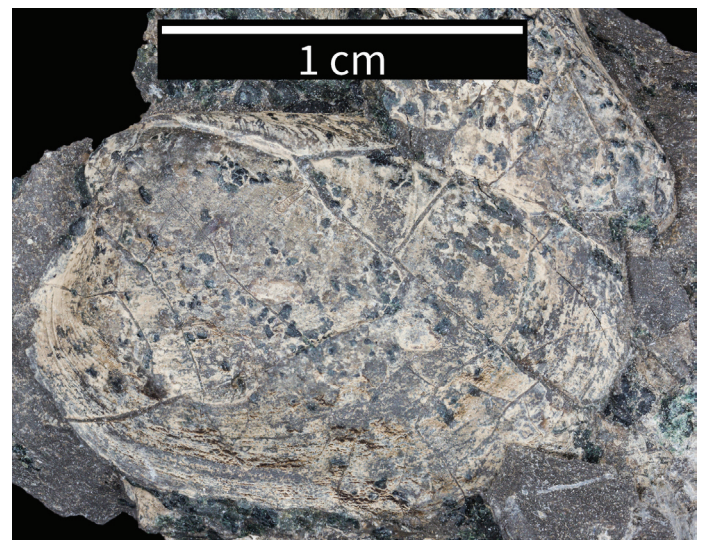
A single incomplete specimen (UCMP 218708) measuring ~3.5 cm long and 2.9 cm high, is tentatively identified here as aff. Tellinidae based on its size and shape. The hinge is needed to differentiate the genera *Macoma* and *Tellina*, so without the hinge our specimen is referred only to family. The family Tellinidae is wide ranging in

world oceans and is of no ecological significance here.

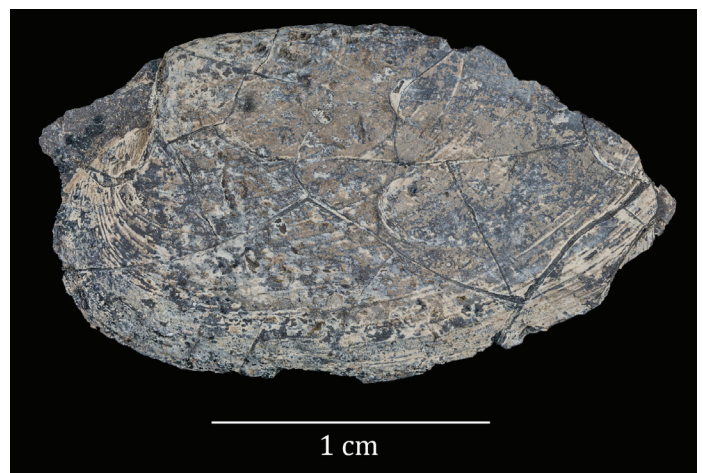
#### VESICOMYIDAE DALL AND STIMPSON, 1901

FIGS. 17–19

Three incomplete, poorly preserved specimens are assigned to Vesicomylidae, genus and species indeterminate based on their shell outline and placement of the hinge towards the anterior end of the shell. Overall they are similar in outline to *Pliocardia*. *Pliocardia* is represented by two modern species in the northern eastern Pacific, one provisionally, "*Pl.*" *stearnsii* (Dall, 1895) and "*Pl.*" *krylovata* Martin and Goffredi, 2011 from Costa Rica. W.H. Dall (1896, p. 17) cites W.H. Dall (1895, p. 693) as



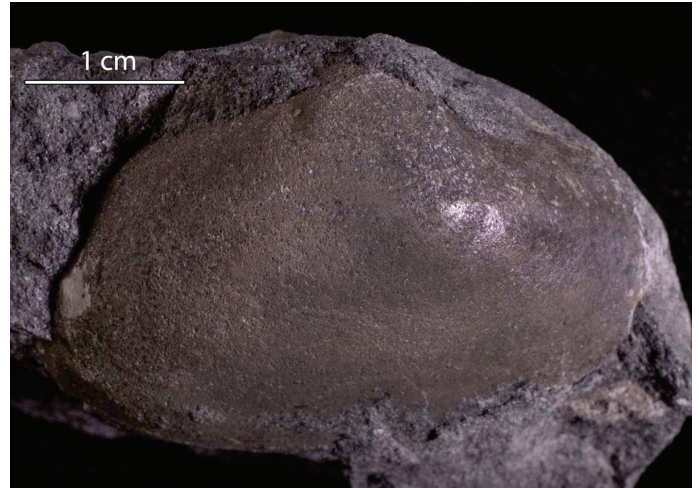
**Figure 17.** Vesicomylidae indeterminate from the Tsm Caldecott Tunnel fauna, right valve. Hypotype from UCMP locality IP16025, UCMP 123686.



**Figure 18.** Vesicomylidae indeterminate from the Tsm Caldecott Tunnel fauna, right valve. Hypotype from UCMP locality IP16027, UCMP 123690.



**Figure 19.** Vesicomysidae indeterminate from the Tsm Caldecott Tunnel fauna, right valve. Hypotype from UCMP locality IP16022, UCMP 123682.



**Figure 20.** *Spisula* aff. *Spi. eugenensis* from the Tsm Caldecott Tunnel fauna, right valve(?). Hypotype from UCMP locality IP13004, UCMP 410439.

the original author of *Vesicomys stearnsii*. However, in footnotes on page 693 is a histologic description attributed to, in part, *Callocardia stearnsii*, within a discussion of *Euciron pacifica* Dall (pp. 688–697). According to Coan et al. (2000, Santa Barbara Museum of Natural History Monographs 2, Studies in Biodiversity 2, p. 338) under *Vesicomys (Vesicomys) stearnsii* and an email from P. Valentich-Scott (7/2018) confirms use of the name is sufficient to establish the author and date. Fossil *Pliocardia* are only questionably known from western North America (Amano and Kiel 2007) they are not recognized with certainty because the hinge has not been preserved; however, they do occur in eastern Asia (Amano and Kiel 2012). All northeastern Pacific vesicomysids and perhaps all species in the family are filter feeders commonly found at cold seeps and in sulfide-rich habitats (e.g., Barry et al. 1997) at water depths greater than about 500 m in the eastern Pacific (Coan et al. 2000).

MACTRIDAE DE LAMARCK, 1809

*SPISULA* GRAY, 1837

FIG. 20

UCMP 410439 is provisionally referred to *Spisula* aff. *Spi. eugenensis* (Clark, 1925) as it closely resembles this species in general outline. *Spisula eugenensis* from the Oligocene Eugene Formation in Oregon figured by Hickman (1969, pl. 4, fig. 13), with its broadly rounded, centrally-placed beak and moderately sloping anterior and posterior dorsal margins from the umbo, is nearly identical to the specimen figured here. In addition, the Tsm Caldecott Tunnel specimen show a slight anterior and posterior umbonal ridge that match well with *Spi.*

*eugenensis*. The Eugene Formation (Oligocene) specimens and the Tsm Caldecott Tunnel (middle Miocene) specimen are very similar but are considered possibly distinct because of the difference in age.

VENERIDAE RAFINESQUE, 1815

FIG. 21

UCMP 410418 is a single small specimen that shows an overall oval shell outline with the umbo positioned at about a third of the shell's length. The umbo overhangs the dorso-anterior margin which is short and steeply inclined. The dorso-posterior margin broadly arches away from the umbo and is partially hidden. The ventral margin is broadly rounded from the anterior to the posterior. A fragment of the shell is present posterior of the umbo and appears moderately thick with strong concentric ribs. The cast shows that these ribs were co-marginal and moderately evenly spaced. These features and the shell outline matches well with some members of the family Veneridae, in particular the genus *Clementia* Gray, 1842, which is well known from the Miocene and possibly into the Pliocene of the West Coast (Woodring 1927). However, the specimen is not well enough preserved for a precise identification.

GASTROPODA CUVIER, 1795

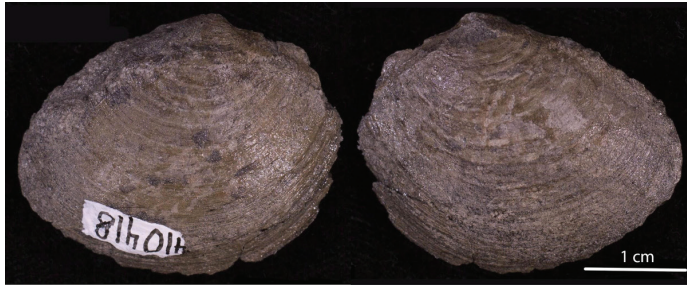
NEOGASTROPODA WENZ, 1938

BUCCINIDAE RAFINESQUE, 1815

*BRUCLARKIA* TRASK IN STEWART 1926(1927)

FIG. 22

The genus *Bruclarkia* is endemic to the Pacific northwest from Alaska to California occurring in rocks of



**Figure 21.** Veneridae, indeterminate from the Tsm Caldecott Tunnel fauna, right valve (left), left valve (right). Hypotype from UCMP locality IP13004, UCMP 410418.

Eocene to middle Miocene age before the genus became extinct. A review of the genus by Vendetti (2009) recognized seven, possibly eight, valid species from the 20 available taxonomic names for western American specimens. A single specimen, UCMP 218695, was recovered from the Caldecott Tunnel excavation. It is decorticated



**Figure 22.** Aperiical view of indeterminate *Bruclarkia* from the Tsm Caldecott Tunnel fauna, UCMP locality IP13003, hypotype UCMP 218695.

and therefore cannot be identified to species.

MURICIDAE RAFINESQUE, 1815

*FORRERIA* JOUSSEAUME, 1880

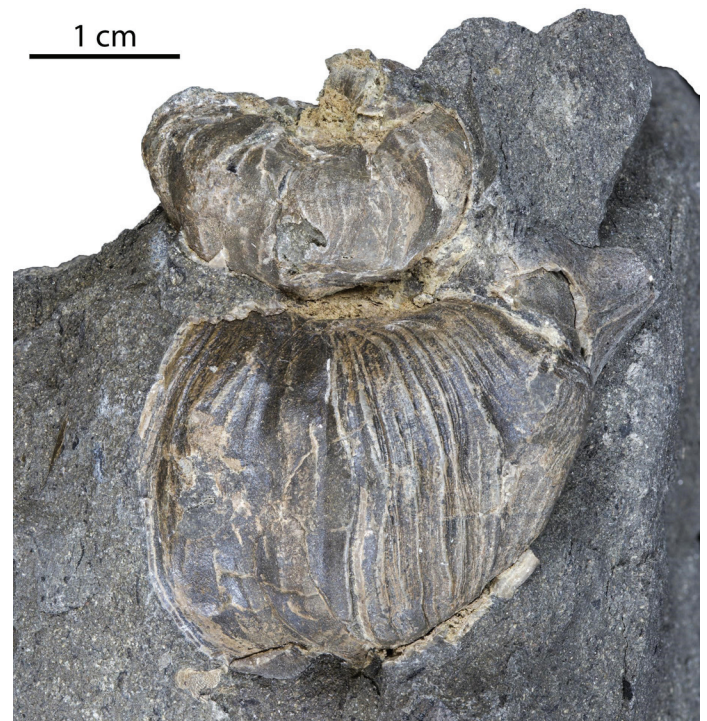
FIG. 23

Fossil *Forreria* occurs from central California south to Baja California, Mexico, in rocks from the lower Miocene, possibly upper Oligocene, to Holocene. Powell (2005) recognized 29 names used for fossil *Forreria*, including two new species, from the California Neogene of which 10 to possibly 12 species are valid. The single Caldecott Tunnel specimen UCMP 412181 is incomplete and mostly decorticated making identification beyond genus impossible. The single modern species, *F. belcheri* (Hinds, 1843) occurs from Mugu Lagoon, Ventura County, California south to Laguna Ojo de Liebre (Scammon's Lagoon), Baja California Sur, Mexico, at water depths from the low intertidal to about 30 m (McLean 1978). However, the genus was more widespread geographically during the Neogene in western North America (Powell 2005).

NASSARIIDAE IREDALE, 1916

*DEMONDIA*(?) ADDICOTT, 1965

FIG. 24



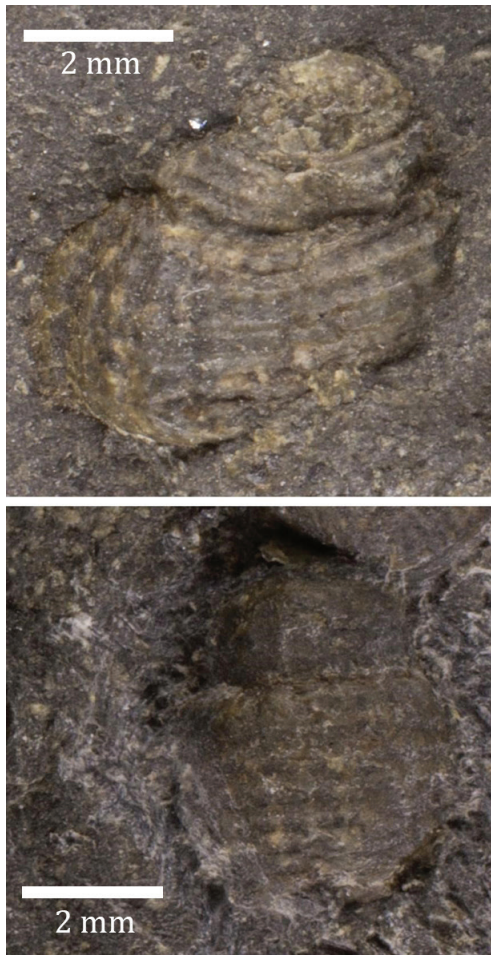
**Figure 23.** An indeterminate *Forreria* from the Tsm Caldecott Tunnel fauna, probably aperiical view. Hypotype from UCMP locality IP13004, UCMP 412181.

Although the specimens show reticulate or papillose sculpture, the aperture of the shells, which has a well-formed callus in *Demondia*, are not preserved making precise identification questionable.

UCMP 218821 and 218822 are two crushed, poorly preserved casts resembling the genus *Demondia*, and are most similar to *Dem. lincolnensis* (Anderson and Martin, 1914). *Demondia lincolnensis* has been previously reported from the middle Miocene Astoria Formation of western Washington (Moore 1963) and Clatsop and Lincoln counties, Oregon (Anderson and Martin 1914, Moore 1963). Unfortunately, the Caldecott Tunnel specimens are not well enough preserved to identify with confidence even to genus despite the resemblance to *Dem. lincolnensis*.

LITTORINIMORPHA GOLIKOV & STAROBOGATOV, 1975  
NATICIDAE GUILDING, 1834

FIG. 25



**Figure 24.** *Demondia?* sp. from UCMP locality IP13003. Hypotype (top), UCMP 218822. Hypotype (bottom), UCMP 218821.



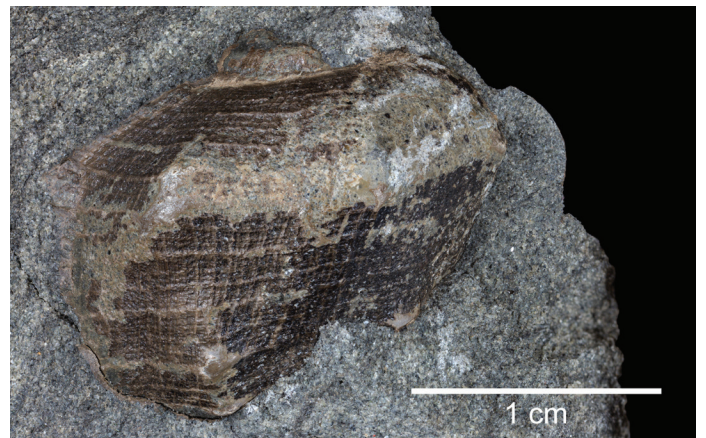
**Figure 25.** Indeterminate Naticidae, partly crushed, from the Tsm Caldecott Tunnel fauna, adapical view (left); aperical view (right). Hypotype from UCMP locality IP13005, UCMP 218737.

UCMP 218737 is a single small, deformed and indeterminate naticid. It has no features preserved that allow for a more precise identification. The family Naticidae is so wide ranging in the eastern Pacific, both chronologically and ecologically, that it is useless in making detailed age and environmental interpretations.

FICIDAE MEEK, 1864  
*TROPHOSYCON* COOPER, 1894

FIG. 26

According to occurrences cited in Grant and Gale (1931) and Addicott (1970), the extinct western United States genus/subgenus *Trophoscyon* is possibly found in rocks of the Temblor Formation, but occurs definitively



**Figure 26.** *Trophoscyon* sp. Adapature view of part of the body whorl and a small portion of the penultimate whorl. Hypotype from UCMP locality IP13004, UCMP 411945.



in the Santa Margarita Sands, and the lower part of the San Diego Formation. These formations indicate a possibly middle Miocene, but definitely upper Miocene to middle Pliocene age. A large number of species have been recorded for this subgenus however Addicott (1970) synonymized many of them. The single fragment from the Caldecott Tunnel excavation shows the nodes and cancellate sculpture characteristic of the taxon, but the fragmentary nature of the specimen does not allow for a more detailed identification.

SCAPHOPODA BORNN, 1862

DENTALIIDA DE COSTA, 1776

DENTALIIDAE CHILDREN, 1834

DENTALIUM LINNAEUS, 1758

FISSIDENTALIUM(?) FISCHER, 1885

*DENTALIUM (FISSIDENTALIUM?) MCGANNA* POWELL, CLITES,  
AND POUST N. SP.

FIGS. 27-30

**Diagnosis**—The coarse radial and moderate to fine concentric sculpture forming a checkerboard pattern both high on the sculpture and low between the radial and concentric sculpture is distinctive to this species, as is large size. The pattern can vary along the length of the shell and radial sculpture can be difficult or impossible to see on casts.

**Holotype**—UCMP 251012.

**Paratypes**—UCMP sp. nos. 14436, 218713, 218799, 412728.

**Referred Specimens**—Caldecott Tunnel locality UCMP IP13001: UCMP sp. nos. 251010, 410431, 412779; Caldecott Tunnel locality UCMP IP13003: UCMP sp. nos. 218690, 218701, 218712, 218719, 218729, 218730, 218801, 218829, 251018, 251024, 251032, 410426, 410925; Caldecott Tunnel locality UCMP IP13004: UCMP sp. nos. 218803, 410434, 410435, 412731, 410438. See Appendix 3 for details.

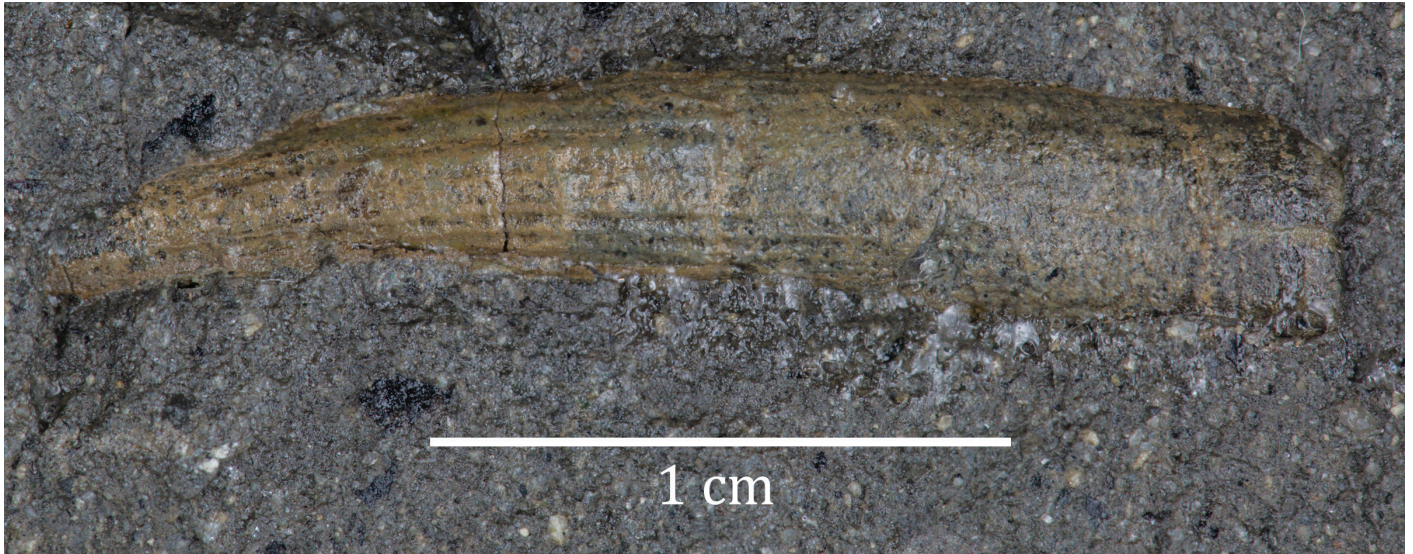
**Type Locality**—UCMP IP13003: Caldecott Fourth Bore, Sobrante first shale, specimens collected from the “First shale” of the Sobrante Formation as described by Page (1950). Note that contractors were not allowed to enter the tunnel, so this designation as “First shale” of the Sobrante is approximate.

**Other occurrences**—Known from the Tsm and possibly Claremont Formation exposed at or near the west side of the Caldecott Tunnel’s fourth boring, Berkeley Hills, Oakland, California. Specimens were recovered from spot collecting and talus piles attributed to Tsm based on the position of the excavator near the west end of the boring and the dark to medium gray fine grained rocks the fossils were preserved in. One specimen (UCMP 412728) is preserved in medium sand and is questionably attributed to the Claremont shale.

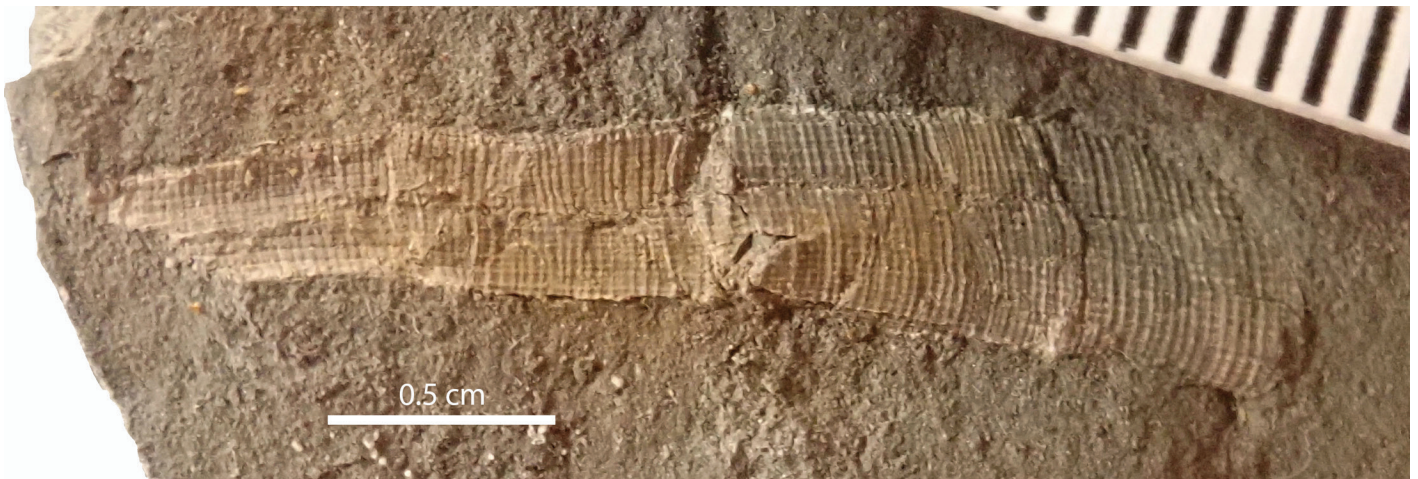
In addition to the Caldecott Tunnel material a single specimen from the Gallaway Formation (=Gallaway Beds of the Mendocino coast of Weaver (1944) *vide* Addicott, 1967; UCMP locality D7149) collected near Point Arena, Mendocino County, northern California present



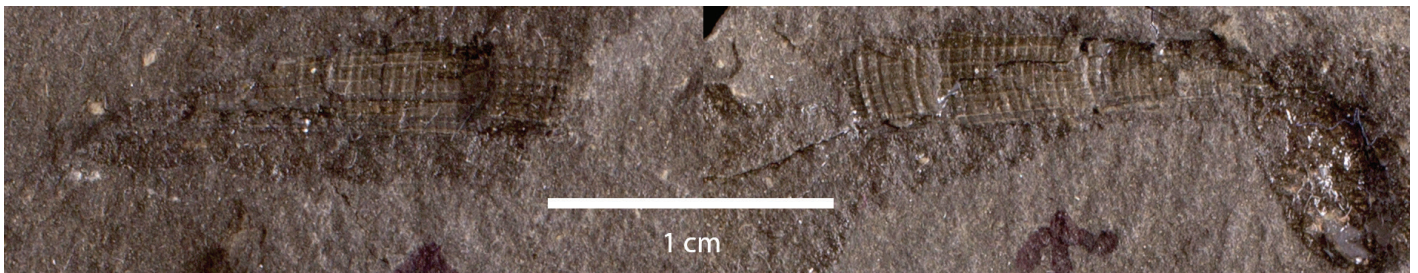
**Figure 27.** *Dentalium (Fissidentalium?) mcganna* Powell, Clites, and Poust n. sp. Holotype from UCMP locality IP13003, UCMP 251012.



**Figure 28.** *Dentalium (Fissidentalium?) mcganna* Powell, Clites, and Poust n. sp. Paratype from UCMP locality IP13003, UCMP 218713.



**Figure 29.** *Dentalium (Fissidentalium?) mcganna* Powell, Clites, and Poust n. sp. Paratype from the Gallaway Formation (UCMP locality D7149) collected near Point Arena, Mendocino County, northern California, UCMP 14436.



**Figure 30.** *Dentalium (Fissidentalium?) mcganna* Powell, Clites, and Poust n. sp. Paratype from UCMP locality IP13003, UCMP 218799, part and counterpart.

in the UCMP collection and reported on by Phillips et al. (1976). Phillips et al. (1976) using benthic foraminifers determined an age of Zemorrian California provincial benthic foraminiferal stage age (33.5–22 Ma; GeoWhen

Database, <http://www.stratigraphy.org/bak/geowhen/stages/Zemorrian.html>, visited 7/2018), while W. Addicott (in Phillips et al., 1976, p. 148) indicated a “Vaqueros” California provincial molluscan stage age (32.6–19.5 Ma;

Smith 1991) for these outcrops, slightly older than either the Tsm unnamed glauconitic mudstone or Claremont Formation in the Berkeley Hills. This specimen (UCMP 14436) is included here as a paratype of *D. mcganna* (Fig. 30) and extends the geographic and age range of this new species from Contra Costa County to Mendocino County and from middle Miocene back to the early Miocene.

**Etymology**—This species is named in honor of Mary McGann (USGS) for her friendship, continuous help and support to the senior author over many years.

**Description**—The holotype is the longest and one of the best preserved specimens measuring ~6.7 cm long and ~0.7 cm at its widest (Fig. 24). It has a circular or oval cross-section (compression of the rocks makes an exact determination impossible), is moderately curved and tapered. It shows coarse radial sculpture consisting of up to 12 ribs on one side crossed with variable weight concentric sculpture, which varies along the length of an individual specimen and varies between specimens from strong to nearly absent due to intraspecific variation and preservation. The radial and concentric sculpture together form a square checkerboard pattern high in the middle of each individual square formed by the sculpture and low on the margins. The interspaces are fine and much smaller than the ribs. The apex was not observed.

**Discussion**—The subgenus *Fissidentalium* has large, solid shells, circular in outline and sculptured by numerous longitudinal striae and an apex mostly with a long slit on the convex side. While in *Dentalium s. s.* the apex is weakly to strongly polygonal and the shell has a number of rounded ribs numbering less than 20 (Keen 1971). Diagnostic features are not observable but the large size and deep water habitat are indicative of the subgenus *Fissidentalium*.

Miocene California and Pacific Northwest *Dentalium* include *D. laneensis* Hickman, 1969, *D. petricola* Dall, 1909 (new name for *Teredo substriata* Conrad, 1849, in part), *D. pseudonyma* Pilsbry and Sharp, 1898 (new name for *Teredo substriata* Conrad, 1849), in part; syn. *D. conradi* Dall, 1909, n. nom. *fide* Clark (1918)], *D. radiolineata* Clark, 1918, *D. radiolineata sobrantensis* Clark, 1918, and *D. schencki* Moore, 1963. These taxa are distinguished from *D. mcganna* n. sp. as follows: *D. laneensis* is smaller and lacks prominent concentric growth lines; *D. petricola* lacks sculpture; *D. pseudonyma* is much smaller and does not show growth lines; in *D. radiolineata* the interspaces are as wide as the ribs, and the ribs fade above and below the middle of the shell easily distinguishing it from the present species. Lastly, *D. schencki*, differs in being smaller and having a smooth, strongly tapered shell.

ECHINODERMATA BRUGUIÈRE, 1791 [EX. KLEIN, 1734]

CRINOIDEA MILLER, 1821

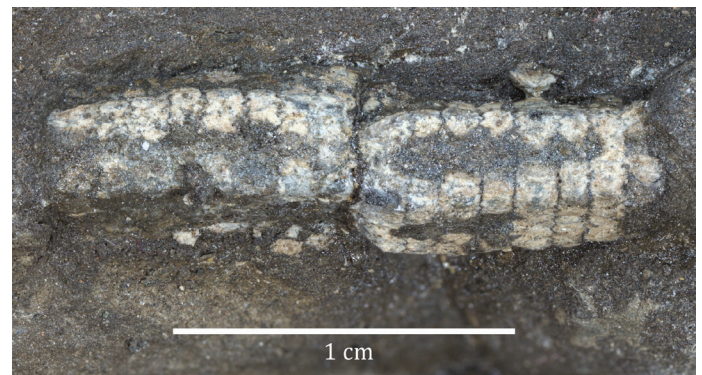
FIG. 31

Two specimens (UCMP 412360) are identified as indeterminate crinoid columnals (Rich Mooi, personal communication, 6/20/2016). Although crinoids are very rare in the Cenozoic of western North America, they have been reported from the Eocene to possibly lower Miocene (Lewis et al. 1960, Burns and Mooi 2003). Eocene occurrences include the Crescent, Lincoln Creek, Makah, McIntosh, Skookumchuck, and Tukwila formations in Washington, and in Oregon the basal Keasey Formation and the Clark and Wilson Sandstone (Burns and Mooi 2003). Oligocene occurrences include the Blakeley and Lincoln Creek formations in Washington and the Keasey Formation in Oregon (Burns and Mooi 2003). In addition, Lewis et al. (1960) report a crinoid from the Oligocene or early Miocene Gunners Cove Formation on Rat Island in the Aleutians, Alaska.

The occurrence of crinoids in the Tsm Caldecott Tunnel fauna extends the stratigraphic range of fossil crinoids in the Cenozoic of western North America from possibly the upper Oligocene/lower Miocene to the middle Miocene, and geographically south from near Mist, Oregon to the San Francisco Bay area.

ECHINOIDEA LESKE, 1778

Very thin sea urchin spines are present in several samples. These spines are less than 0.1 mm in diameter and up to 10 mm long. They are generally smooth, although some appear to show pitting along their length and a few have fine lines parallel to the long axis. The size and lack of details make them impossible to identify past Class.



**Figure 31.** Indeterminate crinoid stem. Hypotype from UCMP locality IP13001, UCMP 412360.

ARTHROPODA VON SIEBOLD, 1848  
 MALACOSTRACA LATREILLE, 1802  
 DECAPODA LATREILLE, 1802

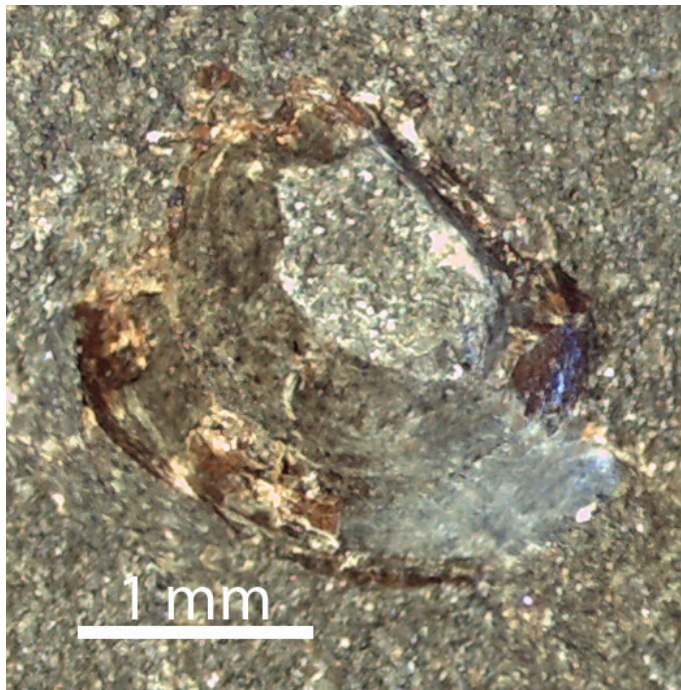
At least three decapod specimens are known from the Tsm Caldecott Tunnel fauna (A. Klompaker, personal communication, 2016-2017). The specimens are represented by a claw (UCMP 410434) and other unidentified fragments. Decapoda are known from at least as old as the Devonian (Feldmann and Schweitzer 2010) to Holocene.

SESSILIA DE LAMARCK, 1818  
 MAXILLOPODA DAHL, 1956  
 BALANIDAE LEACH, 1817

FIG. 32

A very small mold and cast appear to represent a small, short, possibly smooth-sided barnacle. It is not well enough preserved to identify beyond family level. The family goes back to the Cambrian (Collins and Rudkin 1981) and they are widespread in marine and marginal marine environments.

CHORDATA HAECKEL, 1874  
 CHONDRICHTHYES HUXLEY, 1880  
 CARCHARINIFORMES COMPAGNO, 1973  
 CARCHARINIFORMES INDET.



**Figure 32.** Balanidae indeterminate. Hypotype from UCMP locality IP13001, UCMP 218826.

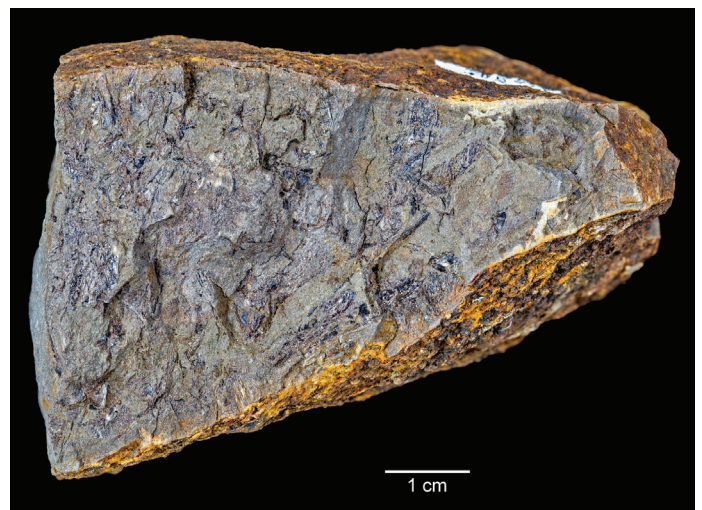
Two small (1–2 mm) fragments of a shark tooth (UCMP 270010) nonetheless preserve portions of a serrated crown. The serrations are very fine, symmetrical, and numerous with 6–7 per millimeter.

It is difficult to identify these fragments, but several shark groups have serrations of similar size and density, including members of the carcharhinids and the Lamni-formes. The fine and dense nature of the serrations are more similar to the genus *Carcharhinus* than the larger serrations of *Carcharocles*, but the incomplete fossil does not permit identification beyond Order.

OSTEICHTHYES HUXLEY, 1880  
 ACTINOPTERYGII KLEIN, 1885  
 ACTINOPTERYGII INDET.

FIG. 33

Dozens of rock samples containing numerous accumulations of fish bone, teeth, and scales were collected from the Caldecott Tunnel Tsm unit (UCMP sp. nos. 218453–218476, 218478–218481, 218503, 218509–218517, 218519–218524, 218526–218529, 218531–218533, 218535–218643, 218646–218674, 218676–218678, 270000–270006, 270008, 270009, 270011, 270012, 270014, 270017, 270018, 270020, 270021, 270023, 270026, 270031, 270033, 270036, 270074–270077, 270079–270114; and in V12003 : UCMP 218477, 218506, 218525, 218644, 218645, 218675, 270007, 270013, 270016, 270024, 270025, 270028, 270029, 270032, 270037–270042, 270046, 270049, 270050, 270052, 270053, 270059, 270061–270073, 270078, 323812). The bones are abundant and the most common



**Figure 33.** Indeterminate Actinopterygii fragments. Hypotype, UCMP 218647.

elements are ribs and small spool-like vertebrae, 1–2 mm in length. The fragments were not identified beyond teleost. Without further detailed study the taxonomic affinities of these fossils cannot be determined, but in the east San Francisco Bay area similar accumulations of fish bone and scales are found in shales along Sobrante Ridge, north of the Caldecott Tunnel. This suggests that small fish were common components of coastal basins throughout the late Miocene and may have provided a significant food source for larger vertebrates, such as the marine mammals described below.

MAMMALIA LINNAEUS, 1758  
MAMMALIA INDET.

FIG. 34

UCMP 270019 and 270092 are partial mid-shaft fragments of what appear to be pinniped ribs. They resemble pinniped ribs in cross-sectional shape and marrow cavity area, but we cannot fully rule out small odontocete cetaceans with ribs of similar size.

Possible candidate taxa for these elements include the smaller early imagotariine walruses, enaliarctine pinnipedimorphs, now known to survive along the West Coast as late as 16.6 Ma (Poust and Boessenecker 2018), and a number of smaller cetacean taxa. Due to the age uncertainty of the Tsm at this locality, the size overlap among the ribs of multiple marine mammal taxa, and the minimal anatomy preserved we feel this justifies only attribution to the Mammalia.

CF. ALLODESMUS KELLOGG, 1922

UCMP 270043 is a very cracked and shattered fragment of a proximal rib preserved in dark, hard, indurated shale. The specimen nonetheless preserves a morphology resembling the proximal ribs of the contemporaneous *Allodesmus*. Comparison with specimens of marine mammals in the UCMP collections suggests that UCMP 270043 is similar to the proximal portions of *Allodesmus* ribs in size, width to height ratio, and the presence of a relatively wide proximal costal groove.

The middle Miocene was a time of marked phylogenetic diversity within pinnipedimorpha, including imagotariine walruses, members of Desmatophocidae including *Allodesmus*, some of the first phocid and otariid relatives, and even relict “enaliarctines” (Berta et al. 2018, Poust and Boessenecker 2018). Thus, the possible presence of two size classes of pinnipedimorphs within the same formation is not surprising, especially if the presence of numerous fossil fish is indicative of a nutrient-rich environment.

CETACEA BRISSON, 1762  
ODONTOCETI FLOWER, 1867

FIGS. 35, 36

Cetacean remains recovered from the Caldecott Tunnel Tsm unit include a partial premaxilla (UCMP 269020) among other less identifiable fragments. The descriptive anatomical terminology used here follows Mead and Fordyce (2009). UCMP 269020 is a left mid-premaxilla



1 cm

Figure 34. Mammalian rib fragment, hypotype, UCMP 270043.

of a medium-sized odontocete cetacean. T-shaped in cross-section, it has a sharp lateral edge which would have been flush with the maxilla and a more rounded medial border where it would have met the opposing right premaxilla in life. The ventral process is crushed and less distinguishable from the surrounding matrix, but does expand ventrally where the palatine surface would be visible in ventral view. The porcelanous part is gently convex. The labial surface, anterolateral sulcus, and any branches of the infraorbital canal are not visible, suggesting that this fragment is from the anterior half of the rostral portion. The convex rostral surface is 32.3 mm wide and the height from the palatine surface of the premaxilla is 32.5 mm. The entire fragment is 80 mm long.

The identification of UCMP 269020 as an odontocete is a strong stratigraphic indicator that the rocks of the western portal of the Caldecott Tunnel are Neogene in age and that the tunnel does not include any of the unnamed Cretaceous Cenomanian/Turonian sedimentary rocks present further west along Highway 24. Though many cetaceans are well known from the Oligocene of North America, including the oldest Odontocetes (Uhen 2010), their diversity is not high until the Miocene. Of the odontocete cetaceans known from the West Coast, several possess premaxillae with convex dorsal surfaces and without further morphology a generic assignment is not warranted. The specimen is relatively large: significantly bigger than Pliocene delphinids from the Purisima Formation, similar or slightly smaller than Physeteroids from the Round Mountain Silt (UCMP collections) and larger than *Kampholophos* which has a 26 mm wide premaxilla (Rensberger 1969).

#### ENVIRONMENTAL INTERPRETATION

The Tsm Caldecott Tunnel fauna is referred to a methane-rich environment, likely a cold seep, based on the occurrences of specimens attributed to indeterminate Vesicomidae and Lucinidae bivalves. Vesicomidae are all known from methane-rich environments (Barry et al. 1997). Furthermore, the association of Vesicomidae and the lucinid *Lucinoma* has been used to interpret methane-rich sites in the Pliocene of southern California (Powell and Groves 2008). The only other record of a methane-rich fauna from the San Francisco Bay area is that of Pyenson and Haasl (2007) who reported a whale fall fauna in the Miocene “Monterey” Formation on Año Nuevo Island in nearby San Mateo County.

We pursue two lines of evidence to determine the depth at which this fauna was deposited: overlapping depth zones of extant molluscan taxa from the fauna and occurrence of glauconite. No extant species are known from the Tsm Caldecott Tunnel fauna, however all the genera and (or) families are known from the modern eastern Pacific fauna. We restrict depth data to western North American bivalves and use the modern compilations of eastern Pacific Bivalvia by Coan et al. (2000) and Coan and Valentich-Scott (2012). Compiled data shows the majority of the taxa overlapping between 360 (deepest occurrence of *Yoldia*) and 370 m (shallowest occurrence of the family Vesicomidae in the eastern Pacific). However, the family Mactridae (questionably reported here) has a modern occurrence only shallower and *Acharax johnsoni* has a range starting slightly deeper. Gastropoda and Scaphopoda were not used in these determinations because modern depth data is generally lacking and in the case of the genus *Forreria* it is only represented by a single living species today,



**Figure 35.** Odontocete premaxilla, dorsal view of hypotype, UCMP 269020.



**Figure 36.** Odontocete premaxilla, lateral view of hypotype, UCMP 269020.

although over a dozen species were present in California during the Miocene (Powell 2005). Most fossil taxa are generally represented by less than five specimens and many are broken; therefore, transport seems likely. As reported by Porrenga (1967), glauconite in modern oceans is commonly deposited at water depths between 30–2,000 m and in low oxygen environments (Parrish 1998). Based on our confidence of the identified fossils, the fine-grained nature of the sediment, and the occurrence of glauconite upper slope water depths probably on the order of 350 to 400 m are indicated.

All taxa have modern latitudinal range zone that overlap the latitude of the fossil locality and therefore do not indicate water temperatures warmer or cooler than off the central California coast today.

AGE

The stratigraphic ranges of specifically identified taxa are discussed above. Overlapping stratigraphic ranges indicate a probable middle Miocene age (Table 1) for the fauna based on the occurrences of the provisionally identified bivalves *Acila empirensis*, *Anadara osmonti*, *Yoldia submontereyensis*, *Y. supramontereyensis* and the gastropod genera *Bruclarkia* and *Trophoscyon*. The presence of odontocete cetaceans and *Allodesmus* indicates a middle Miocene (Langhian Stage age) or younger (< 16 Ma) age,

though the incomplete nature of these specimens means that they should be viewed only as confirmation of the age suggested by the invertebrate taxa.

THE CLAREMONT  
CALDECOTT TUNNEL FAUNA

Taxa recovered from the Claremont Formation are sparse and include only two bivalve mollusks, one scaphopod, one barnacle and three vertebrates (Appendix 4). They are referred to as the Claremont Caldecott Tunnel fauna.

SYSTEMATIC PALEONTOLOGY

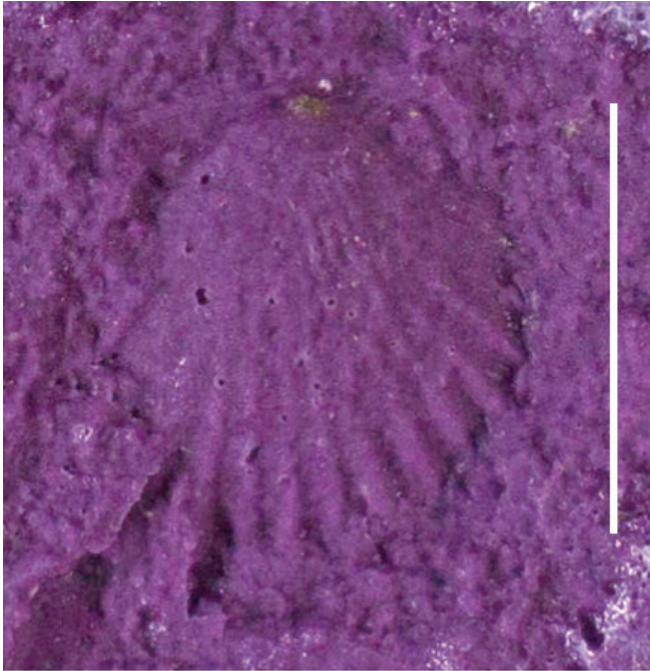
- MOLLUSCA LINNAEUS, 1758
- BIVALVIA LINNAEUS, 1758
- OSTREOIDA DE FÉRUSAC, 1822
- PECTINIDAE WILKES, 1810

FIG. 37

UCMP 412480 is a mold of a small indeterminate Pectinidae. The cast is about 7 mm high with 10, possibly 11, strong radial ribs, with the suggestion of finer concentric sculpture on some ribs. A possible posterior auricle is present although the impression is very faint and difficult to distinguish, and no sculpture is observable. The size and lack of diagnostic features does not allow for identification beyond the family.

**Table 1.** Stratigraphic range of selected molluscan taxa reported from the Tsm Caldecott Tunnel fauna. \* indicates species provisionally identified. <sup>1</sup> Indicates occurrence in the western Pacific ([http://fossilworks.org/bridge.pl?a=taxonInfo&taxon\\_no=85550](http://fossilworks.org/bridge.pl?a=taxonInfo&taxon_no=85550)). <sup>2</sup> Indicates occurrence in the eastern Pacific (Moore, 1983). These taxa indicate a middle Miocene age for the fauna.

Taxa	Epochs				
	Oligocene	lower Miocene	middle Miocene	upper Miocene	Pliocene
<b>Mollusca</b>					
<b>Bivalvia</b>					
<i>Acharax johnson</i> *	x <sup>1</sup>	x <sup>1</sup>	x <sup>1</sup>	x <sup>1</sup>	x <sup>1, 2</sup>
<i>Acila empirensis</i> *	–	–	x	x	x
<i>Anadara (An.) osmonti</i> *	–	–	x	–	–
<i>Yoldia (Kalayoldia) submontereyensis</i> *	–	–	x	–	–
<i>Yoldia (Kalayoldia) supramontereyensis</i> *	–	–	x	–	–
<b>Gastropoda</b>					
<i>Bruclarkia</i> sp.	x	x	x	–	–
<i>Forreria</i> sp.	?	x	x	x	x
<i>Trophoscyon</i> sp.	–	?	x	x	x



**Figure 37.** Pectinidae indeterminate. Hypotype from UCMP locality IP13002, UCMP 412480. Polymer mold from cast. Scale bar=0.5 cm

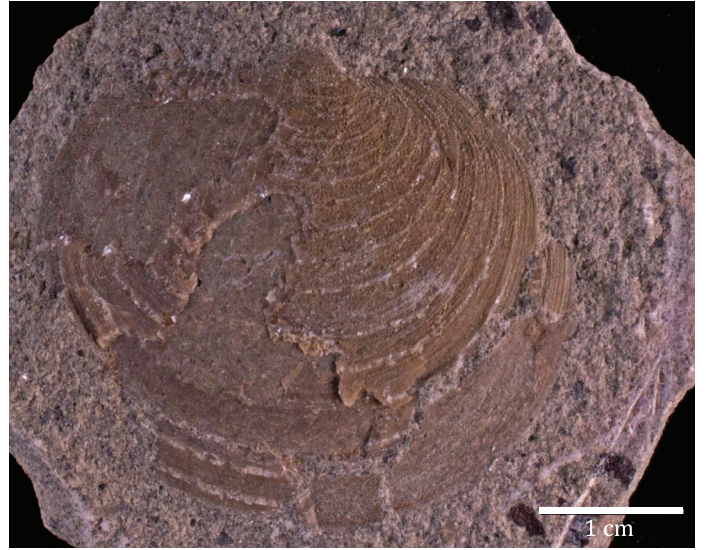
VENEROIDA H. & A. ADAMS, 1856  
LUCINIDAE FLEMING, 1828  
CODAKIINAE KOROBOKOV, 1954

FIG. 38

UCMP 218710, a single right valve in sandstone, is provisionally identified as *Lucinoma* cf. *L. annulatum* (Reeve 1850) based on its shape, sculpture and possibly late Miocene age. *Lucinoma annulatum* occurs from the late Miocene to Holocene of the eastern Pacific but has been reported from the Oligocene in Japan and Russia (Okamoto and Sakai 1995, Kafanov and Ogasawara 2004), however these older ages seem doubtful. No other fossil *Lucinoma* species are known from the late Miocene of California. However *L. annulatum* is very similar to and can be difficult to separate from *Lu. acutilineata* (Conrad,

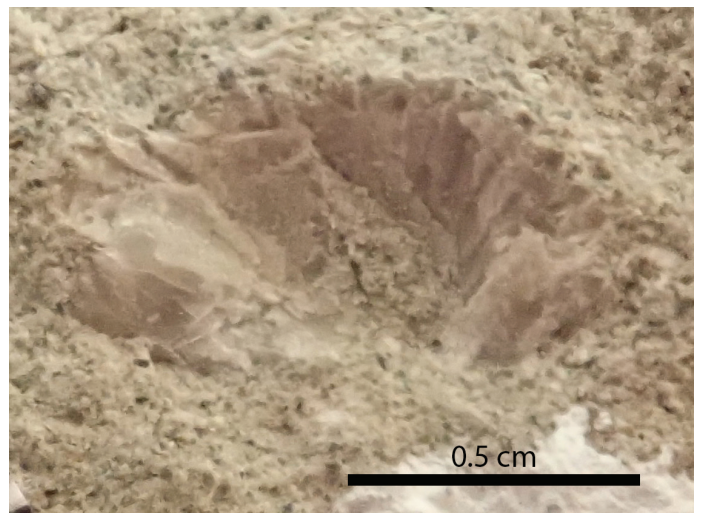


**Figure 39.** *Dentalium* (*Fissidentalium?*) *mcganna* Powell, Clites, and Poust n. sp., paratype from UCMP locality IP13002, UCMP 412728.



**Figure 38.** *Lucinoma* cf. *L. annulatum*. Claremont Caldecott Tunnel fauna, right valve(?). Hypotype from UCMP locality IP13007, UCMP 218710.

1849). *Lucinoma acutilineata* occurs in Oligocene to middle Miocene (Roth 1979, Moore 1988) rocks from Alaska south to southern California (Moore 1988) and *L. hannibali* Clark, 1925 from the Oligocene to middle Miocene of the Pacific Northwest. *Lucinoma acutilineata* is distinguished by its lighter hinge, and longer posterior dorsal margin (Stewart in Tegland 1933, p. 116), while *L. hannibali* is distinguished by its longer and wider lunule, having a longer and more concave dorsal margin, a more subdued sulcus running from near the umbo to posterior margin, and sometimes more irregularly spaced comarginal sculpture. The possibly early Oligocene to



**Figure 40.** Indeterminate barnacle. Hypotype from UCMP locality IP13002, UCMP 218825.





**Figure 41.** *Carcharhinus obscurus* tooth, hypotype UCMP 218505.

early Miocene *L. columbiana* (Clark and Arnold, 1923) is distinguished by its smaller size and being more inflated. *Lucinoma aequizonatum* (Stearns, 1890) occurs in the eastern Pacific, however, it is not known from deposits older than middle Pleistocene (Powell and Ponti 2007), and is easily distinguished by its different shape and broader sculpture.

SCAPHOPODA BORNN, 1862

DENTALIIDA DE COSTA, 1776

DENTALIIDAE CHILDREN, 1834

DENTALIUM LINNAEUS, 1758

FISSIDENTALIUM(?) FISCHER, 1885

DENTALIUM (FISSIDENTALIUM?) MCGANNA POWELL, CLITES,  
AND POUST N. SP

FIG. 39

This species is discussed in detail above under the Tsm Caldecott Tunnel fauna section. A specimen referred to the Claremont Caldecott Tunnel fauna is shown here.

ARTHROPODA VON SIEBOLD, 1848

SESSILIA DE LAMARCK, 1818

MAXILLOPODA DAHL, 1956

BALANIDAE BRUGUIÈRE, 1797 (?) LEACH, 1817

FIG. 40

A very small mold and cast appear to represent a small, short, possibly smooth-sided barnacle. It is not well enough preserved to identify beyond family and that is questionable. The family goes back to the Cambrian

(Collins and Rudkin 1981) and they are widespread in marine and marginal marine environments.

CHORDATA HAECKEL, 1874

CHONDRICHTHYES HUXLEY, 1880

CARCHARINIFORMES COMPAGNO, 1973

CARCHARHINIDAE JORDAN AND EVERMANN, 1896

CARCHARHINUS DE BLAINVILLE, 1816

CARCHARHINUS OBSCURUS LESUEUR, 1818

FIG. 41

UCMP 218505 is a shark tooth exposed in lingual view and, being mesio-distally wide and concave right in this view, represents an upper tooth from the middle to rear of the tooth row. It is a small, asymmetrical tooth measuring 7.6 mm in crown height, 4.2 mm in crown width and 11.6 mm wide at the root.

The tooth is broadly triangular in shape, but with a concave distal inflection at the juncture of the shoulder and distal cutting edge that gives the crown a falcate appearance. The inflexion point on the mesial side between this convex cutting surface and the rootward shoulder is distinctly higher (i.e., closer to the apex) than the angle between the concave edge of the crown and the shoulder on the distal side. The labial side of UCMP 218505 is planar, as visible in the cracked portion of the mesial shoulder and root; the exposed lingual side of the crown is gently and uniformly convex. Any labial or lingual curvature is obscured by the surrounding matrix. The relatively flattened blade is strongly serrated, including serrated shoulders tapering to a narrow apex, but with an apical tip free of serrae. The distal side has a shallow notch between the upper and lower part of the crown and the distal shoulder is slightly bowed rather than straight. The root is damaged so the state of the protuberance is difficult to determine, though by outline it would be slightly rounded and not squared-off.

Referral to *C. obscurus* is supported by the overall morphology described above. In particular the more uniform size of the serrations and their diminution towards the tip on the concave side separates it from *Hemipristis* Agassiz, 1843, and the long shoulders, falcate appearance, and thinner, rounded, more concave root from the Charcarodontids. UCMP 218505 can be distinguished from other taxa within *Carcharhinus* by the presence of a mesial cutting edge with a slight convex curvature terminating at a distally deflected tip (Purdy et al. 2001). A higher inflexion point on the mesial side than on the distal is characteristic of *C. obscurus*. The smooth tip is unlike most reported upper teeth of *C. obscurus* which typically has fine serrations along the entire edge but

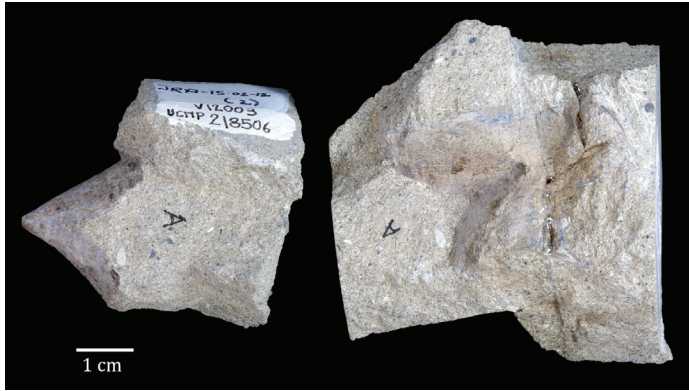


Figure 42. *Thunnus* vertebra, hypotype, UCMP 218506.

still resembles this taxon most closely. The reduced serrations towards the tip result in the apical end appearing rounded rather than peaked which further allies it with the certain species of *Carcharhinus*, especially *C. obscurus*, the dusky shark and *C. leucas*, the bull shark. It can be distinguished from this last due to its greater asymmetry.

*Carcharhinus obscurus* has been reported from both coasts of North America (Applegate 1986, Purdy et al. 2001) and around the world in a distribution that broadly follows occurrences of extant members of the species. The serrations present on UCMP 218505 are finely preserved and the base of the tooth has clear borders; all damage appears to be post-fossilization, suggesting little transport.

OSTEICHTHYES HUXLEY, 1880  
 ACTINOPTERYGII KLEIN, 1885  
 PERCIFORMES BLEEKER, 1859  
 SCOMBRIDAE RAFINESQUE, 1815  
*THUNNUS* SOUTH, 1845  
*THUNNUS* SP.

FIG. 42

The vertebra represented by UCMP 218506 is broken at an oblique angle, with a natural cast of the conical concave surface of the centrum preserved (Fig. 42, left side). The vertebral body is large with a slightly dorsally flattened outline. The septa are relatively simple but do seem to have two lateral fossae. The sides between these septa are deeply incised. The lip of the centrum is smooth and somewhat curved instead of sharp. The whole vertebra is 44 mm in length, of which the central concavities make up 20 mm on each side leaving only a very narrow bony center.

The deeply incised sides, distally wide centra, and large size indicate scombrid affinities, while the dorso-ventrally flattened shape of the centrum with a midline depression is a *Thunnus* synapomorphy. *Thunnus* is also

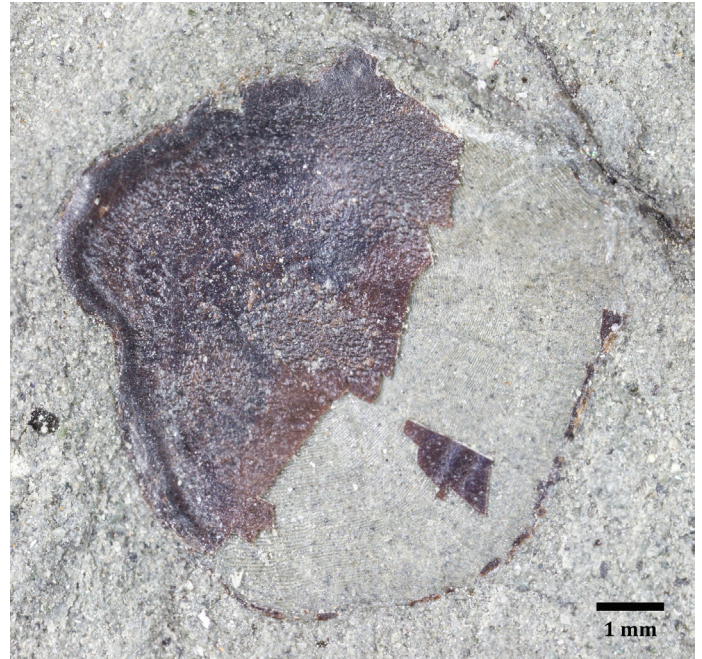


Figure 43. Cycloid teleost scale, hypotype UCMP 270032.

known from the “Monterey” Formation of southern California (David 1943). Boessenecker (2011) described a similar vertebra from the Pliocene Purisima Formation. They are also known from several sites in the Pliocene of the East Coast, including the Yorktown Formation at Lee Creek Mine, North Carolina, where tuna vertebrae are found with puncture marks from the feeding behavior of billfish (Schneider and Fierstine 2004). UCMP 218506 is similar to large vertebrae from the Round Mountain Silt (Shark Tooth Hill), Kern County, found in the UCMP collections. These elements are relatively common and in conjunction with this Claremont specimen indicate that *Thunnus* or a related fish was a widespread member of coastal and basinal ecosystems in California during mid-Miocene times. In spite of this, these elements are not commonly described making this specimen equal in age to the oldest published specimen of *Thunnus* in the eastern North Pacific.

TELEOSTEI INDET.

FIG. 43

UCMP 270032 is a single, relatively large cycloid scale (~7 mm wide) preserved as part and counterpart. It is sub-rounded, with a slightly tapered anterior edge. In the terminology of Bräger and Moritz (2016) it is between true circular and cordate. The scale is preserved in two pieces, a part featuring the majority of the scale in internal view (Fig. 44) and a counterpart with portions preserved in external view. Additionally, some of

the morphology of the external surface is preserved as an impression upon the matrix of the slab. The portion preserved on the slab in internal view comprises most of the anterior field and is mostly the overlapped region (the part covered by the next scale). The internal side of the scale is relatively smooth with strongly downturned ridges outlining the anterior edge of the scale. The external side shows numerous and distinct circuli, visible in the fragments of scale on the counterpart. The circuli are also visible on the slab as negative molds, where at least four radii can be discerned perpendicular to the circuli. These radii extend toward the posterior, non-overlapped region and would have been visible while the fish was alive.

Cycloid scales are generally associated with soft-rayed fishes, and within that group this specimen can be distinguished from many members of the large Cyprinidae by the presence of continuous circuli in the posterior field (compare with e.g., Teimori 2016). This suggests attribution to one of the cyprinids possessing this feature or to a member of Salmonidae. Considering the variability in scale morphology across the body and the incomplete record of fossil fish scales, we refrain from identifying UCMP 270032 below the infraclass, and consider it to represent the scale of a relatively large teleost fish.

#### ENVIRONMENTAL INTERPRETATION

The only specifically identified taxa from the Claremont Formation are the bivalve mollusk *Lucinoma annulatum* (provisionally identified) and the shark *Carcharhinus obscurus*. Modern *L. annulatum* range along the West Coast of North America from Prince William Sound, Alaska (60.8° N) south to Guaymas, Sonora, Mexico (27.9° N) at water depths between the intertidal zone and 665 m (Coan et al. 2000). *Carcharhinus obscurus* is a warm water species and does not currently appear north of ~34° (ICUN redlist). Its occurrence may be accounted for in several ways: 1) time averaging may be obscuring temperature shifts; 2) there may have been differences in temperatures experienced by pelagic and benthic organisms; or 3) the middle Miocene water temperatures may have been similar to that of Santa Barbara today. The occurrence of *Carcharh. obscurus* is interpreted to indicate warmer temperatures than exist along the central California coast today. None of the taxa present aid in determining the depth of deposition.

#### AGE

The bivalve *Lucinoma annulatum* (provisionally identified) occurs in the late Miocene to Holocene in

western North America. The tuna vertebra is of similar size and morphology to specimens commonly found in the middle Miocene Round Mountain Silt, Kern County, California (UCMP collections). *Carcharhinus obscurus* is known from at least the early Miocene (Sánchez-Villagra et al. 2000) and teleost fish with cycloid scales like UCMP 270032 (Fig. 39) have existed since at least the Late Cretaceous (Friedman 2010). Based on the occurrence of *L. annulatum* a late Miocene age for the Claremont shale is reasonable. However, the provisional identification does not allow for a definitive age determination and so the stratigraphic position of the Claremont shale between the Oligocene(?) to middle Miocene unnamed glauconitic mudstone (Tsm unit of Graymer 2000, McDougall and Block 2014; herein) and the late Miocene Orinda Formation (Jones and Curtis 1991; Poust 2017, Poust in prep.) gives a possible middle Miocene to late Miocene age for the Claremont shale.

#### CONCLUSIONS

A small fauna of mostly invertebrates is here attributed to the Caldecott Tunnel Tsm unit based on the position of the excavator near the west end of the fourth bore of the Caldecott Tunnel, and the dark to medium gray, fine- to very fine-grained clastic rocks associated with the fossils. The fauna consists of 32 taxa: one bryozoan, 22 Mollusca (16 Bivalvia, five Gastropoda and one Scaphopoda), two Arthropoda (Decapoda and Maxillopoda), two Echinodermata (Crinoidea and Echinoidea), and five Chordata. In addition, various trace fossils, microfossils, and plant fossils were recovered but are not discussed here. Fossils from this unit are middle Miocene in age based on the co-occurrences of the bivalves *Acila empirensis*, *Anadara osmonti*, *Yoldia submontereyensis*, *Y. supramontereyensis* (all bivalves provisionally identified) and the gastropod genera *Bruclarkia* and *Trophoscyon*. This fauna, based on overlapping range zones of extant taxa, was likely deposited at water depths between 200 and 500 m, although several taxa from shallower depths are present but are assumed to have washed in from shallower depths. The fauna is referred to a methane-rich environment, likely a cold seep, based on the occurrences of specimens attributed to indeterminate Vesicomidae and *Lucinoma*. Vesicomidae are all known from methane-rich environments (Barry et al. 1997) and the association of Vesicomidae and *Lucinoma* has been shown in southern California to occur at fossil methane seep sites (Powell and Groves 2008). By the early Miocene (~20 Mya), vesicomids had begun to colonize whale falls (Kiel and Goedert 2006) and so the co-occurrence of these methane associated

taxa and cetacean remains may suggest that environment. However, this can be ruled out for Tsm because potentially methane seep taxa were not found clustered or in association with any of the cetacean remains, but were instead distributed, suggesting a source of sulfide with a longer duration, or considerable current transport.

In California outside of the Bay Area, methane cold seeps are known from the Mesozoic of the Central Valley (Birgel et al. 2006, Kiel 2013), Miocene rocks of the Santa Cruz Mudstone (Aiello et al. 1999), possibly from the “Temblor” Formation exposed in excavations for the new Calaveras Reservoir in Alameda County (C. Powell, personal observation, 2015–2016), and in the present day Monterey Bay (Barry et al. 1997, Stakes et al. 1999), where they are associated with transpressive faults (Campbell et al. 2002), in Santa Monica Bay (Normark et al. 2003; Hein et al. 2006), and off the Eel River in northern California (Rathburn et al. 2000).

The inferred middle Miocene timing of the faunule indicates that the approaching triple junction of the Farallon, North American, and Pacific plates combined with movement on the San Andreas and accommodating splay faults such as the Hayward and Calaveras may have provided the geotectonic context for the hydrocarbon seeps of the Tsm. The Tsm Caldecott Tunnel fauna records the first crinoids from the Cenozoic of California.

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**Appendix 1.** Details of the *Dentalium (Fissidentalium?) mcganna* Powell, Clites, and Poust n. sp. specimens examined. Number of specimens in parentheses.

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**UCMP loc. IP13001:**

**UCMP 251010**, (1), cast, mineral replacement external details unclear.

**UCMP 410431**, (1), sections of original shell; poor preservation.

**UCMP 412779**, (1), small section well-preserved underneath exterior coating crushed nearly flat, cross hatching preserved.

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**UCMP loc. IP13002:**

**UCMP 412728\***, (1), **Paratype**, cast, sediment infilled.

**UCMP loc. IP13003:**

**UCMP 251012**, (1), **Holotype**, section of original shell over external mold; part and counterpart, fragmented, partial shell section, external mold extends to shell tip.

**UCMP 218713**, (1), **Paratype**, original shell well-preserved, embedded in matrix, possibly complete.

**UCMP 218799**, (1), **Paratype**, section of original shell over external mold; part and counterpart well-preserved, including cross hatching.

**UCMP 218690**, (2), external mold sections; shell sections well-preserved; poorly preserved.

**UCMP 218701**, (1), section of original shell over external mold; fair preservation.

**UCMP 218712**, (1), shell with part and counterpart external mold; fair preservation.

**UCMP 218719**, (1), original shell; good preservation.

**UCMP 218729**, (1), external mold sections; fair preservation.

**UCMP 218730**: (1), shell with part and counterpart external mold; poor, crushed.

**UCMP 218801**, (1), section of original shell; fair preservation.

**UCMP 218829**, (1), section of original shell over external mold; fair preservation.

**UCMP 251018**, (1), section of original shell with counterpart external mold; fair preservation.

**UCMP 251024**, (1), section of original shell; poor preservation.

**UCMP 251032**, (1), section of external mold; fair preservation.

**UCMP 410426**, (5), four sections of original shell, one partial external mold; fair preservation.

**UCMP 410925**, (2), original shell; poor preservation, external details not clear.

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**UCMP loc. IP13004:**

**UCMP 218803**, (3), section of original shell, section of original shell, external mold fair preservation, poor preservation, fair preservation.

**UCMP 410434**, (5), two sections of original shell; three external mold sections good to fair preservation.

**UCMP 410435**, (6), disarticulated small sections, external molds with some infilled casts fair preservation, cross hatching not preserved.

**UCMP 410438**, (1), section of original shell over external mold partial shell section

**Appendix 2.** Fauna associated with the Tsm unit recovered from excavation of the fourth bore of the Caldecott Tunnel, Oakland, western Berkeley Hills, Alameda County, California.

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**Foraminifers**

**Bryozoa**

Cheilostomata(?)

**Mollusca**

Bivalvia

*Acharax* cf. *Ach. johnsoni*

*Acila* cf. *Ac. empirensis*

*Anadara* (*An.*) cf. *An. (An.) osmonti*

*Crenella?* sp.

*Cyclocardia* sp. indeterminate

aff. *Lucinoma* n. sp.

Propeamussiidae, indeterminate

*Lima?* sp.

*Spisula* aff. *S. eugenensis*

aff. *Tehamatea* n. sp.

Tellinidae, indeterminate

Veneridae, indeterminate (probably

*Clementia*)

Vesicomylidae, indeterminate (possibly

*Pliocardia?*)

*Yoldia* cf. *Y. (Kalayoldia) submontereyensis*

*Yoldia* cf. *Y. (Kalayoldia) supramontereyensis*

*Yoldia?* sp. indeterminate

Gastropoda

*Bruclarkia* sp.

*Forreria* sp.

Naticidae, indeterminate

*Trophoscyon* sp.

*Demondia?* sp. indeterminate

Scaphopoda

*Dentalium mcganna* n. sp.

**Echinodermata**

Crinoidea

Indeterminate column

Echinoidea

Indeterminate spines

**Arthropoda**

Decapoda

Indeterminate fragments

Maxillopoda

Balanidae?, indeterminate

**Appendix 2 (cont.).** Fauna associated with the Tsm unit recovered from excavation of the fourth bore of the Caldecott Tunnel, Oakland, western Berkeley Hills, Alameda County, California.

### Chordata

Chondrichthyes

Carcharhiniformes

Osteichthyes

Actinopterygii

Indeterminate teeth, bone, and scale

Mammalia

Indeterminate ribs

cf. *Allodesmus* sp.

Odontoceti

**Appendix 3.** List of the University of California Museum of Paleontology Localities cited in the text. All localities collected by various people at various dates during the excavation.

**UCMP locality IP13001** (=UCMP V12003, UCMP PA1315): Caldecott Fourth Bore Sobrante General, specimens with unknown locality but with lithology matching the unnamed glauconitic mudstone (Tsm).

**UCMP locality IP13002** (=UCMP V12004): Caldecott Fourth Bore Claremont General, specimens with unknown locality but with lithology matching the Claremont Chert.

**UCMP locality IP13003** (=UCMP V12005): Caldecott Fourth Bore Sobrante first shale, specimens collected from the "First shale" of the Sobrante Formation as described by Page (1950). Note that contractors were not allowed to enter the tunnel, so this designation as "First shale" of the Sobrante is approximate. We assign this to Tms.

**UCMP locality IP13004** (=UCMP V12006): Caldecott Fourth Bore Sobrante portal sandstone, specimens collected from the "Portal sandstone" of the Sobrante Formation as described by Page (1950). Note that contractors were not allowed to enter the tunnel, so this designation as "Portal sandstone" of the Sobrante is approximate. We assign this to Tms.

**UCMP locality IP13005** (=UCMP V12007): Caldecott Fourth Bore Sobrante shaly sandstone, specimens collected from the "Shaly sandstone" of the Sobrante Formation as described by Page (1950). Note that contractors were not allowed to enter the tunnel, so this designation as "Shaly sandstone" of the Sobrante is approximate. We assign this to Tms.

**UCMP locality IP13007** (=UCMP V12010): Caldecott Fourth Bore Claremont second sandstone, specimens collected from the "Second sandstone" of the Claremont Formation as described by Page (1950). Note that contractors were not allowed to enter the tunnel, so this designation as "Second sandstone" of the Claremont Chert is approximate.

**Appendix 3 (cont.).** List of the University of California Museum of Paleontology Localities cited in the text. All localities collected by various people at various dates during the excavation.

**UCMP locality IP13008** (=UCMP V12011): Caldecott Fourth Bore Claremont Chert and shale, though this locality is described as the Claremont Formation, all of the invertebrate specimens match the unnamed glauconitic mudstone much more closely. This formation was reassigned on the basis of lithology to the unnamed glauconitic mudstone (Tsm).

**UCMP locality IP16022:** Field number RPF 411, James Allen gave to C. Powell from Fourth Bore of Caldecott Tunnel. Exact location unknown. Lithology matches unnamed glauconitic mudstone (Tsm).

**UCMP locality IP16025:** Field number RPF 412, James Allen gave to C. Powell from Fourth Bore of Caldecott Tunnel. Exact location unknown. Lithology matches unnamed glauconitic mudstone (Tsm).

**UCMP locality IP16027:** General locality for material without field numbers. James Allen gave to C. Powell from Fourth Bore of Caldecott Tunnel. Exact location unknown. Lithology matches unnamed glauconitic mudstone (Tsm).

**Appendix 4.** Fauna associated with the Claremont Formation recovered from excavation of the fourth bore of the Caldecott Tunnel, Oakland, western Berkeley Hills, Alameda County, California.

### Mollusca

Bivalvia

*Lucinoma* cf. *L. annulatum* (Reeve)

Pectinidae, indeterminate

Scaphopoda

*Dentalium* (*Fissidentalium*?) *mcganna* n. sp.

### Arthropoda

Maxillopoda

Balanidae, indeterminate

### Chordata

Chondrichthyes

*Carcharhinus obscurus* (Lesueur)

Osteichthyes

*Thunnus* sp. [vertebra]

Teleostei indeterminate [scale]