THE PURISIMA FORMATION AND RELATED ROCKS (UPPER MIOCENE - PLIOCENE), GREATER SAN FRANCISCO BAY AREA, CENTRAL CALIFORNIA
Review of literature and USGS collection (now housed at the Museum of Paleontology, University of California, Berkeley)

By

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ABSTRACT

Sedimentary rocks more than 1.6 kilometers thick are attributed to the upper Miocene to upper Pliocene Purisima Formation in the greater San Francisco Bay area. These rocks occur as scattered, discontinuous outcrops from Point Reyes National Seashore in the north to south of Santa Cruz. Lithologic divisions of the Formation appear to be of local extent and are of limited use in correlating over this broad area. The Purisima Formation occurs in several fault-bounded terranes which demonstrate different stratigraphic histories and may be found to represent more than a single depositional basin. The precise age and stratigraphic relationship of these scattered outcrops are unresolved and until they are put into a stratigraphic and paleogeographic context the tectonic significance of the Purisima Foramtion can only be surmised. This paper will attempt to resolve some of these problems.

Mollusks and echinoderms are recorded from the literature and more than 70 USGS collections that have not previously been reported. With the exception of one locality, the faunas suggest deposition in normal marine conditions at water depths of less than 50 m and with water temperatures the same or slightly cooler than exist along the present coast of central California. The single exception is a fauna from outcrops between Seal Cove and Pillar Point, where both mollusks and foraminifers suggest water depths greater than 100 m.

Three molluscan faunas, the La Honda, the Pillar Point, and the Santa Cruz, are recognized based on USGS collections and published literature for the Purisima Formation. These biostratigraphically distinct faunas aid in the correlation of the scattered Purisima Formation outcrops. The lowermost La Honda fauna suggests shallow-water depths and an age of late Miocene to early Pliocene. This age is at odds with a younger age determination from an ash bed in the lower Purisima Formation along the central San Mateo County coast. The Pillar Point fauna contains only a single age diagnostic taxon, *Lituyapecten purisimaensis* (Arnold), which is reported as Pliocene in age, but it only occurs in the Purisima Formation, so its age here is an example of circular reasoning. However, based on tentative lithologic correlations this fauna may represent the same period of time as the upper part of the La Honda fauna. This fauna differs from either the La Honda or Santa Cruz faunas in that it represent significantly deeper water. The uppermost Santa Cruz fauna also suggests shallow-water depths and a possible age range of early to late Pliocene.

The bivalve molluscan taxon *Lyonsia*, and gastropod taxon *Rictaxis* sp., cf. *R. punctocaelatus* (Carpenter) are reported here for the first time from the Purisima Formation.

INTRODUCTION

The Purisima Formation is represented in coastal central California by conglomerate, sandstone, shale, diatomite, and minor ash beds in Marin, San Mateo, Santa Clara, and Santa Cruz Counties (Fig. 1). These rocks range in age from late Miocene to late Pliocene, and mostly were deposited in inner sublittoral water depths (low water to 50 m), although at one locality bathyal water depths (> 100 m) are indicated. Where fossils are present, they indicate a normal marine environment, in water possibly slightly cooler than exists at the same latitude today. An exception to this is in the Chittenden Pass/Sargent oil field area and to a lesser extent at Scotts Valley, where warm-water mollusks from the Central Valley Pliocene seaway are evident. These warmer-water mollusks are missing in the open-coast outcrops that comprise the Purisima Formation to the north.

One stratigraphic problem related to the Purisima Formation is its occurrence as scattered outcrops within fault-bounded blocks. Even where thick sections occur, they generally lack internal markers, making correlations tentative at best. One goal of this project is to determine the stratigraphic context for these various scattered outcrops and sections based on biostratigraphy. This report is a first attempt at developing such a biostratigraphy. With the addition of collections from other institutions (i.e., California Academy of Sciences; Museum of Paleontology, University of California at Berkeley; Santa Cruz Museum of Natural History), a more detailed biostratigraphy can be developed.

In this study I review taxonomic names assigned by previous authors, and make changes consistent with modern usage. This review was done by means of an extensive search of names equated to new names in taxonomic catalogues and revisions (i.e., Grant and Gale, 1931; Keen & Bentson, 1944; Moore, 1983, 1984, 1987, 1988; and many others); type specimens were not examined. The ecologic parameters of species identified by earlier authors were also reviewed to see if they fit into the general ecologic character of the Purisima Formation herein described.

STRATIGRAPHY

Brabb (1960) [also Brabb and others, 1977, and Clark and Brabb, 1978] used the earlier work of Clark (1930) to show that the stratigraphy of Tertiary sections on the greater San Francisco Peninsula varies across the San Gregorio, Zayante, and San Andreas faults, which define at least four distinct tectonic blocks. These structural blocks show different sedimentary histories, including that of the Purisima Formation, and so correlations among these blocks are tentative. From north to south (Fig. 1) the structural blocks are 1) the La Honda block; 2) the Pigeon Point block; and 3) the Ben Lomond block, and, east of the San Andreas fault, the San Francisco block (Fig. 1). They are discussed in further detail below under the “Paleontological significance of Purisima Formation outcrops.”

The Purisima Formation was named by Haehl and Arnold (1904) for “an extensive series of conglomerates, fine-grained sandstones and shales” which are typically developed in the vicinity of Purisima Creek (Branner and others, 1909). The lower limit of the Formation is generally marked by an unconformity and consists of basal sandstone and conglomerate beds (Branner and others, 1909), but in Scotts Valley Clark (1981) reported both a conformable and unconformable lower boundary in adjacent areas. Haehl and Arnold (1904) defined the upper limit of the Formation as the base of the Merced Formation of Lawson (1893). Branner and others (1909) reported both the Merced and Purisima Formations at Año Nuevo, but the distinction between these two formations was based solely on fossil preservation rather than lithology (see discussion of Año Nuevo sites be-

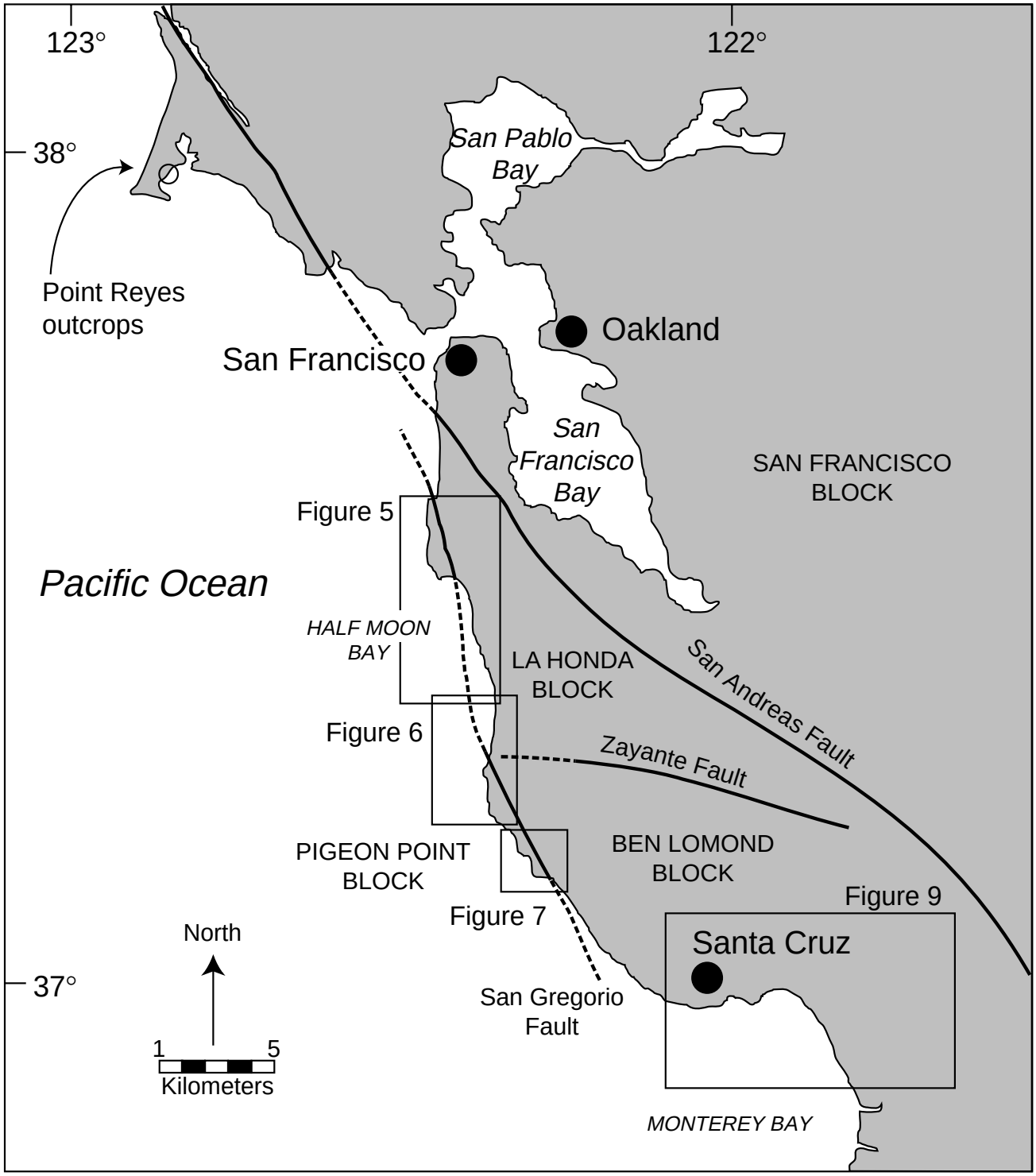

Figure 1.—Generalized locality map showing structural blocks in the San Francisco Bay region. Also shown are areas of finer coverage illustrated by other figures.

low), and both sections at Año Nuevo were mapped as Purisima Formation by Clark (1981). Earlier, Cummings and others (1962) reported that the two formations (Merced and Purisima) are no where in contact and "...rocks mapped as Merced Formation away from the type area are more properly assigned to the Purisima Formation" (Fig. 4). In coastal exposures, the Purisima Formation is unconformably overlain by Pleistocene terrace de-

posits except at Seacliff State Beach where it is overlain by the Aromas Sand. Locally it is in fault contact with other formations from which it is usually easily discernible.

Branner and others (1909) divided the Purisima Formation into three informal members which they reported as representing "...periods of sedimentation...." They are "... a basal sandstone-forming period, a middle diatom-growing period, and an upper sandstone-forming period." Cummings and others (1962) divided the Purisima Formation in the same area into five members, from top to base: Tunitas, Lobitos, San Gregorio, Pomponio, and Tahana. These authors correlated the Tunitas, Lobitos, and San Gregorio Members with the upper sandstone member of Branner and others (1909), the Pomponio Member to the middle diatomaceous shale of Branner and others (1909), and the Tahana Member to the lower sandstone of Branner and others (1909). These members as defined by Cummings and others (1962) are briefly outlined below from youngest to oldest. It must be stressed, however, that these members are generally not lithologically recognizable outside of the La Honda structural block.

Tunitas Member-The Tunitas Member consists of about 120 m (400 ft) of massive, fine-grained sandstone with the principal outcrops along the sea cliffs north of the mouth of Tunitas Creek (Fig. 5). The Tunitas Member overlies the Lobitos Member conformably with the contact being gradational over about 1.5 m (5 ft). Pleistocene terrace deposits are angularly unconformable on the Tunitas Member.

Lobitos Member-The name Lobitos Member is given to massive, silty mudstone, up to about 140 m (450 ft) thick which overlies the San Gregorio Member near the axis of the Pescadero syncline about 1,100 m (3,500 ft) south of the mouth of Purisima Creek. The contact with the underlying San Gregorio Member is conformable and sharp, being easily recognized by the lithologic difference. Both megafossils and microfossils are common in this member and the four highest samples of Goodwin and Thomson (1954) are referable to this member (Touring, 1959).

San Gregorio Member-This member, which is a homogenous unit both laterally and vertically, is exposed along the coast in the axis of the Pescadero syncline, south of the mouth of Purisima Creek. It consists of up to about 140 m (450 ft) of massive, fine- to coarse-grained sandstone with irregularly distributed small pebbles of chert and basic volcanic rocks. Fossils are locally abundant and commonly associated with concretionary beds. The lower contact is conformable and recognized by the lithologic change from underlying siltstone and mudstone to massive sandstone.

Pomponio Member-Rocks referred to the Pomponio Member are generally composed of siliceous siltstone and mudstone up to about 700 m (2,300 ft) thick. Cummings and others (1962) reported the lower half of the member grading laterally into massive, dark-gray, concretionary, fossiliferous mudstone near the mouth of Purisima Creek where the unit is abundantly fossiliferous and has been referred to as the "upper sandstones" by Ashley (1895) and Martin (1916). Goodwin and Thomson's (1954) foraminifers were mostly collected from this member, but included samples referred to the overlying, San Gregorio and Lobitos Members (Touring, 1959). The lower contact with the underlying Tahana Member is sharp and conformable, where siliceous mudstone overlies volcanic arenite (Cummings and others, 1962).

Tahana Member-The Tahana Member is represented by about 650 m (2,150 ft) of medium- to fine-grained sandstone and siltstone with silty mudstone common in some sections. Locally it conformably overlies the Woodhams Shale Member of the Monterey Formation of Cummings and others (1962); elsewhere it unconformably overlies other parts of the Monterey, Mindego and San Lorenzo Formations. It is conformably overlain by the

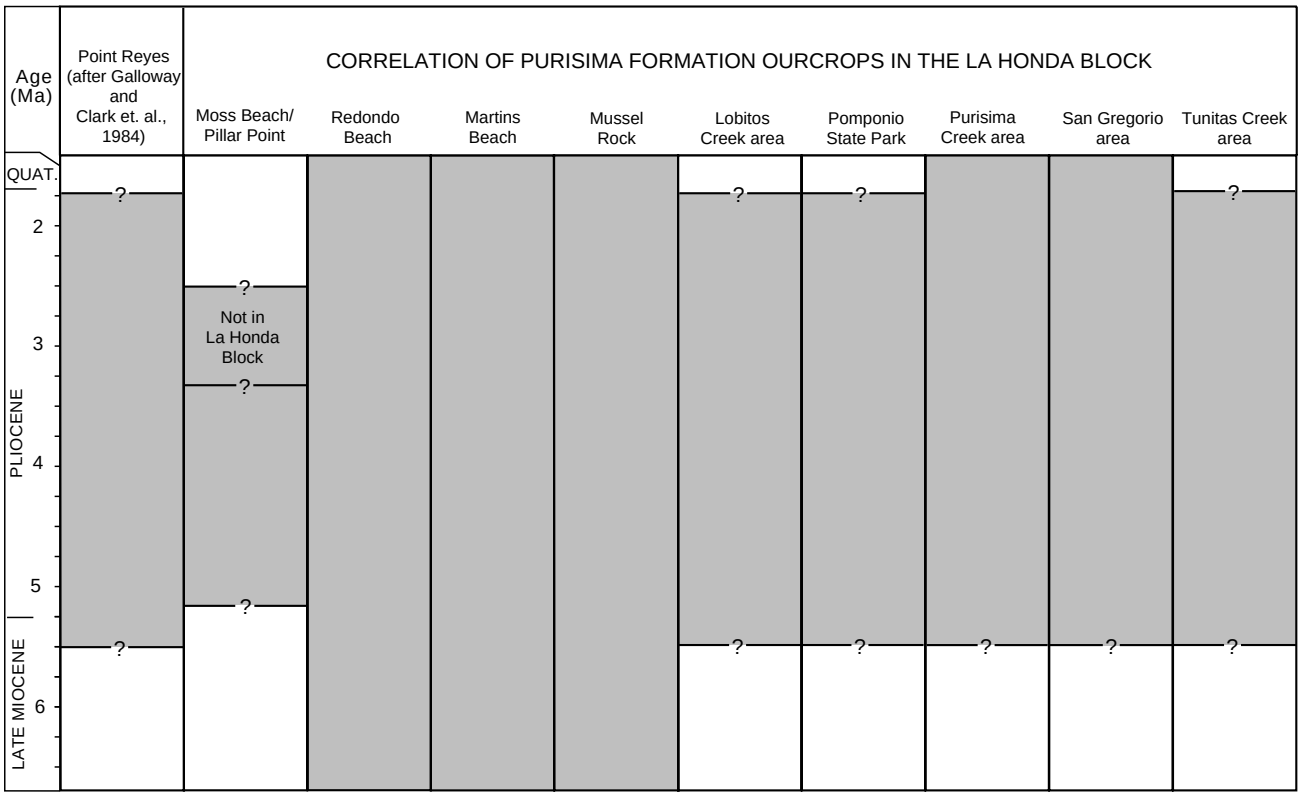

Figure 2.—Correlation chart showing age of outcrops within the La Honda Block as determined by paleontological and other methods. Age determinations based on stratigraphic range of mollusks and correlations of similar faunas and lithologies with section in the Ben Lomond Structural Block by Madrid and others (1986). These correlations may not be age equivalent rocks but only represent similar environments. Point Reyes is outside the La Honda Structural Block and the base of the Formation was defined by Repenning and Tedford (1977) reinterpretation of Galloway's (1977) K-Ar age determination. The lower unit at Moss Beach is not in the La Honda structural block.

Pomponio Member of the Purisima Formation. Cummings and others (1962) reported microfossils and megafossils from the Tahana Member and figured six mollusks from this member.

AGE

Introduction

Since it was first described the Purisima Formation has been considered to range from Miocene to Pliocene in age. It is still considered to range from Miocene to Pliocene and recent biostratigraphic and absolute dating techniques have corroborated and refined this age assignment.

Age determinations for outcrops in the La Honda structural block are illustrated in figure 2, for the Pigeon Point Block in figure 3, and for the Ben Lomond Block in figure 4.

Paleontologic Age

Ashley (1895a) referred his "Merced series," which is in part equivalent to the Purisima Formation, as Miocene to Pliocene. Haehl and Arnold (1904) believed the Purisima Formation, named for outcrops in central San Mateo County, was "early and middle Pliocene." Branner and others (1909) considered the Purisima Formation to be in part "late Miocene." Both Esser (1958) and Mack (1958) considered the Purisima Forma-

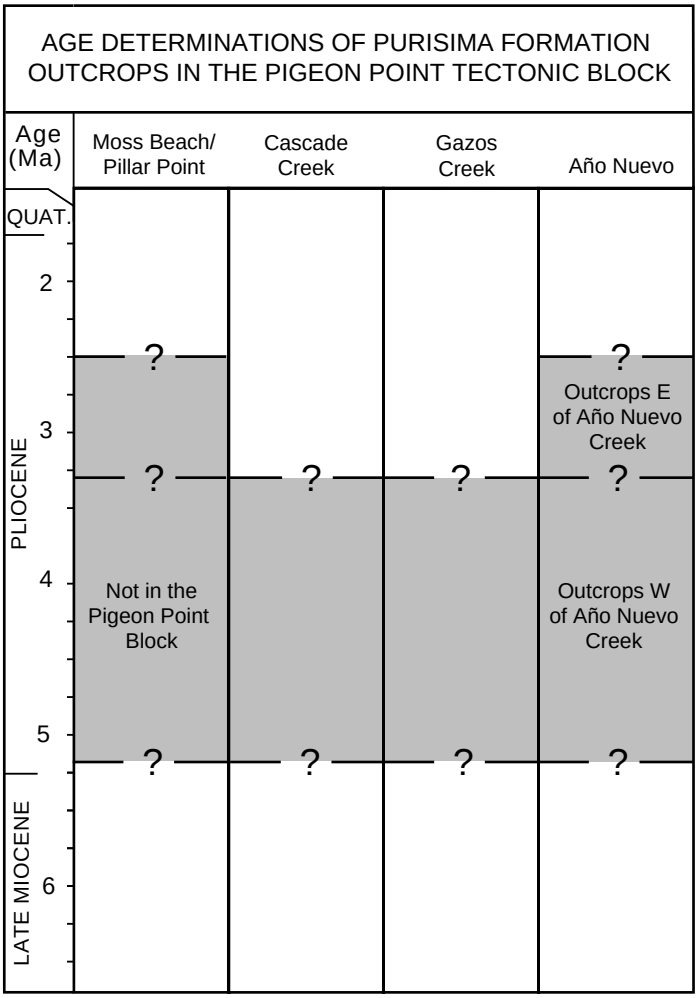

Figure 3.—Correlation chart showing age of outcrops within the Pigeon Point Structural Block. Age determinations based on stratigraphic range of mollusks and correlations of similar faunas and lithologies with section in the Ben Lomond Structural Block by Madrid and other (1986). These correlations may not be age equivalent rocks but only represent similar environments. The Upper unit is not in the Pigeon Point Structural Block.

tion to be Pliocene based on work of previous authors. Touring (1959) and Cummings and others (1962) considered the Purisima Formation be to entirely within the Pliocene, proposing the lower boundary of the formation as the Miocene/Pliocene boundary. More recent work by Repenning and Tedford (1977), Addicott and others (1978b), and Barron *in* Clark (1981) in the Santa Cruz area suggests a latest Miocene to late Pliocene age for the Purisima Formation. Repenning and Tedford (1977) reported vertebrate remains which suggest a latest Hemphillian or Blancan mammalian age (latest early Pliocene or late Pliocene), and Addicott and others (1978b) reported mollusks diagnostic of a late Pliocene age from Capitola and New Brighton/Seacliff State Beaches in the upper part of the Formation. Barron *in* Clark (1981) reported the occurrence of diatoms diagnostic of late Miocene to early Pliocene (North Pacific diatom zone X, subzone a and b) from near the base of the Formation. Madrid and others (1986) report a stratigraphic succession for the Purisima Formation in the Santa Cruz area ranging in age from about 6.07 Ma to >2.47 Ma based on magnetic polarity zonation and first and last occurrences of various diatoms, with a hiatus from 4.5 to 3.5 Ma. Based on high resolution diatom biostratigraphy and magnetic polarity zonation Dumont and Madrid (1987) suggested the Purisima Formation in the Santa Cruz

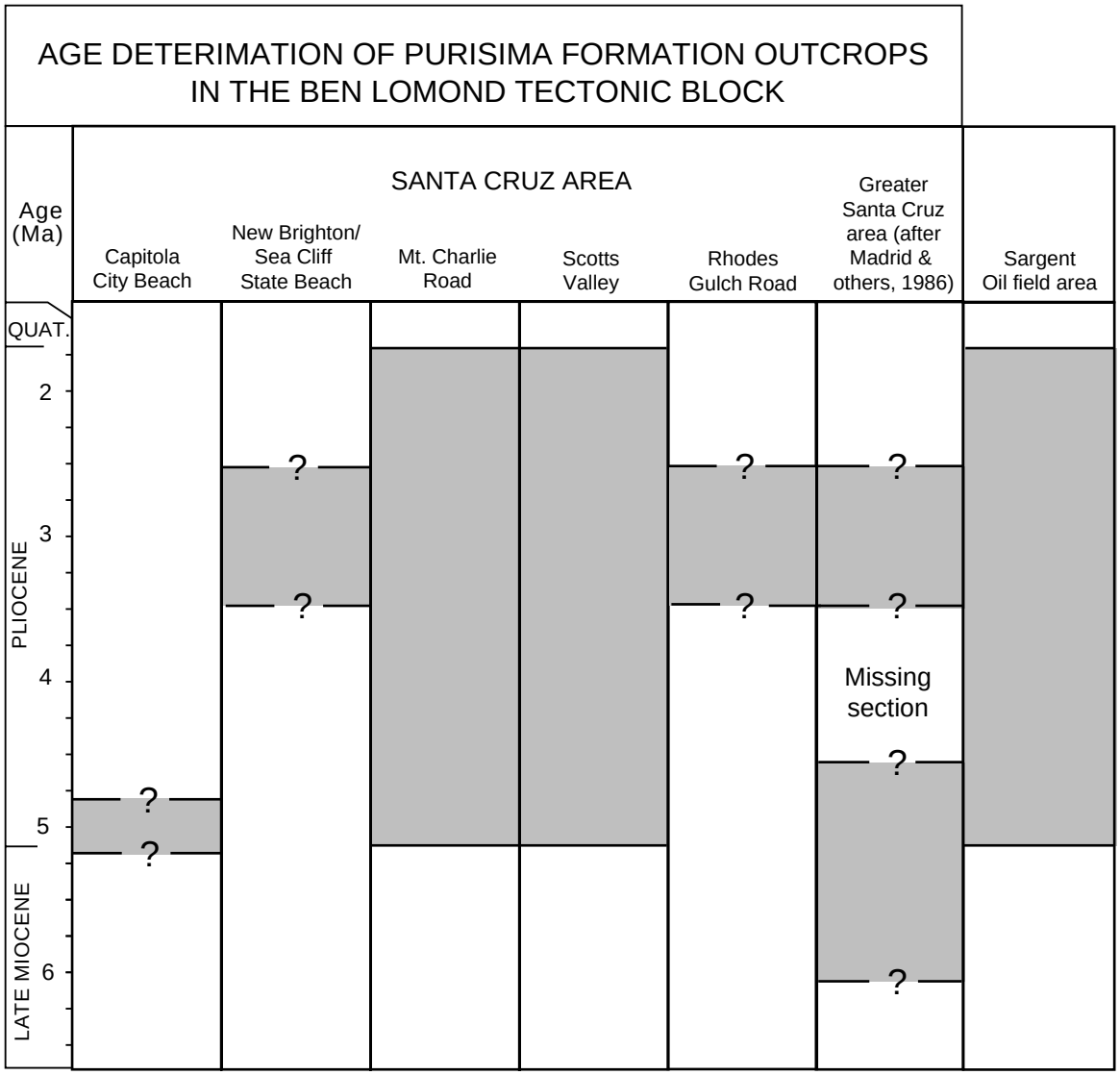

Figure 4.—Correlation chart showing age of outcrops within the Ben Lomond Structural Block as determined by paleontological and other methods. Age determinations based on stratigraphic range of mollusks and correlations of similar faunas and lithologies with section in the Ben Lomond Structural Block by Madrid and other (1986). These correlations may not be age equivalent rocks but only represent similar environments.

area spans the interval from the Chron 5/Chron 6 boundary (5.89 Ma) to the Matuyama/ Gauss boundary (2.47 Ma) with a significant hiatus corresponding to the Gilbert Chron (4.5 to 3.5 Ma). Based on faunal correlations with the Central Valley of California, Durham and Morgan (1978) suggested that the Tahana Member along the coast in central San Mateo County was early Pliocene.

In the Point Reyes area Hanna *in* Galloway (1977) suggested the Drakes Bay Formation is Miocene to Pliocene, based on a diatom age call, and supported by vertebrate and mega-invertebrate age calls. Based on the age assignments and lithologic similarities Clark and Brabb (1997) reassigned part of the Drakes Bay Formation to the Purisima Formation. I propose the continued use of Drakes Bay Formation until outcrops at Drakes Bay and in San Mateo County can be definitely correlated.

Allen (1945) suggested an age of “lower middle to uppermost Pliocene, and may

extend into the lower Pleistocene" for undifferentinted Purisima/Santa Clara beds in the Sargent oil field area east of the San Andreas fault. However, based on the fauna from these exposures, the lithology, and theirposition east of the San Andreas fault, it is questionable that these rocks belong to the Purisima Formation.

Radiometric Dating

The first absolute age determination from the Purisima Formation was performed by J. D. Obradovich *in* Clark (1966) who reported glauconite dated at 6.7±0.5 Ma [adjusted in accordance with new K/Ar constants of Dalrymple (1979) to 6.9 ± 0.5 Ma by Madrid and others (1986)] from sandstone at the base of the Purisima Formation in the Santa Cruz Mountains. More recent work by Barron (*in* Addicott and others, 1978b) supports a latest Miocene age for the same section.

Recent age determinations suggest problems with our understanding of the stratigraphic relationships within the Purisima Formation in San Mateo County, or as suggested by Dumont and Madrid (1987) for the Santa Cruz area, a significant hiatus in the Formation. A thick tuff bed in rocks assigned to the Tehana Member is exposed in the sea cliffs at San Gregorio State Beach and has yielded age determinations of between about 5 and 2 Ma. Naeser *in* Gavigan (1984) reported an age determination of 5.2±1.2 Ma from zircon recovered from this tuff. Holm and Verosub (1987) also cited an age determination of 5.2 ± 1.2 Ma from a fission-track, presumably the same as cited earlier by Naeser *in* Gavigan (1984). Using these data Sarna *in* Gavigan (1984) correlated this tuff with the Nomlaki Tuff Member of the Tuscan Formation suggesting an age of about 3.4 Ma. Later work by Sarna-Wojcicki and others (1991) (and A. Sarna-Wojcicki, oral commun., 1996) has revised this correlation and now suggests that this tuff exposed in the Purisima Formation at San Gregorio Beach correlates with the Ishi Tuff, which has been dated between 2.2 Ma and 2.6 Ma. If this latter age determination is correct, then the stratigraphy of the Purisima Formation along the central San Mateo County coast is poorly understood and outcrops at San Gregorio State Beach are younger than the Tehana Member of Cummings and others (1962). But this age is not in agreement with megafossil data (Durham and Morgan, 1978) about 1 km north on the same beach, which suggests an early Pliocene age.

In the Point Reyes area J. D. Obradovich *in* Galloway (1977) reported glauconite dated at 9.3 ± 0.5 Ma in his Drakes Bay Formation, but Repenning and Tedford (1977) suggested that the sample contained detrital biotite and may be considerably younger. Recently Clark (1997) recollected and processed this glauconite and obtained a K-Ar date of 7.9 ± 0.3 Ma from these sandstone beds, now mapped by Clark and Brabb (1997) as the Santa Margarita Formation, but here considered part of the Drakes Bay Formation. Although not directly related to the Purisima Formation this age determination puts a lower limit on rocks, which in part, are correlated with the Purisima Formation.

PREVIOUS WORK ON PALEONTOLOGY OF THE PURISIMA FORMATION

Fossil mollusks from the Purisima Formation have been known for more than 100 years (Cooper, 1888; Ashley, 1895a, b). Although these early reports are regional in nature, they include lists of Purisima fossils. Cooper (1888) in his catalogue of California fossils lists Pliocene mollusks from Soquel (? = Soquel Landing, = Capitol). In his first work Ashley (1895a) listed mollusks from the Merced Formation (including the Purisima Formation of later usage), at Pillar Point, Purisima, Lobetus (=Lobetos), Tunitas Creek, San Gregoria Creek (=San Gregorio Creek), San Gregoria (=San Gregorio), and Capitola, all of which were later referred to the Purisima Formation. Ashley (1895b) briefly discussed the

Merced Formation (including the Purisima Formation of later usage) in his description of Tertiary stratigraphy of the Santa Cruz Mountains.

Much of the early work dealing directly with Purisima fossils was performed by Ralph Arnold (Haehl and Arnold, 1904; Arnold, 1908a, Branner and others, 1909) and, again, much of it in conjunction with regional work. Arnold's preliminary work on the Purisima Formation (Arnold *in* Haehl and Arnold, 1904) listed 52 mollusks from unspecified localities in the Formation and named these rocks the Purisima Formation, including beds from both sides of the San Andreas fault. Arnold (1908a) later developed a preliminary biostratigraphy for the Purisima Formation using the above mollusks.

Arnold's (1908a) biostratigraphy included three zones, of which only the upper two are now included in the Purisima Formation. From his lowest member, outcropping east of the San Andreas Fault, Arnold (1908a) recorded a fauna of 16 bivalves and seven gastropods (table 1), including three new species. These mollusks suggest a middle Miocene or "Temblor" provincial molluscan stage for the rocks and they are no longer considered part of the Purisima Formation. The following year Arnold called this lowest member the "Barnacle bed" (Branner and others, 1909). Subsequently these rocks were referred to the Los Trancos Formation by Thomas (1949) and Langerfeldt and Vigras (1959), none of whom defined a type section. Dobbs and Forbes (1960) referred to these rocks as Mio-cene sandstone, whereas Dibblee (1966), Page and Tabor (1967), and Pampeyan (1970) called them unnamed sandstone. Later Beaulieu (1970, 1971) referred to them as the "Ladera Sandstone," although it was not until Pampeyan (1993) that these rocks were formally named the Ladera Sandstone. The Ladera Sandstone is interbedded with the Page Mill Basalt and is considered middle Miocene based on a K-Ar date on the basalt which was dated at 14.4±2.4 Ma (Turner, 1970) and later adjusted to 14.8±2.4 Ma (Fox and others, 1985). Also benthic foraminifers of provincial middle Miocene (Relizian or Luisian) age (Clark, 1968) have been collected from the Ladera Sandstone.

Table 1. Molluscan taxa reported by Arnold (1908a) from his lower member of the Purisima Formation, now considered the Ladera Sandstone.

MOLLUSCA
BIVALVIA
Amiantis? mathewsonii Gabb [as *Chione mathewsonii* Gabb, fide Keen and Bentson, 1944]
Anadara trilineata (Conrad) *s.l.* [as *Arca canalis* Conrad]
A. (Scapharca?) sp., cf. *A. (S?) obispoana* (Conrad) *s.l.* [as *Arca* sp., cf. *A. obispoana* Conrad]
Chione sp., cf. *C. temblorensis* Anderson
Compsomyax sp., *C. subdiaphana* Carpenter [as *Saxidomus* (cf.) *gibbosus* Gabb]
Dosinia jacalitosana Arnold [? as *Dosinia ponderosa* (Gray)]
D. mathewsonii Gabb?
Lucinoma acutillineataus (Conrad) [as *Phacoides acutillineataus* Conrad]
Nuculana taphira Dall [as *Leda taphira* Dall]
Pacipecten andersoni (Arnold) [as *Pecten andersoni* Arnold]
Panope abrupta (Conrad) [as *Panopea generosa* Gould]
Periploma sanctaecrucis Arnold
Protothaca sp., cf. *P. staleyi* (Gabb) [as *Tapes* (cf.) *staleyi* Gabb]
Solen sicarius Gould
Spisula catilliformis (Conrad) [? as *Spisula* (cf.) *californica* Conrad]
Yoldia supramontereyensis Arnold
GASTROPODA
Calyptraea radians Lamarck [as *Trochita costellata* Conrad *fide* Woodring, 1931; Keen and Bentson, 1944]

C. inornata (Gabb) [as *Galerus inornatus* Gabb]
Fissurella? sp. indet. [as *Fissuridea*, species, a]
Megatabennus sp., cf. *M. bimaculatus* (Dall)
Neverita andersoni (Clark) [as *Natica* (cf.) *ocoyana* Conrad *fide* Addicott, 1970]
Priscofusus? stanfordensis Arnold
Trophosycon ocoyana (Conrad) [as *Agasoma kernianum* Cooper *fide* Grant and Gale, 1931]

Arnold's (1908) middle member is exposed west of the San Andreas fault and is represented by faunas at Pescadero Creek near the mouth of Jones Gulch and on the Halliday Ranch near Portola. These beds are now considered to be within the lower part of the Purisima Formation. Arnold lists 21 bivalves and 17 gastropods from his middle member (table 2).

Table 2. Molluscan taxa reported by Arnold (1908a) from his middle member of the Purisima Formation.

MOLLUSCA
BIVALVIA
Acila castrensis (Hinds)
Anadara trilineata (Conrad) *s.l.* [as *Arca canalis* Conrad]
Clinocardium meekianum (Gabb)
Chione sp., cf. *C. securis* (Shumard) [as *C.* (aff.) *gnidia* Broderip and Sowerby]
Clementia pretenuis (Gabb)
Compsomyax subdiaphana (Carpenter) [as *Saxidomus gibbosus* Gabb]
Cryptomya californica (Conrad) [as *Cryptoma ovalis* Conrad]
Dosinia jaclitosana Arnold [? as *D. ponderosa* Gray]
Lituyapecten purisimaensis (Arnold)
Lucinisca nuttalli antecedens (Arnold)
Lucinoma annulata (Reeve) [? as *Phacoides acutilineatus* Conrad]
Macoma nasuta (Conrad)
Pandora punctata (Conrad) [as *Clidophora punctata* (Conrad)]
Panope abrupta (Conrad) [as *Panopea generosa* Gould]
Patinopecten healeyi (Arnold)
P. lohri (Hertlein) [as *Pecten oweni* Arnold]
Protothaca staleyi (Gabb)
Solen sicarius Gould
Spisula albaria (Conrad)]
Swiftopecten parmeleei (Dall) s.s. [as *Pecten wattsi* Arnold]
Tellina sp.
GASTROPODA
Acteocina culcitella (Gould) [as *Tornatina culcitella* Gould]
Beringius stantoni (Arnold)
Calicantharus sp., aff. *C. humerosus* (Gabb) [as *Neptunea* (aff.) *humerosa* Gabb]
Calicantharus portolaensis (Arnold) [as *Fusus portolaensis*, new species]
Crepidula princeps Conrad
Cryptonatica affinis (Gmelin) [as *Natica clausa* Broderip and Sowerby]
Nassarius californius (Conrad)? [as *Nassa californiana* Conrad]
Neptunea sp., aff. *N. lyrata* (Gmelin) [as *Chrysodomus* (aff.) *liratus* Martyn]
Nucella imperialis (Dall) [as *Chrysodomus imperialis* Dall]
Nucella lamellosa (Gmelin) [as *Thais crispata* Chemnitz]
Ocenebra sp. [as *Tritonium*, species, a]
Olivella pycna Berry [? as *O. intorta* Carpenter and *O. pedroana* Conrad]
Polinices lewisii (Gould) [as *Lunatia lewisii* Gould]
Solariella sp., aff. *S. permabilis* Carpenter

Tegula lahondaensis Arnold
Turrid indet., possibly *Ophiodermella* or *Megaurcula* [as *Pleurotoma*, species, a]

Arnold's upper member, also exposed west of the San Andreas fault, is "...typically exposed in the sea cliffs in the vicinity of Purisima and south to the mouth of Pescadero Creek, in the region immediately east of Point Año Nuevo and in the region east of Santa Cruz." He reported a fauna of 30 bivalves and 25 gastropods (table 3) from his uppermost Purisima member. Depending on which beds from Purisima and Pescadero Creeks were included, Arnold's (1908a) upper member could include some of the lower members of current usage (Cummings and others, 1962).

Table 3. Molluscan taxa reported by Arnold (1908a) from his upper member of the Purisima Formation.

MOLLUSCA
BIVALVIA
Acila castrensis (Hinds) [as *Nucula (Acila) castrensis* Hinds]
Anadara trilineata (Conrad) *s.l.* [as *Arca canalis* Conrad and *Arca trilineata* Conrad]
Clinocardium meekianum (Gabb) [as *Cardium meekianum* Gabb]
Chlamys hastata (Sowerby) [as *Pecten hastatus* Sowerby]
Compsomyax subdiaphana Carpenter [as *Saxidomus gibbosus* Gabb]
Cryptomya californica (Conrad) [as *Cryptoma ovalis* Conrad]
Lituyapecten purisimaensis (Arnold) [as *Pecten purisimaensis* Arnold]
Lucinisca nuttalli (Conrad) [as *Phacoides nuttalli* Conrad]
Lucinoma annulata (Reeve) [? as *Phacoides acutilineatus* Conrad]
Nanaochlamys nutteri (Arnold) [as *Pecten nutteri* Arnold]
Nuculana taphria (Dall) [as *Leda taphria* Dall]
Macoma nasuta (Conrad)
Modiolus rectus (Conrad) [as *Modiolus directus* Dall]
Panomya sp.
Panope abrupta (Conrad) [as *Panopea generosa* Gould]
Patinopecten healeyi (Arnold) [as *Pecten healeyi* Arnold]
Protothaca staleyi (Gabb) [as *Tapes staleyi* Gabb]
P. tenerrima (Carpenter) [as *Tapes tenerrima* Carpenter]
Siliqua sp., cf. *S. lucida* (Conrad)
S. sp., cf. *S. patula* (Dixon
Spisula albaria (Conrad) [as *Mactra albaria* Conrad]
S. sp., cf. *S. sisquocensis* Arnold
Tellina nuculoides (Reeve) [as *Moerella salmonea* Carpenter]
Tellina sp. [as *T.* (aff.) *congesta* Conrad]
Thracia trapezoides Conrad
Tresus pajaroanus (Conrad) [as *Schizothaerus pajaroanus* Conrad]
Yoldia cooper (Gabb)
Y. sp., aff. *Y. scissurata* Dall
Zirfaea pilsbryi (Lowe) [as *Z. gabbi* Tryon]
GASTROPODA
Admete gracilior Capenter
Beringius stantoni Arnold [as *Chrysodomus stantoni*, new species]
Bittium asperum (Gabb)
Boreotrophon pacificus Dall
Calytptraea sp. [as *Galerus inornatus* Gabb]
Cancellaria sp.
Crepidula nummaria Gould [as *C. navicelloides* Nuttall]
Cryptonatica affinis (Gmelin) [as *Natica clausa* Broderip & Sowerby]

C. princeps Conrad
Cymatium pacifica (Dall) [as *Priene pacifica* Dall]
Homalopoma paucicostatum (Dall) [as *Leptothyra paucicostata* Dall]
Megasurcula remondii (Gabb) [? as *Bathytoma carpenteriana* Gabb, var. *fernandoana* Arnold]
Mitrella gouldii (Conrad) [as *Astyris richthofeni* Gabb]
Nassarius californicus (Conrad)? [as *Nassa californiana* Conrad]
N. grammatus (Dall)? [as *Nassa* (aff.) *perpinguis* Hinds]
Neptunea tabulata (Baird) [as *Chrysodomus tabulatus* Baird]
Neverita recluziana Petit
Olivella pycna Berry [? as *O. intorta* Carpenter and *O. pedroana* Conrad]
Polinices lewisii (Gould) [as *Lunatia lewisii* Gould]
Psephaea oregonensis (Arnold) [as *Miopleiona oregonensis* Dall]
GASTROPODA
Serpulorbis squamigerus (Carpenter)
Sinum scopulosum (Conrad) [? as *Sigaretus debilis* Gould]
"*Voluta*" sp.

Branner and others (1909) published a geologic map of the Santa Cruz Quadrangle (Half Moon Bay to Santa Cruz) and discussed the geology and formations within the quadrangle listing fossils from various formations. They included a list of 33 taxa from the lower part of the Purisima Formation and 36 taxa from the upper part of the Formation, all of which were published earlier by Arnold (1908a).

In the early part of this century several authors mentioned the Purisima Formation in passing as part of other studies. Osmont (1905) was the first, correlating the Wilson Ranch beds (=Wilson Grove Formation) with the Purisima Formation at Capitola because of the common occurrence of *Anadara trilineata* (Conrad) at both sites. As part of a study of the Miocene San Pablo Formation Weaver (1909) listed the occurrences of San Pablo mollusks which co-occur in the Purisima Formation. Later, Martin (1916) reviewed Pliocene outcrops in middle and northern California, including rocks now referable to the Purisima Formation but which he called Merced Formation (i.e., Año Nuevo Bay, Pillar Point), along with the type Purisima Formation. He listed a fauna of 28 taxa from Año Nuevo Bay, eight at Pillar Point, and 57 taxa from the Purisima Formation "...chiefly from the sea-cliffs south of Halfmoon Bay." Grant and Gale (1931) made brief mention of the Purisima Formation in their remarkable work on the Pliocene and Pleistocene mollusks of California, but added nothing significant.

Later works on the paleontology of the Purisima Formation include Hertlein (1951), Glen (1959), Cummings and others (1962), Perry (1977), Addicott and others (1978b), Durham and Morgan (1978), Clark (1981), Wiley and Moore (1983), Norris (1986), and Perry (1993). Hertlein (1951) made no direct mention of the Purisima Formation in his discussion of invertebrate fossils and fossil localities in the San Francisco Bay area, but some of his discussion of the Merced Formation refers to outcrops now assigned to the Purisima Formation. Glen (1959) listed 31 species of mollusks from the Purisima Formation ("Merced" Formation of his usage) at Pillar Point and called the outcrop there middle Pliocene. Cummings and others (1962) listed 65 molluscan taxa from the Purisima Formation and subdivided it into five members. Perry (1977) gave a popular account of the Tertiary and Quaternary fossils, including those from the Purisima Formation, from Santa Cruz County. Addicott and others (1978b) briefly described the Purisima Formation from Capitola State Beach, New Brighton State Beach and Point Santa Cruz and included molluscan faunal lists for Capitola and New Brighton State Beaches. Dealing primarily with echinoids, Durham and Morgan (1978) described two new sand dollars from the Purisima

Formation along the San Mateo Coast between San Gregorio Creek and Pomponio Creek and mentioned associated mollusks. As part of a regional study of the central Santa Cruz Mountains, Clark (1981) reported mollusks, marine vertebrates (mammal and fish), and diatoms from the Purisima Formation and discussed its age and distribution. A short paper by Wiley and Moore (1983) reviewed the Purisima Formation outcrops at Moss Beach, north of the Seal Cove Fault, giving an excellent interpretation of the environment of deposition and, based on *in situ* bivalves, suggesting deposition at depths of less than 45 m. Norris (1986) described a variety of sedimentological settings for the Purisima Formation at various sites, including amalgamated sandstone and coquina at Seacliff State Beach, hummocky cross bedding at Capitola City Beach and east of Año Nuevo Creek, bioturbated sandstone at Capitola City Beach, New Brighton/Seacliff State beaches, Pescadero, and Pomponio County beaches, bioturbated mudstone at Purisima Creek, and five different kinds of fossil beds (i.e., storm, current-winnowed, bone, community, and ecologically condensed) in the different lithologies. Lastly, Perry (1993) described and illustrated the geology and fossils of the sea cliffs between Capitola and New Brighton Beach. In this popular account he divided the Purisima Formation into four biostratigraphic intervals, from base to top, a lower shell bed, *Clinocardium* facies, upper shell bed, and *Crepidula* facies, citing the occurrence of 62 invertebrate taxa in all the unit. The Santa Cruz fauna (herein) includes the four biostratigraphic units of Perry (1993).

The Purisima Formation is also mentioned in several reviews of molluscan taxa. In his review of California Pectinids, Arnold (1906) gave a short review of each of the "typical" formations of the Tertiary and Quaternary of California and their associated fauna. He placeed the greater part of the Purisima Formation in the Pliocene, although the lower portion was said to have species in common, to a lesser extent, with the Vaqueros Formation, and to a greater extent, with the San Pablo Formation. He listed a fauna of 94 taxa, including two echinoids, one brachiopod, one barnacle, and the rest mollusks. In a paper describing 18 new Pliocene and Miocene taxa, mostly from northern California, Martin (1914) described *Chrysodomus purisimaensis* n. sp. (=*Colus? purisimaensis* Martin) from rocks attributed to the Purisima Formation from Año Nuevo Bay (Clark, 1981). Packard (1916) in a review of the Mactrids of the Mesozoic and Cenozoic of the Pacific Coast of North America named *Spisula mercedensis* n. sp. for specimens from the "Merced group" near Mussel Rock, San Mateo County and reported *Spisula albaria* (Conrad) from the "Merced group" near Capitola. Rocks from both these sections are now referred to the Purisima Formation. Carson (1926) described *Cancellaria palmeri* Carson from the Capitola City Beach section of the Purisima Formaiton. Schenck (1936) in a review of the bivalve genus *Acila* reported this genus from the Purisima Formation. Reinhart (1943) in a review of Mesozoic and Cenozoic Arcidae from the Pacific Slope of North America made mention of several taxa occurring in the Purisima Formation. Recent taxonomic works including species from the Purisima Formation include Nations (1975) and Nikas (1977). Nations (1975) reviewed the arthropod genus *Cancer* (crabs) citing two species, one new from the Purisima Formation: *C. fissus* Rathbun and *C. marri* Nations, from outcrops at Capitola and Santa Cruz, respectively. More recently Nikas (1977) described a new *Macoma*, *Macoma addicotti* Nikas, from the "Merced" Formation (of Addicott, 1969) near Felt Lake in San Mateo County east of the San Andreas Fault and from the Purisima Formation at New Brighton Beach, Santa Cruz, thereby suggesting a correlation between these outcrops now on opposite sides of the fault. In a review of northeastern Pacific Naticidae, Marincovich (1977) cited several species from outcrops of the Purisima Formation.

Foraminifers are generally poorly known from the Purisima Formation. Published work including foraminifers includes Crandall (1943), Goodwin and Thomson (1954), and Bandy (1955). Crandall (1943) in a review of the Half Moon Bay oil district mentioned that the foraminifers from the middle Purisima Formation (at 7,982 ft in the Wilshire Oil Company Cowell #1 well) are similar to those from the Sisquoc Formation in Santa Barbara County. Goodwin and Thomson (1954) reported a small fauna of 27 taxa from exposures between Redondo Beach and Martins Beach south of Halfmoon Bay. They divided their section into two zones suggesting deposition at about the same depth, but with the lower, *Uvigerina juncea* Cushman and Todd zone, suggesting cooler temperatures. The environment of deposition was thought to be one of relatively quiet water in an unrestricted basin at a depth of about 125 feet (circa. 40 m). Reviewing the data of Goodwin and Thomson (1954), Bandy (1955) reinterpreted their fauna suggesting that the upper zone was deposited at depths suggested by Goodwin and Thomson (1954), but that the lower zone represents much deeper water depths [300 to 1,800 m (1,000 to 6,000 ft)].

Fossil vertebrates have been studied in detail from the Purisima Formation for only about 35 years (Mitchell, 1962; Packard, 1962), although they may have been reported as early as 1827 when Lt. Edward Belcher, the ship's surveyor for *H. M. S. Blossom*, recorded "petrified bones of a cylindrical form" in cliffs of loose sandstone at Santa Cruz (VanderHoof, 1951). Other early reports of fossil vertebrates from the Purisima Formation are the description of a fossil vertebrate (Leidy, 1868) and various newspaper reports in Santa Cruz and San Francisco papers during the 1860's to 1880's. Leidy (1968) described *Delphinus occiduus* Leidy (Leidy, 1868) from a vertebrate collected in "... upper miocene formation of Half-moon Bay" which is here questionably attributed to the Purisima Formation. In the Santa Cruz Sentinel, August 5, 1865, "petrified bones, teeth, and fossils of different kinds," were reported from downtown Santa Cruz, the report also stated that "all along the coast above and below Santa Cruz the chalk-rock and solid sand cliffs are perfectly indurated with fossil remains of petrified teeth and bones, of known and unknown animals, birds, fishes and vegetations." (F. Perry, written commun., 1998) Later, two 25 foot long whale skeletons were excavated nearby and reported in the Santa Cruz Surf (January 9, 1887) (F. Perry, written commun., 1998). Unfortunately none of these specimens seems to have survived to the present.

Kellogg (1927) described the holotype of the pinniped *Dusignathus santarcruzensis* Kellogg from the sea cliffs at Santa Cruz incorrectly assigning the fossil to the Santa Margarita Formaiton. A Pinniped (seal) and obodenid (walrus) assemblage of three taxa was described from the Purisima Formation at and near Point Santa Cruz by Mitchell (1962). He also redefined the type locality of *Dusignathus santacruzensis* Kellogg (near Point Santa Cruz) which was previously assigned to the Santa Margarita Formation, but which belongs in the Purisima Formation (see Repenning and Tedford, 1977 for notes on the type locality). A fairly extensive Cetacean (whale) assemblage has been reported from the Purisima Formation. It includes, in the family Cetotheriidae: aff. *Herpetocetus* and an unidentified genus and species; in the family Balaenopteridae: cf. *Plesiocetus*; in a possibly undescribed family a new genus and species related to the Stenodelphininae; an unidentified broad-headed beluga (Delphinapterinae) in the family Monodontidae; in the family Delphinidae an indeterminate *Stenella* or *Delphinus* species and aff. *Tursiops* (the recent bottlenosed dolphin); in the family Phocoenidae (porpoises) an indeterminate genus and species; and in odontoceti *incertae sedis Lonchodelphis occiduus* (Leidy) and an indeterminate genus and species. Packard (1962) reported the occurrence of a small toothed-whale collected in Pomponio Creek (by R. M. Touring) along with many other bone fragments

(collected by D. Knapp) and several large cetacean vertebrates collected from along the coast in central San Mateo County (by J. Cummings). Repenning and Tedford (1977) reported the Otarioids *Dusignathus santacruzensis* Kellogg and questionably *Thalassoleon macnallyae* Repenning and Tedford from the Purisima Formation around Santa Cruz. Interestingly they also reported the same two taxa from the Drakes Bay Formation of Galloway (1977); in fact *Thalassoleon macnallyae* Repenning and Tedford was described from the Drakes Bay Formation in the Point Reyes area. *Dusignathus santacruzensis* Kellogg is also questionably reported from the Purisima Formation at Moss Beach. Although both of these taxa were reported from the basal glauconite at Point Reyes recent work by Clark(1998, personal communication) indicates that the locality where they were collected does not contain glauconite and is in part of the Drakes Bay Formation Clark and Brabb (1984) attribute to the Purisima Formation. In his popular account of fossils from Santa Cruz County, Perry (1977) increased the vertebrate fauna of the Purisima Formation by recording the shark genera *Carcharodon* (great-white shark), *Hexanchus* (six-gilled shark), and *Notorynchus* (seven-gilled shark) [this taxon has since been removed from the Purisima Formation fauna as its occurrence is based on an anomalous specimen of *Hexanchus* (F. Perry, personal commun., 1998)], the bat ray *Myliobatis*, other bony fish remains, and the bones, including a skull, of the bird *Sula* (boobies).

PALEONTOLOGIC SIGNIFICANCE OF PURISIMA FORMATION OUTCROPS

Sites below are alphabetically grouped within the fault-bounded structural blocks outlined above (figure 1). These structural blocks are listed from north to south. The outcrops at Point Reyes do not fit into this arrangement and are treated first. Outcrops from the Sargent oil field area also do not fit into this arrangement, but are similar to those in the Ben Lomond block and are treated there. Other fossil localities which do not have a significant fauna (generally less than 3 taxa) and which add nothing to the disussion are listed at the end of this section.

Point Reyes (not within the structural block arrangement)

Rocks attributed to the Purisima Formation at Point Reyes (Clark and others, 1984; Clark and Brabb, 1997) were originally mapped as Monterey Formation (Anderson, 1899; Dickerson, 1922) and as part of the Drakes Bay Formation (Galloway, 1977). Galloway (1977) cited a subsurface thickness for the Drakes Bay Formation of more than 470 m (1,543 ft), and presumably under 300 m (1,000 ft) from surface exposures in the broad synclinal section at Drakes Bay (Galloway, 1977, fig. 3B). But Clark and Brabb (1997) reported a thickness of as much as 490 m in this same synclinal section and stated that the Drakes Bay Formation includes rocks they attribute to the Santa Margarita Sandstone, Santa Cruz Mudstone, and Purisima Formations. Stratigraphic relationship between the various fault blocks has not been resolved for the Purisma Formation and I have some reservations but will follow Clark and Brabb (1997) and retain the name Purisima Formation for the Point Reyes outcrops.

Galloway (1977) reported a late Miocene to Pliocene age for his Drakes Bay Formation (in part = Purisima Formation of Clark and others, 1984) based on diatoms, mollusks, and a K/Ar age determination of 9.3 ± 0.5 Ma from the basal glauconite bed. Recently Clark (1997) recollected and processed this glauconite and obtained a K-Ar date of 7.9 ± 0.3 Ma from these sandstone beds, which Clark and Brabb (1997) now map as the Santa Margarita Formation. Hanna *in* Galloway (1977) reported 44 species of diatoms from the Drakes Bay Formation exposed at two localities and suggested a late Miocene age for the

fauna but tempered this determination based on Galloway's stratigraphic data suggesting that some of the diatoms are reworked. Galloway (1977) also reported a small megafossil fauna of nine taxa from the Drakes Bay Formation including 7 mollusks [Bivalves (4): *Lucinoma annulata* Reeve, *Nuculana* sp., cf. *N. taphria* Dall, *Solen* sp. cf., *S. sicarius* (Gould) and indeterminate valves questionably referred to either *Spisula* or *Macoma*; Gastropods (3): *Megasurcula carpenteriana* (Gabb), *Neptunea tabulata* (Baird) (as *N. colmaensis* Martin; also reported by Repenning and Tedford, 1977) and *Polinices* sp., cf. *P. lewisii* (Gould)] and two echinoderms [*Megapetalus* sp., cf. *M. loveniodes* Clark and *Ophioplocus*? sp.]. All these taxa with the exception of the questionably identified *Megapetalus lovenoides* Clark have been reported from the Pliocene to Holocene. The nominal species *Megapetalus lovenoides* Clark has been reported from the upper Miocene in Ventura County, southern California (Grant and Hertlein, 1938). Repenning and Tedford (1977) disucss a Otariod seal and walrus from a part of the Drakes Bay Formation which Clark (1998, personal communication) attributes to the Purisima Formation in rocks which do not contain glauconite. The concept of offset of the Purisima Formation of Clark and Brabb (1984) at Point Reyes along the San Gregorio fault to the type area seems reasonable, but the type Purisima Formation (Cummings and others, 1959) has several members that have not yet been recognizied at Point Reyes, and piercing points for the two units have not been established.

Galloway (1977) reported pine cones (*Pinus lawsoniana* Axelrod) from rocks he attributed to the Drakes Bay Formation, but Repenning and Tedford (1977) suggested that these deposits do not belong in the Purisima Formation but overlie it. Axelrod (1983) later reported the Gowen Cypress (*Cupressus goveniana* Gordon) from these same exposures, which is about 200 km north of the present northernmost occurrences of this species in the vicinity of Monterey and Gibson Creek, Monterey County. Axelrod (1983) further states that the fossil locality from which both the pine and cypress have been collected is a turbidite deposit that rests unconformably on the Drake's Bay Formation, and gives an approximate age of 500 ka.

La Honda Block

The La Honda block, defined by Tertiary rocks which lie east of the northward-trending San Gregorio fault, west of the northwest-trending San Andreas Fault and north of the east-west Zayante Fault, contains numerous outcrops of the Purisima Formation with the most easily accessIble being along the San Mateo County coast. In this block the Purisima Formation is as much as 1,725 m thick (Cummings and others, 1962), which is similar to the thickness of about 1,640 m (5,400 ft) reported by Branner and others (1909) for the same area. Crandall (1943) reported a thickness of about 2,900 m (9,500 ft) near Purisima Creek, but Cummings and others (1962) thought this thickness to be excessive and suggested a duplication of section in the Purisima anticline. The Purisima Formation section from this block represents the classic sequence described by Haehl and Arnold (1904) (type section) and by Cummings and others (1962) (type of members which they defined). These members cannot be recognized outside the La Honda block. Fossiliferous sections from this block include outcrops at Moss Beach (discussed under Pigeon Point Block), Redondo Beach, Arroyo Canada Verde, Purisima Creek, Lobitos Creek and Martins Beach, Tunitas Creek, Mussel Rock, the San Gregorio State Beach area, Pomponio State Beach, and Pescadero State Beach and are illustrated in figures 5 and 6.

Redondo Beach: This locality, represented by USGS collection M8932, is in the surf zone just south of the end of Redondo Beach Drive south of Half Moon Bay. The outcrop

contains random stringers and small clumps of *Crepidula princeps* (Conrad) without orientation, indicating that they were not preserved *in situ*. Foraminiferal work by Goodwin and Thomson (1954) just south of this outcrop suggests deep inner sublittoral water depths (circa. 40 m) for the Purisima Formation in this area. Only a single taxon was collected or observed from this locality, *Crepidula princeps* (Conrad), which ranges in age from Miocene to Pleistocene and geographically from Alaska to Baja California Norte (Grant & Gale, 1931).

Purisima Creek area: Early collections from Purisima [Creek] (Ashley, 1895a) recorded 63 taxa from this area (table 4). Norris (1986) reported north of Purisima Creek massive or very thick bedded, fossiliferous, bioturbated mudstone which grades upward into rhythmically interbedded turbidites. Touring (1959) and Cumings and others (1962) included these beds in his Pomponio Member, but he also noted a fault at the mouth of Purisima Creek which cuts off the base of the unit. Cummings and others (1962) reported their San Gregorio Member as occurring 760 m (2,500 ft) south of Purisima Creek. In these sediments, Norris's (1986) bioturbated mudstone facies, he reported isolated articulated infaunal bivalves *Tresus, Lucinoma*, and *Anadara* as common throughout. Underlying this mudstone Touring (1959) reported a series of six very fine grained, silty, sandstone beds which contain abundant megafossils. He referred these fossiliferous beds to the "upper sandstone" of Ashley (1895a, p. 327) and Martin (1916, p. 243). Part of Goodwin and Thomson's (1954) work includes this area and suggests deep inner sublittoral water depths (circa. 40 m).

Sixteen taxa have been identified from the general area around the mouth of Purisima Creek (USGS collections M8849, M8869?, M8880, M8933, M8934, M8935, M8936, M8937?) (table 5), whereas two collections (M8929, M8930) are recorded along the course of Purisima Creek. The latter are represented by poorly preserved specimens with only a single identifiable taxon: *Solen*? sp. This razor clam is not well enough preserved for precise identification, but generally suggests deposition in shallow subtidal water depths along an open coast in sandy to silty sediments. Recent field attemps to recollect these localities failed because of heavy undergrowth. From the collections around the mouth of Purisima Creek the co-occurrence of *Anadara trilineata* (Conrad), *Tresus pajaroanus* (Conrad), and *Crepidula princeps* (Conrad) suggests a Pliocene to Pleistocene age. The extant taxa found here co-occur between southern California (33°N) and about Point Reyes, northern California (38°N). *Mya truncata* (Linnaeus) is the only extra-limital northern taxon in this collection and its modern range is from Puget Sound, Washington north to Alaska (Bernard, 1983), although it has many fossil occurrences as far south as San Diego County, California (Grant and Gale, 1931). The extant taxa suggest deposition in outer sublittoral water depths (= 45 m to 180 m; Valentine, 1961).

Table 4. Mollusks from the Purisima Formation in the general area of Purisima [Creek?] from recent USGS collections and from the literature [Ashley, 1895a and Martin, 1916 (as Purisima)].

MOLLUSCA BIVALVIA	Ashley (1895a)	Martin (1916)	USGS collections
Acila castrensis Hinds	x	x	-
Anadara sp., cf. *A. trilineata* (Conrad)	as *Arca canalis* Conrad, *A. microdonta* Conrad, and *A. sulcicosta* Gabb	x and as *Arca canalis* Conrad	x

MOLLUSCA	Ashley (1895a)	Martin (1916)	USGS collections
BIVALVIA	*Clinocardium* sp.	-	- ?
Clinocardium meekianum (Gabb)	-	x	-
Compsomyax subdiaphana (Carpenter)?	-	? as *Marcia gibbosus* Gabb	x
Cryptomya californica (Conrad)	-	x and as *C.*, cf. *ovalis* Conrad	- -
Lituyapecten purisimaensis (Arnold)	-	x	-
Lituyapecten turneri (Arnold)	as *Pecten propatulus* Conrad	-	-
Lucinoma annulata (Reeve)	as *Lucina borealis* Linnaeus	x	x
Macoma calcarea Gmelin	-	x	-
Macoma inquinata (Deshayes)	-	x	-
Macoma nasuta Conrad	x	x	-
Macoma? sp.	-	-	x
Modiolus rectus (Conrad)	-	x	-
Mya truncata Linnaeus?	x	-	-
Mytilus? sp.	-	-	x
Nanaochlamys nutteri (Arnold)	-	x	-
Nuculana taphria (Dall)	-	x	-
Pandora punctata Conrad)	-	x	-
Panomya sp., cf. *P. chrysis* Dall	-	x	sp.
Panopea abrupta (Conrad)	-	as *P. generosa* Gould	-
Patinopecten healeyi (Arnold)	-	x	-
Patinopecten lohri (Hertlein)	-	as *Pecten oweni* Arnold	-
Pectinid indet.	-	-	x
Protothaca staleyi (Gabb)	-	x	-
Protothaca tenerrima (Carpenterf)	-	*x*	-
Siliqua patula (Dixon)	-	as *S. nuttalii* Conrad	-
Solen sicarius Gould	x	x	-
Spisula albaria (Conrad)	-	x	-
Spisula catilliformis Conrad	-	x	-
Spisula hemphilli (Dall)	-	x	-
Thracia trapezoides Conrad	-	x	-
Tresus nuttallii (Conrad)	-	x	-
Tresus pajaroanus(Conrad)	x	x	x
Yoldia cooperi Gabb	-	x	sp.
Zirfaea pilsbryi Lowe	as *Zirphoea crispata* Linnaeus	as *Zirphaea gibbii* Tryon	-
GASTROPODA			
Antiplanes catalinae (Raymond)	-	as *A. perversa* Gabb	-
Astyris gausapata (Gould)	x	x	-
Beringius stantoni (Arnold)	-	x	-
Bittium asperum Gabb	-	x	-
Calicantharus portolaensis (Arnold)	-	x	-
Calyptraea sp.	as *C. inornata* (Gabb)	x and ? as *C. filosa* Gabb and *Trochita radians* (Lamarck)	x

MOLLUSCA GASTROPODA	Ashley (1895a)	Martin (1916)	USGS collections
Colus? purisimaensis (Martin)	-	x	-
Crepidula onyx (Sowerby)	-	x	-
Crepidula princeps (Conrad)	as *C. grandis* Middendorff	x	x
Cryptonatica affinis (Gmelin)	-	as *Natica clausa* Broderip & Sowerby	-
Fusitriton oregonensis (Redfield)	-	x	x
Megasurcula carpenteriana Gabb	-	x	-
Nassarius californius (Conrad)	-	? as *Nassa mendica* Gould	-
Nassarius sp.	-	x	-
Neptunea lyrata (Gmelin)	-	x	-
Neptunea tabulata (Baird)	x	x	x
Neptunea sp.	-	-	x
Nucella lamellosa (Gmelin)	-	x	-
Ophiodermella graciosana Arnold	-	? as *O. mercedensis* (Martin)	-
Polinices lewisii (Gould)	x	cf. as “near”	-
Psephidia oregonensis (Dall)	? as *Volutilites indurata* Conrad	x	-
Turrid indet.	-	-	x
POLYPLACOPHORA			
Cryptochiton sp., cf. *C. stelleri* Middendorff	x	-	-
ECHINODERMATA ECHINODEA			
Dendraster gibbsii Rémond	-	x	-
Merrimaster sp.	-	? as *Scutella perrini* Weaver	-
Scutellaster sp., cf. *S. oregonensis* (Clark)	-	? as *Scutella interlineata* Stimpson	-

Lobitos Creek (USGS collection M8931) and Martins Beach (USGS collection M8926) area (Fig. 5): Cummings and others (1962) described their Lobitos Member as massive, silty mudstone that overlies the San Gregorio Sandstone Member with a type locality about 1,100 m (3,500 ft) south of the mouth of Purisima Creek, and about halfway between Purisima Creek and Lobitos Creek, although it is named for Lobitos Creek where additional outcrops are exposed. According to Cummings and others (1962) the Lobitos Member consists of dark-gray fresh to reddish or yellowish-brown weathering mudstone with fossiliferous lenses and concretions. They also reported a thick white tuff bed south of the mouth of Lobitos Creek along the coast.

Ashley’s (1895a) Lobitos locality is not well documented and it is assumed here to be in the sea cliffs along the coast, as other outcrops along Lobitos Creek interior of the coast have not been reported. Ashley (1895a) reported seven, (possibly six) mollusk species from Lobitos (=Lobetus) [Creek], [*Compsomyax subdiaphana* Carpenter (as *Saxidomus gibbosus* Gabb), *Lucinoma annulata* (Reeve) (as *Lucina borealis* Linnaeus), *Patinopecten lohri* (Hertlein) (as *Pecten pabloensis* Conrad), *Lituyapecten turneri* (Arnold) (as *Pecten propatulus* Conrad), *Spisula catilliformis* Conrad (as *Standella california*

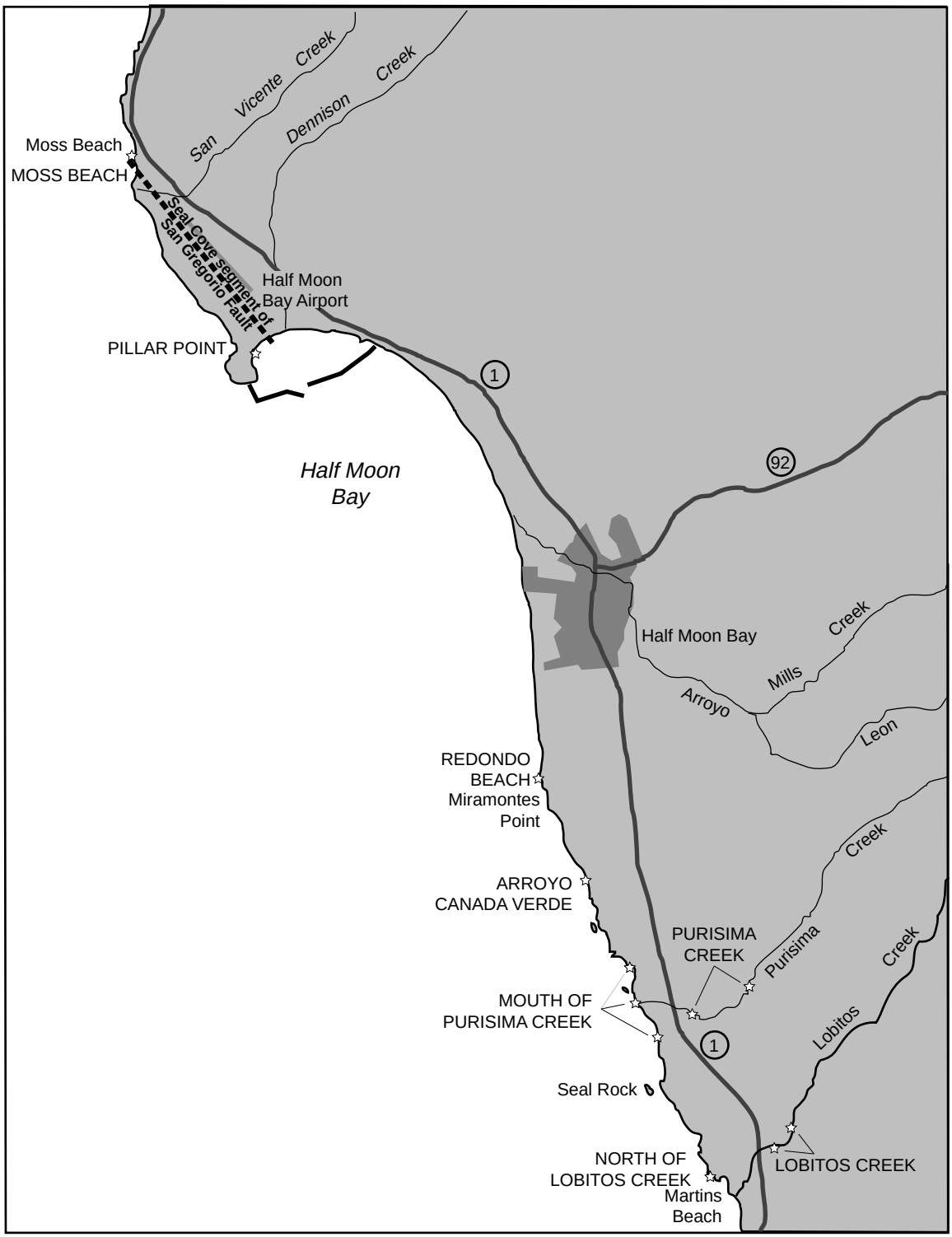

Figure 5.—Index map of Purisima Formation fossil occurrences discussed in the text. Map covers the coast from Moss Beach to Martins Beach in San Mateo County. Outcrops discussed occur from north to south, at Moss Beach, Pillar Point, Redondo Beach, Purisima Creek, Lobitos Creek, and Martins Beach.

Conrad), and *Tresus pajaroanus* (Conrad)] but their exact locality and stratigraphic position are unknown. Only a single fossil species, *Compsomyax subdiaphana* (Carpenter), has been identified from this area in recent collections.

From Martins Beach only a single taxon has been found, an indeterminate *Neptunea*, which has large ecologic and age range making interpretations inconclusive and vague.

Tunitas Creek (USGS collections M8912, M8846) (Fig. 6): The massive, very fine grained sandstone beds exposed along the sea cliffs for three miles north of the mouth of Tunitas Creek were named the Tunitas Member of the Purisima Formation by Cummings and others (1962). Cummings and others (1962) cited this member as being between about 75 m (250 ft) and about 120 (400 ft) thick and composed of light-gray to very pale-orange weathering, greenish-gray fresh, very fine-grained, well sorted sandstone locally cemented with calcite or chlorite.

A small fauna of six taxa has been collected from the sea cliffs north of Tunitas Creek (USGS collections M8912, M8846). These taxa include the bivalves: *Anadara trilineata* (Conrad), fragments questionably referred to an indeterminate *Macoma*, a *Panomya* with affinities to *P. ampla* Dall, and unidentifiable bivalve fragments. In addition the gastropod *Crepidula princeps* (Conrad) has also been collected from this area. The only other megafossil occurrence in the general area is from the sea cliffs south of Martins Beach (M8926) where only an indeterminate *Neptunea* has been collected. Extinct taxa in the USGS collection from the sea cliffs north of Tunitas Creek suggest an age of Pliocene to Pleistocene for this outcrop. Interesting from this outcrop is the occurrence of the genus *Panomya*, whose modern representatives occur from the Chukchi Sea, Alaska (71°N) to British Columbia, Canada (51°N) in water depths from the intertidal zone to 200 m (Bernard, 1983). This range is far north of the fossil locality and suggests cooler water during deposition of the Purisima Formation than present along the coast today, or a change in the ecological preference of *Panomya*.

Two outcrops occur along Tunitas Creek inland from the ocean. The first is in the road cut just north of the emergence of the East Fork Tunitas Creek into Tunitas Creek proper. Here the Purisima Formation consists of highly fractured medium- to fine-grained sandstone. A fauna of four bivalve taxa occurs at these two sites (USGS collections M8918, M8919). The fauna includes *Acila castrensis* (Hinds), *Compsomyax subdiaphana* (Carpenter)?, *Cyclocardia californica* (Dall) fide Woodring and Bramblette, 1950, and indeterminate bivalve fragments that cannot be assigned to any of the above taxa. Also observed in the field were the bivalves *Clinocardium* sp., and *Spisula*? sp. and the gastropod *Crepidula princeps* (Conrad). Together these taxa occur between northern California (40°N) and Baja California Norte, Mexico (28°N) in water depths from 5 to 45 m (Bernard, 1983). The second outcrop is a little farther up the canyon just north of where Rings Gulch enters Tunitas Creek and consists of highly fractured medium sandstone with abundant Pectinids preserved as original shell material, whereas other mollusks are preserved as iron-stained casts and molds. Pectinids are common and well preserved here, suggesting that this is the location cited by Ashley (1895a) as Tunitas Creek. Ashley (1895a) reported eight taxa from Tunitas Creek, the bivalves: *Acila castrensis* Hinds, *Compsomyax subdiaphana* Carpenter (as *Saxidomus gibbosus* Gabb), *Lituyapecten turneri* (Arnold) (as *Pecten propatulus* Conrad), *Patinopecten lohri* (Hertlein) (as *Pecten pabloensis* Conrad), *Protothaca tenerrima* (Carpenter), *Solen sicarius* Gould, *Tresus pajaroanus*(Conrad), and the gastropod *Polinices lewisii* (Gould). No USGS collection exists for this area so the faunas cannot be compared but field observations indicate large Pectinids similar to the ones reported by Ashley (1895a) are common there.

Mussel Rock (USGS collections M8913, M8928) (Fig. 6): A limited fauna of three taxa, two bivalve mollusks (*Clinocardium* sp., *Tresus* sp.) and one echinoid (*Dendraster*

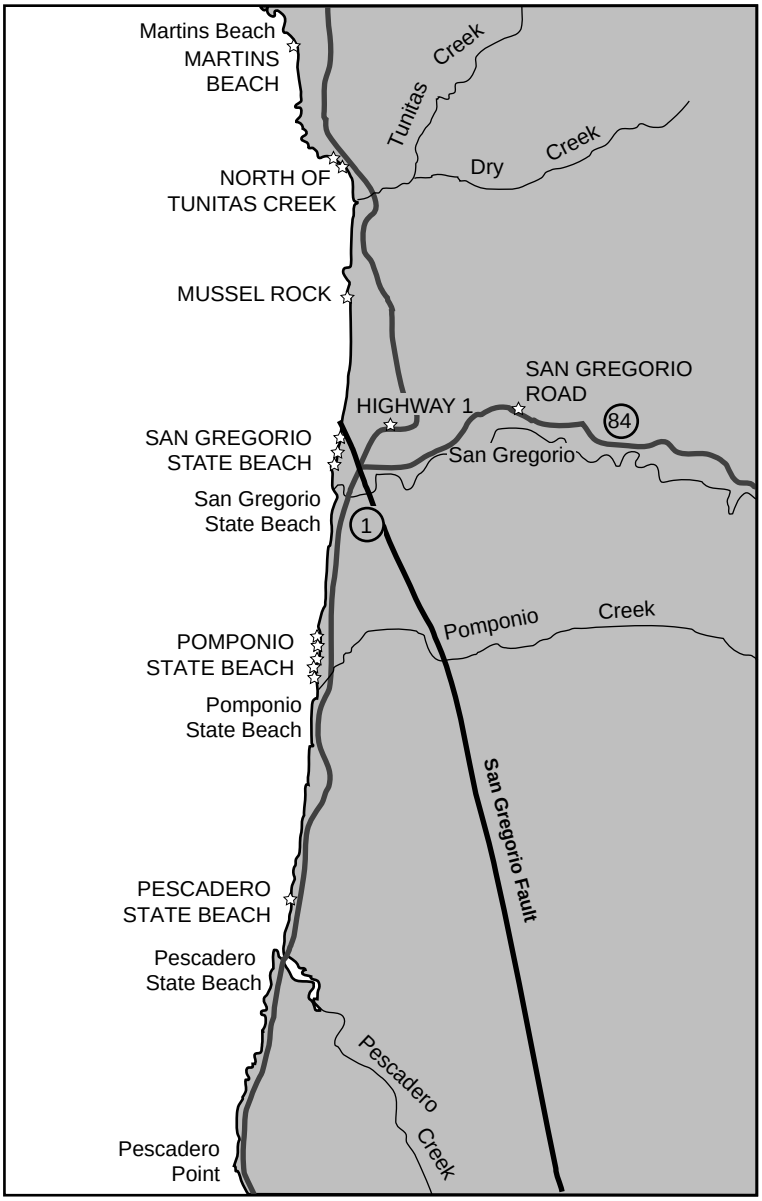

Figure 6.--Index map of Purisima Formation fossil occurrences discussed in the text. Map covers the coast from Martins Beach to Pescadero Point in San Mateo County. Outcrops discussed occur from north to south, at Martins Beach, Tunitas Creek, Mussel Rock, San Gregorio (including San Gorgorio Road), Pomponio State Beach, and Pescadero State Beach.

sp.) is recorded from this area. These taxa are broadly ranging and do not give definitive ecological or age interpretations.

San Gregorio and San Gregorio Creek (USGS collections M8911) (Fig. 6): Ashley (1895a) reported fossils from the Purisima Formation at San Gregorio Creek and from San Gregorio. Both localities are questionably grouped with recent collections from San Gregorio Road because their geographic and stratigraphic position are not precisely known but are inferred to have been close to the San Gregorio Road locality. From San Gregorio Creek he reported only two taxa, the chiton *Cryptochiton* sp. cf. *C. stelleri* Middendorff and the gastropod *Nassarius californica* (Conrad), whereas from San Gregorio he reported 15 taxa (table 5).

Only a single taxon, *Olivella* sp. cf. *O. pycna* Berry, is in recent USGS collections from this general area (USGS collection M8911), but recent work has recognized indeterminate *Clinocardium*, *Macoma* and questionably *Cryptomya* in the field. The modern occurrence of *Olivella pycna* Berry is from Seaside Rock, Clatsop County, Oregon (Gifford & Gifford, 1948) to Morro Rock, San Luis Obispo County, California in water depths from the intertidal zone to 27 m (Burch, ed., 1944-46). Taxa reported by Ashley (1895a) (table 5) include 10 extant forms which suggest water depths between about 5 m and 10 m with *Neptunea tabulata* (Baird) suggesting deeper water. These taxa have modern latitudinal ranges which overlap from Point Reyes (38°N), northern California to south of Cape Mendocino (40°N), northern California, which suggest cooler water than exists along the central San Mateo County coast today.

Table 5.—Fossils reported from the Purisima Formation at San Gregorio by Ashley (1895a).

MOLLUSCA
BIVALVIA
Anadara trilineata (Conrad) [as *Arca sulcicosta* Gabb]
Compsomyax subdiaphana Carpenter [as *Saxidomus gibbosus* Gabb]
Macoma nasuta (Conrad)
Modiolus rectus Conrad [as *Modiola flabellata* Gould of Ashley, 1895a]
Patinopecten caurinus (Gould)
Panope abrupta (Conrad) [as *Glycymeris generosa* Gould of Ashley, 1895a]
Spisula albria (Cornad) [? as *Standella nasuta* Gould?]
Spisula falcata (Gould)
Yoldia cooperi Gabb
Zirfaea pilsbryi Lowe [as *Zirphoea crispata* Linnaeus]
GASTROPODA
Cantharus humerosa (Gabb)? [as *Neptunea humerosa* Gabb?]
Nassarius grammatus (Dall) [? as *Nassa perpinguis* Hinds]
Neptunea tabulata Baird
Polinices lewisii (Gould)
POLYPLACHOPORA
Cryptochiton sp., cf. *C. stelleri* (Middendorff)

San Gregorio State Beach (USGS collections M8848, M8857, M8925) (Fig. 6): A small fauna of six taxa in addition to indeterminate mollusk fragments has been collected from the vicinity of San Gregorio State Beach just north of San Gregorio Creek. The fauna is poorly preserved and includes the bivalve mollusks: *Clinocardium*? sp., *Mytilus*? sp., *Panope*? sp., *Patinopecten*? sp., *Siliqua*? sp., and the gastropod *Crepidula princeps* (Conrad). These taxa are too poorly preserved and too broadly ranging for ecological or age interpretations.

Pomponio State Beach (USGS collections M8498?, M8910, M8915, M8916, M8920, M8921, M8927) (Fig. 6): Purisima Formation rocks here are referable to the upper part of the Tahana Member and Pomponio Member (Cummings and others, 1962; Durham and Morgan, 1978) and are about 76 m thick, exposed in a gentle east-west trending anticline (Durham and Morgan, 1978), of massive marine sandstone with some interbedded siltstone and a rhyolitic tuff. A Pleistocene non-marine conglomerate as much as 7 m thick overlies the Purisima Formation (Durham and Morgan, 1978) in this area.

Durham and Morgan (1978) reported several small faunules from this area which include the bivalves *Clinocardium nuttallii* (Conrad)?, *Patinopecten healeyi* (Arnold),

Lituyapecten falorensis MacNeil, *L. purisimaensis* (Arnold), *L. tuneri* (Arnold), *Spisula albaria* (Conrad), *Swiftopecten parmeleei parmeleei* (Dall), *Yoldia scissurata* Dall [as *Y. scissurata* subsp. *strigata* (Dall)], the gastropod *Nassarius grammatus* (Dall), and the barnacle *Balanus gregarius* (Conrad). U. S. Geological Survey collections from this area contain a small, poorly preserved fauna with no stratigraphic control which includes the bivalves *Macoma* sp., *Modiolus*? sp., *Panope*? sp., *Patinopecten?* sp., and *Tresus pajaroanus* (Cornad), the gastropods *Neptunea tabulata* (Baird) and an indeterminate *Neptunea*, and an indeterminate barnacle *Balanus*? sp. Most of these taxa are too poorly preserved for precise identification and determination of ecological or age parameters. The exceptions are *Tresus pajaroanus* (Conrad), which occurs from Washington to southern California in rocks from Miocene to Pleistocene age, and *Neptunea tabulata* (Baird) which occurs in rocks of Miocene to Holocene age. The modern occurrence of *Neptunea tabulata* (Baird) is very broad and does not lend itself to paleoecologic interpretations, being found in water depths from the intertidal zone to over 250 m, from north of Queen Charlotte Island, British Columbia, Canada to San Diego County, California (Grant and Gale, 1931).

Pescadero Creek (Fig. 6): No USGS collections are located at or near Pescadero Creek but this has been the site of numerous historical collections (Arnold, 1908; Cummings and others, 1962). Cummings and others (1962) reported their Tahana Member as being well exposed on the south flank of the Pescadero syncline, in Pescadero Creek. They reported the Tahana Member as composed of medium-grained to very fine-grained sandstone and siltstone with dark-gray silty mudstone being fairly common in the Pescadero Creek section. Along Pescadero Creek in the vicinity of Memorial Park, Cummings and others (1962) reported several beds of sandy conglomerate and pebbly sandstone about 30 m (100 ft) thick and stratigraphically about (300 m) 1,000 ft above the base of the Formation. Arnold (1908) cited Pescadero Creek near the mouth of Jones Gulch as a typical locality of his middle member and reports many fossils taxa from this area.

Pigeon Point Block

The Pigeon Point block consists of outcrops west of the San Gregorio fault and includes rocks assigned to the Purisima Formation and Merced Formation by early authors at Pillar Point and east of Año Nuevo. A maximum thickness for the Purisima Formation and related rocks of about 360 m is recorded for this block (Clark and Brabb, 1978). Interestingly, at Pillar Point rocks attributed to the lower part of the Purisima Formation represent a deep-water environment and are faulted against shallow-water rocks, also referred to the Purisima Formation, in the La Honda block (discussed here as the literature is unclear as to which outcrops were previously collected). Also in this block shallow and deeper water sections of Purisima Formation rocks crop out at Año Nuevo where they are separated by a fault in Año Nuevo Creek. Rocks correlated with the upper part of the Formation occur east of Año Nuevo Creek. These rocks are also correlated with sections at Moss Beach (La Honda Block), and at Capitola, New Brighton, and Sea Cliff State Beaches (Ben Lomond Block) based on lithology and similarities of the faunas. West of the Creek are rocks which were deposited in deeper water and are similar and correlated with outcrops at Cascade Creek and Old Woman Creek based on lithology and the sparse fauna. Other faults occur in this section and represent larger displacements, but are not significant to the discussion here.

HALF MOON BAY AREA (Fig. 5)

Moss Beach/Pillar Point: Sedimentary rocks on both sides of the Sea Cove segment

of the San Gregorio Fault have been referred to the Purisima Formation. These rocks were reported by Martin (1916) as Merced Formation, by Glen (1959) as “Merced” Formation who equated to the Purisima Formation, and Purisima Formation by Wiley (1983) and Wiley and Moore (1983). Two different sections referred to the Purisima Formation are present between Moss Beach and Pillar Point (recognized by Glen, 1959). East of the Seal Cove segment of the San Gregorio Fault are thin beds of highly indurated, calcareous cemented, medium- to fine-grained, gray sandstone interbedded with abundantly fossiliferous, pebbly conglomerate and several moderately thick, angular pebble beds that lack fossils. The fossils from these beds have been transported downslope and may represent periodic deposition in substantially deeper water than where they lived. Toward the north end of the beach the beds are folded into a northwest plunging syncline beautifully exposed in the intertidal zone. West of the Seal Cove segment of the San Gregorio Fault (between Moss Beach and Pillar Point), rocks referred to the Purisima Formation consists of well indurated tan to buff siltstone and fine sandstone, gray muddy siltstone, silty mudstone, and fissile shale with some thick beds of hard shaly diatomite (Glen, 1959). Different fossil faunas have been collected from these two outcrop areas. Glen (1959) and Clark (1997) suggested 16 to 19 km of movement on the Seal Cove segment of the San Gregorio Fault and suggested a correlation between the rocks and foraminiferal faunas between Pillar Point and the type section of the Purisima Formation.

Glen (1959) reported only four taxa from the Purisima Formation west of the Seal Cove fault (i.e., *Lucinoma annulata* (Reeve) [as *Lucina acutilineata* Conrad], *Panope*? sp., *Lituyapecten purisimaensis* (Arnold), and *Conchocele disjuncta* Gabb [as *Thyasira bisecta* (Conrad)]), all of which were not reported east of the fault. Martin’s (1916) report of *Lucinoma annulata* (Reeve) (Table 6) from this general area is here referred to the rocks west of the fault. Unfortunately Martin’s precise locality is not known, but it is likely collected west of the fault because *Lucinoma annulata* (Reeve) occurs in this section and has not been recognized during field work east of the fault . Glen (1959) reports deep-water taxa from west of the fault [*Lucinoma annulata* (Reeve) and *Conchocele disjuncta* Gabb], which co-occurring in water depths of 100 m to 750 m (Bernard, 1983) in the eastern Pacific. Recent work on this section has recovered foraminifers which suggest upper to middle bathyal depths (150 to 1,500 m) (R. S. Boettcher, written comm., 1996).

Repenning and Tedford (1977) reported specimens questionably referred to the primitive walrus *Dusignathus santacruzensis* Kellogg from Moss Beach west of the Seal Cove fault. Its occurrence here, in combination with the correlation of these beds with the type Purisima Formation cited above (Glen, 1959 and Clark, 1997), suggests either 1) a problem with our understanding of the stratigraphy of the Purisima Formation; 2) an upward extended age range for *D. santacruzensis* Kellogg broader then suggested by its previous occurrences; or 3) the specimens are not referrable to *D. santacruzensis* Kellogg. The occurrence of *D. santacruzensis* Kellogg from the Drakes Bay Formation is questionably late Miocene in age; other Purisima Formation occurrences are unclear and cannot be dated with certainly. The occurrence here, if correct, combined with the correlation of Glen (1959) and Clark (1997), suggests its occurrence significantly higher in the Purisima Formation than previously reported. An interesting point related to movement on the Seal Cove segment of the San Gregorio Fault is defined by the above data. If the deposits east of the fault are late Pliocene as suggested by Glen (1959) and herein, and the rocks west of the fault are early Pliocene, as suggested by Glen (1959) and Clark (1997) then most of the Purisima Formation [<1,800 m (< 6,000 ft)] is missing across the Seal Cove segment of the San Gregorio Fault in this area.

East of the Seal Cove segment of the San Gregorio Fault Glen (1959) reports 29 taxa (table 6). Most of Martin's (1916) taxa are probably from this section as they have not been recorded in later collections from west of the fault. Extant taxa from east of the fault co-occur in the eastern Pacific between about Santa Cruz, central California (37°N) and north of Fort Bragg, northern California (40°N) in water depths from 5 to 10 m, with this shallow depth restricted by the occurrence of *Protothaca staminea* (Conrad). Wiley and Moore (1984) have given an excellent description of the sediments exposed at Moss Beach east of the Seal Cove Fault, which are shallow-water sediment gravity flows. Also based on the occurrence of the *in situ* bivalves *Tresus nuttallii* (Conrad) and questionably *Spisula catilliformis* (Conrad), they suggested deposition in less than 45 m of water. This fauna is similar to those reported from east of Año Nuevo Creek, but west of the San Gregorio fault, and around Santa Cruz. It is assumed that these faunal similarities reflect similar age, although alternatively, they may be environmentally controlled.

Table 6. Fossils from the Purisima Formation east of the Seal Cove fault at Moss Beach, San Mateo County, CA.

MOLLUSCA	Martin (1916)	Glen (1959)
BIVALVIA		
Anadara sp., cf. *A. trilineata* (Conrad)	-	x
Clinocardium meekianum (Gabb)	-	x
Lituyapecten purisimaensis (Arnold)	? as *Patinopecten* sp. aff. *P. coosensis* Shumard	-
Lucinoma annulata (Reeve)	x	-
Macoma sp., cf. *M. identata* Carpenter	sp.	x
Mytilus sp., cf. *M. coalingensis* Arnold	-	x
Nanaochlamys nutteri (Arnold)	-	x
Parapholas californica (Conrad)	-	in part as Pholad indet.
Patinopecten lohri (Hertlein)	as *Pecten oweni* Arnold	x
Pectinid indet.	-	x
Penitella sp., cf. *P. penita* (Cornad)	-	in part as Pholad indet.
Protothaca staminea (Conrad)	-	x
Siliqua sp., cf. *S. alta* (Broderip & Sowerby)	-	x
Siliqua patula (Dixon)	as *S. nuttalli* Conrad	
Spisula albaria Conrad	x	? as *Pseudocardium* aff. *P. densatum* (Conrad)
Spisula hemphilli (Dall)	x	x
Spisula mossbeachensis Glen	-	x
Swiftopecten parmeleei etchegoini (Anderson)	-	x
Tresus nuttallii (Conrad)	-	x
Tresus pajaroanus (Conrad)	-	x
Yoldia cooperi (Gabb)	-	x
Zirfaea pilsbryi Lowe	-	x
GASTROPODA		
Astyris gausapata (Gould)	? as *Astyris richthofeni* Gabb	x
Aulacofusus? recurva (Gabb)	-	cf.
Diodora sp. cf. *D. aspera* (Eschscholtz)	-	x
Margarites? sp.	-	x
Nucella lamellosa (Gmelin)	x	x
Nucella sp. cf. *N. lima* (Martyn)	-	x
Ocenebra sp. cf. *O. interfossa* (Carpenter)	-	x
Polinices sp.	-	x

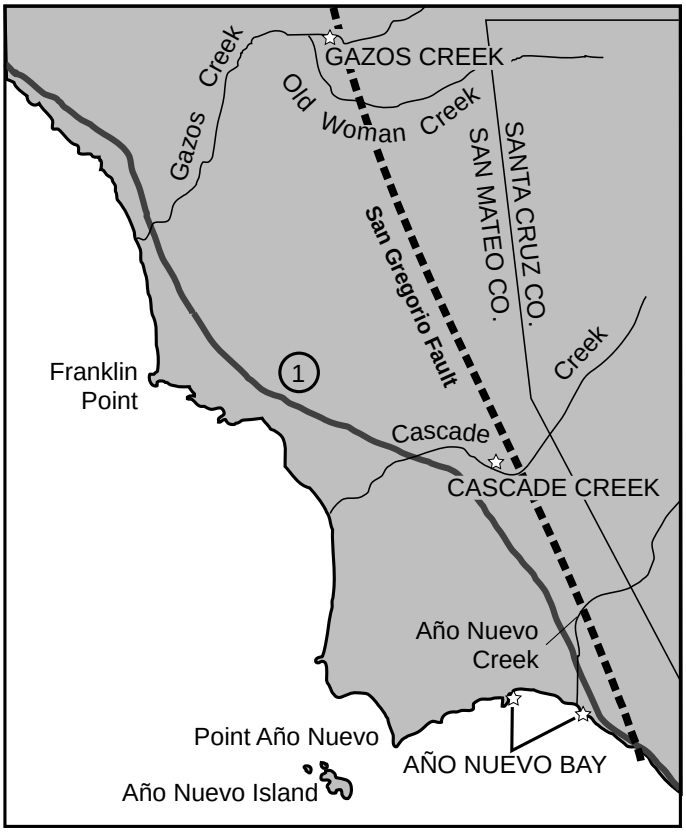

Figure 7.— Index map of Purisima Formation fossil occurrences discussed in the text. Map covers the coast from north of Franklin Point to Año Nuevo Bay in San Mateo and Santa Clara Counties. Outcrops discussed occur from north to south, at Gazos Creek, Cascade Creek, and Año Nuevo Bay.

AÑO NUEVO AREA (Figure 7)
(Franklin Point to Año Nuevo Bay)

Gazos Creek: Two taxa have been recorded in a collection (M4289) from this locality: *Acila* sp. cf. *A. castrensis* (Hinds) and indeterminate bivalve fragments. Outcrops from where these taxa presumably came are in a road cut and consist of highly fractured to massive, fine- to medium-grained, light-tan, tan to light-brown weathering sandstone with some reddish-brown iron staining, but no fossils were observed during recent field work. The Miocene to Holocene *Acila castrensis* (Hinds) has a modern occurrence from the Bering Sea, Alaska (57°N) to Baja California Norte, Mexico (28°N) in water depths from 5 to 200 m (Bernard, 1983). Generally its occurrence suggests deeper water and fine-grained, sandy-mud, sediments.

Cascade Creek: Recent attempts to relocate this and the previous locality have failed to find any fossils although outcrops from which these fossils probably were collected have been located. They are presumed to have come from these outcrops, because they are the only exposures present in the general area where the fossils were reported, although heavy undergrowth may hide other outcrops. The locality in Cascade Creek consists of several small outcrops of massive, fine- to medium-grained, yellow-tan, tan to gray weathering sandstone with reddish-brown iron staining. A small fauna of only three taxa occur at this locality (M4288): the bivalves *Lucinoma annulata* (Reeve), indeterminate bivalve fragments, and an indeterminate Naticid gastropod. The only specifically identified taxa, *Lucinoma annulata* (Reeve), occurs in water depths of 25 to 750 m (Bernard, 1983)

from Alaska to Baja California Sur (Moore, 1988).

Año Nuevo Bay: Clark (1981) informally divided the Purisima Formation between Año Nuevo Point and the San Gregorio fault into a mudstone member and a sandstone member separated by the Green Oaks fault. The lower mudstone member is exposed west of the Green Oaks fault and unconformably overlies the Monterey Formation. Barron *in* Clark (1981) reported a small diatom flora from about 15 m stratigraphically above the base of the formation and identified a flora correlated with North Pacific diatom Zone IX of early Pliocene age. Recent field work by Ken Lajoie is illustrated here (figure 8) and shows the four fold division of the Purisima Formation in this area which corresponds to the two fold division recognized by Martin (1916).

Another fault generally coincides with Año Nuevo Creek and separates different parts of the Purisima Formation both of which Clark (1981) attributed to his sandstone member. Between the Green Oaks fault and Año Nuevo Creek is a syncline of well-sorted, fine- to medium-grained, lithic sandstone which is typically thick- to very-thick bedded and locally crossbedded. These outcrops contain *Clinocardium* sp., *Lucinisca annulata* (Reeve) and other indeterminate bivalves and gastropods which suggest water depths of 25 m to 750 m based on the single specifically identified taxon in the fauna [*Lucinisca annulata* (Reeve)]. This is the typical Purisima Formation reported from Año Nuevo by Martin (1916) (Clark, 1981).

East of Año Nuevo Creek (Table 7) fossils are well represented and well preserved in stringers and small lenses of current-accumulated shells in hummocky cross-bedded to thin-bedded fine sandstone and siltstone, some of which show soft sediment deformation suggesting downslope transportation. Based on preservation and taxa present fossils

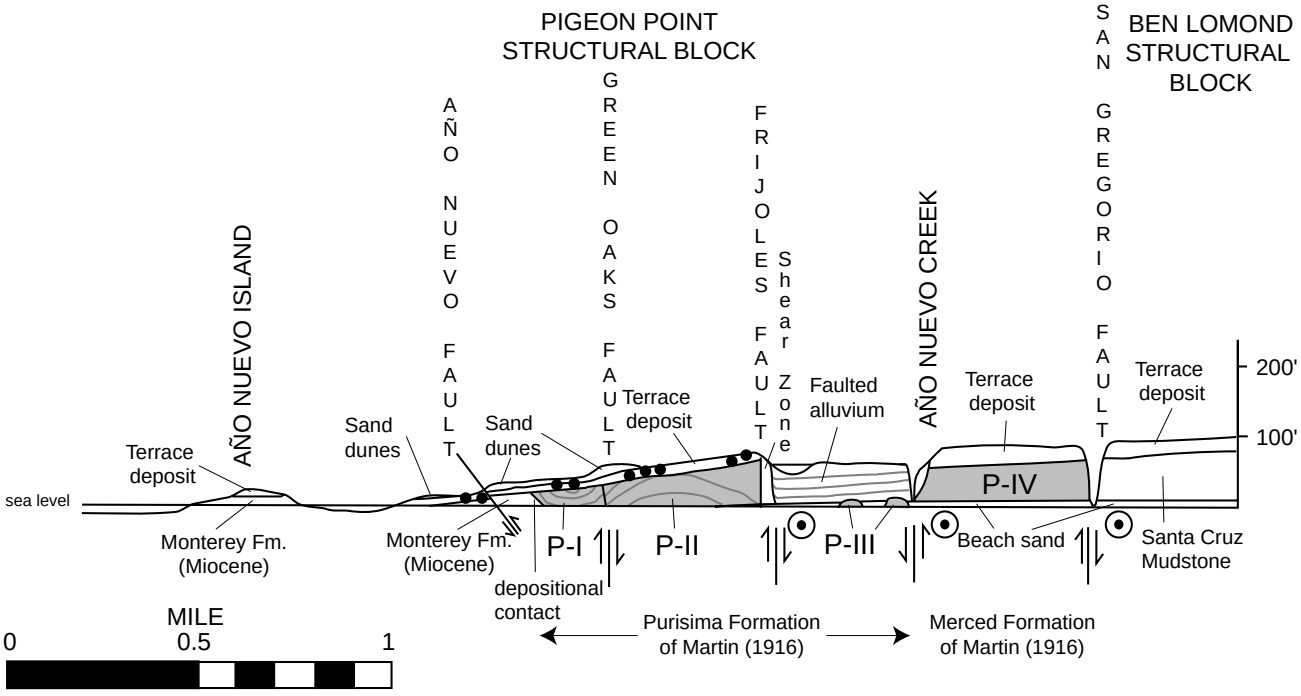

Figure 8.—Generalized sea cliff geology on south side of Punta del Año Nuevo, San Mateo County. P-I is the base of the Purisima Formation in depositional contact with the Monterey Formation. P-II is an anticline; = Purisima Formation of Ashley, 1895a. P-III is also the Purisima Formation of Ashley, 1895a. P-IV is the "Merced" Formation of Ashley, 1895a. Small black circles in terrace deposits are late Pleistocene fossil localities (see Addicott, 1969). Vertical exaggeration x 10. After K. Lajoie, 1997, written communication.

previously reported from Año Nuevo Bay (Martin, 1916) most likely came from east of the Creek. Norris (1986) suggests that the section east of Año Nuevo Creek (= his Coastways Ranch section) was deposited in water depths of 10 to 80 m, based on depth of channels in the section. Fossils from east of Año Nuevo Creek have yielded a fauna of 28 taxa [USGS collections (M2146, M5154) and those of Martin (1916) which have not been reexamined] cited in table7. These mollusks suggest a late Pliocene to possibly Pleistocene age for this outcrop. Extant taxa reported here are found living today between Monterey Bay and the California/Oregon border. The depth range suggested by the extant mollusks in this section is in doubt as the fossils are not in place and possible downslope transport of these fossils is indicated by soft sediment deformation mentioned above, but most of the extant taxa lived in water depths between the intertidal zone and 10 m. *Colus? purisimaensis* Martin described from the Purisima Formation at Año Nuevo Bay has not been reported by later authors.

The Purisima Formation both east and west of Año Nuevo Creek is overlain by Pleistocene terrace deposits. Addicott (1966) reported a late Pleistocene fauna of 143 taxa from the terrace west of the Creek. Pholad boring by Pleistocene bivalve mollusks are common along the contact between the two formations in the top of the Purisima Formation.

Table 7. Mollusks from the Purisima Formation at Año Nuevo Creek.

MOLLUSCA	Recent USGS collections	Martin (1916)
BIVALVIA		
Acila castrensis Hinds	-	x
Anadara trilineata (Conrad)	x	x
Clinocardium meekianum Gabb	sp. observed in field	x
Compsomyax subdiaphana (Carpenter)	-	as *Marcia oregonensis* Conrad
Cryptomya californica Conrad	-	x
Macoma nasuta Conrad	sp.	x
Modiolus rectus Conrad	-	x
Panomya chrysis Dall	-	as *Panomya ampla* Dall
Panope abrupta (Conrad)	sp. observed in field	x
Protothaca staleyi (Gabb)	-	x
Protothaca tenerrima (Carpenter)	-	x
Solen sicarius Gould	sp.	x
Tresus pajaroanus(Conrad)	x	x
GASTROPODA		
Astyris gauspata (Gould)	x	as *Astyris richthofeni* Gabb
Beringius stantoni (Arnold)	-	x
Crepidula princeps (Conrad)	x	x
Epitonium indianorum Carpenter	-	x
Megasurcula carpenteriana (Gabb)	x	x
Nassarius californius (Conrad)	x	? as *Nassa mendica* Gould
Nassarius grammatus (Dall)	x	as *Nassa moraniana* Martin
Nassarius sp.	x	-
Neptunea sp.	x	-
Neverita reclusianus (Deshayes)?	x	as *Neverita* sp.
Olivella pycna Berry	sp.	as *Olivella biplicata* (Sowerby), *Olivella intorta* Carpenter & *Olivella pedroana* Conrad

MOLLUSCA GASTROPODA	Recent USGS collections	Martin (1916)
Ophiodermella graciosana (Arnold)	-	? as *Drilla mercedensis* Martin
Polinices lewisii (Gould)	x	-
ARTHROPODA CRUSTACEA *Balanus sp.*	-	x

Ben Lomond Block

The Ben Lomond Block includes Salinian basement and Tertiary rocks in the triangular area south of the east-west Zayante Fault, west of the northwest trending San Andreas Fault and east of the north trending San Gregorio Fault. Outcrops of the Purisima Formation in this block occur in the Santa Cruz Mountains, around Scotts Valley, along the coast in Santa Cruz, and just west of the San Andreas fault in the Chittenden Pass area. In the Santa Cruz area the Purisima Formation is as much as 210 m thick and divided into lower and upper units (Clark, 1981). Both units are composed of coarse to fine sandstone with other minor components. Outcrops in Scotts Valley and in the Santa Cruz Mountains contain limited fossil assemblages, but appear older than the deposits at Capitola, New Brighton, Seacliff State Beaches. Around Point Santa Cruz the lower part of the Formation is exposed and an extensive vertebrate fauna has been collected. Few faunal elements have been collected in the Chittenden Pass area west of the San Andreas fault.

Just east of the Ben Lomond Block in the Chittenden Pass/Sargent oil field area rocks attributed to the Purisima/Santa Clara Formation are exposed (Allen, 1945). The Purisima Formation of Allen (1945) in this area has been referred to the Santa Margarita, Purisima/Santa Clara Group, and Merced Formations by various early authors. These rocks are composed dominantely of sandstone and conglomerate and are about 3,000 m thick (10,000 ft) (Allen, 1945). The lower part of the section represents shallow water and shows faunal similarities to the the Pancho RicoFormation in Monterey County (see Durham and Addicott, 1965) to the southeast, suggesting a possible seaway to the south. The upper part of the Formation in this area is similar, faunally, to the Purisima and Merced Formations to the north. These outcrops do not fit into the tectonic block structure outlined above, but they are included here as they have been referred to the Purisima Formation by earlier authors and are generally the same age as the type Purisima in San Mateo County. But the question remains - should these rocks be included in the Purisima Formation? Were they part of the same structural basin in which the type Purisima Formation was deposited - the location east of the San Andreas fault, the fauna, and lithology suggest that these rocks should probably be attributed to some other formaiton.

SANTA CRUZ AREA

Capitola City Beach (Fig. 9): The uppermost 50 to 100 m of the Purisima Formation is exposed in the sea cliffs at Capitola City Beach eastward for about 4 km to Seacliff State Beach. These sediments consist of massive, medium- to coarse-grained, gray concretionary sandstone with occasional shell beds overlain by 4 to 5 m of late Pleistocene terrace deposits (Addicott and others, 1978b).

Mollusks from the Capitola Beach section (Table 8) have been reported by Ashley (1895a) and Addicott (1978b). The fauna listed here of 27 mollusks comes from previous work and USGS collections (M4749, M8845, M8856, M8858, M8861?, M8862, M9023, M9110). The geographic and depth ranges of extant taxa represented here suggest a

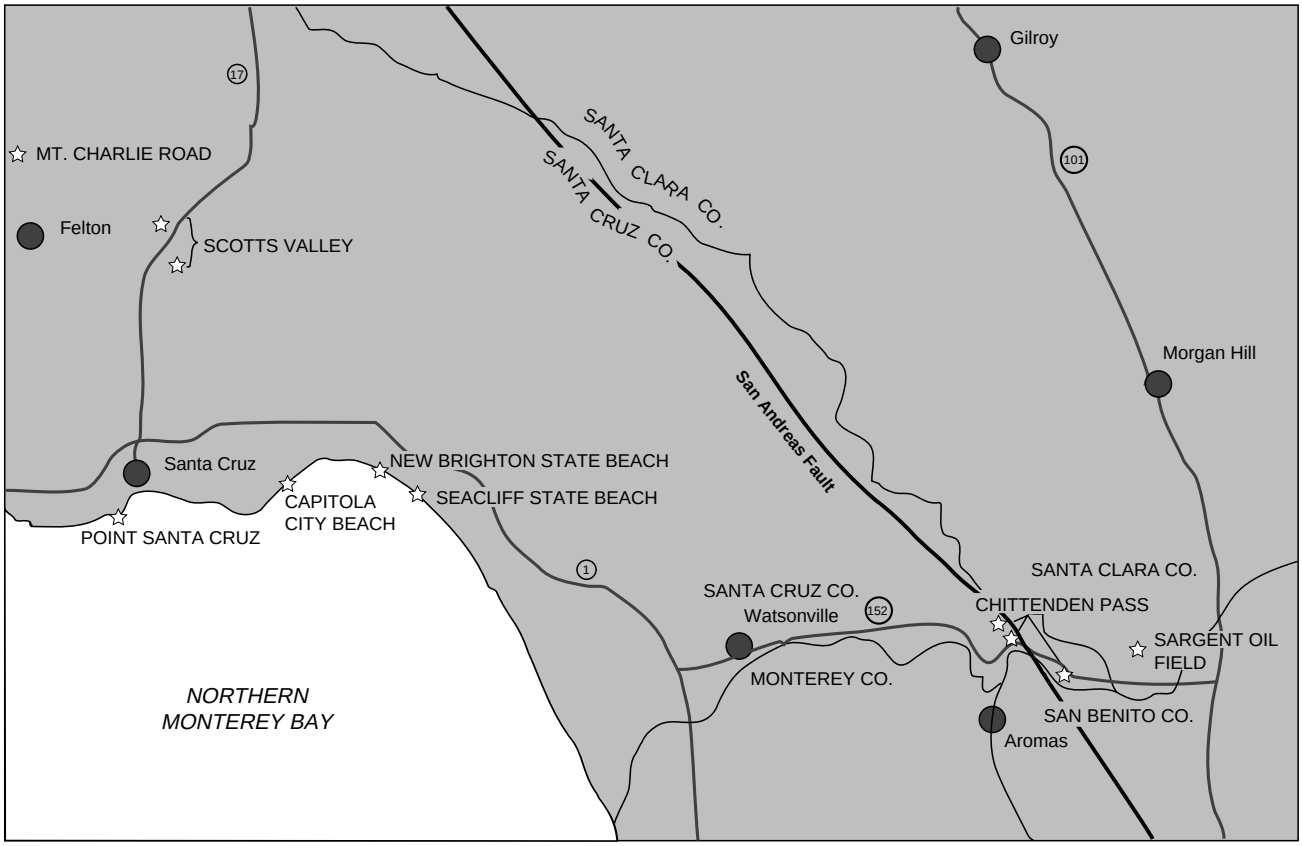

Figure 9.— Index map of Purisima Formation fossil occurrences discussed in the text. Map covers the Santa Cruz County occurrences. Outcrops discussed occur from west to east, at Mt. Charlie Road, Scott's Valley, Point Santa Cruz, Capitola, New Brighton State Beach, Sea Cliff State Beach, Chittenden Pass, and the Sargent oil field area.

shallow marine environment probably between 5 and 10 m depth with a water temperature equivalent to that between Monterey Bay (37°N) and Point Arena (39°N) in northern California today. Two taxa reported by Ashley (1895a) could not be equated with modern species, *Meretrix traskii* Conrad? and *Pachydesma ineziana* Conrad?. Otarioid seal remains are reported from these exposures by Repenning and Tedford (1977).

Table 8. Mollusks reported from the Purisima Formation at Capitola City Beach.

MOLLUSCA BIVALVES	Recent USGS collections	Ashley, 1895a	Addicott and others, 1978b
Anadara trilineata (Conrad)	-	as *Arca microdonta* Conrad & *A. sulcicosta* Gabb	x
Chione sp.	-	as *Chione similima* Sowerby?	-
Clinocardium meekianum (Gabb)	sp.	x (& in part as *Cardium corbis* Martyn)	x
Cryptomya californica (Conrad)	-	x	x
Gari californica (Conrad)?	-	as *Psamnobia rubroradiata* Conrad	-

MOLLUSCA BIVALVES	Recent USGS collections	Ashley, 1895a	Addicott and others, 1978b
Lucinoma annulata (Reeve)	cf.	as *Lucina borealis* Linnaeus	cf.
Macoma addicotti Nikas	-	? as *Macoma edulis* Nuttall?	x
Macoma nasuta (Conrad)	-	x	x
Modiolus rectus Conrad	-	as *Modiola flabellata* Gould	sp.
Panope abrupta (Conrad)	x	? as *Glycymeris generosa* Gould	-
Patinopecten caurinus (Gould)	-	x	-
Protothaca staleyi (Gabb)	-	? as *Tapes staminea* Conrad	x
Siliqua patula Dixon	-	x	sp.
Solen sicarius Gould	-	x	x
Spisula albaria (Conrad)	x	? as *Standella nasuta* Gould?	x
Spisula falcata Gould	-	x	-
Transennella tantilla (Gould)	-	? as *Cyrena californica* Gabb	-
Tresus nuttalli (Conrad)	-	x	-
Tresus pajaroanus (Conrad)	-	x	x
Yoldia sp	x	-	x
GASTROPODS			
Astyris gauspata Gould	x	x	x
Calicantharus portolaensis (Arnold)	-	-	x
Calyptraea sp.	-	-	as *C. inornata* (Gabb)
Cancellaria tritonidae Gabb	x	x	-
Crepidula princeps (Conrad)	-	as *C. grandis* Middendorff	x
Cryptonatica affinis (Gmelin)	-	as *Natica clausa* Broderip & Sowerby	-
Forreria coalingensis (Arnold)	-	*? as Forrreria belcheri* (Hinds)	-
Megasurcula carpenteriana (Gabb)	-	as *Surcula carpenteria* Gabb	sp.
Nassarius californius (Conrad)	cf.	x	-
Nassarius grammatus (Dall)	x	-	x
Olivella pycna Berry	-	-	as *O. biplicata* Sowerby
Ophiodermella graciosana (Arnold)	sp.	-	x
Polinices lewisii (Gould)?	x	x	x
Polinices reclusianus (Deshayes)	x	-	x
ECHINODERMATA ECHINOIDEA			
Dendraster gibbsi (Rémond)	-	as *Scutella gibbsi* Remond	-

New Brighton-Seacliff State Beaches (Fig. 9): About 1 km northeast of the Capitola City Beach section are outcrops at New Brighton State Beach (M3618, M8939, M9108), which continue east to Seacliff State Beach (M8823, M8940?, M9022, M9106). This sec-

tion has a similar composition to the Capitola City Beach section, but is slightly higher stratigraphically and includes thick shell beds to the east at Seacliff State Beach. Here the Purisima Formation is conformably overlain by nonmarine sands of the Pliocene and Pleistocene Aromas Formation (Addicott and others, 1978b). The contact has been placed at the highest occurrence of marine fossils near the pier at Seacliff State Beach (E. Brabb *in* Addicott and others, 1978b).

Mollusks from the New Brighton-Seacliff section (table 9) yield a fauna of 21 taxa. Diagnostic Pliocene taxa include the gastropods *Beringius stantoni* (Arnold) and *Ophiodermella graciosana* (Arnold). The five wide-ranging extant taxa represent a shallow marine environment probably between the intertidal zone and 10 m depth, and living representatives of these taxa now occur between Orange County (33°N) in southern California and southern-most Alaska (51°N).

Table 9.—Mollusks from Purisima Formation at New Brighton -Seacliff State Beaches.

	Recent USGS collections	Addicott and others, 1978b
MOLLUSCA		
BIVALVES		
Anadara trilineata (Conrad)	x	x
Clinocardium sp.	x	-
Cyclocardia? sp.	x	-
Macoma addicotti Nikas	sp.	x
Macoma nasuta (Conrad)	-	x
Modiolus? sp.	x	-
Solen sicarius Gould	-	x
Spisula albaria (Conrad)	x	-
Tresus pajaroanus (Conrad)	-	x
Yoldia sp.	x	-
GASTROPODS		
Astyris gausapata (Gould)	x	x
Beringius stantoni (Arnold)	-	x
Crepidula princeps (Conrad)	-	x
Cryptonatica affinis (Gmelin)	-	as *Natica clausa* (Broderip and Sowerby)
	Recent USGS collections	Addicott and others, 1978b
Megasurcula remondii (Gabb)	x	-
Nassarius sp., cf. *N. californianus* (Conrad)	x	-
Nassarius grammatus (Dall)	x	x
Neptunea sp.	x	-
Ophiodermella graciosana (Arnold)	sp.	x
Polinices lewisii (Gould)?	-	x
ECHINODERMATA		
ECHINOIDEA		
Indet. genus and species	x	-

Point Santa Cruz-Exposures of the Purisima near Point Santa Cruz yield several significant specimens of otarioid seals (Mitchell, 1962; Repenning and Tedford, 1977), and whales (Barnes, 1976). Marine terrace deposits that unconformably overlie the Purisima Formation on a small promontory at the west edge of the beach have yielded a large marine invertebrate fauna of late Pleistocene age (Addicott, 1966). No Purisima mollusks have been reported from this section.

SANTA CRUZ MOUNTAINS/SCOTTS VALLEY

Mountain Charlie Road (Fig. 9): A fauna of five bivalve taxa occurs in collections from this area (M5115, M5160). The fauna is poorly preserved occurring as casts and molds in fine grained sediments making identification difficult. The Mountain Charlie faunule consists of indeterminate specimens of: *Clinocardium* sp., *Ensis?* sp., *Macoma* sp., *Siliqua?* sp., and *Yoldia* sp. These taxa are too widely ranging and poorly preserved for precise ecological or age interpretations. They all occur in the north Pacific in water depths from the intertidal zone to outer sublittoral zone and no age diagnostic taxa are recorded. Attempts to relocate the localities where these collections were made have failed. Many new houses have been built in the area possibly eliminating the outcrops.

Scotts Valley (M5117, M5137) (Fig. 9): Clark (1981) reported a maximum thickness of 60 m for the lower part of the Purisima Formation west of Scotts Valley, with outcrops occurring as a discontinuous unit along ridge tops and consisting of "... very thick yellowish-gray tuffaceous and diatomaceous siltstone beds with thick yellowish-gray to locally bluish-gray andesitic sandstone interbeds." He also reported a molluscan fauna consisting of the bivalves *Chlamys hericius* (Gould)?, *Lucinoma* sp., cf. *L. annulata* (Reeve), *Macoma* sp., *Yoldia* sp., and the gastropod *Neptunea tabulata* (Baird) from these beds. These are all living taxa which have broad latitudinal ranges overlapping from 33°N to 55°N in the eastern Pacific. Water depth suggested by these taxa is more restricted and their co-occurrence suggests water depths from 90 m to 150 m.

Southeast of Scotts Valley Clark (1981) reported a maximum thickness of 150 m of the Purisima Formation with similar composition to that west of Scotts Valley. Clark (1981) suggested that these rocks are higher stratigraphically than those west of Scotts Valley and contain a different mollusk fauna including the bivalves *Acila castrensis* (Hinds), and *Macoma* sp., cf. *lama* (Bartsch) (the nominal species = *M. planiuscula* Grant and Gale), and the gastropods *Crepidula* sp., cf. *C. onyx* Sowerby and *Forreria coalingensis* (Arnold). *Forreria coalingensis* (Arnold) is the only extinct taxa here and is reported from the late Miocene to early Pliocene Etchegoin Formation in the Coalinga region of central California. Living representatives of the mollusks reported for outcrops southeast of Scotts Valley (Clark, 1981) give an unclear picture of conditions during deposition of this part of the Purisima Formation. It is suggested later that the occurrence of *Crepidula onyx* Sowerby (questionably reported here) is a mis-identification because this is a subtropical faunal element not in keeping with the rest of the fauna reported from the Purisima Formation. The other two taxa suggest cold water as they have overlapping latitudinal ranges from 53°N to 60°N which is probably colder than really existed during deposition of the Purisima Formation. The extant taxa also co-occur in water depths of 5 m to 185 m in the eastern Pacific.

Only three taxa are in USGS collections from the vicinity of Scotts Valley: the bivalves *Lucinoma annulata* (Reeve) and *Macoma* sp., and the gastropod *Boreotrophon*? sp. The only specifically identified taxon, *Lucinoma annulata* (Reeve), occurs in the modern eastern Pacific Ocean at water depths of 25 to 750 m (Bernard, 1983) from Alaska to Baja California Sur (Moore, 1988). These taxa are not age diagnostic.

CHITTENDEN PASS/SARGENT OIL FIELD (Fig. 9)

There are major problems with using the name Purisima Formation in the Chittenden/Sargent Oil field area. First, rocks in the Chittenden/Sargent Oil field area are probably not part of the Purisima Formation as it was defined in coastal San Mateo County. Outcrops in both areas are similar in that they seem to represent the same period of time

and are lithologically similar in the broad sense of being composed of congomerate, sandstone and siltstone, for the most part.

In the early part of the century formational names, in California, were commonly used in a time-stratigraphic sense instead of the lithostratigraphic sense, of sediments layed down in a continuous basin, as is now used. This appears to be the case with rocks described as the Purisima Formation in this area and probably in other areas (i.e., Point Reyes). The second problem is that the Purisima Formation is reported on both sides of the San Andreas Fault in the San Juan Bautista Quadrangle. This juxposition is unlikely considering movement on the San Andreas fault system since the latest Miocene. Taking into account movement on the San Andreas fault, rocks between the San Andreas and Sargent Faults would have been deposited many miles south of the type Purisima Formation, while rocks west of the San Andreas Fault, adjacent to those east of the fault, would have been deposited even further from the type area. This suggests that these rocks are not part of the type Purisima Formation, but only represent similar age deposits. That said, it is beyond the scope of this study to resolve these problems and so rocks assigned to the Purisima Formation by various authors in the San Juan Bautista quadrangle are treated here.

Rocks referred to the Purisima Formation in Chittenden Pass and Sargent oil field east of Watsonville appear intermediate between the type Purisima Formation and the Pancho Rico Formation of Durham and Addicott (1965), both faunally and lithologically. These sediments occur both west and east of the San Andreas fault, although they are most extensive between the San Andreas and the Sargent Faults. Rocks referred to the Purisima Formation by Allen (1945) were previously referred to the San Pablo, Santa Margarita, Purisima, and Merced Formations by Jones (1911) (Allen, 1945). The San Pablo Formation of Jones (1911) in the Sargent oil field was referred to the Etchegoin Formation by Martin (1913) and later to the Purisima Formation by Allen (1945). Rocks called the Santa Margarita Formation by Jones (1911) are white, friable sandstone containing sand dollars. Allen (1946) observed sediments similar to Jones' (1911) Santa Margarita Formation, but because his exposures lacked fossils, he suggested they might be part of the Purisima Formation. Sediments containing an unidentified *Astrodapsis*?and fragmented molluscan fossils are exposed along State Highway 129, between the San Andreas and Sargent Faults. These sediments are nearly identical to those discussed by Jones (1911) and Allen (1946) as the Jones' (1911) Santa Margarita Foramtion, but based on a poorly preserved molluscan fauna (i.e., Mollusca, Bivalves: *Dendostrea? vespertina* (Conrad), *Mytilus* sp.; Mollusca, Gastropoda: *Forreria*? sp.; Arthropoda: *Balanus* sp. cf. *B. gregarius* (Conrad); Echinodermata: *Astrodapsis*? sp.) are likely the same age as Purisima and Pancho Rico Formations, from which all these taxa have been reported. A few years later Martin (1913) suggested a correlation of these sediments with the Etchegoin Formation in the Coalinga region, based on similar faunas. Martin (1916) reported both the Etchegoin [? = San Pablo Formation of Jones (1911)] and Merced [? = Santa Margarita, Purisima, and Merced Formations of Jones (1911)] Formations from the Sargent oil field differentiating the two based on faunas and minor lithologic differences. Allen (1945) later referred the San Pablo (Jones, 1911), Santa Margarita (Jones, 1911), Etchegoin (Martin, 1913), Purisima (Martin, 1916), Merced (Jones, 1911; Martin, 1916), and Santa Clara Formations to his undifferentiated Purisima/Santa Clara Formation in the region.

Allen (1945) reported over 3,000 m (> 10,000 ft) of undifferentiated Purisima/Santa Clara Formation sediments in the Sargent Oil field area. He reported abundant marine fossils in the lower part of the Formation (table 10) and scarce fresh-water mollusks in the

upper part of the Formation (table 11). Later, Allen (1946) continued to use the name Purisima Formation for Pliocene rocks in this area reporting only the occurrence of *Dendostrea? vespertina* (Conrad) and *Mytilus* species from these outcrops. Most of the extant mollusks reported by Allen (1945) occur today between the Ventura County coast (34°N), southern California and Monterey Bay (37°N), central California in water depths from the intertidal zone to about 10 m depth.

Table 10.— Marine fossils reported from the lower part of the Purisima Formation in the Sargent oil field area.

	Martin (1916) "Merced" Formation	Martin (1916) "Etchegoin" Formation	Allen (1945)
BRACHIOPODA			
ARTICULATA			
Terebratalia arnoldi etchegoini Hertlein and Grant	x	-	x
MOLLUSCA			
BIVALVIA			
Acila castrensis (Hinds)	x	-	x
Anadara trilineata (Conrad)	x and as *Arca canalis* Conrad	x	x
Chione securis Shumard	-	x	? as *C.* n. sp.? cf. *elsmerensis* English
Clinocardium meekianum (Gabb)	x	x	-
Compsomyax subdiaphana (Carpenter)	? as *Marcia oregonensis* Conrad	-	as *Venerella (Compsomyax)* cf. *subdiaphana* (Carpenter)
Cryptomya californica (Conrad)	as *C. ovalis* Conrad and *C. quadrata* Arnold	as *C. quadrata* Arnold	x and as *C. ovalis* Conrad, and *C. quadrata* Carpenter
Cyclocardia sp.	-	-	? as *Cardita* sp.
Dendostrea? vespertina (Conrad)	-	as *Ostrea atwoodi* Gabb	x
Dosinia jaclitosana Arnold	? as *D. ponderosa* Gray	-	? as *D. ponderosa* Gray
Glycymeris septentrionalis (Middendorff)	-	-	as *G. subobsolita* Carpenter
G. coalingensis Arnold	-	x	x
Lucinoma annulata (Reeve)	-	x	as *Lucina acutilineata* Conrad
Macoma inquinata Deshayes	-	x	x
M. nasuta (Conrad)	x	x and ? as *M. indentata* Carpenter and ? as *M. secta* Conrad	x as *M. kelseyi* Dall
M. sp.	-	-	x
Mactromeris polynyma (Stimpson)	x	-	x

MOLLUSCA BIVALVIA	Martin (1916) "Merced" Formation	Martin (1916) "Etchegoin" Formation	Allen (1945)
Modiolus rectus (Conrad)	x	-	x
Mya sp.	-	x as *M. japonica* Jay?	x as *M. japonica* Jay?
Mytilus coalingensis Arnold	x	x	x
Nanaochlamys nutteri (Arnold)	-	x	-
"*Ostrea*" sp.	-	-	as *Ostrea* sp.
Pandora punctata (Conrad)	x	-	x
Panomya chrysis Dall	-	x as *P. ampla* Dall	-
Panope abrupta (Conrad)	as *Panope generosa* (Gould)	as *Panope generosa* (Gould)	as *Panope generosa* (Gould)
Patinopecten lohri (Hertlein)	-	as *Pecten oweni* Arnold	-
Pectinid indet. and *Pecten* sp.	-	-	as *Pecten* n. sp.?
Pholad indet.	-	-	as Pholadidae sp.?
Protothaca staleyi (Gabb)	x	x	as *Chione staleyi* Gabb
P. staminea (Conrad)	x	x and as *Paphia staminea*, var. *orbella* Carpenter	x
P. tenerrima (Carpenter)	as *Paphia tenerrima* Carpenter	-	x
Saxidomus nuttalli Conrad	-	x	-
Semele rubropicta Dall	x	-	x
Siliqua lucida (Conrad)	-	-	x
S. patula (Dixon)	as *Siliqua nuttalli* Conrad	as *Siliqua nuttalli* Conrad	x
Solen sicarius Gould	x	x	x
Spisula albaria (Conrad)	sp.	sp.	x as *S. albaria coosensis* Howe
S. coalingensis Arnold	as *Mactra coalingensis* Arnold	-	x
S. falcata Gould	x	-	x
Swiftopecten parmeleei etchegoini (Anderson)	-	as *Pecten wattsi*, var. *etchegoini* Anderson	as *Chlamys (Swiftopecten) wattsi* var. *morani* Arnold
S. parmeleei parmeleei (Dall)	-	as *Pecten wattsi* Arnold	-
Thracia trapezoides (Conrad)	-	sp.	x
Transennella tantialla (Gould)	as *T. californica* Arnold	-	as *T. tantilla* (Gould) var. *californica* Arnold
Tresus nuttallii (Conrad)	x	x	x
T. pajaroanus (Conrad)	x	x	x
Yoldia cooperi Gabb	-	x	cf.
Zirfaea pilsbryi Lowe	-	as *Zirfaea gabbi* Tryon	x
GASTROPODA			
Astyris gausapata (Gould)	as *Astyris richthofeni* Gabb	-	as *Mitrella carinata gausapata* (Gould)
Bittium sp.	as *B. asperum* (Gabb)	-	as *B. asperum* (Gabb)

MOLLUSCA BIVALVIA	Martin (1916) "Merced" Formation	Martin (1916) "Etchegoin" Formation	Allen (1945)
Calyptraea sp.	as *C. filosa* (Gabb)	as *C. filosa* (Gabb)	as *C. filosa* (Gabb)
Cancellaria tritonidae Gabb	x	-	x
Cantharus sp.	-	-	x
Calicantharus portolaensis (Arnold)	-	x	x
Crepidula princeps Conrad	-	x	x
Cryptonatica affinis (Gmelin)	as *N. clausa* Broderip & Sowerby		sp. as *N. clausa* Broderip & Sowerby
Kelletia kettlemensis (Arnold)	- Formation	x Formation	x
Littorina sp.	as *L. scutulata* Gould	-	as *L. remondi* Gabb, as *L. scutulata* Gould, and ? as *L*. sp.
Nassarius californianus (Conrad)	? as *N. mendicus* (Gould)	-	x and ? as *N. mendicus* (Gould)
N. grammatus (Dall)	? as *N. moranianus* (Martin)	? as *N. fossatus* Gould	? as *N. moranianus* (Martin)
Neverita reclusianus (Deshayes)	x	x	x
Nucella canaliculata (Duclos)	x	-	x
N. lamellosa (Gmelin)	x	-	x
N. lima (Martin)	-	-	x
N. transcosana (Arnold)	-	-	x
Olivella pycna Berry	? as *O. biplicata* Sowerby) & ? as *O. pedroana* (Conrad)	-	? as *O. biplicata* (Sowerby) & ? as *O. pedroana* (Conrad)
Ophiodermella graciosana (Arnold)	? as *Drillia mercedensis* Martin	-	? as *Moniliopsis graciosana* var. *mercedensis* Martin
Polinices lewisii (Gould)	-	-	x
Trophosycon sp. indet.	-	-	x
ECHINODERMATA ECHINOIDEA			
Dendraster arnoldi Twitchell	-	-	x
D. gibbsi (Rémond)	-	x	x
D. sp. indet.	-	-	x
ARTHROPODA CRUSTACEA			
Balanus sp. indet.	x	x	x

Table 11.—Fresh-water mollusks reported from the upper part of the undifferentiated Purisima/Santa Clara Group rocks in the San Juan Bautista quadrangle by Allen (1945) (identifications by A. M. Keen, circa. 1945). These taxa are not included in the taxonomic discussion below.

MOLLUSCA
BIVALVIA
Amicola longinqua Gould
Savaginius williamsi (Hannibal) [as *Fluminicola willliamsi* (Hannibal)]
GASTROPODA
Gonidea coalingensis Arnold

Allen (1946) reported the Purisima Formation from the San Juan Bautista quadrangle east of Watsonville noting *Dendostrea? vespertina* (Conrad) from these rocks. Wilkinson (1963, 1967) noted the occurrence of *Dendostrea? vespertina* (Conrad) from rocks assigned to the Purisima Formation in the Hollister oil field.

San Francisco Block

Finally, in the San Francisco Bay Block rocks attributed to the Purisima Formation crop out adjacent to the San Andreas Fault. These outcrops are poorly known and no thickness or lithologies are recorded (in part, Esser, 1958; Mack, 1959), except in a very general way.

Miscellaneous Collection

Fossils from several other localities in several of the structural blocks are represented in USGS collections by either very poorly preserved material which can not be identified, or, by only one or two taxa which do not allow accurate ecological and/or age determinations. These collections include M5078, M5080, M5091, M5109, M5123, M5124, M5130, M5136, M5161, M8922, M8938, M8941 and their locations can be found in Appendix II. One collection, M8859 listed as from Rodeo Gulch Road, proved impossible to relocate and based on correlation with the Santa Cruz fauna, it is believed that this collection was mis-recorded, as the fauna has not been observed in the area where it was reportedly collected, but is common in the coastal areas of Santa Cruz. This is unfortunate as this collection contains the first record of *Rictaxis punctocaelatus* (Carpenter) (questionably reported here) from the Purisima Formation.

BIOSTRATIGRAPHY

Mollusks from the Purisima Formation are here divided into three faunas (La Honda, Pillar Point, and Santa Cruz) which differ in taxa present, the depositional environments they represent, and probably age. These faunas are not well dated and the mollusks are wide ranging, giving, at best, a general age for individual outcrops. It is possible that these fauna are ecologically based and time transgressive, but in the case of the La Honda fauna and Santa Cruz fauna they form a stratigraphic succession from older to younger. This biostratigraphic succession allows some correlations of outcrops across structural block boundaries suggest older and younger portions of the Purisima Formation in adjacent areas.

The oldest fauna is from the middle member of the Purisima Formation of Arnold (1908a) and is here referred to the La Honda fauna because it is best expressed in the La Honda structural block. The La Honda fauna contains many extinct bivalves, including: *Chione* sp., cf. *C. securis* Shumard, *Clementia pretenuis* (Gabb), *Dendostrea? vespertina* (Conrad), *Dosinia jacalitosana* Arnold, possibly *Glycymeris coalingensis* Arnold, *Mytilus coalingensis* Arnold, *Swiftopecten parmeleei* (Dall), the gastropods *Nassarius californicus* (Conrad), and the endemic *Tegula stantoni lahondaensis* Arnold. Extant and extinct taxa from these outcrops suggest correlation with the “Jacalitos - Etchegoin” molluscan stages of central California, or a late Miocene to early Pliocene age. The La Honda fauna includes mollusks from the Tahana and Pomponio Members as outlined by Cummings and others (1962). Ecologically this fauna suggests normal marine conditions and water depths less than 50 m. A problem exists with the age of this fauna as outlined under “Radiometric dating” above. An ash age determination from one outcrop is much younger than suggested by the mollusks and recognized in the lower part of the formation elsewhere [in

coastal San Mateo County (Durham and Morgan, 1978), at Santa Cruz (Repenning and Tedford, 1977), and at Point Reyes (Galloway, 1977; Repenning and Tedford, 1977)]. Based on faunas reported in the literature and from USGS collections, outcrops including the La Honda fauna occur at Lobitos Creek, Pomponio State Beach, Purisima Creek, Chittenden Pass/Sargent oil field area, and questionably at Point Reyes, Redondo Beach, and San Gregorio, Cascade Creek, Gazos Creek, Año Nuevo west of Año Nuevo Creek, Mountain Charlie Road, and Scotts Valley.

The middle, Pillar Point fauna occurs only at Pillar Point west of the Seal Cove segment of the San Gregorio Fault. This fauna is very small containing only *Conchocele disjuncta* Gabb, *Lituyapecten purisimaensis* (Arnold), *Lucinisca annulata* (Reeve) and *Panope*? sp. none of which can be used to date this deposit. The occurrence of *L. purisimaensis* (Arnold) might be thought to provide an age call but it only occurs in the Purisima Formation, so ths would be a case of circular reasoning. The Pillar Point fauna represents much deeper water (> 100 m) than the other faunas reported here. Lithologically the rocks containing the Pillar Point fauna appear to correlate with part of the Pomponio Member to the south (Glen, 1959 and Clark, 1997b). This suggests that the Pillar Point fauna is also late Miocene to early Pliocene in age.

The upper, Santa Cruz fauna is best described by Addicott and others (1978b) for outcrops at Capitola City Beach and New Brighton-Seacliff State Beaches. This fauna contains a smaller percentage of extant taxa then the La Honda fauna, and taken together with the extinct taxa suggests correlation with the “San Joaquin” provincial molluscan stage (early to late Pliocene) and at some outcrops possibly the upper part of the “Jacalitos-Etchegoin” provincial molluscan stage (late Miocene to early Pliocene). Extinct taxa include the bivalves *Macoma addicotti* Nikas, *Nanochlamys nutteri* (Arnold), and the gastropods *Searlesia portolaensis* (Arnold), *Nassarius grammatus* (Dall), *Psephaea oregonensis* (Arnold), *Thais imperialis* (Dall) and the endemic taxa *Beringius stantoni* (Arnold) and possibly *Spisula mossbeachensis* Glen. The Santa Cruz fauna includes mollusks from the San Gregorio and Lobitos members as defined by Cummings and others (1962). Ecologically the Santa Cruz fauna suggests very shallow water depths, commonly less than 10 m, but the fauna is generally not preserved in place and lithologic evidence presented by Norris (1986) suggests slightly deeper water, but less than 50 m. Based on faunas reported in the literature and from USGS collections, outcrops including the Santa Cruz fauna occur at Capitola, New Brighton State Beach, Sea Cliff State Beach, Año Nuevo east of Año Nuevo Creek and west of the San Gregorio Fault, and at Moss Beach northest of the Seal Cove Fault, contain this fauna.

CONCLUSIONS

Stratigraphic sections assigned to the Purisima Formation have a wide outcrop area from Marin County in the north to Santa Clara and Santa Cruz Counties in the south. The rocks have a maximum thickness of nearly 1.6 km (1 mi). In San Mateo County the Purisima Formation has been divided into five members, but these units cannot be recognized elsewhere. In many areas sections have been separated by faults making it nearly impossible to put these separate blocks into stratigraphic order. Also, several of the larger structural blocks, which include numerous smaller faulted outcrop areas, show different depositional histories so the use of the name Purisima Formation may not be appropriate for some of these areas. Development of a preliminary biostratigraphy for rocks assigned to the Purisima Formation allows stratigraphic positioning and correlation of similar-age blocks across fault boundaries. On the whole rocks assigned to the Formation range in

age from late Miocene to late Pliocene based on diatom floras, and vertebrate and molluscan faunas. These determinations are generally supported by magnetostratigraphy and glauconite dates which are in accord with the ages based on the fossils.

The preliminary biostratigraphy, developed here, divides the Purisima Formation into lower and upper faunas, with a possible middle fauna, which appear to be recognizable throughout the outcrop area.

The lower, La Honda fauna is characterized by the bivalves *Chione*, *Dendostrea? vespertina* (Conrad), *Dosinia*, *Mytilus coalingensis* Arnold, *Swiftopecten parmeleei* (Dall) and the gastropods *Nassarius californicus* (Conrad), and the endemic *Tegula stantoni lahondaensis* Arnold. These extinct taxa, and others, suggest correlation with the Jacalitos and Etchegoin provincial molluscan stages of the California Central Valley and are generally considered late Miocene to early Pliocene in age. Taxa attributed to this biozone are all shallow water taxa and ecologically represent normal marine conditions in less than 50 m water depth.

The middle, Pillar Point fauna is found only at Pillar Point and is characterized by the bivalve mollusks *Lucinisca annulata* (Reeve) and *Conchocele disjuncta* Gabb. These taxa co-occur today in deep water between 100 m to 600 m and are not age diagnostic.

The upper, Santa Cruz fauna is characterized by the bivalve mollusks: *Macoma addicotti* Nikas, *Nanochlamys nutteri* (Arnold), and the gastropods *Nassarius grammatus* (Dall), and *Psephaea oregonensis* (Arnold) among others. These taxa suggest correlation, for the most part, with the “San Joaquin” provincial molluscan stage, suggesting an age of early to late Pliocene for this fauna. Ecologically most of these taxa suggest very shallow water depths (circa 10 m or less), although sedimentological evidence points to a slightly deeper depth for deposition (< 50 m).

The bivalve molluscan taxon *Lyonsia*, and gastropod taxon *Rictaxis punctocaelatus* (Carpenter) are reported for the first time from the Purisima Formation.

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APPENDIX 1: FAUNAL NOTES

The taxonomic arrangement of families and higher classifications follows Vaught (1989). The comments presented here are from the literature (see table 12) and from specimens examined in USGS collection (see table 13). Examination of specimens in other institutions has not been done to this point. Many of the names presented for Purisima Formation taxa have not been reviewed by paleontologists to see if they fit with the age and temperature regime represented by the majority of the fauna from the Purisima Formation. In several cases the names applied in the literature are probably incorrect as the taxon is well outside their known geographic and/or stratigraphic range [i.e., *Dosinia ponderosa* (Gray)]. This work hopes to resolve many of these problems but they are just a 'best guess' until such time as all specimens can be examined.

The following acronyms are used:

LACMIP - Los Angeles County Museum, Invertebrate Paleontology, Los Angeles, CA.
UCB - Museum of Paleontology, University of California, Berkeley, Berkeley, CA.
USGS M - U. S. Geological Survey, Menlo Park, CA collections; now housed at the Museum of Paleontology, University of California, Berkeley, CA.

Phylum Brachiopoda
Class Inarticulata

Family Discinidae

Indeterminate *Discinisca* were reported from the Purisima Formation by Perry (1993). The specimens were supposedly collected from the Capitola City Beach section sometime during the 1930's, and were referred by Perry (1993) to his *Clinocardium* facies. These specimens are in the collections of the Santa Cruz City Museum of Natural History.

Class Articulata

Family Terebratellidae

Terebratalia arnoldi etchegoini Hertlein & Grant has been reported from the upper half of the San Joaquin Formation in the Coalinga region (Hertlein & Grant, 1944; Adegoke, 1969) where it is common. The occurrence in the Sargent oil field/Chittenden area (Allen, 1945) further strengthens the correlation between the Purisima Formation in this area and the Etchegoin/San Joaquin Formations in the California central valley.

Phylum Mollusca
Class Polyplacophora

Family Mopaliidae

Ashley (1895a) questionably reported *Cryptochiton stelleri* (Middendorff) from the

Purisima Formation at Purisima [Creek?], San Gregorio Creek, San Gregorio, and Capitola. This taxon is large, distinctive, and easily identified, but has not been reported from the Purisima Formation since Ashley (1895a) so its occurrence is in doubt until Ashley's specimens can be examined.

Class Bivalvia

Family Nuculidae

Acila castrensis (Hinds) lives today from Punta San Pablo, Baja California Norte, Mexico (27°N) to the Cook Inlet, Alaska (60°N) (Bernard, 1983), in water depths from 5 to 200 m (Bernard, 1983), although Moore (1983) citing Woodring and others (1946) reported a much greater depth range of 7 m to 1,280 m. From the Purisima Formation it has been reported by Ashley (1895a), Arnold (1908a), Martin (1916), Allen (1945), Mack (1959), Mack *in* Esser (1958), Touring (1959), Cummings and others (1962), and Clark (1981). It has been reported by Ashley (1895a) from Purisima [Creek?] (also by Martin, 1916) and Tunitas Creek, by Arnold (1908a) from his middle member and upper member, by Martin (1916) from near Año Creek and the Sargent oil field area (also by Allen, 1945), by Touring (1959) and Cummings and others (1962) from the Tahana and upper Pomponio Member, by Mack (1958) and Mack *in* Esser (1958) from outcrops in Woodside quadrangle, and by Clark (1981) above the lowermost Purisima southeast of Scott's Valley, Santa Cruz County. In the fossil record it has been reported in rocks as old as Miocene (Bernard, 1983; Moore, 1983). Its fossil occurrences are in the Capistrano (Vedder, 1974), Etchegoin (Arnold, 1909), and Towsley (Kern, 1973) Formations all in southern California.

Family Nuculanidae

Nuculana taphria (Dall) has a modern occurrence from central Baja California, Mexico (28°N) to Point Reyes, central California (37° N) in water depths from 10 to 85 m (Bernard, 1983). It has a fossil record questionably from the Miocene (Trask, 1922) to Pleistocene from northern California to Baja California Sur, Mexico (Grant and Gale, 1931). Arnold (1908a) reported this taxon from his upper member, Martin (1916) from Purisima [Creek?], and Galloway (1977) questionably reported it from the Point Reyes area.

Family Yoldiidae

Three species of *Yoldia* have been reported from the Purisima Formation [i.e., *Yoldia cooperi* (Dall), *Yoldia scissurata* Dall (as *Yoldia scissurata* v. *strigata* Dall) and *Yoldia thraciaeformis* (Storer)].

Yoldia cooperi (Dall) has been reported from the Purisima Formation by Ashley (1895b) from San Gregorio, from Arnold's upper member (Arnold, 1908a), from Purisima [Creek?] and the Sargent oil field area (Martin, 1916 and Allen, 1945 from the latter), from Pillar Point (Glen, 1959), from the Tahana Member (Cummings and others, 1962), questionably from Sargent oil field (Grant and Gale, 1931), and from the lower shell bed facies and upper shell facies in the Capitola section by Perry (1993). It is found in rocks of Miocene to Holocene age from Washington state to San Diego County, California (Grant and Gale, 1931; Hertlein and Grant, 1972). Its modern occurrence is from off Cape Mendocino, California (40°N) to Isla Cedros, Baja California Norte, Mexico (28°N) in water depths from 9 to 124 m (Hertlein and Grant, 1972).

Bernard (1983) reported the modern occurrence of *Yoldia scissurata* Dall (syn. *Y. scissurata* ssp. *strigata* (Dall) from the Point Barrow, Alaska (71°N) to Redondo Beach, Los Angeles County, California (34°N) in water depths from 9 to 400 m (Foster, 1991). It

has been very questionably (aff.) reported from the Purisima Formation by Arnold (1908a) from his upper member, and by Touring (1959) and Cummings and others (1962) from the Lobitos, Pomponio and Tahana Members in San Mateo County. Durham and Morgan (1978) also reported it from the Tahana Member north of Pomponio Beach in San Mateo County. Other fossil occurrences of this taxon in northern California and southern Oregon are from the Miocene Empire Formation near Coos Bay, Oregon (Dall, 1909; Arnold and Hannibal, 1913), from Pliocene rocks at the mouth of the Elk River in Oregon (Grant and Gale, 1931), and the Rio Dell Formation near Scotia, northern California (Roth, 1979).

Yoldia thraciaeformis (Storer) is regarded as a northern taxon occurring from the Columbia River, Oregon/Washington boundary (46°N) to the Beaufort Sea off Alaska (70°N) in water depths from 25 m to 600 m, also in Miocene to Holocene rocks (Bernard, 1983). It has been reported from the Tunitas, Lobitos, Pomponio, and Tahana members of the Purisima Formation in San Mateo County (Touring, 1959; Cummings and others, 1962).

Family Arcidae

The genus *Anadara* is generally considered a warm-water genus, but has been found as far north as Kodiak Island in the Gulf of Alaska during warm periods in the late Neogene. So during the Neogene this distinction is probably not well deserved. *Anadara trilineata* (Conrad) ranges in age from Miocene to Pleistocene and has been reported from Kamchatka and Sakhalin in the western Pacific and from British Columbia, Canada to southern California in the eastern Pacific (Moore, 1983). Ashley (1895a) reported it from Purisima [Creek?] (also by Martin, 1916), San Gregorio, and along the coast in Santa Cruz (also by Addicott and others, 1978b). Arnold (1908a) reported this taxon from his middle and upper member, Martin (1916) from near Año Nuevo Creek and the Sargent oil field area (in part as *Arca canalis* Conrad) (also by Allen, 1945), Mack (1958) and Mack *in* Esser, 1958 from the Woodside Quadrangle, Glen (1959) from Moss Beach, and Touring (1958) and Cummings and others (1962) from their Tahana, Pomponio and San Gregorio Members. Perry (1993) reported it from all four of his facies in the Capitola City Beach section. It is also recorded in USGS collections from Ashby Gulch (M5890) and Rodeo Gulch Road (M8859).

Family Glycymerididae

Martin (1916) and Allen (1945) both reported *Glycymeris grewingki* Dall (as *G. coalingensis* Arnold fide Moore, 1983) while only Allen (1945) recorded *G. septentrionalis* (Middendorff) (as *G. subobsolita* Carpenter [sic. *G. subobsoleta* (Carpenter) =*G. septentrionalis* (Middendorff) fide Powell, 1991] from the Purisima Formation in the Sargent oil field area. *Glycymeris grewingki* Dall was also reported from the Capitola City Beach section, *Clinocardium* facies, by Perry (1993). Modern eastern Pacific Glycymerid taxonomy is in need of revision (Powell, 1991) and the above records will have to be verified. The only specimen in USGS collections is a small valve fragments of an unidentified *Glycymeris* species have been collected from Pomponio State Beach (M8914), but it is to incomplete for precise identification. *Glycymeris septentrionalis* (Middendorff) occurs in the eastern Pacific from 60°N to 28°N in water depths from the intertidal zone to 250 m. It's fossil record is unclear but extends back at least to the Pliocene. *Glycymeris grewingki* Dall is a Miocene to possibly Pleistocene taxon which occurs from Alaska to southern California (Moore, 1983).

Ashley (1895a) reported *Glycymeris generosa* Gould from the Purisima Formation. Keen and Bentson (1944) refer *G. genosa* Gould to *Panope genosa* (Gould) which is a

synonym of *P. abrupta* (Conrad) (Moore, 1963) and not included in this family.

Family Mytilidae

Five Mytilid taxa are reported from the Purisima Formation although only three may be present: *Megacrenella columbiana* Dall, *Modiolus rectus* (Conrad), *Modiolus* sp. indet. (possibly poorly preserved specimens of one of the former) and *Mytilus coalingensis* Arnold and indeterminate fragments of *Mytilus* (possibly poorly preserved specimens of the former).

Megacrenella columbiana (Dall) occurs in the eastern Pacific from Acapulco, Mexico (17°N) to the Gulf of Alaska (60°N) in water depths from 20 to 550 m (Bernard, 1983). Five slightly crushed specimens have been reported from the lower part of the Pomponio Member in the Woodside Quadrangle (Touring, 1959; Cummings and others, 1962) and it was tenatively (cf.) reported from the lower shell bed facies of the Capitola City Beach section by Perry (1993).

Modiolus rectus (Conrad) (syn. *Modiolus directus* Dall and *Mytilus (Modiola) flabellatus* Gould) has a modern occurrence in the intertidal zone from Morro Bay, central California (35°N) to Queen Charlotte Island, British Columbia Canada (54°N) (Bernard, 1983). Ashley (1895a) was the first to record this species (as *Modiolus flabellatus* Gould) from San Gregorio and Capitola (also by Addicott and others, 1978b). Arnold (1908a) also reported it from his upper member, followed by Martin (1916) who reported it from east of Año Nuevo Creek, Purisima [Creek?], and in the Sargent oil field area (also by Allen, 1945). Touring (1959) reported this taxon (as *Modiolus directus* Dall) from the Pomponio and Tahana Members, and Cummings and others (1962) illustrated a specimen (as *Modiolus directus* Dall) from the lowest Tahana Member. It has also been reported from the Woodside Quadrangle (Mack, 1958; Mack *in* Esser, 1958) and the lower shell bed facies, upper shell bed facies, and *Crepidula* facies of the Capitola City Beach section by Perry (1993). This taxon has been reported in rocks as old as Miocene from southern Oregon to southern California (Moore, 1983).

Mytilus coalingensis Arnold has been reported in rocks from Miocene to Pleistocene in age from central to southern California and from Kamchatka (Moore, 1983). From the Purisima Formation it has been reported by Martin (1916) and Allen (1945) in the Sargent oil field, by Glen (1959) questionably at Pillar Point, and by Touring (1959) and Cummings and others (1962) from a single locality in the Tahana Member along Pescadero Creek near Judy Creek.

Family Limidae

Touring (1959) and Cummings and others (1962) reported a single fragmentary specimen referred to the genus *Lima* associated with *Lituyapecten purisimaensis* (Arnold) in the Tahana Member in San Mateo County. The genus *Lima* is a strictly tropical taxon and the occurrence from the Purisima Formation should probably be referred to "*Lima*" sp. indet.

Family Pectinidae

Chlamys group

Chlamys hastata (Sowerby) has a modern range from Bolinas Bay, central California to San Diego, southern California in water depths from 18 to 90 m (Hertlein and Grant, 1972; Moore, 1984). It has a fossil record in late Miocene to Pleistocene from central California to Baja California Norte, Mexico (Moore, 1984). It has been reported from the Purisima by Arnold (1906, 1908a) and Perry (1993). The later reference of Arnold refers to

his upper member. Perry's (1993) report of this taxon from the *Crepidula* facies of the Purisima Formation at Capitola City Beach suports the earlier identification of Arnold.

Clark (1981) reported *Chlamys hastata hericius* (Gould) from the lower part of the Purisima Formation west of Scott's Valley. *Chlamys hastata hericius* (Gould) has a modern range from Port Althorp, Alaska to Santa Barbara, southern California in water depths from the low tide line to 145 m (Moore, 1984). It has been found in rocks from Miocene to Pleistocene in central and southern California (Moore, 1984).

Nanaochlamys nutteri (Arnold) ranges in age from late Miocene to Pleistocene occurring in unnamed Miocene outcrops on Mount Hamilton, Santa Clara County (Arnold, 1906), and from the Etchegoin (Nomland, 1917; Woodring and others, 1940), Purisima, San Joaquin (Adegoke, 1969), Merced (Arnold, 1906), and Rio Dell (Faustman, 1964) Formations in central and southern California (Moore, 1984). In the Purisima Formation it has been reported from Arnold's (1908a) upper member exposed from Purisima to Pescadero Creeks (most abundantly in the sea cliff 0.5 mile south of the mouth of San Gregorio Creek) (Arnold, 1906, 1908a), from Purisima [Creek?] and the Sargent oil field area (Martin, 1916), in the Woodside Quadrangle (Mack, 1958; Mack *in* Esser, 1958), and at Pillar Point (Glen, 1959).

Swiftopecten parmeleei parmeleei (Dall) ranges in age from late Miocene to Pliocene and occurs from Alaska to southern California (Moore, 1984). Arnold (1908a) reported this taxon (as *Pecten wattsi* Arnold) from his middle member. Touring (1959) and Cummings and others (1962) combined this taxon with *Nanaochlamys nutteri* (Arnold) so its stratigraphic occurrence is in question until specimens are examined, although they reported it from the Tahana and Pomponio Members. Cummings and others (1962) illustrated a specimen from the lowest Tahana Member of the Purisima Formation which is referable to this taxon and not *Nanaochlamys nutteri* (Arnold). It has also been reported from the Tehana Member by Durham and Morgan (1978), the Sargent oil field area by Martin (1916) (as *Pecten wattsi* Arnold), and from the upper shell and *Crepidula* facies of Perry (1993) at the Capitola City Beach section.

Swiftopecten parmeleei etchegoini (Anderson) has also been reported from the Purisima Formation by Glen (1959). This taxon occurs from northern California to Baja California Sur, Mexico in rocks from late Miocene to early Pleistocene in age (Moore, 1984). Its occurrence in the Purisima Formation at Moss Beach is based on two specimens - one incomplete collected by W. Glen and another far more complete specimen collected some years earlier by L. G. Hertlein (Glen, 1959) and from the Sargent oil field area (Martin, 1916 and Allen, 1945). The difference between this and the previous taxon is based solely on the presence of concentric swellings on the shell disk.

Patinopecten subgroup

Five species from the Patinopecten subgroup, Pecten group of Pectinids have been reported from the Purisima Formation, three taxa from the same genus. This argues either for our not understanding the range of variability within individual species or a very rapidly evolving lineage of Pectinids. Durham and Morgan (1978) argued for the later as they reported three of these species in stratigraphic succession (*L. turneri* (Arnold), *L. falorensis* MacNeil, and *L. purisimaensis* (Arnold) from bottom to top) within the Tahana Member of the Purisima Formation.

Lituyapecten falorensis MacNeil appears to be restricted to the Pliocene and is known only from the Purisima (MacNeil, 1961; Durham and Morgan, 1978) and Falor Formations (MacNeil, 1961). Durham and Morgan (1978) reported it from the lowest part of the Purisima Formation in coastal San Mateo County, the Tahana Member.

Lituyapecten purisimaensis (Arnold) also appears restricted to the Pliocene and is known only from the Purisima (Arnold, 1906, 1908a; Cummings and others, 1962; Durham and Morgan, 1978; Mack, 1958; Mack *in* Esser, 1958) and Ohlson Ranch (Peck, 1960) Formations. Arnold (1908a) reported it from his middle and upper members, Martin (1916) reports it very questionably from Moss Beach (as *Patinopecten* sp., aff. *coosensis* Shumard) and from Purisima [Creek?]. Cummings and others (1962) reported it from the Tahana Member and questionably, from a single specimen, from the Lobitos Member in San Mateo County. They also illustrated a specimen from the lowest part of the Tahana Member. Glen (1959) reported this taxon from his deep-water Pillar Point section of the Purisima Formation at Moss Beach. Durham and Morgan (1978) reported it from the Tahana Member north of Pomponio Beach, and Mack (1958) and Mack *in* Esser (1958) from the Woodside Quadrangle in San Mateo County.

Lituyapecten turneri (Arnold) has only been reported from the Merced Formation (Arnold, 1906; Dickerson, 1922) and the Purisima Formation (Durham and Morgan, 1978). The Purisima Formation occurrence of Moore (1984) citing Arnold (1906) as authority is not correct; Arnold (1906) listed this species only from the Merced Formation. But it was reported from the Purisima Formation by Ashley (1895a) (as Pecten propatulus Conrad) from Lobitos Creek, Purisima [Creek?], and Tunitas Creek (also by Martin (1916) from Purisima Creek). Durham and Morgan (1978) reported it from the Tahana Member in San Mateo County.

Patinopecten healeyi (Arnold) is a Pliocene index-taxon occurring from northern California to Baja California Norte, Mexico. For information on its occurrences in California and Baja California refer to Moore (1984). From the Purisima Formation Arnold (1908a) reported this taxon from his middle and upper members, Martin (1916) from Purisima [Creek?], Touring (1959) reported it as common in only one bed south of the mouth of San Gregorio Creek in rocks of the Tahana Member, and Durham and Morgan (1978) from the central San Mateo Coast. Touring (1958) also stated that another species occurs stratigraphic higher in the Pomponio Member with affiliated to *P. healeyi* (Arnold) but intermediate between *P. healeyi* (Arnold) and *P. lohri* (Hertlein) (also reported by Cummings and others, 1962). This latter taxon is referred to *P*. aff. *P. healeyi* (Arnold). Cummings and others (1962) reported it from the Tehana Member and illustrated a specimen from the lower part of the Tahana Member. Since the time of Arnold (1908) *P. healeyi* has been reported only from the central San Mateo Coast although early authors Ashley (1895) and Arnold (1908a) reported it also from the Santa Cruz area.

Ashley (1895b) reported *Patinopecten caurinus* (Gould) from Pillar Point, San Gregorio, and Capitola. *Patinopecten caurinus* (Gould) has a modern occurrence from Shumagin Islands, Alaska to Point Sur, Califonria at depths between 15 and 275 m (Moore, 1984). Its fossil occurrences are in Miocene to Pliocene rocks from central and southern California (Moore, 1984), although the Miocene occurrence is based on specimens from the Purisima Formation. No specimens referrable to *Patinopecten caurinus* havebeen recorded from the Purisima Formation since Ashley (1895a) and none are present in LACMIP, UCB, or USGS collections. So Ashley's (1895a) report of this taxon is questionably referred to *P. healeyi* (Arnold) until such time as Ashley's collections can be examined.

Patinopecten lohri (Hertlein) (syn. *Pecten oweni* Arnold) ranges in age from late Miocene to Pliocene occurring in the Pancho Rico (Durham and Addicott, 1964), San Pablo (Arnold, 1906), Pismo (Hall, 1973), Etchegoin (Arnold, 1906; Woodring and others, 1940; Adegoke, 1969; Addicott, 1974), Towsley (Kern, 1973), and Sisquoc (Woodring and Bramblette, 1950) Formations in California. From the Purisima Formation it has been

reported by Ashley (1895a) from Lobitos and Tunitas Creeks (as *Pecten pabloensis* Clark), from Arnold's (1908a) middle member, from Pillar Point (also by Glen, 1959), Purisima [Creek?], and the Sargent oil field by Martin (1916) (all as *Pecten oweni* Arnold), and from the Pomponio and San Gregorio Members (Touring, 1959; Cummings and others, 1962) who reported it as occurring at a higher stratigraphic interval than *P. healeyi* (Arnold). This stratigraphic arrangement is just the opposite of that reported by Woodring and Bramblett (1950) in the Santa Maria Basin where *P. lohri* (Hertlein) occurs stratigraphically lower than *P. healeyi* (Arnold). Cummings and others (1962) illustrated a specimen from the Pomponio Member.

Family Gryphaeidae

Touring (1959) and Cummings and others (1962) reported two specimens questionably referred to *Pycnodonte erici* (Hertlein) from the upper part of the San Gregorio Member. The specimen illustrated by Cummings and others (1962) is decorticated and its identification is questionable. Outside of the Purisima Formation *Pycnodonte erici* (Hertlein) has been reported from warm water Miocene to Pleistocene faunas in southern California south to Baja California Sur, Mexico (Moore, 1987). Its occurrence from the Purisima Formation is questioned.

Family Ostreidae

Dendostrea? vespertina (Conrad) *s.l.* occurs in Miocene [Castaic Formation (Stanton, 1966); Santa Margarita Formation (Nomland, 1917; Adegoke, 1969)] to Pliocene [Almejas Formation (Emerson & Hertlein, 1964); Boleo Formation (Wilson, 1948); Carmen Formation (Durham, 1950); Gloria and Infierno Formations (Wilson, 1948); Ignacio Formation (Mina, 1957); Imperial Formation (Hanna, 1926); Etchegoin Formation (Adegoke, 1969); Capistrano Formation (Kern and Wichander, 1974); Paso Robles Formation (Addicott and Galehouse, 1973); Pico and Towsley Formations (Winterer and Durham, 1962), and the San Joaquin Formation (Woodring and others, 1940)] rocks in Baja California, southern and central California. It was described from the Imperial Formation in eastern San Diego County and western Imperial County from deposits associated with the ancestral Gulf of California. Specimens referred to this species from coastal California are generally larger than the typical form but in all other features are very similar to Imperial Formation specimens. In my opinion these specimens are referable to a different taxon, but separating the two species is beyond the scope of this paper. From the Purisima Formation it has only been reported from the Sargent oil field area by Martin (1916) (as *Ostrea atwoodi* Gabb) and Allen (1945).

Family Lucinidae

There has been much confusion in the literature, especially the early literature, between *Lucinoma annulata* (Reeve) and *L. acutilineata* (Conrad). *Lucinoma annulata* (Reeve) can be differentiated from *L. acutilineata* (Conrad) of the basis of the latter's heavier hinge, slight differences in the teeth, shorter posterior dorsal margin, and generally smaller size (Moore, 1964). It appears from the post-Moore (1964) literature that *L. acutilineata* (Conrad) occurs questionably from the Juanian (=upper Oligocene and lower Miocene) and from Pillarian (lower Miocene) to Newportian (lower and middle Miocene) (= upper "Vaqueros" and "Temblor") (Moore and Addicott, 1987) rocks mostly in the Pacific Northwest and to a lesser extent in California. While *L. annulata* (Reeve) ranges in rocks from Moclipsian (most of the Pliocene) to Holocene in the Pacific Northwest (Addicott,

1976), Roth (1979) believed it to extend back to the Wishkahan (early late Miocene). *Lucinoma annulata* (Reeve) has been reported mostly in California and to a lesser extent in the Pacific Northwest. This hypothesis is mainly from the literature and has yet to be tested, but is used here to refer all *Lucinoma* from the Purisima Formation to *L. annulata* (Reeve) since most are poorly preserved. USGS collections with specimens which allow precise identification from the Purisima Formation support this hypothesis, but this is far from a stringent test.

Ashley (1895a) was the first to record *Lucinoma annulata* (Reeve) (as *Lucina borealis* Linnaeus) from the Purisima Formation with occurrences at Moss Beach (also by Glen, 1959 from the deep water Pillar Point sediments), Purisima [Creek?] (also Martin, 1916), Lobitos, and Capitola (also by Addicott and others, 1978b). Later Arnold (1908a) reported *Lucinoma annulata* (Reeve) (as *Phacoides acutilineatus* Conrad) from his middle and upper members, Martin (1916) and Allen (1945) from the Sargent oil field area, Mack (1958) and Mack *in* Esser (1958) from outcrops in Woodside quadrangle, and Touring (1958) from the Pomponio and upper part of the Tahana Member, while Cummings and others (1962) reported it only from the Tahana Member in San Mateo County. Galloway (1977) reported it from the Point Reyes area, Clark (1981) questionably from the lower Purisima exposed west of Scott's Valley, Santa Cruz County, central California, and Perry (1993) from his *Clinocardium*, upper shell, and *Crepidula* facies in the Capitola City Beach section. Here it is reported in Purisima Creek (M8849), Cascade Creek north of Año Nuevo (M4288), west of Año Nuevo Creek (field observation), from several outcrops in and around Scott's Valley (M5078, M5080, M5091, M5137), and questionably from Capitola State Beach (M8845). It is widespread in thick sandstone sequences in the lower part of the Purisima Formation, but has also been reported from the uppermost Purisima Formation exposed near Capitola. Its distribution within the Purisima Formation is more likely due to water depths at which the sediments were deposited than to biostratigraphy. Its modern occurrence is at depths of 25 to 750 m (Bernard, 1983) from Kodiak Island, Alaska to Baja California Sur (Moore, 1988; Foster, 1991).

Arnold (1908a) also reported *Lucinisca nuttalli antecedens* Arnold from his middle member and *L. nuttalli* (Conrad) from his upper. *Lucinisca nuttalli antecedens* Arnold is very similar to the nominate species *L. nuttallii* (Conrad) but can generally be distinguished by its more widely spaced and better developed concentric ribs, but this feature may be of little taxonomic value (Hertlein and Grant, 1972). Interesting are the stratigraphic ranges of both taxa, which are very similar, from the Miocene to Pleistocene from California to Baja California Sur, Mexico. The difference is that only *L. nuttalli* (Conrad) has been found in the modern fauna in the eastern Pacific, whereas *L. nuttalli antecedens* Arnold appears to have become extinct sometime during the Pleistocene. The modern occurrence of *L. nuttalli* (Conrad) is from southern California to Mexico on sand and mud from the intertidal zone to 46 m (Hertlein and Grant, 1972), although Bernard (1983) reports it in water depths from 10 to 75 m.

Family Thyasiridae

Conchocele disjuncta Gabb ranges in age from Oligocene to Holocene (Moore, 1988). In the modern eastern Pacific it is a cold water taxon, occurring from Puget Sound, Washington (48°N) to the Bering Sea, Alaska (60°N) in water depths from 100 to 750 m (Bernard, 1983). The only fossil record of this deep water taxon from the Purisima Formation is that of Glen (1959) who reported this species from the deep water Pillar Point outcrop.

Family Carditidae

Cyclocardia californica (Dall) *fide* Woodring and Bramblette, 1950 occurs in diatomaceous strata of the Sisquoc Formation, the Foxen Mudstone and Careaga Sandstone (all Pliocene) of the Santa Maria District, California (Woodring and Bramblette, 1950) and questionably (cf.) from the Capistrano Formation in Orange County, southern California (Kern and Wicander, 1974). The specimens reported here and the ones from the Santa Maria District are different than specimens of *Cyclocardia californica* (Dall) collected from the type area in deep water off Santa Barbara, California in collections of the California Academy of Sciences, but until all specimens can be examined the name is retained here following the usage of Woodring and Bramblette (1950). This taxon was reported previously from the Purisima Formation by Touring (1959) and Cummings and others (1962) who restricted its occurrence to the lower part of the Pomponio Member. Mack (1958) and Mack *in* Esser (1958) also reported it from Purisima Formation, from outcrops in Woodside Quadrangle. It is reported here from Tunitas Creek (M8919) based on two well preserved specimens.

Family Cardiidae

Clinocardium meekianum (Gabb) s.l. is a variable taxon and Roth (1979) recognized two subspecies, but neither of these names hasbeen published. It is an extinct taxon with a fossil record from the Pliocene of southern Oregon and northern to central California (Grant and Gale, 1931; Roth, 1979). It has been reported from the Purisima Formation by Arnold (1908a) from his middle and upper member, by Martin (1916) at Purisima [Creek?], Año Nuevo Creek, and Sargent oil field area, by Glen (1959) from Moss Beach, by Addicott and others (1978b) and Perry (1993) from Capitola City Beach from his *Clinocardium* and upper shell facies.

Clinocardium nuttallii (Conrad) ranges in the eastern Pacific from Orange County (33°N) to Chukchi Sea, Alaska (Baxter, 1987) in water depths from the intertidal zone to 30 m (Bernard, 1983). It has a fossil record from the Miocene to Pleistocene from central California to Baja California Norte (Moore, 1998b). This taxon has been reported from the Capitola area by Ashley (1895a), and from the San Gregorio and Tunitas Members by Touring (1959) and Cummings and others (1962) in San Mateo County. It has also been questionably reported from the Tahana Member by Durham and Morgan (1978) from the central San Mateo Coast.

Family Mactridae

Mactrids are notoriously difficult to identify because of the small differences between species and because they are commonly poorly preserved in the fossil record. Also some species have been misidentified in the literature. Eleven Mactrids have been reported from the Purisima Formation [i.e., *Spisula albaria* (Conrad), *S. albaria coosensis* Howe, *S.* sp., cf. *S. catilliformis* Conrad, *S. falcata* Gould, *S. hemphilli* (Dall), *S. mossbeachensis* Glen, *S.* sp., cf. *S. sisquocensis* Arnold, *S. voyi* (Gabb), and an indeterminate species reported by both Touring (1959) and Perry (1993), also *Tresus pajaroanus* (Conrad) and *T. nuttallii* (Conrad)]. It is possible when a thorough review of specimens from the Purisima Formation is completed the number of taxa will be significantly fewer.

Mactromeris albaria (Conrad) is a variable taxon and determining its stratigraphic range and aerial distribution is beyond the scope of this report, although Moore (1998c) uncritically cited early reports of its range as Oligocene to Pleistocene from Oregon to central California. From the Purisima Formation it has been questionably reported by

Ashley (1895a) (as *Standella nasuta* Gould?), by Arnold (1908a) from his middle and upper members, by Martin (1916) from Purisima [Creek?] and Moss Beach, by Touring (1959) and Cummings and others (1962) from the San Gregorio, Pomponio, and Tahana Members in San Mateo County, by Durham and Morgan (1978) from the Tahana Member south of San Gregorio Beach, and by Packard (1916), Addicott and others (1978b), and Perry (1993) (as *Spisula coosensis* Howe), from Capitola Beach State Park and from the Sargent oil field area by Allen (1945). Packard's (1916) reports of this taxon in the Merced Formation are referable to the "Merced Group" and specifically to outcrops now referred to either the Pliocene Ohlson Ranch Formation (Peck, 1958) or the Purisima Formation at Capitola State Beach. Perry's (1993) record is from his lower and upper shell beds.

Interestingly, from published photographs, *Spisula albaria* (Conrad) appears to have been reported as *Pseudocardium densatum* (Conrad) of Arnold, var. cf. *gibbii* Rémond by Woodring and others (1950; pl. 17, fig. 14; pl. 19, fig. 2) from the Santa Margarita District, California. Woodring and others (1950) equated their taxon (*Pseudocardium densatum* (Conrad) of Arnold, var. cf. *gibbii* Rémond) to specimens given the same name in the Kettlemen Hills (Woodring and others, 1940; pl. 37, figs. 7, 8, and 10) but when comparing illustrations, especially of the hinge, they seem to have represented *Macromeris albaria* (Conrad). Records of *Pseudocardium densatum* (Conrad) from the Purisima Formation (Glen, 1959) from Moss Beach are herein referred questionably to *M. albaria* (Conrad) until such time as specimens can be examined.

Mactromeris catilliformis Conrad has a modern range from 30°N to 34°N in water depths from 5 to 20 m (Bernard, 1983), athough Moore (1998c) reported a modern occurrence from Washington state to southern California. Grant and Gale (1931) questionably synonymized *M. mercedensis* Packard with this taxon because the differences between the two species are slight and they are sympatric in the Merced Formation, a view supported by Bernard (1983), but not by Moore (1998c). It was first reported from the Purisima Formation questionably by Ashley (1895a) as *Standella californica* Conrad, later by Martin (1916) from Purisima [Creek?], and questionably from a single specimen from the Tunitas Member in San Mateo County (Touring, 1959; Cummings and others, 1962). This taxon has been reported in rocks from the Miocene (Smith, 1912) to Pleistocene (Arnold, 1903) from central California (Grant and Gale, 1931) to Baja California Norte, Mexico (Jordan, 1926) with many intermediate occurrences.

The status of *Macromeris? coalingensis* Arnold is in question as the hinge of this species has not been reported (Packard, 1916; Grant and Gale, 1931), so comparison with other Tertiary *Macromeris* is impossible. That said it has been reported only from the Etchegoin Formation [Arnold, 1909 (1910)] and from rocks now referred to the Purisima Formation in the Sargent oil field area (Martin, 1916 and Allen, 1945).

Macromeris hemphilli (Dall) has a modern occurrence from northern Baja California Norte, Mexico (32°N) to Monterey Bay, central California (37°N) in water depths from the intertidal zone to 50 m (Bernard, 1983). According to Woodring and Bramlette (1950) Arnold's *M. sisquocensis* Arnold is probably referable to this species. From the Purisima Formation Arnold (1908a) questionably reported *M. sisquocensis* Arnold from his upper member, and Martin (1916) at Purisima [Creek?] and Pillar Point (also at Moss Beach of Glen, 1959). It has been reported in Pliocene and Pleistocene rocks elsewhere in California. From the Pliocene in addition to the Purisima Formation it has been reported from the Etchegoin Formation (Nomland, 1917) and questionably from the Fernando Formation (Arnold, 1907b). From the Pleistocene it has been reported from the Merced Formation (Martin, 1916) and from the San Pedro, Los Angeles County (Arnold, 1903) to San Diego

(Arnold, 1903), and in northern Baja California Norte, Mexico (Dall, 1921b) as *S. cameronis* Dall (*fide* Grant and Gale, 1931).

Mactromeris mossbeachensis Glen was named for its type and only occurrence in the Purisima Formation at Moss Beach. According to Glen (1959) “this species may be differentiated from other ... [*Spisula*]... by its extreme length and large umbonal angle.” From Glen's (1959) illustration of the type this species appears to be distinct from other eastern Pacific *Mactromeris*. It has also been reported from the lower part of the Merced Formation exposed at Twelvemile Creek in San Mateo County (Yancey, 1978).

Mactromeris polynyma (Stimpson) (syn. *Spisula alaskensis* Dall, *Callista voyi* Gabb) has a modern occurrence in the eastern Pacific from Neah Bay, Washington to Point Barrow, northern Alaska (Foster, 1991) in water depths from the intertidal zone to 110 m (Bernard, 1983). This taxon has been reported as a fossil from the Pliocene of Alaska (Dall, 1919; Dall *in* Moffitt, 1913; USGS collections) and central to northern California and southern Oregon (Martin, 1916; Dickerson, 1922; Roth, 1979). Pleistocene records are restricted to Alaska (MacNeil and others, 1945; MacNeil, 1957; USGS collections). From the Purisima Formation it has been questionably reported from Tahana Member in San Mateo County (Touring, 1959; Cummings and others, 1962) and from the Sargent oil field area (Martin, 1916; Allen, 1945).

Touring (1959) and Cummings and others (1962) reported a few poorly preserved specimens that they referred to *Spisula* sp. indet. which they believed might represent a new species from Pescadero Creek near Jones Gulch in the Tahana Member. Until these specimens can be examined and compared with modern eastern Pacific taxa they are referred to *Macromeris?* sp. indet.

Simomactra falcata Gould occurs from about San Diego, southern California (32°N) to the Gulf of Alaska (57°N) in water depths from the intertidal zone to about 50 m (Bernard, 1983). According to Grant and Gale (1931) this species is very similar in form to *M. polynyma* (Stimpson), *M.? planulata* Conrad, and *M.? dolabriformis* (Conrad). Much of the literature involving these species is hopelessly confused until such time as specimens of all are examined. With that caveat the fossil occurrence of *S. falcata* Gould is very questionably in the Miocene of central California (Gabb, 1866-69; Clark, 1915), and from the Pliocene of northern and central California (Cooper, 1888; Martin, 1916). No central California Pleistocene occurrences are known. It has been reported from the Purisima Formation by Ashley (1895a) from Capitola and questionably from San Gregorio and by Martin (1916) and Allen (1945) from the Sargent oil field area. Until such time as these specimens are examined this taxon is included in the Purisima Formation fauna.

Tresus nuttallii (Conrad) has been reported from the Purisima Formation from Lobitos (as Lobetus), Tunitas Creek, San Gregorio (=San Gregoria), and Capitola by Ashley (1895a), also by Martin (1916) from Purisima [Creek?] and the Sargent oil field area (also by Allen, 1945), and by Glen (1959) at Moss Beach. In the eastern Pacific it has a modern occurrence from 28°N to 58°N in water depths from the intertidal zone to 50 m (Bernard, 1983). It has been reported as a fossil from rocks of Miocene (Dall, 1909) to Pleistocene (Arnold, 1903) age from Washington to Baja California Norte, Mexico (Grant and Gale, 1931).

Tresus pajaroanus(Conrad) occurs from Washington to southern California in rocks of Miocene to Pleistocene age. The Pleistocene age is based on its occurrence in an excavation below Interstate 405 near Cherry Ave, Long Beach, Los Angeles Co., California, which Kennedy (1975) called Pliocene [based on the occurrence of *Tresus pajaroanus*(Conrad)], but which recent amino-acid racemization data have suggested is

mid-Pleistocene (K. Lajoie, personal communication, 1988). This taxon is widespread in the Purisima Formation and has been reported by Ashley (1895a) from Moss Beach (also Glen, 1959), Purisima [Creek?] (also by Martin, 1916), Lobitos (as Lobetus), Tunitas Creek, San Gregorio (as San Gregoria), and Capitola, by Arnold (1908) from his upper member, by Martin (1916) from near Año Nuevo Creek and the Sargent oil field area (also by Allen, 1945), from the Woodside quadrangle by Mack (1958) and Mack in Esser (1958), from the Lobitos, San Gregorio, Pomponio, and Tahana Members in San Mateo County by Touring (1959) and Cummings and others (1962), and by Addicott and others (1978b) and Perry (1993) from the Santa Cruz area. Perry's (1993) record is from his upper shell and *Crepidula* facies in the Capitola City Beach section. It is also in USGS collections from sea cliffs at the mouth of Purisima Creek (M8849).

Family Cutellidae

This family is represented in the Purisima Formation by poorly preserved material, generally internal molds, which make identification difficult and in most cases questionable.

Siliqua alta (Broderip and Sowerby) is an extra-limital northern taxon. Its modern occurrence is from the Bering Sea to Cook Inlet, Alaska in water depths from the intertidal zone to 80 m (Foster, 1991). It has been questionably reported from the Purisima Formation by Glen (1959) at Moss Beach and by Touring (1959) and Cummings and others (1962) from two specimens collected in the San Gregorio Member in San Mateo County. Elsewhere this taxon has only been reported as a fossil in the Pliocene to Pleistocene of northern Alaska (questionably reported by MacNeil, Mertie, and Pilsbry, 1943 as *S. media* (Gray); Brigham, 1985; also in USGS collections).

Siliqua lucida (Conrad) has a modern occurrence from central Baja California, Mexico (28°N) to San Francisco Bay (38°N) in water depths from the intertidal zone to 50 m (Bernard, 1983). It has an extensive fossil record from Miocene to Pleistocene from central California to Baja California (Grant and Gale, 1931; Moore, 1998a). It wasquestionably reported from the Purisima Formation by Arnold (1908a) from his upper member and by Allen (1945) from the Sargent oil field area.

Siliqua patula (Dixon) (syn. *S. nuttalii* Conrad) occurs from Monterey Bay, California (37°N) to the Port Moller and Bristol Bay on the Alaska Peninsula (60°N) in water depths from the intertidal zone to 55 m (Bernard, 1983; Foster, 1991). Grant and Gale (1931) reported this taxon in rocks of Pliocene to Holocene age and questionably from the Miocene if *S. oregonia* Dall is placed in synonymy. The Miocene record of this taxon is restricted to the occurrence of *S. oregonia* Dall in Oregon which Grant and Gale (1931) synonoimize, but which Moore (1998a) holds separate. Pliocene records are from central California (Arnold and Hannibal, 1913; Martin, 1916; Yancey, 1978), while Pleistocene records range from northern Alaska (Meek, 1923) to San Diego, southern California (Arnold, 1903). It has been reported from the Purisima Formation from Capitola (Ashley, 1895a), by Arnold (1908a) from his upper member, from Moss Beach, Purisima [Creek?] and the Sargent oil field area by Martin (1916) (also by Allen, 1945 from the latter).

Solen sicarius Gould occurs in water depths from the intertidal zone to about 40 m from southern Orange County, California (33°N) to northern British Columbia, Canada (56°N) (Bernard, 1983). From the Purisima Formation it has been reported by Ashley (1895a) from Purisima [Creek?] (also by Martin, 1916), Tunitas Creek, and Capitola, by Arnold (1908a) from his middle member, by Martin (1916) from Purisima [Creek?], near Año Nuevo Creek, and the Sargent oil field area (also by Allen, 1945 from the latter), and by Esser (1959) and Esser in Mack (1958) from the Woodside quadrangle. Touring (1959)

and Cummings and others (1962) reported this as a common species in the Pomponio Member and noted that it also occurs in the San Gregorio and Tahana Members. It was also questionably reported by Galloway (1977) from the Point Reyes area, by Addicott and others (1978b) from the New Brighton/Sea Cliff State Beaches section, and Perry (1993) from the Capitola City Beach section, upper shell and *Crepidula* facies, in Santa Cruz. Fragments assigned only to genus but which represent new occurrences of this taxon are reported from the Santa Cruz Mountains (M5161), questionably Mountain Charlie Road (M5160), and from New Brighton State Beach (M3618). Elsewhere it has been reported in rocks from Miocene to Holocene (Grant and Gale, 1931) from Washington state (Weaver, 1916) to Bahia San Quintin, Baja California Norte, Mexico (Dall, 1921a).

Family Tellinidae

Over the years there has been much confusion as to the identification of many eastern Pacific *Macoma* species. In 1971 Eugene Coan reviewed all northwest American Tellinids setting a standard for each species which was not previously available. Ten *Macoma* species have been reported from the Purisima Formation: *M. addicotti* Nikas, *M. calcarea* (Gmelin), *M*. sp., cf. *M. inconspicus* (Broderip & Sowerby), *M. irus* (Hanley), *M*. sp., cf. *M. lama* (Bartsch), *M. lipara* Dall, *M. nasuta* (Conrad), *M. nasuta kelseyi* Conrad, *M. planiuscula* Grant & Gale, and *M. yoldiformis* Carpenter. A brief discussion of these taxa is presented below but from a review of the literature possibly only five *Macoma* species occur in the Purisima Formation.

Macoma addicotti Nikas was reported as *M*. new species? aff. *M. nasuta* (Conrad) by Addicott (1969) from the “Merced” Formation near Felt Lake, San Mateo County (Nikas, 1977). In describing this species and citing its occurrence Nikas (1977) reported its from the Purisima Formation along the sea cliffs at Capitola City Beach and New Brighton State Beach-Seacliff State Beach. Perry (1993) also reported it from the Capitola City Beach section in his upper shell and *Crepidula* facies.

Macoma balthica (Linnaeus) [syn. *M. inconspicua* (Broderip & Sowerby)] is a distinct small species that is circum-arctic in distribution and in the eastern Pacific has been recorded throughout the Alaskan coast south to San Francisco, California in water depths from the intertidal zone to about 37 m in quiet offshore areas in silt (Burch, 1945-47; Coan, 1971). There are also isolated records from Santa Cruz, Monterey, Pismo Beach, Santa Barbara, San Pedro, and San Diego (Coan, 1971). In the fossil record it has been reported from numerous Pliocene(?) to Pleistocene exposures from northern Alaska (USGS collections), and from Pleistocene deposits from southern Alaska (Dall, 1904) south to Puget Sound, Washington (Henderson, 1927). It has been questionably reported under the name *M. inconspicus* (Broderip & Sowerby) from the Tahana Member in San Mateo County by Touring (1959) and Cummings and others (1962).

Macoma inquinata (Deshayes) [syn. *M. irus* (Hanley) of authors] occurs in the eastern Pacific from the southeastern Bering Sea south to San Pedro, southern California (Foster, 1991), in intertidal areas in bays and offshore to 48 m, below the surf line in silt (Coan, 1971). From the Purisima Formation Martin (1916) reported it from Purisima [Creek?] and the Sargent oil field area (also by Allen, 1945 as M. irus (Hanley). Elsewhere it has been reported in Pleistocene deposits from British Columbia (Newcombe, 1914) to Punta Baja, Baja California Norte, Mexico (Emerson and Addicott, 1958). Reports of this species from the Pliocene of California are unclear as some of these occurrences may be referable to the ancestral species *M. affinis* Nomland and/or *M. affinis plena* Stewart *in* Woodring, Steward, and Richards (1940).

Touring (1959) and Cummings and others (1962) reported *M. lama* (Bartsch) (syn. *M. planiuscula* Grant and Gale) questionably from the Tahana Member in San Mateo County, and Clark (1981) questionably reported this taxon from above the lower part of the Purisima Formation southeast of Scotts Valley in Santa Cruz County, central California. This taxon is very similar to several other eastern Pacific *Macoma* and its identification is questioned from the Purisima Formation until specimens can be examined. But its occurrence is generally in keeping with the cool water aspect of the Purisima Formation. It has a modern occurrence in the eastern Pacific from Queen Charlott Island, British Columbia, Canada (53°N) to Dease Inlet, arctic Alaska (71°N) in water depths from the intertidal zone to 183 m (Coan, 1971).

Macoma nasuta (Conrad) [syn. *Macoma nasuta kelseyi* (Conrad)] ranges in age from Oligocene to Holocene (Grant & Gale, 1931). Modern occurrences in the eastern Pacific are in water depths from the intertidal zone to 50 m (Bernard, 1983), along the coast from southern Baja California (27°N) north to Kodiak Island, Alaska (60°N) (Bernard, 1983; McLean, 1978) and Sitkalidak Island, Alaska (Foster, 1991). From the Purisima Formation it has been reported by Ashley (1895a) from Purisima [Creek?], San Gregoria (=San Gregorio) and Capitola, by Arnold (1908a) from his middle and upper members, by Martin (1916) from near Año Nuevo Creek and the Sargent oil field area (also by Allen, 1945), by Touring (1959) and Cummings and others (1962) from the Pomponio Member in San Mateo County, and by Addicott and others (1978b) from Capitola City Beach, and New Brighton State Beach, Santa Cruz. Lastly Perry (1993) reported it from lower shell bed and upper shell facies in the Capitola City Beach section.

Several other taxa reported from the Purisima Formation are probably referable to *Macoma nasuta* (Conrad).

Touring (1959) and Cummings and others (1962) reported and illustrated a *Macoma* under the name *Macoma brota* Dall var. *lipara* Dall from the lowest Tahana Member. It is difficult from their photograph to identify this specimen but it is probably referable to *M. nasuta* (Conrad). *Macoma lipara* Dall has a modern range from the Bering Sea south to Eureka, northern California, with a single lot from Cordell Bank just north of San Francisco, in water depths from 26 m to 259 m (Coan, 1971), so its occurrence from the Purisima Formation is within reason but until better specimens are found, or the specimens collected by Cummings and others (1962) examined, its presence in the Purisima Formation is in doubt.

Macoma calcarea (Gmelin) has been reported from the Purisima Formation by Touring (1959) and Cummings and others (1962) from the Tahana, Pomponio and San Gregorio Members in San Mateo County. Its modern occurrence is circum-arctic and in the eastern Pacific from throughout the Bering Sea south to Sooke, Vancouver Island, British Columbia, Canada in depths from 2 to 320 m (Coan, 1971). It is doubtful that this northern taxon is found in the Purisima Formation as it represents much colder temperature regime than other Purisima Formation taxa represent. Specimens referred to *M. calcarea* (Gmelin) are probably immature *M. nasuta* (Conrad) which are quite similar in outline.

Macoma indentata Carpenter has been reported from the Purisima Formation by Martin (1916) from the Sargent oil field area, Glen (1959) from Moss Beach, and Perry (1993) from Capitola City Beach sections. While the occurrence of this taxon is not unexpected from the Purisima Formation its shape and size are similar to *M. nasuta* (Conrad) and its identification can be difficult. Until such time as well preserved specimens can be examined or Martin's, Glen's, or Perry's specimens reexamined it's occurrence in the Purisima Formation is questioned. *Macoma indentata* Carpenter has a modern occurrence

from Trinidad, northern California to Isla Cerralvo, Baja California Sur and Guaymas, Sonora on mandland Mexico, in water depths from 10 to 91 m (Coan, 1971). It also has fossil occurrences from Miocene to Pleistocene rocks in southern California, but the older occurrences are in need of verification (Coan, 1971).

Macoma sp., cf. *M. lama* (Bartsch) is reported from the Scott's Valley area (Clark, 1981). *M. lama* (Bartsch) is a northern taxon with a modern occurrence form Dease Inlet, Arctic Alaska south to Queen Charlotte Island, British Columbia, Canada in water depths from the intertidal zone to 183 m (Coan, 1971). Coan (1971) also reports that it does not have a fossil record and specimens previously attributed to it are *M. elimata* Dunnill and Coan. The questionable Purisima Formation occurrence of *M. lama* (Bartsch) is probably referrable to *M. nasuta* (Conrad) which is similar in shape, at least until such time as Clark's (1981) specimens can be critically examined.

Lastly Ashley (1895a) reported *M. secta* Conrad from Santa Cruz (as *M. edulis* Nuttall?) and Martin (1916) from the Sargent oil field area. *Macoma secta* Conrad ranges from Vancouver Island, British Columbia, Canada to Bahia Magdalena, Baja California Sur, Mexico in water depths from 10 to 46 m (Coan, 1971) and has a fossil record from the Pliocene and Pleistocene of southern California and Miocene of Washington, Oregon, and California (Coan, 1971). Because *M. secta* Conrad is very similar to M. nasuta (Conrad) records of it occurring in the Purisima Formation are herein referred to M. nasuta (Conrad) until specimens can be critically examined.

Macoma yoldiformis Carpenter is a distinctive *Macoma* that is not easily mistaken for other species. Coan (1971) reported its modern occurrence from Dall's Island, southern Alaska to Bahía San Bartolomé, Baja California Sur, Mexico in water depths from the intertidal zone to 93 m in bays and offshore in silt and sand (Burch, 1945-47; Coan, 1971). It has been reported as a fossil in Pliocene and Pleistocene deposits from San Pedro, southern California to central California (Coan, 1971). Touring (1959) and Cummings and others (1962) questionably reported it from the McCormick Creek in the La Honda quadrangle in rocks referred to the Tahana Member.

Arnold (1908a) reported *Tellina (Cadella) nuculoides* (Reeve) (as *Morella salmonea* Carpenter) from his upper member of the Purisima Formation. *Tellina nuculoides* (Reeve) has a modern occurrence from Attu Island, Aleutians and Saint George Island in the Pribiloff Islands south to Isla Los Coronados, Baja California Norte, Mexico in water depths from the intertidal zone to 73 m mostly in protected areas (Coan, 1971). It has been reported as a fossil from the late Pleistocene from Cayucos (Valentine, 1958) to Huntington Beach (Valentine, 1959) with many records in the San Pedro area (Arnold, 1903; Oldroyd, 1925; Burch, 1947) all in southern California. Clark (1915) reported it from the Miocene of central California, but this record is most in doubt and may be referred to some other taxon.

Also reported by Arnold (1908a) from his upper member is *Tellina* sp., aff. *T. congesta* Conrad. *Tellina congesta* (Conrad) is a virtually unknown Miocene taxon which Conrad (1855) originally described from the "Miocene" of "San Diego". This type locality may be in error as he later referred to this taxon from the Miocene Monterey Formation in Monterey County (Conrad, 1857). The type material is lost (Keen and Bentson, 1944) so its identity is in doubt and it appears to represent a *nudum dubia*. Until such time as Conrad's species can be better defined and Arnold's specimens examined these specimens should be referred to *Tellina* species indeterminate.

Lastly in the Tellinids Perry (1993) reported *Tellina modesta* (Carpenter) from his upper shell facies in the Capitola City Beach section. This species has a modern occurrence from Montagu Island, Alaska south to Bahia San Bartolome, Baja California Sur,

Mexico in water depths from below wave level to 91 m in silty-sand to fine sand (Coan, 1969). It has previously been restricted to the Pleistocene occuring from Año Nuevo (Addicott, 1966) to Laguna San Ignacio, Baja California Sur, Mexico (Jordan, 1924; Hertelin, 1934).

Family Semelidae

Semele rubropicta Dall is a widespread species occurring from about the Kenai Peninsula, Alaska (59°N) south to possibly Guaymas, Sonora, Mexico (27°N) in water depths from the intertidal zone to 55 m (Coan, 1988). In the fossil record it has been reported from the Pliocene by Hertlein and Grant (1972) from the San Diego Formation, from the early Pleistocene from the San Pedro area (Oldroyd, 1925; Clark, 1931), and from the late Pleistocene of southern California (Valentine, 1958) to northern Baja California (Jordan, 1936). From the Purisima Formation it has only been questionably reported from the Sargent oil field area by Martin (1916) and Allen (1945).

Family Psammobiidae

Ashley (1895a) reported *Nuttallia nuttallii* (Conrad) (as *Sanguinolaria nuttalliana* Conrad) from the Purisima Formation at Capitola. This is a large, distinctive and easily identified taxon which is easily recognized. Because it has not been reported since Ashley (1895a) its occurrence in the Purisima Formation is in doubt and must await examination of Ashley's (1895a) specimens.

Ashley (1895a) also reported *Psamnobia rubroradiata* Conrad questionably from the Capitola. According to Coan (1973) this taxon should be referred to *Gari californica* (Conrad). *Gari californica* (Conrad) occurs from Shilikof Strait, Alaska south to Bahia Magdalena, Baja California Sur, Mexico from the intertidal zone to 168 m (Coan, 1973). Coan (1973) also cited its occurrence in the Pliocene and Pleistocene of southern California. This report may be referable to *Siliqua alta* (Broderip and Sowerby), above, but this will have to wait until specimens can be examined.

Family Veneridae

Chione securis (Shumard) ranges in age from late Miocene to Pleistocene (Roth, 1979) from Newport Bay, southern California (Zinsmeister, 1971) to southern Washington state (Weaver, 1942). The Newport Bay occurrence is probably referable to the southern taxon *C. allisoni* Hertlein & Grant, which was described from the San Diego Formation (Hertlein & Grant, 1972) and is also known from and Niguel Formation (LACMIP collections). If so the southern range of *C. securis* (Shumard) would probably be the Etchegoin Formation in central California (Turmbull, 1958), which is more likely. This species has been reported from the Purisima Formation by Martin (1916) from the Sargent oil field area (also questionably by Allen, 1945 in addition to the discussion below), and by Touring (1959) and Cummings and others (1962) from a single specimen collected on Pescadero Creek near Jones Gulch in the Tehana Member.

Two reports of *Chione* assigned to species unlikely to be found in the Purisima Formation have been reported (Arnold, 1908a, Allen, 1945). Arnold (1908a) reported *Chione* sp., aff. *C. gnidia* Broderip & Sowerby, a tropical eastern Pacific species, from his lower member, and Allen (1945) reported *Chione* n. sp.? cf. *elsmerensis* English from the Sargent oil field area. These specimens are probably referable to *C. securis* (Shumard) because it is the only Pliocene *Chione* known from the area. In any case they are unlikely to be *Chione gnidia* Broderip & Sowerby which has not been reported in rocks older than

late Pleistocene (Grant & Gale, 1931) and no further north than the Potrero Canyon, Los Angeles County, southern California (Valentine, 1956). In the modern eastern Pacific fauna it ranges from northern Baja California (32°N) south to northern Peru (6°S) (Bernard, 1983), well outside the expected range of Purisima Formation fossils. Ashley (1895a) reported *Chione simillíama* Sowerby questionably from the Purisima Formation at Capitola. This species is also questionably referred to *C. securis* as *C. simillíama* Sowerby [=*C. undatella* (Sowerby)] is a tropical species occurring from southern California to Paita, Peru (Keen, 1971).

Arnold (1908a) reported *Clementia pertenuis* (Gabb) (as *Venus pertenuis* Gabb) from his middle member exposed in Pescadero Creek near the mouth of Jones Gulch. This taxon has been reported by Woodring (1927) as occurring in middle Miocene (possibly lower Miocene) (Kew, 1924) to early Pliocene rocks in central California. The Pliocene records are based on Arnold's (1908a; Branner and others, 1909) records from the Purisima Formation. This species is probably mis-identified from the Purisima Formation and represents some other taxon, but until such time as specimens can be examined it will be included in the Purisima fauna.

Compsomyax subdiaphana (Carpenter, 1864) occurs in the eastern Pacific in rocks as old as Miocene (Bernard, 1983). Its modern occurrence in the eastern Pacific is from 28°N to 61°N in water depths from 2 to 550 m (Bernard, 1983). This taxon and *Crepidula princeps* (Conrad) are unique in being reported by Touring (1959) and Cummings and others (1962) from every member of the Purisima Formation in San Mateo County. It has also been reported from the Purisima Formation by Ashley (1895a) from Lobitos Creek, San Gregorio, and Tunitas Creek (as *Saxidomus gibbosus* Gabb), by Arnold (1908a) from his middle and upper members, by Martin (1916) from Purisima [Creek?] (as *Marcia gibbosus* Gabb), near Año Nuevo Creek (as *Macia oregonensis* Clark), and the Sargent oil field area (also by Allen, 1945). It has also been reported from the Capitola City Beach section in the upper shell facies by Perry (1993) as *Katherinella subdiaphana* (Carpenter). Other occurrences questionably referred to this species are from USGS collections at Lobitos Creek (M8931) and Tunitas Creek (M8918).

Dosinia ponderosa (Gray) has been reported from the Purisima Formation by several authors (Arnold, 1908a; Martin, 1916; Allen, 1945) from Arnold's middle member and from the Sargent oil field area. *Dosinia ponderosa* (Gray) *s.s*. is an exclusively tropical species with a modern range from Scammon's Lagoon, Baja California Sur, Mexico (28°N) through the Gulf of California and south to Paita, Peru (5°S) offshore to 80 m (Keen, 1971; Bernard, 1983). Its occurrence in the Purisima Formation, which reflects temperate to cool water conditions, is extremely doubtful. It is most likely that the specimens reported as *D. ponderosa* (Gray) are actually *D. jacalitosana* Arnold which is known from the Pliocene and Miocene of central California (Grant and Gale, 1931), which is the name applied here. There is also the possibility that the Purisima Formation specimens are *D. ponderosa diegoana* Hertlein and Grant described from the San Diego Formation but also reported form the Careaga Formation in the Santa Maria District (Hertlein and Grant, 1972). It is less likely to be this taxon as both the San Diego and Careaga Formations have warmer water faunas. A precise identification of which species occurs in the Purisima Formation must wait until specimens can be examined.

Protothaca staleyi (Gabb) is extinct and occurs in Miocene (Addicott and others, 1978a) to Pliocene or possibly Pleistocene rocks from the Santa Maria, California to Coos Bay, Oregon (Woodring & Bramblette, 1950). This taxon has been reported from the Purisima Formation by Ashley (1895a) from Tunitas Creek, by Arnold (1908a) from his

middle and upper members, by Martin (1916) from Purisima [Creek?], near Año Nuevo Creek, and from the Sargent oil field area (also Allen, 1945 for Sargent oil field), and from Capitola by Addicott and others (1978b) and Perry (1993) from his lower shell bed and upper shell facies at Capitola.

Protothaca staminea (Conrad) is abundant is sandy areas in bays and in coarse gravel under loose rocks along the open coast, middle to lower intertidal zones from the Aleutian Islands, Alaska, to southern Baja California (McLean, 1978). Purisima Formation occurrences were reported by Glen (1959) at Moss Beach, by Touring (1959) and Cummings and others (1962) in the Tahana Member in San Mateo County, in the Woodside Quadrangle by Mack *in* Esser (1958) and Mack (1959), and at Sargent oil field area (Allen, 1945) (also by Martin, 1916). Martin (1916) reported it from what is now Capitola Beach City Park, but it has not been reported there since (Addicott and others, 1978b; Perry, 1993), but *P. staleyi* (Gabb) has, so Martin's (1916) specimens are questionably referred to that taxon) which is commonly encountered at Capitola Beach City Park.

Protothaca tenerrima (Carpenter) occurs from Vancouver, British Columbia, Canada, to southern Baja California (McLean, 1978). From the Purisima Formation it has been reported by Arnold (1908a) from his upper member, by Martin (1916) from Purisima [Creek?], Año Nuevo Creek and Sargent oil field area, also by Allen (1945) from the latter, from the Pomponio and Tahana Members in San Mateo County by Touring (1959) and Cummings and others (1962), from Tunitas Creek by Ashley (1895a), and from the upper shell facies at Capitola City Beach by Perry (1993). Other fossil occurrences for *P. tenerrima* (Carpenter) are from the Pliocene and Pleistocene from central California to Baja California Norte, Mexico (Grant and Gale, 1931). In addition to those records Yancy (1978) reported it from the Merced Formation.

Saxidomus nuttalli Conrad is a common constituant of the modern eastern Pacific fauna, occurring from Humboldt Bay, northern California to Isla San Gregonimo Island, Baja California Norte, Mexico commonly buried in sandy areas of bays at low tide and in sand near rocky areas along the open coast (McLean, 1978). In the Purisima Formation it wa cited as occurring in the Sargent oil field area by Martin (1916). It is widespread as a fossil occurring in Miocene to Pleistocene sediments from central California to Baja California Sur, Mexico (Grant and Gale, 1931).

Transennella tantilla (Gould) (syn. *T. tantilla* var. *californica* Arnold) has a modern occurrence from central California (35°N) to northern Baja California (28°N) in water depths from the intertidal zone to 120 m (Bernard, 1983). I follow Woodring and others (1940) in suggesting that *Transennella californica* Arnold described from the upper Etchegoin Formation is referable to this species. *Transennella tantilla* (Gould) (as *T. tantilla* var. *californica* Arnold) has been reported from the Purisima Formation by Martin (1916) and Allen (1945) from the Sargent oil field area. It was also questionably reported from Capitola as *Cyrena californica* Gabb by Ashley (1895a) and as "*Transennella*" sp. indet. by Perry (1993), the latter from his *Clinocardium* facies. Woodring and others (1946) questionably report this taxon from the Miocene Altamira Shale at San Pedro. This identification is questioned because aside from the Altamira Shale occurrence it has only been recorded in rocks as old as Pliocene [i.e., San Diego Formation (Hertlein and Grant, 1972) and questionably from the upper Etchegoin Formation and San Joaquin Formation (Woodring and others, 1940)]. It has also been reported from numerous Pleistocene locations (see Grant and Gale, 1931).

Family Myidae

Cryptomya californica (Conrad) (syn. *C. ovalis* Conrad and *C. quadrata* Carpenter) is common in sand and sandy mud from the intertidal zone to 80 m (Foster, 1991) along the open coast from the Prince William Sound, Gulf of Alaska (Foster, 1991) to northern Peru (McLean, 1978). Grant and Gale (1931) reported this taxon as a fossil from the Miocene to Pleistocene from western North America, citing references to its occurrence from Washington state south to Baja California Sur, Mexico. It has been reported from the Purisima Formation by Ashley (1895a) from Capitola (also by Addicott and others, 1978b), by Arnold (1908a) from his middle and upper members (as *C. ovalis* Conrad from the latter), by Martin (1916) from Purisima [Creek?], near Año Nuevo Creek, and the Sargent oil field area (as *C*. sp., cf. *C. ovalis* Conrad and *C. quadrata* Arnold; also by Allen, 1945 from the latter), by Touring (1959) and Cummings and others (1962) from the Pomponio, San Gregorio, and Tunitas Members in San Mateo County, and by Perry (1993) from all of his facies (lower shell bed, *Clinocardium*, upper shell, and *Crepidula*) at Capitola City Beach. Cummings and others (1962) illustrated a decorticated specimen which is questionably referable to this taxon from the San Gregorio Member of the Purisima Formation.

Mya truncata Linnaeus occurs in rocks of early middle Miocene to Holocene age (MacNeil, 1965). Its eastern Pacific modern occurrences are from the Puget Sound, Washington (48°N) to the Arctic Ocean (71°N) in water depths from the intertidal zone to 100 m (Bernard, 1983). From the Purisima Formation it has been questionably reported by Ashley (1895a) from Purisima [Creek?]. Martin (1916) and Allen (1945) reported *M. japonica* Jay from the Purisima Formation in the Sargent oil field area, but MacNeil (1965) indicated that the oldest verified occurrence of this species is late Pleistocene and that was in the western Pacific. Therefore until Martin's and Allen's specimens are re-examined they are referred to *Mya* species indeterminate.

Family Hiatellidae

Panomya chrysis Dall has been reported from undifferentiated Purisima Formation by Dall (1909), from Purisima [Creek?] and near Año Nuevo Creek, as *P. ampla* Dall (Martin, 1916), and from the San Gregorio, Pomponio, and the Sargent oil field area, and Tahana Member in San Mateo County by Touring (1959) and Cummings and others (1962). It is also questionably in USGS collections from Tunitas Creek (M8846) in San Mateo County. The modern occurrence of this species is from Puget Sound, Washington (51°N) to Kodiak Island in the Gulf of Alaska (60°N) in waters from 10 to 150 m deep (Strauch, 1972; Bernard, 1983). Grant and Gale (1931) combine P. chrysis Dall with *P. ampla* (Dall), which can be distinguished from each other muddling the fossil occurrence in California. According to Strauch (1972) and Roth (1979) *P. chrysis* Dall is questionably synonymized with *Panomya trapezoidis* Strauch. The fossil occurrence of this species is somewhat in question also, but Strauch (1972) reported *P. trapezoidis* Strauch from Oligocene to Pleistocene rocks from Washington, Oregon, California, Iceland, England, and the Netherlands. The Oligocene occurrence is based on a *Panomya* from the Poul Creek Formation (Gulf of Alaska) illustrated by Clark (1932) as *P. turgida* Dall, but which Kanno (1971) later referred to *P. arctica* (Lamarck). From the above discussion it is obvious that the fossil representatives of this genus are in need of revision.

Panomya arctica (Lamarck) (syn. *P. arctica turgida* Dall) occurs in the eastern Pacific from Bering Sea, Alaska (60°N) to the Chukchi Sea (66°N) in water depths from the intertidal zone to 80 m and is circumboreal in the Arctic Ocean (Bernard, 1983). This taxon has been reported in Oligocene (see comments under *P. chrysis* Dall, above), Pliocene

(Dall *in* Moffitt, 1913) and Pleistocene rocks in the eastern Pacific (Dall, 1898). This taxon has been reported from the Purisima Formation by Mack (1958) and Mack *in* Esser (1958) in the Woodside Quadrangle.

Arnold (1908a) reported an indeterminate *Panomya* from his upper member of the Purisima Formation. Another indeterminate specimen is recorded from Purisima Creek (M8933) in USGS collections.

Panopea abrupta (Conrad) [=*Glycymeris genosa* Gould *fide* Keen and Bentson, 1944; =*Panope generosa* (Gould) *fide* Moore, 1963] lives in sandy mud in bays at a depth of several feet in the sediment, with the siphon extending to the surface. It occurs from Sitka, Alaska (Foster, 1991) to Scammons Lagoon, central Baja California (McLean, 1978). It has been reported in rocks as old as Miocene (Bernard, 1983). It was first reported from the Purisima Formation by Ashley (1895b) from San Mateo County and Capitola, as *Glycymeris genosa* Gould. Arnold (1908a) reported it from his middle and upper members, Martin (1916) reported it from Purisima [Creek?], near Año Nuevo Creek, and the Sargent oil field area (also by Allen, 1945), Touring (1959) and Cummings and others (1962) reported it as common in the Tehana Member along the coast south of the San Gregorio fault, and Perry (1993) reported it from his *Clinocardium*, upper shell, and *Crepidula* facies at Capitola State Beach. It is also in USGS collections from San Gregorio Creek (M8925), between San Gregorio and Pomponio State Beaches (M8916, M8927).

Family Pholadidae

Perry (1993) reported *Barnea subtruncata* (Sowerby) from the Purisima Formtion at Capitola City Beach in his lower shell bed and *Clinocardium* facies. This record is the oldest occurrence of this taxon as previous reliable records are all from the Pleistocene (Kennedy, 1974). The modern range of this taxon is from Newport, Oregon south to Atacama Province, Chile (Kennedy, 1974) in water depths from the intertidal zone to 30 m (Beranrd, 1983).

Zirfaea pilsbryi Lowe, 1931 (in part reported as *Z. gabbi* Tryon) has been reported from the Purisima Formation at Moss Beach (Ashley, 1895a; Glen, 1959), south of Halfmoon Bay (Ashley, 1895a [as *Zirphoea crispata* Linnaeus]; Martin, 1916 [as *Zirphaea gibbi* Tryon]), from Arnold's (1908a, also 1906) upper member, and from San Gregorio (=San Gregoria) and the Sargent oil field area (Martin, 1916 and Allen, 1945). It has been reported in rocks as old as Pliocene (Kennedy, 1974) in central and southern California. The modern occurrence of this taxon is from southern Baja California Sur, Mexico (24°N) to Point Lay, northern Alaska (71°N) (USGS collections; beach collected valves) in water depths from the intertidal zone to 125 m (Bernard, 1983).

Touring (1959) and Cummings and others (1962) reported the questionably identified *Penitella* sp., cf. *P. penita* (Conrad) from two specimens collected by Touring in the Tahana Member. Interestingly Kennedy (1974) in his review of Pholads of west American did not mention these specimens, but did record specimens from the Purisima Formation at Moss Beach which Glen (1959) referred to in part as Pholad indet. *Penitella penita* (Conrad) has been recorded in rocks as old as Pliocene (Kennedy, 1974). Its modern occurrence is from Baja California Sur, Mexico (26°N) to the Bering Island, western Bering Sea, Alaska (60°N) (Foster, 1991) in water from the intertidal zone to about 5 m (Bernard, 1983).

A fourth pholad *Parapholas californica* (Conrad) has been reported from the Purisima Formation. Glen (1959) reported indeterminate pholads from Moss Beach which Kennedy (1974) later assigned, in part, to this species. Kennedy (1974) also reported

chimneys of this species collected as float from Capitola City Beach. This species has not been collected in situ in the Purisima Formation at Capitola, but modern specimens are common along the beach suggesting that the specimens of Kennedy (1974) may be modern (F. Perry, personal commun., 1998). The oldest occurrence of this taxon is reported above from Moss Beach. The modern occurrence of *P. californica* (Conrad) is from Baja California Sur, Mexico (26°N) to Marin County, northern California (38°N) from the intertidal zone to about 10 m (Bernard, 1983).

Family Pandoridae

Arnold (1908a) reported *Pandora punctata* Conrad from his middle member of the Purisima Formation, Martin (1916) reported it from Purisima [Creek?], and the Sargent oil field area (also by Allen, 1945), Touring (1959) and Cummings and others (1962) reported it from the Tunitas Member in San Mateo County, and Perry (1993) reported it from his *Clinocardium* and upper shell facies at Capitola City Beach in Santa Cruz. The modern range of this taxon is from Baja California Norte, Mexico (28°N) to the Gulf of Alaska (55°N) in water depths from 2 m to 50 m (Bernard, 1983).

Family Lyonsiidae

A single broken valve questionably assigned to the genus *Lyonsia* has been collected from Capitola (M8862).

Family Thraciidae

Thracia trapezoides Conrad occurs in the eastern Pacific Ocean from off Isla Cedros, Baja California Norte, Mexico (28°N) to Wide Bay on the south side of the Alaska Peninsula (57°N) in water depths from 11 to 199 m (Coan, 1990). It has an extensive fossil record from the middle Miocene to Pliocene from Washington, Oregon, and California (Coan, 1990). Pleistocene records are restricted to southern California (Clark, 1931; Hoots, 1931; Rodda, 1957; Woodring and others, 1946; and Coan, 1990). It has also been reported from the Purisima Formation by Arnold (1908a) from his upper member, by Arnold and Hannibal (1913), by Martin (1916) from Purisima [Creek?], and by Allen (1945) from the Sargent oil field area. Touring (1959) and Cummings and others (1962) reported a single specimen from the Pomponio Member in San Mateo County.

Perry (1993) reported *Thracia kanakoffi* Hertlein & Grant from his upper shell facies, along with an indeterminate *Thracia* from the *Clinocardium* facies. *Thracia kanakoffi* Hertlein & Grant was previously known only from the Pico Formation in Los Angeles County and the San Diego Formtion in San Diego County (Hertlein and Grant, 1972). Its occurrence in the Purisima Formation represents a major range extension of over 900 km.

Family Periplomatidae

Periploma discus Stearns occurs in the eastern Pacific from Mazatlan, Mexico (23°N) to Monterey Bay, central California (37°N) in water depths from the intertidal zone to 40 m (Bernard, 1983). According to Bernard (1983) it was not previously reported as a fossil, but both Touring (1959) and Cummings and others (1962) reported it from the Lobitos and Tunitas Members of the Purisima Formation in San Mateo County.

Class Gastropoda

Family Fissurellidae

The key-hole limpet *Diodora aspera* (Rathke) has questionably been reported from

the Purisima Formation as a single specimen collected by W. Glen at Moss Beach (Glen, 1959). *Diodora aspera* (Rathke) occurs from Crescent City, northern California to San Martin Island, northern Baja California and is exclusively subtidal, but becomes uncommon below 9 m (30 ft) (McLean, 1978). In the fossil record it has been reported from the Pliocene [Wilson Grove Formation (Bedrossian, 1974), Careaga Formation (Woodring and others, 1950), Fernando Formation (Soper and Grant, 1932), and San Diego Formation (LACMIP collections)] and the Pleistocene, with numerous occurrences from northern California [Battery Formation (Kennedy, 1978)] to southern California [Bird Rock Terrace on Point Loma, San Diego County (Kern, 1977)].

Family Lottiidae

Limpets referred to the genus *Acmaea* have been reported from two sites in the Woodside Quadrangle by Mack (1958) and Mack *in* Esser (1958). Lindberg (1986) reassigned most northeastern Pacific limpets to the family Lottiidae leaving only the monotypic *Acmaea mitra* Rathke in the family Acmaeidae. This suggests that the limpets referred to by Mack (1958) and Mack *in* Esser (1958) are probably referable to this family, but an exact determination will have to wait until Mack's specimens can be examined.

Family Trochidae

Solariella permabilis Carpenter was very questionably (aff.) reported from the middle member of the Purisima Formation by Arnold (1908a). It has not been reported in later Purisima Formation collections. Abbott (1974) reported its modern occurrence as from Alaska to the Gulf of California where it is moderately common in water depths from 40 to about 170 m (20 to 339 ftms.). Grant and Gale (1931) reported a fossil occurrence for this taxon from the Pliocene Pico Formation in Ventura County; it is also known from the Capistrano Formation in Orange County (Kern and Wicander, 1974). It has also been reported from the Pleistocene Lomita Marl by Woodring and others (1946) (San Pedro area) and "Pliocene" (now Pleistocene) deposits at Deadman Island formerly in the San Pedro Harbor, Los Angeles County (probably also from the Lomita Marl).

Tegula lahondaensis (Arnold) is known only from its type locality on Pescadero Creek near Jones Gulch in pebbly sandstone referred to the Tahana Member (=Arnold's 1908a middle member) (Arnold, 1908a; Touring, 1959; Cummings and others, 1962).

Turcia brevis Stewart *in* Woodring, Stewart and Richards was reported by Touring (1959) from a single specimen from the Tahana Member collected in central San Mateo County. It was described by Woodring, Stewart and Richards (1940) from the *Pecten* and *Acila* zones in the Etchegoin Formation, Kettlemen Hills oil field. It has also been reported from the Careaga Sandstone and possibly from the Foxen Mudstone in the Santa Maria District, central California (Woodring and Bramblett, 1950) and in the San Diego Formation at Pacific Beach, southern California (Woodring, Stewart and Richards, 1940). From these occurrences it ranges from late Miocene to late Pliocene in age.

Glen (1959) reported a specimen questionably identified as *Margarites*? sp. indet. from the Moss Beach area. This taxon must await better preserved specimens before its identification can be acertained. Perry (1993) reported an indeterminate *Calliostoma* from his upper shell and *Crepidula* facies at Capitola City Beach. Specimens representing this taxon are in collections at Santa Cruz City Museum of Natural History and await assignment to species.

Family Turbinidae

Homalopoma paucicostatum (Dall) has been reported by Arnold (1908a) from his upper member of the Purisima Formation. McLean (1978) cited the modern occurrence of this taxon from Monterey Bay, central California to Isla San Martin, Baja California Norte, Mexico, in gravel under kelp, strictly subtidal. This species is very similar to *H. radiatum* (Dall) and according to McLean (1978) occupies the same range so distinguishing between the two may be difficult, especially in the fossil record. *Homalopoma paucicostatum* (Dall) has a fossil record from the "Pliocene" (possibly Pleistocene) of Santa Barbara, Santa Barbara County, southern California (Arnold, 1903; Berry, 1908) and the Pleistocene of the San Pedro area, Los Angeles County, southern California (Arnold, 1903; Woodring and others, 1946).

Family Littorinidae

Littorina remondi Gabb, *L. scutulata* Gould, and indeterminate *Littorina* shells have all been reported from the Sargents oil field area (Martin, 1916; Allen, 1945). In addition *L. petricola* Dall has been identified in internal USGS reports (USGS E&R WEG-76-11M) from the Chittenden Pass area. Because of the difficulty in identifying littorinas all the taxa reported above from the Sargents oil field area are herein referred to *Littorina* sp. indet. until such time as the specimens can be examined.

Family Cerithiidae

The subgeneric subdivisions of *Bittium* as defined by Bartsch (1911) are artificial and should be discarded (Grant and Gale, 1931) so no subgeneric taxa are used here. Also several species within this genus in the eastern Pacific are poorly understood and the genus is in need of a review. *Bittium asperum* Gabb has been reported by Arnold (1908a) from his upper member, by Martin (1916) from Purisima [Creek?] and the Sargents oil field area (also by Allen, 1945), and by Mack (1958) and Mack *in* Esser (1959) from the Woodside Quadrangle. Touring (1959) referred Bittiums from the Purisima Formation to *B.* sp., cf. *B. vancouverensis* Dall and Bartsch, stating that they have only three spiral cords, while he reported *B. asperum* Gabb has four or five. According to Bartsch (1911) *B. asperum* Gabb has only one or two spiral cords. So, until such time as the specimens can be examined they are here referred to *B. asperum* Gabb following Arnold (1908) and Myra Keen who identified Mack (1958) and Esser's (1958) specimens. *Bittium asperum* Gabb is reported by Abbott (1974) from Catalina Island to San Diego, southern California in water depths from 100 m to 150 m (50 to 75 ftms). Specimens from the Purisima Formation will have to be reviewed against modern specimens because they are unlikely to be this southern taxon as the Purisima Formation fauna, as a whole, suggests cooler water conditions than exist along the central California coast today

Family Vitrinellidae

An indeterminate *Vitrinella* has been reported from the upper shell facies in the Capitola City Beach section of the Purisima Formation by Perry (1993). Better preserved specimens are needed to further refine their identification. The genus *Vitrinella* is widespread in the eastern Pacific.

Family Vermetidae

Serpulorbis squamigerus (Carpenter) ranges, in the modern eastern Pacific, from Santa Barbara, California to Point Abreojos, Baja California Sur usually in colonies at-

tached to wharf pilings, breakwater rocks, and the upper surfaces of stones in some protected intertidal areas (McLean, 1978). Arnold (1908a) reported it from his upper member, and Touring (1959) and Cummings and others (1962) reported it from the Tahana Member, their lowest member is San Mateo County. Judging from the specimen illustrated by Cummings and others (1962) and the known occurrence of this taxon it would be out-of-place in the Purisima Formation and specimens referred to this taxon should probably be referred to indeterminate worm tubes similar to the one reported by Woodring and others (1950). As a fossil *Serpulorbis squamigerus* (Carpenter) has been reported in rocks from Pleistocene to Holocene from southern California and Baja California Norte, Mexico (Grant and Gale, 1931). Woodring and others (1950) mentioned "worm tubes" similar to this species from the Sisquoc formation, Foxen Mudstone and Careaga Sandstone, but the specimens they examined were distinguished by being larger, thicker walled, and without ornamentation.

Family Calyptraeidae

Tertiary representatives of the genus *Calyptraea* are generally poorly defined, poorly preserved, and difficult to identify. Four taxa, *Calyptraea fastigiata* Gould, *C. filosa* (Gabb), *C. inornata* (Gabb), and *C. radians* Lamarck, have been reported from the Purisima Formation. It is doubtful that more than two species actually exist, one with a smooth shell and one with radial sculpture (if previous identifications are reliable), but until such time as specimens can be examined all taxa reported are here referred to *Calyptraea* sp. indet.

Calyptraea fastigiata Gould occurs from Alaska to southern California and has been dredged commonly from depths of 18 to 140 m (10 to 75 ftms.) (Abbott, 1974), although Rice (1972) cites its occurrence form "Alaska" to Puget Sound, Washington from the intertidal zone to about 100 m (300 ft). Cummings and others (1962) reported it from the Lobitos Member of the Purisima Formation and Perry (1993) from his lower shell bed, upper shell bed and *Crepidula* facies at Capitola City Beach. The fossils record of this taxon is from the Pleistocene (Addicott, 1966; Kennedy, 1978) from Oregon to central California. Grant and Gale's (1931) concept of this species included several other taxa which are probably distinct and because of this their occurrence records are muddled. Arnold and Hannibal (1913) reported *Calyptraea fastigiata* Gould from the "Elk River beds" but their concept of this formation included the upper Pleistocene terrace material at Cape Blanco where this taxon occurs (Kennedy, 1978). Based on Rice's (1972) occurrence data and the fossil record of later authors this taxon may be too cold a faunal element to be found in the Purisima Formation and its occurrence must await conformation.

Calyptraea filosa (Gabb) was described from the late Miocene San Pablo Formation. It has since been reported from the Oligocene to Miocene Vaqueros Formation in San Luis Obispo County (Loel and Corey, 1932), from the Pliocene Capistrano Formation in Orange County (Kern and Wicander, 1974), from the Pliocene Purisima Formation at Purisima [Creek?] (Martin, 1916), and in the Sargent oil field area (Martin, 1916; Allen, 1945), and from the Pleistocene Merced Formation exposed at Twelvemile Creek, San Mateo County, central California (Yancey, 1978). If all these occurrences are correct this taxon ranges in age from late Oligocene to early Pleistocene. It seems more acceptable that this taxon as defined by these authors is probably a composite species of two or more taxa, but this will have to await further study of this group.

Calyptraea inornata (Gabb) is a poorly known species reported from the Vaqueros Formation (Loel and Corey, 1932). It has also been reported from the Purisima Formation by Arnold (1908a) from his upper member and from east of Santa Cruz (also by Addicott

and others, 1978b from Santa Cruz area). Again the discontinuous occurrences both in time and space of specimens referred to this taxon argues for more than one species being associated with the name.

Martin (1916) reported *Trochita radians* (Lamarck) from Purisima [Creek]. Grant and Gale (1931) and Keen (1971) combined this species with *T. trochiformis* (Gmelin), a modern, much larger species which occurs from Panama to Peru. But this does not seem to be generally accepted as Woodring and others (1950) referred specimens from the Santa Margarita district to *Calyptraea radians* (Lamarck). Undoubtedly specimens referred to *Calyptraea radians* (Lamarck) from the Tertiary of California are in need of a new name, but this must wait until a detailed study of the California Tertiary and modern radially sculptured *Calyptraea*.

Crepidula nummaria Gould (as *C. navicelloides* Nuttall) has been reported from the Purisima Formation by Arnold (1908a) from his upper member. The modern range of this taxon is confused as early records combine *C. nummaria* Gould and *C. perforans* (Valenciennes), which is distinct and has a more southern occurrence (McLean, 1978). *Crepidula nummaria* Gould appears to have a range from Plover Bay, Bering Strait, Alaska (Dall, 1921a) to southern California (Morris and others, 1980), generally in the low intertidal zone (Morris and others, 1980). It has been reported as a fossil from the Pliocene of the San Diego region (Dall, 1874; Arnold, 1903 - as *C. navicelloides* Nuttall) and from the Pleistocene from the Los Angeles Basin, southern California (Arnold, 1903; Oldroyd, 1925).

Martin (1916) reported *Crepidula onyx* Sowerby from Purisima [Creek?]. Clark (1981) also reported it from above the lowermost 60 m of his Purisima Formation exposed southwest of Scott's Valley, Santa Cruz County, central California. According to McLean (1978) this *Crepidula* is "Abundant in bays and lagoons, common elsewhere at low tide to sublittoral depths on shells and rocks from southern California to Peru." Grant and Gale (1931) reported it from Miocene to Pleistocene rocks from southern Oregon to southern California. The identification of this species from the Purisima Formation is in some doubt because *C. onyx* Sowerby is generally considered a subtropical faunal element and would be out of place in the Purisima Formation, but it has been reported from the Etchegoin Formation (Adegoke, 1969), so it may be another indicator of the Neogene seaway that existed between the southern exposures of the Purisima Formation and the California Central Valley.

Crepidula princeps (Conrad) ranges from Alaska to Baja California Norte in rocks from Miocene to Pleistocene (Grant & Gale, 1931). Arnold (1908a) reported this taxon from his middle and upper members. *Crepidula princeps* (Conrad) and *Compsomyax subdiaphana* (Carpenter, 1864) are unique in being reported by Touring (1959) and Cummings and others (1962) from every member of the Purisima Formation in San Mateo County. It has also been reported from the Purisima Formation by Ashley (1895a) from Purisima [Creek?] (as *C. grandis* Middendorff) (also by Martin, 1916), and Capitola (also by Addicott and others, 1978b and Perry, 1993), from Año Nuevo Creek (Martin, 1916), the Sargent oil field area (Martin, 1916; Allen, 1945), by Mack (1958) and Mack *in* Esser (1958) from outcrops in Woodside Quadrangle, and by Addicott and others (1978b) from the New Brighton-Seacliff State Beaches. In field work it is found abundantly on the beach in the intertidal zone at Redondo Beach on the south side of Halfmoon Bay.

Family Naticidae

Cryptonatica affinis (Gmelin) (=*Natica clausa* Broderip & Sowerby, 1829 *fide* McLean and Grosliner, 1996) has a circumboreal modern occurrence, but in the eastern Pacific it

occurs from northern Alaska south to San Diego, California, in water depths from 9 to 970 m, although it is generally found in progressively deeper depths from north to south (Marincovich, 1977). This taxon has been reported in rocks from early Miocene to Pleistocene in the eastern Pacific, from northern Alaska (USGS collections) to the Los Angeles Basin (Arnold, 1903; Clark, 1931) and questionably from Baja California Norte, Mexico (Valentine, 1961). It was first reported from the Purisima Formation by Ashley (1895a) from Capitola, then by Arnold (1908a) who recorded it from both his middle and upper members. Martin (1916) reported it from Purisima [Creek?], and Touring (1959) and Cummings and others (1962) reported this taxon from the Tahana, Pomponio, and Tunitas Members all in San Mateo County. Ashley (1895a), Addicott and others (1978b), and Perry (1993) report ed it from the Santa Cruz area, while Martin (1916) and Allen (1945) report it from the Sargents oil field area.

Neverita (Glossaulax) reclusianus (Deshayes) is fairly common in lagoons and shallow bays (not characteristic of offshore sandy bottoms), from Crescent City, California (42°N), to Mazatlan, Mexico (23°N), although it is rare north of Magu Lagoon in southern California (34°N) (Marincovich, 1977; McLean, 1978). Marincovich (1977) reported this species in rocks from the Eocene to Pleistocene from Vancouver Island, British Columbia, Canada to the Gulf of California. It has been reported from the Purisima Formation by Ashley (1895a) from Capitola State Beach (also by Addicott and others, 1978b and Perry, 1993), by Arnold (1908a) from his upper member, and by Martin (1916) from the Sargent oil field area (also by Allen, 1945). It is questionably (cf.) in USGS collections from east of Año Nuevo Creek.

Polinices (Euspira) lewisii (Gould) is occasionally common at low water in bay and lagoons, also offshore on sandy bottoms from Duncan Bay, British Columbia to San Geronimo Island, Baja California Norte, Mexico (McLean, 1978). It has been reported from the Purisima Formation by Ashley (1895a) from San Gregorio, Purisima [Creek?] ("near" lewisii), Tunitas, and Capitola, by Arnold (1908a) from his middle and upper members, by Martin (1916) from near Año Nuevo Creek, by Allen (1945) from the Sargent oil field area, and by Touring (1959) and Cummings and others (1962) from the Tahana, Pomponio, and Tunitas Members in San Mateo County. More recently it has questionably been reported by Galloway (1977) from the Point Reyes area, and by Addicott and others (1978b) from Capitola Beach (also by Perry, 1993 from his *Clinocardium* and *Crepidula* facies) and New Brighton/Sea Cliff State Beaches. In the fossil record this species has questionably been reported from the late Miocene in Los Angeles County (Stanton, 1966) and definitely from the Pliocene to Pleistocene from northern California (Roth, 1979) to Bahia Magdalena, Baja California Sur, Mexico (Jordan, 1924).

Perry (1993) reported *Sinum scopulosum* (Conrad) from his *Crepidula* facies at Capitola City Beach. Arnold (1908a) reported *Sinum debilis* (Gould) from his upper member. *Sinum debilis* (Gould) is a subtropical to tropical species with a modern range from La Paz, Baja California Sur, Mexico to Panama Bay, Panama (Marincovich, 1977). This tropical species is not expected from the Purisima Formation and Arnold's (1908a) specimen(s) are probably referable to *S. scopulosum* (Conrad). *Sinum scopulosum* (Conrad) has an extensive fossil record in California and has been recorded by Arnold (1903, 1906, 1908b) from other sites in southern California as *S. debilis* (Gould) (Marincovich, 1977). The modern range of *S. scopulosum* (Conrad) is from Monterey, central California (36°N) to Bahia Tortolo, Baja California Sur, Mexico (28°N) in water depths of 15 to 171 m. Marincovich (1977) reported the fossil record of this species from the late Oligocene to Pleistocene from northern Washington to southern California.

Family Cymatiidae

Fusitriton oregonensis (Redfield) occurs from the Bering Sea, Alaska to off San Nicolas Island, southern California in progressively deeper water depths from north to south (from the intertidal zone in the north to 2,400 m off southern California) (Smith, 1970). Smith (1970) reported its fossil occurrence from Miocene to Holocene from Alaska to southern California. Martin (1916) reported it from Purisima [Creek?] and Touring (1959) and Cummings and others (1962) reported it from the Pomponio Member of the Purisima Formation from a single fragment which Touring (1959) identified because of its distinctive sculpture. Arnold (1908a) reported *Priene pacifica* Dall from his upper member. *Priene pacifica* Dall was synonimized *F. oregonensis* (Redfield) by Smith (1970), but separated by Roth (1978). Determining if these taxa should be differentiated or synonimized is beyond the scope of this paper. Arnolds (1908a) citation is here attributed to *F. oregonensis* (Redfield) until the specimen(s) can be examined.

Perry (1993) reported *Mediargo mediocris* (Dall) from the Purisima Formation at Capitola City Beach in his upper shell facies. This taxon has been reported in late, possibly middle Miocene to Pliocene rocks from the Olympic Peninsula, Washington to San Diego, California. According to Smith (1970) young specimens of *M. mediocris* (Dall) are easily confused with those of *Fusitriton oregonensis* (Redfield), but can be separated "...by differences in spiral sculpture, outline, and apertural features."

Family Epitoniidae

Nitidiscala indianorum Carpenter has been reported from Bahia Todos Santos, Baja California Norte, Mexico (32°N) to Forrester Island, Alaska (55°N) in water depths from the intertidal zone to 114 m on sandy mud substrate (DuShane, 1979). It has a fossil record from the late Pliocene to late Pleistocene from southern Oregon to San Diego County, southern California (DuShane, 1979). From the Purisima Formation it has been reported from east of Año Nuevo Creek (Martin, 1916). Its occurrence in the Purisima Formation is in need of conformation as it does occur in the terraces overlying the Purisima Formation in this area (Addicott, 1966) and it has not been reported from the Purisima since Martin (1916).

Family Muricinae

Subfamily Ocenebrinae

Perry (1993) reported *Ceratostoma foliatum* (Gmelin) from the upper shell bed at Capitola City Beach. This is the only reported occurrence in the Purisima Formation, but its occurrence is not unexpected as it has been recorded in late Miocene to Pleistocene deposits from the northwestern Pacific (Roth, 1978). Its modern occurrence is from southeast Alaska to Santa Cruz Island, southern California (Roth, 1978) in water depths from the intertidal zone to 70 m (Radwin and D'Attilio, 1976).

Glen (1959) reported a single specimen questionably attributed to *Ocenebra interfossa* (Carpenter) from the Purisima Formation at Moss Beach. *Ocenebra interfossa* (Carpenter) has a modern occurrence from Price Williams Sound, Alaska (Talmadge, 1966) to Baja California (Rice, 1971) in the intertidal zone to 93 m (Kennedy, 1978). Its occurrence in the Purisima Formation is questionably included here until better preserved specimens are obtained. Arnold (1908a) reports an unidentified *Ocenebra* species (as *Tritonium* species, a) from his middle member and its occurrence needs confirmation.

Subfamily Thaidinae

Clark (1981) reported *Forreria coalingensis* (Arnold) from above the lowermost 60 m

of his Purisima Formation exposed southeast of Scotts Valley, Santa Cruz County, central California. This species appears to be restricted to the Pliocene as it has been previously reported only from the Etchegoin (Arnold, 1910) and the Jacalitos (Nomland, 1916) Formations both in the Coalinga District of central California. If the identification proves correct this taxon indicates a tie with the California Central Valley through the Santa Cruz-Sargent oil field area. Ashley (1895a) reported *F. belcheri* (Hinds) from Capitola. Modern specimens of *Forreria belcheri* (Hinds) are reported from Mugu Lagoon, Ventura County, southern California to Scammons Lagoon, central Baja California Mexico (McLean, 1978). Its occurrence from the Purisima Formation is not expected and Ashley's (1895a) specimen(s) are here referred questionably to *F. coalingensis* (Arnold) until such time as they can be examined.

Five Muricids all in the genus *Nucella* (i.e., *N. canaliculata* (Duclos*), N.? imperialis* (Dall), *N. lima* (Gmelin), *N. lamellosa* (Gmelin), and *N. transcoana* Arnold) have been reported from the Purisima Formation. Usually when so many taxa from a single genus are represented from a formation there has been misuse of names and the total number of taxa occurring in the formation is significantly less. This does not seem to be the case with the genus *Nucella* as all these taxa are fairly distinct.

Nucella canaliculata (Duclos) occurs from the Aleutian Islands, Alaska to Monterey Bay, California and is moderately common on rocks and mussel beds (Abbott, 1974). From the Purisima Formation it has been reported from the Sargent oil field area by Martin (1916) and Allen (1945) and questionably from Pillar Point (Glen, 1959). It has been reported as a fossil from the Elk River, Moonstone Beach. and questionably from the Carlotta Formations (Roth, 1979), the Merced Formation (Yancey, 1978), the Millerton Formation (Weaver, 1949), and from Pleistocene deposits from Big Hope Island, Washington (Henderson, 1927) to Cayucos, California (Valentine, 1958).

Arnold (1908a) reported *Nucella? imperialis* (Dall) (as *Chrysodomus imperialis* Dall) from his middle member of the Purisima Formation. Grant and Gale (1931) suggested that Arnold's specimens may not be cospecific with specimens exposed elsewhere under this name. *Nucella? imperialis* (Dall) is an extinct taxon which occurs in late Miocene to Pliocene rocks from Washington state to central California (Arnold and Hannibal, 1913; Arnold, 1910). Since it has not been reported since Arnold's time its occurrence in the Purisima Formation needs to be confirmed.

Nucella lamellosa (Gmelin) occurs in the eastern Pacific from the Bering Sea to Santa Cruz, California (Abbott, 1974). This species shows extensive variability, from smooth to heavily frilled (Kincaid, 1957), and varieties proposed by Dall (1915) are of no taxonomic value. It has been reported in rocks from Miocene to Holocene from Alaska to southern California (Grant and Gale, 1931). From the Purisima Formation it has been reported by several authors including Arnold (1908a) from his middle member, by Martin (1916) from Purisima [Creek?], by Allen (1945) from the Sargent oil field area, by Glen (1959) from Moss Beach, by Touring (1959) and Cummings and others (1962) from their Tahana Member, and by Perry (1993) from his *Crepidula* facies in the Capitola City Beach section.

Nucella lima (Gmelin) has been reported from the Purisima Formation in the Sargent oil field by Allen (1945) and questionably from Pillar Point (Glen, 1959). Abbott (1974) reported the modern occurrence of this taxon as common in the intertidal zone from Alaska to northern California in the eastern Pacific. Previously reported in rocks as old as early Miocene (Anderson, 1911) those occurrences are now referred to another species (Addicott, 1970). The oldest authenticated occurrence of *N. lima* is middle Miocene

(Etherington, 1931 *fide* Addicott, 1970). Grant and Gale (1931) also reported it from Pliocene and Pleistocene rocks from northern to southern California.

The last species of *Nucella* reported from the Purisima formation is *Nucella transcoana* Arnold. A significant discussion of it was presented by Addicott (1969). From the Purisima Formation it has been reported from the Sargent oil field area (Allen, 1945) and the *Clinocardium* facies in the Capitola City Beach section (Perry, 1993). Other fossil occurrences are from the Merced Formation (Hertlein and Allison, 1959), "Merced" Formation near Felt Lake (Addicott, 1969), and Cantil Costero Formation in northwestern Baja California (Hertlein and Allison, 1959).

Subfamily Trophoninae

Boreotrophon pacificus Dall has been reported from the Purisima Formation by Arnold (1908a). Arnold (1908a) reported it from his upper member, but this occurrence needs confirmation as it has not been recorded since that time. It has a modern range from Point Barrow, Alaska (MacGinitie, 1959) to deep water off Acapulco, Mexico (Dall, 1921a) in the eastern Pacific. As a fossil, aside from the Purisima Formation occurrence, it has been recorded from the Pleistocene of the San Pedro area, Los Angeles County, southern California (Arnold, 1903; Grant and Gale, 1931).

Family Buccinidae

Seven Buccinidae have been reported from the Purisima Formation: *Aulacofusus? recurva* (Gabb), *Beringius stantoni* (Arnold), *Colus.? purisimaensis* (Martin), *Kelletia kettlemensis* (Arnold), *Neptunea* sp., cf. *N. andersoni* (Martin), *N.* sp., aff. *N. lyrata* (Martyn), and *N. tabulata* (Baird). Most of these are represented by one or a few specimens and their occurrence in the Purisima Formation has not been verified.

Glen (1950) reports a single crushed specimen from Moss Beach which he questionably refers to *Aulacofusus? recurva* (Gabb) finding it different only in its stronger axial ribs. Because of the poor quality of the single specimen available its occurrence in the Purisima Formation need confirmation.

Beringius stantoni (Arnold) was described from the upper member of the Purisima Formation with a type locality in the sea cliffs between Tunitas and Pescadero Creeks, San Mateo County (Arnold, 1908a). It has also been reported by Arnold (1908) from near the mouth of Año Nuevo Creek (also by Martin, 1916), in the sea cliffs between Tunitas and Pescadero Creeks, in the sea cliffs west of Capitola (also by Addicott and others, 1978b and Perry, 1993 from his upper shell and *Crepidula* facies). In addition Mack, 1958 and Mack *in* Esser, 1958 reported it from the Woodside Quadrangle, and Touring (1959) and Cummings and others (1962) from the Tahana and Lobitos Members along the San Mateo Coast. These are the only known fossil occurrences of this taxon and it is restricted to the Purisima Formation.

Martin (1914) described *Colus? purisimaensis* (Martin) from the Purisima Formation at Año Nuevo Bay. It was also reported from Purisima [Creek?] by Martin (1916). Later, Cummings and others (1962) reported it from the Tunitas Member along the San Mateo County coast. This taxon is extinct and appears restricted to the Purisima Formation.

Both Martin (1916) and Allen (1945) reported *Kelletia kettlemensis* (Arnold) from the Purisima Formation in the Sargent oil field area. This is another species which by its distribution in the Purisima Formation and other occurrences outside the Purisima strongly suggest a Neogene seaway to the California Central Valley. *Kelletia kettlemensis* has been reported from the Etchegoin (Arnold, 1909 and Adegoke, 1969) and Jacalitos (Arnold, 1909, Arnold and Anderson, 1910) Formations.

Neptunea andersoni (Martin) is only known with certainty from the Rio Dell Formation in Humboldt County, northern California (Nelson, 1974). But it has been questionably reported from the Pomponio Member by Touring (1959) and Cummings and others (1962). Its occurrence in the Purisima Formation needs confirmation.

Arnold (1908a) reported *Neptunea* sp., aff. *N. lyrata* (Gmelin) [as *Chrysodomus* (aff.) *liratus* Martyn] from his middle member of the Purisima Formation. It has also been reported by Martin (1916) from Purisima [Creek?]. Nelson (1974) differentiated eight *N. lyrata* s.l. taxa in his review of world wide *Neptunea*. *Neptunea lyrata* (Gmelin) has not been recognized from the Purisima Formation since Martin's (1916) report and all references to this taxon have been questionable, so its occurrence needs confirmation.

The modern occurrence of *Neptunea tabulata* (Baird) is from Dixon Entrance, north of Queen Charlotte Island, British Columbia, Canada to San Diego, southern California in water depths between 90 m and 250 m (Nelson, 1974). From the Purisima Formation it has been reported by Ashley (1895a) from San Gregorio (as San Gregoria), by Arnold (1908a) from his upper member, by Martin (1916) from Purisima [Creek?], by Touring (1959) and Cummings and others (1962) from the Tahana Member in San Mateo County, by Galloway (1977) from Point Reyes (as *N. colmaensis* Martin), and by Clark (1981) from the lower part of the Purisima Formation west of Scott's Valley, Santa Cruz County, central California. Fossil occurrences elsewhere are in Pliocene and Pleistocene rocks from Clallam County, Washington to southern Orange County, southern California (Nelson, 1974).

Family Columbellidae

Three Columbellid taxa have been reported from the Purisima Formation: *Alia gausapata* (Gould), *Columbella richthofeni* Gabb in early literature, and *Mitrella gouldii* (Conrad), but these names all refer to a single species - *Astyris gauspata* (Gould) (McLean and Grosliner, 1996). All specimens examined from the Purisima Formation in USGS collections have been referred to this species. It has also been reported from the Purisima Formation at Purisima [Creek?] (Ashley, 1895a; Martin, 1916), by Arnold (1908a) from his upper member, by Martin (1916) from Año Nuevo and Martin (1916) and Glen (1959) from Moss Beach, in the Woodside Quadrangle by Mack (1958) and Mack *in* Esser (1958), in the San Juan Bautista Quadrangle (Allen, 1945), by Cummings and others (1962) who illustrated a specimen from their Pomponio Member, and by Addicott and others (1978b) from New Brighton/Seacliff State Beaches and Perry (1993) from the lower shell bed and upper shell facies in the Capitola city Beach section. It is also in USGS collection M8895 from Rodeo Gulch Road. *Astyris gausapata* (Gould) is reported to occur from the Alaska Peninsula Alaska to Punta San Pablo, Baja California Sur, Mexico (McLean and Grosliner, 1996) in rocks from Pliocene to Holocene age (Grant and Gale, 1931).

Family Photinae

Searlesia portolaensis (Arnold) was described in Arnold's (1908a) paper on new Cretaceous and Tertiary fossils from the Santa Cruz Mountains. He reported this taxon as very abundant in the Purisima Formation exposed on Sausal Creek, southwest of Portola (Arnold's middle member). Martin (1916) reported it from Purisima [Creek?] and the Sargents oil field area (also by Allen, 1945), and Addicott and others (1978b) and Perry (1993) reported it from Capitola Beach State Park. Elsewhere Arnold (1908a) reported it as occurring in eastern Monterey County and western Fresno County, giving the type locality as White Creek northwest of Coalinga in Fresno County (Etchegoin Formation). It has also been reported by Adegoke (1969) from the Etchegoin Formation. Based on its occurrences

it is assumed to range in age from late Miocene to Pliocene.

Family Pisaniinae

Cantharus humerosa (Gabb) has been reported from the Purisima Formation at San Gregorio by Ashley (1895a) and very questionably (aff.) by Arnold (1908a) from his middle member. Grant and Gale (1931) reported this taxon from Pliocene rocks in southern California and questionably from a single specimen from Crawfish George's (late Pleistocene) in San Pedro, Los Angeles County, but they suggested the Crawfish George's specimen is an error in labeling. This taxon is probably best restricted to the Pliocene as Crawfish George's appears to have a high percentage of reworked taxa.

Family Nassariidae

Six *Nassarius* taxa have been reported from the Purisima Formation (i.e., N*. californicus* (Conrad), *N. fossatus* (Gould), *N. grammatus* (Dall), *N. mendicus* (Forbes), *N. moranianus* (Martin), and *N. perpinguis* (Hinds). Based on modern concepts of the species involved (Addicott, 1965a, 1965b) and review of specimens in USGS collections only two taxa [*N. californicus* (Conrad) and *N. grammatus* (Dall)] appear to occur in the Purisima Formation.

Nassarius californius (Conrad) was redefined and identified as a Pliocene taxon by Addicott (1965b) who reported it from the Merced, Merced(?), Purisima, Etchegoin, San Joaquin, Foxen and Careaga Formations in central California and from unnamed Pliocene strata in the Ventura Basin (Addicott, 1965a). In the past specimens referable to this species have been assigned many names, but Addicott (1965a) resolved those problems redefining and illustrating the species. Citations of this species prior to Addicott (1965b) should be questioned. Ashley (1895a) reported it from Capitola (also by Perry, 1993 from his lower shell bed and upper shell facies), Arnold (1908a) from his middle and upper members, and Martin (1916) reported it from Purisima [Creek?] and near Año Nuevo Creek. Records of *N. mendicus* (Forbes) from the Purisima Formation (Martin, 1916 from the Sargents oil field area; Mack, 1958; Mack *in* Esser, 1958 from the Woodside Quadrangle) are probably referable to this species.

Nassarius grammatus (Dall) has been reported from Pliocene formations from Humboldt County, northern California to San Diego and possibly Baja California Norte, Mexico (Addicott, 1965a). All larger *Nassarius* in USGS collections from the Purisima Formation are referable to this species. Specimens from the Purisima Formation referred to *N. fossatus* (Gould) and *N. moranianus* (Martin) are probably *N. grammatus* (Dall), because both of these taxa occur in rocks that are generally younger. *Nassarius moranianus* (Martin) has a late Pliocene to Pleistocene range and does not seem to co-occur with *N. grammatus* (Dall), so its occurrence in the Purisima Formation is questionable. *Nassarius fossatus* (Gould) does not seem to have been reported from rocks older than Pleistocene. From the Purisima Formation Ashley (1895a) reported it from San Gregorio (also as *Nassa perpinguis* Hinds), Martin (1916) reported it from Año Nuevo Creek and the Sargent oil field area [questionably as *N. moranianus* (Martin) (also by Allen, 1945) and *N. fossatus* Gould], Touring (1959) and Cummings and others (1962) reported it as *N. moranianus* (Martin) from the Tahana and Tunitas Members, Durham and Morgan (1978) reported it from the central San Mateo coast, and Addicott and others (1978b) reported it from Capitola Beach (also by Perry, 1993 in his lower shell bed, *Clinocardium*, and upper shell facies) and Seacliff-New Brighton State Beaches. The report of *Nassarius* cf. *N. paroinguis* (Hinds) [sic. *N. perpinguis* (Hinds)] (Cummings and others, 1962) from the

Tahana, Pomponio and Tunitas Members, was referred by Addicott (1965b) to *N. grammatus* (Dall) which is followed here. Other reports of *N. perpinguis* (Hinds) from the Purisima Formation (Arnold, 1908a (aff.); Mack, 1958; Mack *in* Esser, 1958) are probably also referable to juvenile specimens of *N. grammatus* (Dall).

Family Volutidae

Arnold's (Arnold, 1908a) illustration of a volutid under the name *Miopleiona oregonensis* Dall from the Purisima Formation at Año Nuevo preceded by about 8 months the description of this taxon by Dall (1909) thereby making Arnold the author, his specimen the type, and Año Nuevo Point the type locality. *Psephaea oregonensis* (Arnold) has been reported in rocks of Miocene to Pliocene age from Coos Bay, Oregon to San Diego, California (Grant and Gale, 1931). Arnold (1908a) reported it from his upper member, Martin (1916) from Purisima [Creek?], Cummings and others (1962) from the Pomponio Member, and Mack (1958) and Mack *in* Esser (1958) from the Woodside Quadrangle. Arnold's specimen (Arnold, 1908a) is referred to undifferentiated Purisima until its type locality can be ascertained with precision.

Arnold (1908a) also reports an indeterminate "*Voluta*" from his upper member. What this specimen represents is unknown until Arnold's specimen can be reexamined.

Family Olividae

Four species of *Olivella* have been reported from the Purisima Formation, *Olivella baetica* Carpenter, *O. biplicata* (Sowerby), *O. intorta* Carpenter, and *Olivella pedroana* (Conrad). All *Olivella* in USGS collections and observed in the field are referable to *O. pycna* Berry [=*Olivella biplicata* (Sowerby), slender var. of Woodring and Bramblette, 1950, *Olivella* cf. *O. pedroana* (Conrad) of Addicott (1966)]. Until such time as examples of *O. baetica* Carpenter, *O. biplicata* (Sowerby) and/or *O. pedroana* (Conrad) (syn. *O. intorta* Carpenter) are found in the Purisima Formation their occurrence there is in doubt. *Olivella pycna* Berry has a modern occurrence from Seaside Rock, Clatsop County, Oregon (Gifford and Gifford, 1948) south to Morro Rock, San Luis Obispo Co., California in water depths from the intertidal zone to 27 m (Burch, 1944-46). *Olivella pycna* Berry has been reported from the Purisima Formation by Arnold (1908a) (as *O. intorta* Carpenter and *O. pedroana* Conrad) from his middle and upper members, by Martin (1916) from near Año Nuevo Creek and the Sargent oil field area [as *O. biplicata* (Sowerby) and *O. pedroana* (Conrad)] (also by Allen, 1945 from the later site), by Touring (1959) and Cummings and others (1962) (as *O. baetica* Carpenter) from the San Gregorio and Tunitas Members in San Mateo County, and by Addicott and others (1978b) (as *O. biplicata* Sowerby) and Perry (1993) [as *O. pedroana* (Conrad)] from the Capitola City Beach area. Other fossil occurrences of this taxa are from the Careaga Sandstone (Woodring and Bramblette, 1950), from the Elk River Formation, Moonstone Beach Formation, and Carlotta(?) Formation by Roth (1979), and from Pleistocene terrace deposits at Año Nuevo State Reserve (Addicott, 1966).

Family Cancellariidae

Admete gracilior Carpenter has a modern occurrence from Baja California Sur to Monterey Bay, California in water depths from 60 to 250 m (McLean and Grosline, 1996). It has been reported from the Purisima Formation only by Arnold (1908a), from his upper member. Woodring and Bramlette (1950) reported specimens identified as *A. gracilior* Carpenter from Fugler Point in the Santa Maria Basin, southern California, but stated "The

relationship of two named but unfigured Recent forms, *A. rhyssa* and *A. woodworthi*, to *A. gracilior* are undetermined, but one or both are probably *gracilior*." This was recently confirmed by McLean and Grosliner (1996) who report both as synonymous. According to Woodring and Bramlette (1950) *Admete gracilior* Carpenter was described from the Pleistocene Santa Barbara Formation but it was not mentioned by Grant and Gale (1931) in their review of Pleistocene and Pliocene mollusks of California.

Cancellaria arnoldi (Dall) has been reported from the Purisima Formation by Addicott and others (1978b) and Perry (1993) and is well represented in USGS collections from the Santa Cruz area. Perry (1993) reported it occurring in his lower three facies, lower shell bed, *Clinocardium*, and upper shell facies. It has been previously reported in the Pliocene to possibly early Pleistocene in southern California, from the following formations: Fernando (Vedder, 1972), Foxen Mudstone, and Careaga Sandstone (Woodring and Bramlette, 1950), Niguel (LACMIP collections), and San Diego (Dall, 1909). It is represented in USGS collections from the Purisima Formation at Capitola City Beach (M8845) and Rodeo Gulch Road (M8859).

Carson (1926) described *Cancellaria palmeri* Carson from the Purisima Formation at Capitola. Grant and Gale (1931) synonymizied this taxon under *Cancellaria tritonidae* Gabb s.l. also synonymizing *C. rapa* Nomland, *C. hamlini* Carson, *C. altispira* Gabb, *C. fernandoensis* Arnold, and *C. crassa* Nomland. As defined by Grant and Gale (1931) *C. tritonidae* Gabb occurs in rocks of Pliocene to Pleistocene age in southern to central California . Other records of *Cancellaria tritonidae* Gabb from the Purisima Formation are Ashley (1895a) from Capitola, and Martin (1916) and Allen (1945) from the Sargent oil field area, all as *C. tritonidae* Gabb. It has also been found in one USGS collection (M8845) from Capitola City Beach. The name *Cancellaria palmeri* Carson is resurrected here for the smooth form lacking varices which occurs in the Purisima Formation and all the specimens above are attributed to that species. Arnold (1908a) also reported an indeterminate *Cancellaria* from his upper member of the Purisima Formation. This taxon is in need of verification and may be referable to *C. palmeri* Carson when Arnold's (1908a) specimens are re-examined.

In the same paper Carson (1926) described *Cancellaria oldroydi* Carson from the Purisima Formation near the mouth of Purisima Creek. This species is related to the modern *C. crawfordiana* Dall differing in its larger size, coarser sculpture of more prominent external siphonal fasciole. It has not been reported since Carson's time and is not in USGS collections.

Family Turriculinae

Three *Megasurcula* taxa have been reported from the Purisima Formation (i.e., *Bathytoma carpenteriana* Gabb, *Bathytoma carpenteriana* Gabb var. *fernandoana* Arnold, and *Megasurcula* sp. *fide* Addicott and others, 1978b) from Capitola State Beach in Santa Cruz, but in USGS collections only *M. stearnsiana* (Raymond) has been reported.

Megasurula carpenteriana (Gabb) has been reported in rocks as old as Pliocene from central California (Grant and Gale, 1931). It has been reported from the Purisima Formation at Capitola (Ashley, 1895a), Purisima [Creek?] (Martin, 1916) and near Año Nuevo Creek (Martin, 1916), at Point Reyes (Galloway, 1977). The modern occurrence is from Bodega Bay, central California to Cedros Island, central Baja California, Mexico offshore on sandy bottoms from 15 to 100 m (50 to 300 ft) (McLean, 1978), although Talmadge (1973) reported specimens as far north as Eureka, California (about 41°N).

Megasurcula stearnsiana (Raymond) [=*Megasurcula remondii* (Gabb); = *M.*

carpenteriana fernandoana Arnold] occurs in rocks of Miocene to Holocene age occurring from Washington to southern California (Grant & Gale, 1931). Modern occurrence is from Monterey Bay, central California, to Todos Santos Bay, Baja California Norte, Mexico (McLean, 1978) commonly offshore on sandy bottoms. This taxon has been reported by Arnold (1908a) from his upper member and by Perry (1993) from his upper shell facies at Capitola City Beach. Arnold (1908a) also reported an indeterminate *Pleurotoma* from his middle member. Until such time as this specimen can be re-examined it will have to be questionably referred to *Megasurcula?* sp. indet.

Family Turridae

Martin (1916) reported *Antiplanes catalinae* (Raymond) (as *A. perversa* Gabb) from Purisima [Creek?]. *Antiplanes perversa* Gabb has just recently been synonymized under *A. catalinae* (Raymond) with a modern occurrence from Queen Charlotte Sound, British Columbia (51.5°N) to San Diego, California (33°N) on soft bottoms from 90 m to 270 m (McLean and Gosliner, 1996). The fossil record of this taxon is confused as Grant and Gale (1931) placed all sinstral and dextral *Antiplanes* described from the eastern Pacific in synonymy. They believed that both forms could occur in the same species, but this has proved untrue. Until such time as the stratigraphic occurrences of this taxon can be sorted out I know of no definite occurrences older than Pleistocene, but would not be surprised if this taxon occurs in the Pliocene.

Family Borsoniinae

Ophiodermella graciosana Arnold is an extinct Pliocene taxon which has been reported from the Purisima Formation by Arnold (1908a) from his upper member, by Martin (1916) from Año Nuevo Point, from east of Santa Cruz (Addicott and others, 1978b and Perry, 1993), and from the Sargent oil field area by Allen (1945). Martin (1916) cited *Ophiodermella mercedensis* (Martin) from Purisima [Creek?] and the Sargent oil field area, but Yancey (1978) showed that this taxon is stratigraphically younger than *O. graciosana* Arnold and probably should not be expected in the Purisima Formation. Here the specimens cited by Martin (1916) and Allen (1945) are referred to *O. graciosana* Arnold, until such time as they can be examined. The fossil record of *Ophiodermella graciosana* Arnold is from the Careaga Sandstone of the Santa Maria District of southern California (Woodring and others 1950), from a single specimen from the lower part of the Merced Formation in the Twelvemile Creek area (Yancey, 1978) and from the "Merced" Formation near Felt Lake, San Mateo County (Addicott, 1969).

Family Odostomiinae

The genus *Odostoma* is represented by a single poorly preserved specimen in USGS collections from Capitola (M8856) and has been reported by Perry (1993) from his upper shell facies at Capitola.

Family Turbonillinae

Perry (1993) reported indeterminate *Turbonilla* from the upper shell facies of the Purisima Formation at Capitola City Beach. Taxonomically the genus *Turbonilla* is in need of review and until such time as that is accomplished this taxon is referred only to genus.

Family Acteonidae

Acteocina culcitella (Gould) is locally common on sand and mudflats in bays, but

also offshore on soft bottoms from Kodiak Island, Alaska to San Ignacio Lagoon, Baja California Sur, Mexico (McLean, 1978). Arnold (1908a) reported this taxon from his middle member and its occurrence in the Purisima Formation is in need of confirmation. Grant and Gale (1931) recorded it only from the Pliocene and Pleistocene from southern California and northern Baja California, Mexico.

Rictaxis punctocaelatus (Carpenter) is locally common on sandy bottoms in bays, at low tide and in shallow sublittoral zones from Ketchikan, Alaska, to Magdalena Bay, Baja California, Mexico (McLean, 1978). It is reported from the Purisima Formation by a single well preserved specimen from Rodeo Gulch Road in USGS collections.

Family Trimusculidae

Trimusculus reticulatus (Sowerby) is found in colonies on overhung surfaces along rock ledges at about the mid-tide level from Kayostla Beach, northern Washington (Goddard, Wayne, and Wayne, 1997) to Acapulco, Mexico (McLean, 1978). It has been reported from a single specimen from the Tahana Member along the central San Mateo County coast (Touring, 1959; Cummings and others, 1962) and its occurrence needs to be confirmed.

Class Scaphopoda

Family Dentaliidae

Touring (1959) reported three specimens questionably referred to the genus *Dentalium* from the San Gregorio Member along the central San Mateo County coast. Perry (1993) also reported indeterminate *Dentalium* from his upper shell facies at Capitola.

Phylum Echinodermata
Class Ophiuroidae

Family Ophiuridae

Galloway (1977) questionably reported the brittle-star *Ophioplocus*? sp. from Point Reyes. According to Durham and others (1966) the genus (questionably identified from the Purisima Formation) has only been reported from the modern ocean. Brittle stars are notoriously difficult to identify and are commonly poorly preserved. Until such time as better material is available this taxon is left as Galloway (1977) cited it.

Class Asteroidea

Family Asteriidae

Perry (1977) reported the starfish *Piaster* sp. from near Soquel Point. This was later refined by Perry (1993) to his upper shell facies in the Capitola City Beach section of the Purisima Formation. A beautiful specimen awaiting study is on display at the Santa Cruz City Museum of Natural History.

Class Echinoidea

Family Echinarachniidae

Arnold (1908a) reported a new species of *Astrodapsis* from his upper member of the Purisima Formation which he stated is exposed in the sea cliffs in the vicinity of Purisima Creek, east of Point Año Nuevo, and east of Santa Cruz. Interestingly specimens questionably referred to the genus *Astrodapsis* have been collected from the Sargent oil field area, so its occurrence in the Purisima Formation is possible, although it could easily be con-

fused with the genus *Merrimaster* (see below).

Family Dendrasteridae

Allen (1945) reported *Dendraster ashleyi* (Arnold) from the Sargent oil field area. It has also been reported by Cummings and others (1962) questionably from the San Gregorio Member in San Mateo County. No other occurrences of this taxon from the Purisima Formation are known and its identification will have to be verified. It has also been reported in Pliocene rocks from the Gracisa Member of the Careaga Sandstone in the Santa Maria District in Santa Barbara County (Arnold and Anderson, 1907; Woodring and Bramlette, 1950), the San Diego Formation (Hertlein, 1929), from unnamed sediments near San Isidro, Baja California Sur, Mexico (Santillán and Barrera, 1930), and at Turtle Bay, Baja California Sur, Mexico (Hertlein, 1933).

Dendraster gibbsii (Rémond) was reported from the the Purisima Formation by Ashley (1895a) at Capitola (also by Perry, 1993 from his *Clinocardium* and upper shell facies), by Martin (1916) at Purisima [Creek?] and the Sargent oil field area (also by Allen, 1945), and by Cummings and others (1962) in their San Gregorio Member. There are no other references to this taxon from the Purisima Formation and its identification will have to be verified as it could have been confused with the newer taxon described by Durham and Morgan (1978), *D. sullivani* Durham and Morgan and/or *D. ashleyi* (Arnold) (R. Mooi, oral commun., 1998). *Dendraster gibbsii* (Rémond) also occurs in the Jacilotus, Etchegoin, and San Joaquin Formations of the California central valley (Woodring and Bramlette, 1950). These formations range in age from late Miocene to late Pliocene in age.

Dendraster sullivani Durham and Morgan from the Tahana Member of the Purisima Formation appears to be restricted to the type locality near San Gregorio Beach, San Mateo County, California (Durham and Morgan, 1978).

Also recently described is *Merrimaster weaveri* Durham and Morgan from the Tahana Member of the Purisima Formation and it appears to be restricted to its type locality near San Gregorio Beach, San Mateo County, California (Durham and Morgan, 1978). Martin (1916) recorded *M. perrini* (Weaver) (as *Scutella perrini* Weaver) from Purisima [Creek?] in San Mateo County and Allen (1945) recorded *M. arnoldi* (Twitchell) from the Sargent oil field area. Specimens referred to the former were later questionably referred to Durham and Morgan's (1978) new taxon. Specimens of the latter were not studied here but will have to be examined before *M. arnoldi* (Twitchell) can be definately reported from the Purisima Formation.

Cummings and others (1962) reported *Scutellaster oregonensis* (Clark) from the San Gregorio Member in San Mateo County, and Glen (1959) reported it from Mussel Rock. *Scutellaster oregonensis* (Clark) has been previously reported from Miocene Empire Formation near Fossil Point and Empire City, Coos Bay, Oregon (Clark *in* Dall, 1909). Martin (1916) reported *S.* sp. cf. *S. interlineata* (Stimpson) occurring at Purisima [Creek?}, but *S. interlineata* (Stimpson) appears to be restricted to the Pleistocene Merced Foramtion so the specimens are questionably referred to *S.* sp., cf. *S. oregonensis* (Clark).

Family Asterostomatidae

The report of *Megapetalus* sp., cf. *M. lovenoides* H. L. Clark from the Purisima Formation at Point Reyes seems out of place. *Megapetalus lovenoides* Clark is a late Miocene taxon which has previously only been reported from Santa Margarita equivalent sediments in the Ventura Quadrangle (Grant and Hertlein, 1938), over 600 km to the south. While the age of the specimen may be in keeping with reported age determinations of the

lower part of the Purisima Formation, the Purisima specimen occurrence so far north of the reported occurrence of this taxon to suggests a misidentification.

Phylum Arthropoda
Class Crustacea

Family Balanidae

Balanus (Tamiosoma) gregarius (Conrad) ranges in age from early Miocene through Pleistocene in central, southern, and Baja California and was thought to represent warm, shallow embayments with high sedimentation rates (Zullo, 1964). It has been reported from the Purisima Formation by Touring (1959) and Cummings and others (1962) from the Pomponio and Tahana Members in San Mateo County, from the *Crepidula* facies in the Capitola City Beach section (Perry, 1993), and from the Sargent oil field area (USGS collections).

Balanus nubulis Darwin is common on rocks, pier pilings, and hard-shelled animals from the low intertidal zone to about 90 m from southern Alaska to La Jolla, San Diego County, California (Morris and others, 1980). This species is easily confused with *B. aquila* Pilsbry and its occurrence and the occurrence of *B. aquila* Pilsbry from the Purisima Formation need to be checked. This species has been reported from the Purisima Formation by Cummings and others (1962) who illustrated a specimen from the Pomponio Member of the Purisima Formation and questionably reported it from the Tunitas, Pomponio, and Tahana Members in San Mateo County (also reported by Touring, 1959).

Balanus aquila Pilsbry occurs on rocks, pier pilings, and abalone shells from the low intertidal zone to about 18 m from San Francisco, central California to San Diego, San Diego County, California (Morris and others, 1980). The only fossil record of this species is the questionable report from the Foxen Mudstone and Careaga Sandstone in the Santa Maria District, central California (Woodring and others, 1950), although Morris and others (1980) stated that “This species... is one of the last surviving member of the *concavus* group, known as fossils from the Oligocene - Pleistocene period in Europe and in North and South America and from the Pliocene period in Japan.” Cummings and others (1962) illustrated a specimen from the Pomponio Member and with Touring (1959) reported it questionably from the Pomponio Member in San Mateo County.

Touring (1959) and Cummings and others (1962) reported a small barnacle growing on a worn indeterminate *Neptunea* from the Tahana Member in San Mateo County.

Family Callianassidae

Perry (1993) reported *Callianassa gigas* Dana (as *C. longimana* Stimpson) from his upper shell bed in the Capitola City Beach section. This species is common in the intertidal zone from southern Alaska to Estero de Punta Banda, Baja California Sur, Mexico (Morris, Abbott, and Haderlie, 1980).

Family Majidae

Perry (1977, 1993) reported the genus *Loxorhynchus* from the Purisima Formation. Specimens in the Santa Cruz City Museum of Natural History verify these records and are in need of further study.

Family Cancridae

Four species of the crab genus *Cancer* have been reported from the Purisima Formation (Nations, 1975; Perry, 1993). The first is *Cancer fissus* Rathbun which is known

only from the late Miocene to late Pliocene (Nations, 1975 and Purisima Formation occurrences). It has been reported from the Miocene Etchegoin Formation (Rathbun, 1908), the Pliocene Cascajo Conglomerate (Nations, 1975) and Purisima Formation (Nations, 1975). The second taxon is *C. marri* Nations which Nations (1975) reported from the Etchegoin, Purisima, and Merced Formations indicating a late Miocene to possibly early Pleistocene age for this taxa. The third is *Cancer magister* Dana, a modern species which ranges from Unalaska, Alaska south to Monterey Bay, central California (Nations, 1975). It has a fossil record from the Pliocene and Pleistocene from northern to southern California (Nations, 1975) and has been reported from the Purisima Formation by Perry (1993) from his upper shell bed in the Capitola City Beach section. The fourth is *C. productus* Randall which Perry (1993) reported from the upper shell and *Crepidula* facies in the Capitola City Beach section. *Cancer productus* Randall is a modern taxa which ranges from Kodiak Island, Alaska to Laguna Beach southern California at depths from the intertidal zone to 43 fathoms (Rathbun, 1930). It has also been reported as a fossil from the Pliocene and Pliestocene of California (Nations, 1975).

Order Stomatopoda

Perry (1993) reported an indeterminate Mantis shrimp from his upper shell bed in the Capitola City Beach section.

APPENDIX 2 - FOSSIL LOCALITIES

USGS Cenozoic localities, Menlo Park register

M2146. Field No.: WA603. Seacliff exposure between Año Nuevo Creek and Finny Creek about 1.5 mi E of Point Año Nuevo, Año Nuevo 7.5' Quadrangle, San Mateo Co., CA. Coll. by W. O. Addicott and J. Miller, June 1964.

M3618. Field No.: none. Seacliff at NW end of New Brighton Beach State Park, Capitola, Soquel 7.5' Quadrangle. Santa Cruz Co., CA. Coll. J. G. Vedder, 1958.

M4288. Field No.: 70CB861. Dirt road up the ridge at bend in Cascade Creek about 6,100 ft W and 6,400 ft N from 122°17'30" W tick at S boundary of the grid, Franklin Point 7.5' Quadrangle, San Mateo Co., CA. Coll. by E. Brabb, 1970.

M4289. Field No.: 70CB863. Base of knoll SE of mouth of Old Woman Creek at Gazos Creek, 8,400 ft S and 1,250 ft W from 37°12'30" N and 122°20' W, Franklin 7.5' Quadrangle, San Mateo Co., CA. Coll. by E. Brabb, 1970.

M5078. Field No.: JC57. 1,950 ft S of 37°02.5' N by 2.500 ft E of 122°2.5'W, Felton 7.5' Quadrangle at an elevation of 840 ft, Santa Cruz Co., CA. Coll. by J. C. Clark.

M5080. Field No.: JC59A. 2,250 ft E and 1,200 ft S of SW corner of section 18, T. 10 S., R. 1 W., unsectioned, in Felton 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark.

M5091. Field No.: JC70. 750 ft N and 1,600 ft E of SW corner of section 1, T. 10 S., R. 2 W., Felton 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark.

M5109. Field No.: JC27. 2,150 ft E and 2,050 ft N of SW corner of section 30, T. 9 S., R. 1 W., Felton 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark, 1966.

M5115. Field No.: JC32. On E side of Mountain Charlie Gulch about 3,900 ft W and 3,350 ft N of SE corner of section 32, T. 9 S., R. 1 W., Laurel 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark, 1966.

M5117. Field No.: JC34. E of Scotts Valley 4,450 ft N and 250 ft W of SE corner of section 19, T. 10 S., R. 1 W., Felton 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark, 1966.

M5123. Field No.: JC41. 1,250 ft E and 1,750 ft N of SW corner of section 1, T. 10 S., R. 2 W., Felton 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark, 1966.

M5124. Field No.: JC43. 1,350 ft W and 550 ft N of SE corner of section 1, T. 10 S., R. 2 W., Felton 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark, 1966.

M5130. Field No.: JC45A. 1,150 ft E and 750 ft S of NW corner of section 12, T. 10 S., R. 2 W., Felton 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark, 1966.

M5136. Field No.: JC77. 1,150 ft W and 2,700 ft N of SE corner of section 30, T. 10 S., R. 1 W., Felton 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark, 1962.

M5137. Field No.: JC79. E side of Scott's Valley about 3,800 ft E and 3,200 ft S of SW corner of section 18, T. 10 S., R. 1 W., Felton 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark.

M5154. Field No.: JC107. From bank of Año Nuevo Creek 200 ft W of San Gregorio fault, about 150 ft S and 2,950 ft W of NW corner of section 27, T. 9 S., R. 4 W., Año Nuevo 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark, 1968.

M5160. Field No.: JC18. Just W of Mountain Charlie Road about 2,050 ft W and 2,750 ft N of SE corner of section 32, T. 9 S., R. 1 W., Laurel 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark, 1960.

M5161. Field No.: JC5. 400 ft W and 550 ft N of SW corner of section 17, T. 10 S., R.1 W., Laurel 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by J. C. Clark, 1966.

M5890. Field No.: none. Ashbury Gulch near headwaters of Soquel Creek, Laurel 7.5' Quadrangle, Santa Cruz Co., CA. Latitude: 36.100° N., Longitude: 121.897° W. Coll. by A. Sarna-Wojcicki, 1973.

M6545. Field No.: EB75-1415. W end of Chittenden Pass Rd., 4,000' S and 8,500' E of NW corner of T. 12 S., R. 3 E., Watsonville East 7.5' Quadrangle, Santa Cruz Co., CA. Latitude: 36.914°N, longitude: 121.661°W. Coll. by E. Brabb, 1975.

M6546. Field No.: EB75-1424. In SSW trending gully N of Chittenden Pass Rd. about 1 mi W of Pajaro Gap at an altitude of about 400', about 3,900' S and 12,700' E of NW corner of T. 12 S., R. 3 E., Watsonville East 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by E. Brabb, 1975.

M6547. Field No.: 75EB-1414. W end of Chittenden Pass Rd., about 2 mi. W of Pajaro Gap, 2,950' S and 8,900' E of NW corner of T. 12 S., R. 3 W., Watsonville East 7.5' Quadrangle, Santa Cruz Co., CA. Latitude: 36.915°N, longitude: 121.660°W. Coll. by E. Brabb, 1975.

M6548. Field No.: 75EB-1413. Ridge W of Pajaro Gap, 2.050' S and 3,500' W of 35.882°N and 121.623°W., Watsonville East 7.5' Quadrangle, Santa Cruz Co., CA. Coll. by E. Brabb, 1975.

M6549. Field No.: 75CB-1406. Along road on ridge S of Mattos Gulch, 250' N and 7,700' E of SW corner T. 11 S., R. 3 E., Watsonville East 7.5' Quadrangle, Santa Cruz Co., CA. Latitude: 36.927°N, longitude: 121.665°W. Coll. by E. Brabb, 1975.

M8498. Field No.: CaMe84P26. *Patinopecten* collected from near beach level about 170 ft S of crest of anticline about 1/2 way between San Gregorio and Pomponio Beaches, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Latitude: 37.693°N., longitude: 122.497°W. Coll. by E. & G. Moore, 1984.

M8823. Field No.: CaMe85-5. Specimen from base of shell bed about 230 ft S of electric gate at S end of row of houses, Seacliff, Santa Cruz Co., CA. Soquel 7.5' Quadrangle. Coll. by E. Moore, 1985.

M8845. Field No.: CaMe85-20. Collection from 155 ft E of E end of Capitola breakwater from *Clinocardium* "facies" of Frank Perry, Santa Cruz Co., CA. Soquel 7.5' Quad-

rangle. Coll. by E. J. Moore, June 1985.

M8846. Field No.: CaMe85-13. Fossils from 1,800 ft N of Tunitas Creek about 3 m above a horizon which makes water and could mark the top of the Lobitos Mudstone Member of the Purisima Formation, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by E. Moore, June 1985.

M8848. Field No.: CaMe85-14. About 1,270 ft N of Point at San Gregorio public beach, San Mateo Co., California. San Gregorio 7.5' Quadrangle. Coll. by E. Moore, June 1985

M8849. Field No.: CaMe85-11. Mudstone in sea cliff about 225 ft N of Purisima Creek in type section of Gregorio Member of the Purisima Formation, San Mateo Co., CA. Half Moon Bay 7.5' Quadrangle. Coll. by E. Moore, June 1985.

M8856. Field No.: CaMe85-18. Collection from 150 ft E of E end of Capitola breakwater from *Clinocardium* "facies" of Frank Perry, Capitola Beach, Santa Cruz Co., CA. Soquel 7.5' Quadrangle. Coll. by E. Moore, June 1985.

M8857. Field No.: CaMe85-14. Specimens from 1,270 ft N of point at public beach, San Gregorio Beach, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by E. Moore, June 1985.

M8858. Field No.: CaMe85-17. Specimens from *Clinocardium* facies of Frank Perry located 650 ft E of E end of Captola breakwater, Capitola Beach, Santa Cruz Co., California. Soquel 7.5' Quadrangle. Coll. by E. Moore, June 1985.

M8859. Field No.: CaMe85-21. Rodeo Gulch Road about 0.1 mi S of Laurel Glen Road, Santa Cruz Co., CA. Coll. by E. Moore, September 1985.

M8861. Field No.: CaMe85-15. Shell-lag facies of Frank Perry located 1,520 ft E of E end of Capitola breakwater, Captiola Beach, Santa Cruz County, CA. Soquel 7.5' Quadrangle. Coll. by E. Moore, June, 1985.

M8862. Field No.: CaMe85-16. *Clinocardium* facies of Frank Perry located about 930 ft E of E end of Capitola breakwater, Capitola Beach, Santa Cruz County, CA. Soquel 7.5' Quadrangle. Coll. by E. M. Moore, June, 1985.

M8869. Field No.: CaMe85-10. In mudstone sea cliff 530 ft N of Purisima Creek, San Mateo Co., CA. Half Moon Bay 7.5' Quadrangle. Coll. by E. Moore, 1985.

M8870. Field No.: CaMe85-12. *Crepidula* bed at point at S end of beach about 2,000 ft S of Purisima Creek in the type section of the San Gregorio Member of the Purisima Formation, San Mateo Co., California. Half Moon Bay 7.5' Quadrangle. Coll. by E. Moore, June 1985.

M8880. =M8870.

M8910. Field No.: 470-1. Seacliff about 3,550 ft N of mouth of Pomponio Creek, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8911. Field No.: 672. San Gregorio Rd about 250 ft from E edge of Quadrangle, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8912. Field No.: 469-3. Sea cliff about 2,700 ft N of mouth of Tunitas Creek, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8913. Field No.: 482-3. Sea cliff about 4,000 ft S of mouth of Tunitas Creek, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8914. Field No.: 467-7. Sea cliff about 700 ft S of mouth of Pomponio Creek, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8915. Field No.: 470-2. Sea cliff about 4,250 ft N of mouth of Pomponio Creek, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8916. Field No.: 469-5. Sea cliff about 1,900 ft N of mouth of Pomponio Creek, San

Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8918. Field No.: 667. E fork of Tunitas Creek about 100 ft above Tunitas Road in section 26, T. 6 S., R. 5 W., San Mateo Co., CA. Woodside 7.5' Quadrangle. Coll. by R. M. Touring.

M8919. Field No.: RMT 653. Tunitas Creek about 150 ft below mouth of the east fork in section 26, T. 6 S., R. 5 W., San Mateo Co., CA. Woodside 7.5' Quadrangle. Coll. by R. M. Touring.

M8920. Field No.: 480-1. Sea cliff about 3,900 ft N of mouth of Pomponio Creek, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8921. Field No.: 469-2. Sea cliff about 2,900 ft N of mouth of Pomponio Creek, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8922. Field No.: 681. Collected along State Highway 1 northwest of San Gregorio, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8924. Field No.: 788A. Collected along Dry Creek about 950 ft W of E edge of San Gregorio 7.5' Quadrangle, San Mateo Co., CA. Coll. by R. M. Touring.

M8925. Field No.: 481-2. Sea cliff about 1,300 ft N of mouth of San Gregorio Creek, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8926. Field No.: 688. Sea cliffs S of Martins Beach, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8927. Field No.: 469-4. Sea cliff about 2,500 ft N of mouth of Pomponio Creek, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8928. Field No.: 482-4. Sea cliff about 4,000 ft S of mouth of Tunitas Creek, San Mateo Co., CA. San Gregorio 7.5' Quadrangle. Coll. by R. M. Touring.

M8929. Field No.: 625. Purisima Creek in section 16, T. 6 S., R. 5 W., Half Moon Bay 7.5' Quadrangle, San Mateo Co., CA. Coll. by R. M. Touring.

M8930. Field No.: 632. Purisima Creek in section 21, T. 6 S., R. 5 W., Half Moon Bay 7.5' Quadrangle, San Mateo Co., CA. Coll. by R. M. Touring.

M8931. Field No.: 693. Sea cliff 1,300 ft N of mouth of Lobitos Creek, San Mateo Co., CA. Half Moon Bay 7.5' Quadrangle. Coll. by R. M. Touring.

M8932. Field No.: 643. Seacliff in section 6, T. 6 S., R. 5 W., San Mateo Co., CA. Half Moon Bay 7.5' Quadrangle. Coll. by R. M. Touring.

M8933. Field No.: 692. Seacliff at mouth of Purisima Creek, San Mateo Co., CA. Half Moon Bay 7.5' Quadrangle. Coll. by R. M. Touring.

M8934. Field No.: 645. Seacliff at mouth of Purisima Creek, San Mateo Co., CA. Half Moon Bay 7.5' Quadrangle. Coll. by R. M. Touring.

M8935. Field No.: 701. Sea cliff about 1,850 ft N of mouth of Purisima Creek, San Mateo Co., CA. Half Moon Bay 7.5' Quadrangle. Coll. by R. M. Touring.

M8936. Field No.: 645-3. Sea cliff about 1,150 ft N of mouth of Purisima Creek, San Mateo Co., CA. Half Moon Bay 7.5' Quadrangle. Coll. by R. M. Touring.

M8938. Field No.: 685-3. Sea cliff about 3,000 ft S of mouth of Arroyo Canada Verde, San Mateo Co., CA. Half Moon Bay 7.5' Quadrangle. Coll. by R. M. Touring.

M8939. Field No.: RMT803. New Brighton Beach State Park, Santa Cruz Co., CA. Coll. by R. M. Touring.

M8940. Field No.: RMT802. Sea Cliff Beach State Beach, Santa Cruz Co., CA. Coll. by R. M. Touring.

M8941. Field No.: Field No.: none. Collected near Santa Cruz at base of Tahana Member of Purisima Formation, Santa Cruz Co., CA. Coll. by R. M. Touring.

M9022. Field No.: CaMe86-5. Specimens collected from near base of 120-foot high bluff

about 3 m E of electric gate at S end of row of houses between New Brighton and Sea Cliff State Beach, Santa Cruz Co., CA. Soquel 7.5' Quadrangle. Latitude: 36.979°N, longitude: 121.927°W. Coll. by E. Moore, July 1986.

M9023. Specimens collected as float from coastal bluff about 0.3 km E of Soquel Creek, Capitola State Beach, Capitola, Santa Cruz Co., CA. Soquel 7.5' Quadrangle. Latitude: 36.972°N, longitude: 121.981° W. Coll. by E. Moore, July 1986.

M9106. Field No.: CaMe86-5. Base of shell bed about 230 ft S of electric gate at S end of row of houses at Seacliff, Santa Cruz Co., CA. Soquel 7.5' Quadrangle. Coll. by E. Moore, 1986

M9108. Field No.: CaMe85-25. Collection from area of New Brighton Beach, Santa Cruz Co., CA. Soquel 7.5' Quadrangle. Coll. by E. Moore, 1985.

M9110. Field No. CaMe85-23. 310 ft E of E end of breakwater along Capitola cliffs, Captola, Santa Cruz Co., CA. Soquel 7.5' Quadrangle. Coll. by E. Moore, September 1985.