WEST AMERICAN CENOZOIC PHOLADIDAE (MOLLUSCA: BIVALVIA)

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Frontispiece. Fossilized wood with the wood-boring pholadid *Martesia s.l.* (top) and the calcarous tubes of teredos (family Teredinidae). Collected from the Eocene Lodo Formation on the west side of the San Joaquin Valley, Merced County, California (USGS loc. 5712). X 1.

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INTRODUCTION

The Pholadidae are a highly specialized family of Bivalvia that have adapted to mechanically excavating burrows in mud, soft rock, coral, shell, and wood. The Cenozoic fossil record of this family in western North America is meager. And, partly because of the previous lack of a sound classification for the Recent species, they have long been misinterpreted in the fossil record.

The last major summary of the fossil Pholadidae of North America appeared more than seventy years ago when Dall (1898) included the western Atlantic species in his study of the Tertiary Mollusca of Florida. Although fossil pholadids have been cited frequently as occurring in Cenozoic rocks of western North America for over a hundred years, the literature is scattered and work on the group has suffered because of the lack of a general revision. This study is an attempt to gather together available data, and to provide an evaluation and synthesis of the west American Cenozoic species of Pholadidae.

The classification used herein is that of Turner (1954, 1955), except that a new subgenus of the genus *Martesia* is proposed, and the subgenus *Pholadopsis* is provided full generic rank. For the most part subfamilial and generic descriptions follow those of Turner (1954, 1955, 1962).

Twenty-four, valid, shallow-water species from three subfamilies presently live on the west coast of North America from Panama (one may have been introduced through the Canal) to arctic Alaska. In addition, ten species of Xylophagainae, mostly deeper water forms, also occur in this region. Of the Recent shallow-water species, only thirteen range northward from the outer coast of central Baja California and are included in this study. In this area, eight species names have been proposed previously for Cenozoic fossils, and one species is described herein. In addition, two species described from fossil occurrences in Japan also occur in the northeastern Pacific today.

MATERIAL

Because of the known effect of substrate on the size, shape and sculpture of pholadid shells, and because neither series nor complete specimens are generally found fossilized, it is often difficult to adequately define fossil species. In order to determine ranges of population variation and ascertain which features are consistently independent of external variables and therefore useful in defining species, I studied a large number of Recent specimens whose identifications were known. The most important collection of those studied was that assembled by Dr. Ruth D. Turner at the Museum of Comparative Zoology, Harvard University. Other collections studied included those of the San Diego Natural History Museum, the Los Angeles County Museum of Natural History, Stanford University, the California Academy of Sciences, the University of California Museum of Paleontology (Berkeley), the Academy of Natural Sciences of Philadelphia, and the U.S. National Museum. In addition to these Recent collections, a large series of fossil specimens were assembled for comparative study from the collections of the aforementioned institutions, as well as those at San Diego State College, the University of California at Los Angeles, and the U.S. Geological Survey, Menlo Park and Washington, D.C. Other specimens were borrowed from the University of Oregon (Eugene), and the University of Washington (Seattle).

ABBREVIATIONS

The following abbreviations are used for the museums (or collections), universities, and grid references listed below.

Catalogue numbers are indicated solely by the abbreviation and number. Localities are indicated by "loc." following the abbreviation and preceding the number. Type numbers, if serially separate, are indicated as such.

ANSP	Academy of Natural Sciences of Philadelphia, Pennsylvania.
CAS	California Academy of Sciences, San Francisco, California.
CIT	California Institute of Technology, Pasadena, California.
CSMB	California State Mining Bureau collection, now at the California Academy of Sciences.
HBM	Humboldt Base and Meridian (California).
HH	Henry Hemphill collection, at the California Academy of Sciences.
LACMNH	Los Angeles County Museum of Natural History, Los Angeles, California.
MCZ	Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.
MDBM	Mount Diablo Base and Meridian (California and Nevada).
RM	Redpath Museum, McGill University, Montreal, Quebec, Canada.
SBBM	San Bernardino Base and Meridian (California).
SDSC	San Diego State College, California.
SDSNH	San Diego Society of Natural History, California.
SU	Stanford University, Stanford, California.
UCD	University of California at Davis, California.
UCLA	University of California at Los Angeles, California.
UCMP	University of California Museum of Paleontology, Berkeley, California.
UO	University of Oregon Museum of Natural History, Eugene, Oregon.
USGS	United States Geological Survey, Washington, D.C.
USGS-D	United States Geological Survey, Denver, Colorado.
USGS-M	United States Geological Survey, Menlo Park, California.
USNM	National Museum of Natural History, Washington, D.C.
UW	University of Washington, Seattle, Washington.
WBM	Willamette Base and Meridian (Oregon and Washington).

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Finally to Ruth D. Turner, I owe special thanks for reading the manuscript, and for the many kindnesses and professional courtesies shown me throughout the course of this study.

MORPHOLOGY

As a result of the high degree of specialization of the Pholadidae for boring into hard substrates, and because two subfamilies (Martesiinae, Jouannetiinae) have an unusual two-stage life history, a special terminology exists for morphological features not present in other bivalve groups (except on occasion in the Teredinidae) (see also Fig. 2). The morphological terminology used herein follows.

APOPHYSIS (Pholadinae, Martesiinae).— A gently curved styloid projection extending from beneath the umbo which provides an attachment site for the foot muscles. It may be solid or hollow, spoon-shaped or blade-like.

BEAK (Pholadinae [some], Martesiinae, Jouannetiinae, Xylophagainae).— As used herein, the projected or constricted anterior extremity on forms which are not broadly rounded anteriorly. This is *not* equivalent to the umbo.

CALLUM (Martesiinae, Jouannetiinae).— A smooth, hemispherical portion of shell filling the anterior pedal gape formed upon cessation of active boring. It is calcareous, either complete or partial, and assumes the shape of the anterior portion of the excavated burrow. A dorsal extension of the callum extends between the beaks and over the umbonal reflection to form an enclosure,

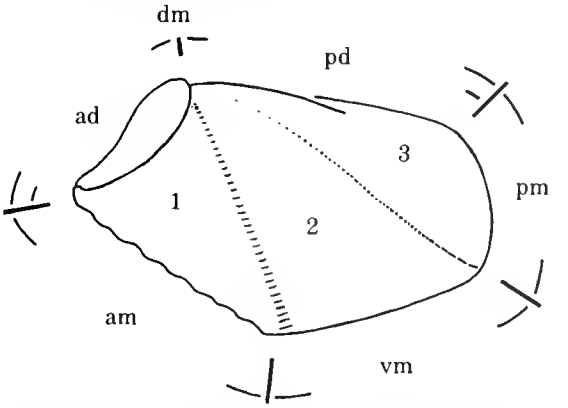


Figure 1. Major shell regions of typical pholadids. 1, anterior slope; 2, disc; 3, posterior slope; dm, dorsal margin (ad, anterior dorsal; pd, posterior dorsal); am, anterior margin; vm, ventral margin; pm, posterior margin.

either narrow and elongate or widely lobate, for the anterior-dorsal mantle lobe and anterior portion of the anterior adductor muscle.

SIPHONOPLAX (Martesiinae [some], Jouannetiinae).— Posterior extension of the shell for the protection of the siphons. It may be calcareous or periostracal, paired or present on only one valve.

UMBONAL REFLECTION (Pholadinae, Martesiinae, Jouannetiinae, Xylophagainae). — A constriction, groove, or dividing line running from the umbo to the ventral margin and separating the sculptured anterior slope from the disc. It is manifested internally as the UMBONAL-VENTRAL RIDGE.

CHIMNEY (Martesiinae [some], Xylophagainae [some]).— A tube built into the siphonal end of the burrow composed of fine particles flushed from the anterior end of the hole during active boring, and cemented together. It may extend anteriorly as far as the mesoplax.

CHONDROPHORE (Pholadinae [some], Martesiinae [some], Jouannetiinae, Xylophagainae).— A modification of the hinge area of the umbo to support the internal ligament. The chondrophore of the right valve is a small swelling with a central depresion, whereas that of the left valve is a small shelf-like projection (Turner, 1954: 13).

CONDYLE (Pholadinae [some], Martesiinae, Jouannetiinae, Xylophagainae).— The ventral knob-like point of contact situated at the junction of the ventral margin and the sulcus. The condyle and umbo

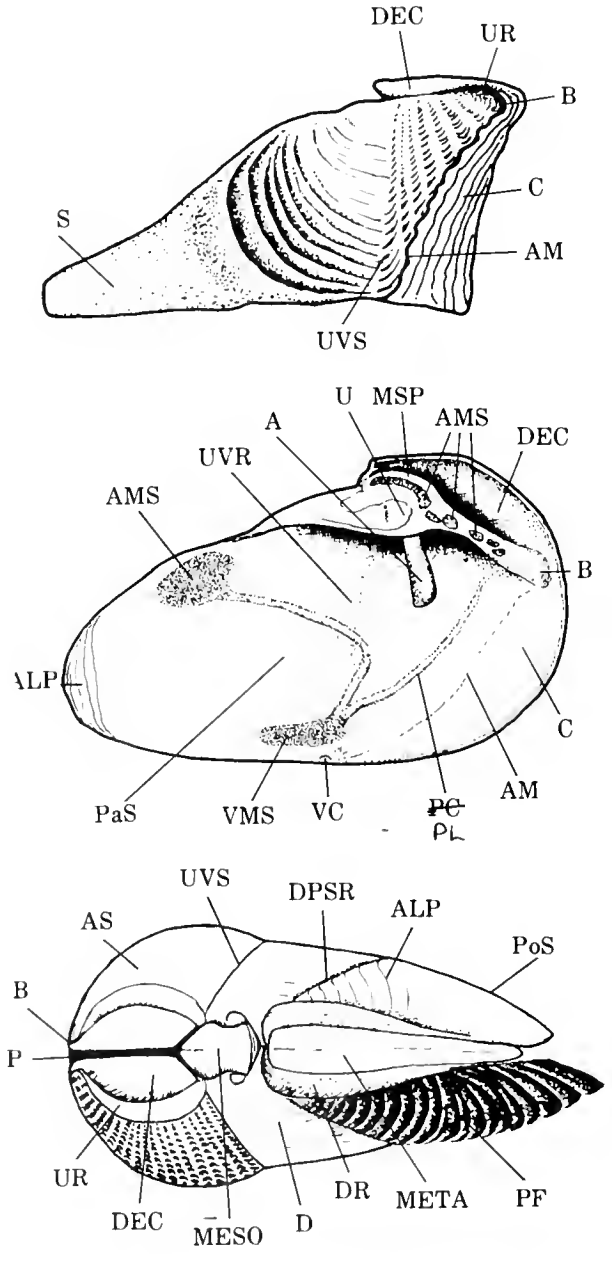


Fig. 2. Morphologic structures of common west American Pholadidae. From top: *Nettastomella*, *Penitella*, and hypothetical pholadid.

A	—	apophysis
ALP	—	attachment lines of periostracum
AM	—	anterior margin
AMS	—	anterior muscle scar
AS	—	anterior slope
B	—	beak
C	—	callum
D	—	disc
DEC	—	dorsal extension of callum
DPSR	—	disc-posterior slope ridge
DR	—	dorsal reflection of valve
MESO	—	mesoplax
META	—	metaplax
MSP	—	muscle scar pad
P	—	periostracum between valves
PF	—	periostracal flaps or leaves
PL	—	pallial line
PMS	—	posterior muscle scar
PaS	—	pallial sinus
PoS	—	posterior slope
S	—	siphonoplax
U	—	umbo
UR	—	umbonal reflection
UVR	—	umbonal-ventral ridge
UVS	—	umbonal-ventral sulcus
VC	—	ventral condyle
VMS	—	ventral muscle scar

together form a double ball joint about which the valves can move in a rocking motion during active boring (Lloyd, 1897: 308).

DISC (Pholadinae, Martesiinae, Jouannetiinae, Xylophagainae).— The central median region of the valve between the anterior slope (or sulcus), and the posterior slope.

HYPOPLAX (Martesiinae [some]).— The narrow longitudinal accessory plate situated on the ventral margin. It covers the narrow ventral gape.

MESOPLAX (Pholadinae [some], Martesiinae, Jouannetiinae [some], Xylophagainae).— A transverse calcareous accessory plate situated on the dorsal margin either anterior or posterior to the umbo. In actively boring animals it is situated ventral to the adductor muscle. In those individuals which cease active boring, a dorsal covering is added. The plate may be in one or two pieces, and may have lateral wings.

METAPLAX (Pholadinae [some], Martesiinae [some]).— Longitudinal calcareous accessory plate situated on the dorsal margin posterior to the umbo. It covers the narrow dorsal gape, and should not be confused with dorsal reflections of the valve itself.

PROTOPLAX (Pholadinae [some]).— Restricted by Turner (1954: 12) to the simple nearly flat accessory plate situated anterior to the umbo and resting on the anterior adductor muscle. It may be in one or two pieces, and is calcareous or periostracal. It should not be confused with the dorsal extension of the callum or the umbonal reflection.

LIFE HISTORY AND VARIABILITY

In the Martesiinae and Jouannetiinae there is a striking change in the appearance of the shell at sexual maturity. In these subfamilies boring ceases at maturity, and the animal secretes a callum over the anterior pedal gape and dorsal mantle lobe, one or more accessory plates over the gaping areas along the margins of the shell, and (or) a siphonoplax at the base of the siphons. In addition, in all genera the shell outline as well as the nature of the ornamentation on the anterior slope is directly affected by the relative hardness of the substrate penetrated and is responsible for much variation in overall shell form within a single species.

Because the number of species in most genera is small, shell morphology alone is often sufficient for species identification, especially in restricted time-geographic areas. In *Penitella* and *Martesia*, however, accessory plate morphology is the most reliable means of separating species. In specimens from geologically older strata (Mesozoic and early Tertiary age) too little is known about the limits of population variation of nominal taxa to accurately define them. Also, earlier workers were overly concerned with general shape or outline of the shell, while neglecting to comment on those features which are more reliable in the definition and recognition of species.

It is for these reasons that I have added the following section on general pholadid variability so that features which might seem important at first glance can be recognized for what they actually represent.

LIFE HISTORY

Little is known of the reproductive and early embryonic stages of pholadids. The veliger stage of some species can remain in the plankton for up to thirty days (e.g. *Martesia striata*; R.D. Turner, *in litt.*), and it is during this period that dispersal occurs in the mud- and rock-boring groups. Wood-boring species, transported in floating wood, expand their ranges in this manner.

Several species of deep water *Xylophaga* do not have pelagic larvae, but instead protect the young in a brood pouch until the late veliger stage, only releasing them after metamorphosis of the juvenile shell into its adult form (Knudsen, 1961: 200). Apparently there is some substrate selection, and metamorphosis can be delayed until a suitable substrate is found. Initial attachment by byssal threads occurs in some, if not all, species. Boring begins after metamorphosis from the veliger stage and is concomitant with growth. Initial penetration is probably more of a plucking action than a true boring, the grains being too large for rasping away, thus explaining the paucity of rock-borers in coarse grained sedimentary rocks. A newly settled, and actively boring, specimen of *Penitella penita* is figured by Evans (1968b: pl. 3). Boring and growth are combined in a re-occurring two-stage cycle (Evans and LeMessurier, 1972: 1251) lasting in *Penitella penita* about 15 days. Most growth takes place during a 7 to 10 day period of quiescence and is then followed by a 5 to 8 day period of active boring and little or no growth.

There are two definable stages in the ontogeny of the Martesiinae and Jouannetiinae, the active or boring (juvenile), and the inactive and reproductive (adult). (The Pholadinae and Xylophagainae remain active borers throughout their lives and growth does not cease.) In the first stage, the hole is excavated until either physiological or physical processes spontaneously inhibit further boring. Those genera which cease active boring at maturity subsequently produce a callum, accessory plates, or siphonoplax, and resorb the foot. The space once occupied by the foot becomes filled with the reproductively mature gonads, no further growth occurs, and the individual enters its reproductive stage. The ultimate size of the adult may be directly related to the size of the entrance diameter during the late active period, possibly because more food is available to animals with larger burrow entrances (Evans, 1968b: 118).

VARIABILITY

Stenomorphism is a common phenomenon in the Pholadidae. More larvae are able to settle on an exposed surface than can live within the substrate, due to the expansion of the anterior ends of the burrows during boring. In *Martesia*, particularly, there may be extremely heavy settlement of larvae on small pieces of floating wood, and callum-producing adults are often only 4 mm in length (Turner, 1954: 6). Evans (1968a: 276) noted that in extreme crowding, when an animal cannot bore in any direction without breaking into a neighboring burrow, boring is inhibited altogether. *Martesia* will, however, bore into teredinid tubes (Turner, 1955: 65, pl. 35).

The relationship of substrate to shell morphology has not often been recognized in the past, and explains the presence of a number of synonyms in the literature. The general outline of the valves and the nature of the anterior sculpture depends greatly on the hardness of the substrate in which the pholadid is boring. Studies on *Penitella penita* by Evans (1968a, 1968b, 1968d) on these interrelationships are generally applicable to other genera and species.

If the substrate is soft and easily penetrated, the shell will be relatively longer than normal. Shell growth is proportional to the size and shape of the excavation, and since boring proceeds only at the anterior end, obviously more rapidly in softer sediment, the shells are longer. The valves will also be thin and the concentric ridges of the anterior slope spaced further apart and turned upward. If there are any imbrications or spines on the ridges, they may be pronounced. In rock-borers, the callum may extend further anteriorly, the umbonal reflection will be narrower, and the dorsal extension of the callum will be raised and not as broad or lobate as in typical specimens. In elongate specimens (see Fig. 46), additional material may be added to the ventral margins when the callum is formed. In *Martesia*, additional shell is often added to the posterior end, increasing overall length by up to a third. The above situation

will occur if a typically rock-boring species fortuitously settles in stiff mud or clay. Crowding also will cause an elongation of the shell without apparent increase in the diameter of the burrow (Evans, 1968a: 276).

If, however, the developing larva settles on a substrate substantially harder and less easy to penetrate, the shell will usually be proportionately shorter and the valves thicker and heavier. Furthermore, the concentric ridges will be thicker and more closely spaced, often so tightly that recognition of individual ridges is impossible (see Fig. 49). Also, the adductor muscles may be disproportionately enlarged, and the muscle scars roughened. The umbonal reflection is wider and, in some species, more appressed to the anterior slope. The dorsal extension of the callum, which is a manifestation of the size and shape of the anterior adductor muscle, may be low and greatly lobate anteriorly. Above the umbones a heavy muscle scar pad is built up and serves for attachment of the primary anterior adductor muscle (see Figs. 43 and 50).

Boring is accomplished by mechanical rasping with the fore edge of the last concentric ridge of the anterior slope on the burrow wall. Concentric ridges behind the leading edge apparently play no role in boring as they show no progressive increase in wear with age (Evans, 1958b: 116). The concentric ridges in soft-rock borers are worn little, while those boring in harder rocks are almost smooth from wear (compare Figs. 21 and 24 and Figs. 46 and 49). Commonly, in *Chaceia*, *Penitella*, and *Parapholas*, the last concentric ridge produced before the formation of the callum shows no wear and is raised higher than those of the anterior slope. Given two specimens of equal maturity, one boring into a soft substrate, and the other in a hard one, the latter will produce a greater number of concentric growth ridges in a given period of time, but will be smaller in overall size than the former. However, specimens mature at a greater overall size in harder rocks than those living in relatively soft rocks (Evans, 1968b: 119).

In older specimens of several species, but most notably in *Parapholas californica*, the interior of the shell may become thickened with scattered deposits of aragonite or calcite, giving the interior an irregular appearance. When occurring along the margins of the shell, they in effect fuse the accessory plates to the valves. In other genera, the apophyses seem to be the most vulnerable spot for malformation, though usually be resorption rather than by accretion. Shell material on the inner surface of the anterior slope may also be resorbed, exposing the pattern of concentric ridges normally seen only on the exterior. In gerontic pholadids, especially in the Martesiinae, calcite is often deposited on the muscle scars and pallial line, making them readily distinguishable from the dull white aragonite of rest of the shell (*cf.* Figs. 43 and 61).

In occasional specimens of *Chaceia*, though only rarely in *Penitella*, the interior of the callum may be structurally braced with several high, thin struts (see Fig. 23). Their functional significance or cause of formation is not understood, though they are peculiar to old and heavy shelled specimens.

The radial arrangement of the imbrications or undulations (radial "ribs" of Turner) on the anterior slope is quite variable and apparently of no taxonomic importance. They may be paired, or every second one may be more prominent than its neighbors; the grooves between the "ribs" may be wide in some places and narrow in others without any set pattern.

The shapes of the accessory plates, formed after active boring ceases, are not seriously affected by the nature of the substrate, unless mantle tissue has somehow been injured by boring. Accessory plate morphology is thus usually more reliable in species definition and recognition than shape of the valves.

ENDOLITHIC COMMUNITY

One of the most interesting aspects of the Pholadidae, especially the Martesiinae, is their relationship to the substrate and the associated faunal communities. The Martesiinae, because of their rock-boring habit, are important in the creation of holes in the rocky shore suitable for habitation by a large number of marine invertebrates. For the community inhabiting hard marine substrates, Kühnelt (1951; see Evans, 1967a: 148) proposed the term endolithic, which includes those animals living wholly within the rock, or endolithion.

In the absence of marine rock-borers, the endolithic community normally will not develop (Evans, 1967a: 149). Since the rate of erosion is considerably higher where rock-boring pholadids live, there is a constant "exfoliation" of surface rock, due in part to the weakening of the substrate by the numerous burrows, and to wave action in these habitats. This constant erosion exposes a range of burrow sizes, from tiny siphonal holes of complete burrows with live animals, to broad rounded depressions left as the only remnant of once existing burrows. In infested rocks in Coos Bay, Oregon, Evans (1968c: 159) estimated the erosion rate to be about 12 mm/year. After 11 or 12 years an average burrow of 150 mm would be reduced to a shallow bowl-shaped depression.

In the fossil record the endolithic community is more often preserved *in situ* than in detrital deposits. Barrows (1917: 970) noted that in the presence of violent changes in depositional conditions over a given area, the free living fauna may readily move away, and the sessile fauna may either be destroyed or washed away. Further, boring forms trapped in the rock would thus constitute the only relics of the former fauna and would be indicative of the past environment.

A large variety of animals inhabit vacant pholadid burrows. Evans (1967a: 150) listed thirty species of marine invertebrates from the Coos Bay region of Oregon, including coelenterates, annelid worms, sipunculids, crabs, shrimp, chordates, and mollusks other than pholadids. Sediment free burrows are often internally encrusted by bryozoa, barnacles, and various algae. In protected localities the burrows are likely to become filled with mud and finer sediments, while those on the open coast are not usually filled, or filled with coarser sediment. These protected microhabitats are thus ideal for the settlement of small mud and sand living invertebrates, as well as the common bivalve nestlers. Some of the mollusks found by Evans in these microhabitats were *Trimusculus reticulatus* (Sowerby, 1835), *Irus lamellifer* (Conrad, 1837), *Macoma nasuta* (Conrad, 1837), *Entodesma saxicola* (Baird, 1863), *Saxicava* sp., *Kellia suborbicularis* (Montagu, 1904), and *Adula californiensis* (Philippi, 1847). Mollusks found by Evans and also found by Addicott (1963b: 144) in pholadid burrows on a Pleistocene terrace at Point Año Nuevo, California, include *Crepidula nummaria* Gould, 1846, *Tresus nuttallii* (Conrad, 1837), *Petricola carditoides* Conrad, 1837, and *Protothaca staminea* (Conrad, 1837) [*P. s.* var. *ruderata* (Deshayes, 1853) as fossil].

The presence of more than one nestler per pholadid burrow is not unusual, and Chace (1942: 42) reported the occurrence of six bivalves from within a single dead *Parapholas californica* found in a shale block thrown onto Del Monte Beach, near Monterey. The largest of these nestlers, a *Protothaca staminea*, measured 57 mm in length, while four others ranged from 20 to 27 mm in length. A single *Irus lamellifer* was 42 mm long.

In Coos Bay, silt-filled burrows are most commonly inhabited by the terebellid worm *Thelepus* sp. and its commensal scale worm, *Halosydna brevisetosa* Kinberg (Evans, 1967a: 149). *Thelepus* seems to extract $CaCO_3$ from the pholadid shell, using at least part for its own parchment burrow, while gradually dissolving the pholadid shell completely.

While pholadid burrows may provide excellent habitats for small bivalve nestlers,

the young of larger species also occur here, and subsequent growth often finds these individuals greatly restricted within the confines of the burrow, resulting in extreme shell deformation or death. Addicott (1963b) reported a specimen of *Tresus nuttallii* in the Pleistocene of Point Año Nuevo, California, which was oriented in the wrong direction, and had become quite misshapen, the siphons protruding through another, but intersecting pholadid burrow. Three examples from the Pleistocene Palos Verdes Sand of Newport Beach, California also illustrate such deformation: *Anomia peruviana* d'Orbigny (Fig. 95) which began growing in a truncated burrow and was quite restricted until reaching the surface and spreading out; *Chama pellucida* Sowerby (Fig. 96) which abandoned its normal growth pattern and thereafter grew straight up; and *Ostrea lurida* Carpenter (Fig. 97) which was forced to assume the shape of the pholadid burrow it was living in.

BURROWS

The Pholadidae are not the only bivalves which bore into hard substrates. Sand- and mud-filled burrows, or "sand-pipes", of several other bivalve groups may be confused with those of the pholadids. Within the family itself, members of the Pholadinae are mostly mud- or soft sediment-borers, and their burrows are rarely preserved in the fossil record. Most preserved burrows belong to the Martesiinae, though a few may be assigned to the Jouannetiinae. Of those which are preserved, excluding variability, the general shape is that of an inverted ice cream cone, with a large bulbous anterior end that tapers posteriorly to the siphonal opening. This conical shape results from mechanical scraping by the valves only at the rounded anterior end of the burrow. Burrows of Jouannetiinae and most Martesiinae are about one to two times the length of the shell. Burrows of Xylophagainae are five to ten times the length of the shell, and can usually be separated from those of teredinids, which have long worm-like burrows (Turner, 1969: 704).

Crowding often affects the shape of the burrow, as more pholadids can settle on the substrate surface than can live in the rock or wood below (Evans, 1968a: 276). Burrows in uncrowded conditions are relatively straight, while those in crowded conditions are often twisted (Evans, 1968a: 276; see also Fig. 100). Apparently pholadids can detect boring activity in neighboring burrows and usually avoid these other individuals. This may be accomplished by changing direction of boring, by elongating the burrow without increasing its relative diameter, or by cessation of boring altoghter. *Martesia* will bore through teredinid tubes, though the reverse does not hold true (Turner, 1955: pl. 35). Figure 52 shows a specimen of *Penitella penita* which was bored into while alive and subsequently repaired its shell.

Erosion of the substrate is also responsible for shorter burrows. Evans (1968c: 159) showed that substrate erosion is substantially increased in areas with a high pholadid density. As the tops of the burrows are truncated, making the burrows shorter, the diameter of the siphonal opening is increased, and the animal within is more susceptible to predation. In soft rock the siphons may also enlarge the entrance diameter of the burrow by several millimeters (Evans, 1968a: 276), which is more apparent in larger individuals or species.

Where the substrate is relatively soft, grooves left by the mechanical rasping of the valves are preserved in the burrow wall, and molds of these are preserved as ornamentation on some "sand-pipes" (Fig. 103; see also Itoigawa, 1963: pl. 3, Fig. 5-6, 8).

"Sand-pipes" found in rock are difficult to assign to a specific genus without first exposing the valves inside. The burrows of Martesiinae are similar in appearance. Those burrows found in shell *may* belong to gastrochaenids, to *Penitella*, or to *Diplothyra* only because shell may be inhabited by species of these genera. The burrows of species of *Penitella* are so variable that specific classification by burrows *per se* is impossible. The burrows of large *Chaceia ovoidea* may reach a length of 40 to 50 cm, and do not taper rapidly. The burrows of Jouannetiinae usually have more bulbous anterior ends than those of Martesiinae (*cf.* Turner, 1969: Fig. E191). Evans (1967b: pl. 17) figures Recent burrows of *Nettastomella rostrata* and *P. penita* for a comparison of general shape. Fossil burrows of *Penitella* are also figured by Adegoke (1966: pl. 21; 1967: fig. 17, 21-22, 25-26). Burrows figured by MacNeil (1957: pl. 12, fig. 1; USNM 561882) as possibly belonging to *Martesia* were made by teredinids. Rock- and wood-boring bivalves and their associated burrows from the Miocene Mizunami Group of central Japan have been studied by Itoigawa (1963).

The burrows of rock-boring mytilids, such as *Lithophaga*, are readily distinguishable from those of pholadids by their vertically constant cross sectional area in relation to length, and to their bilateral symmetry at the siphonal end. They are usually lined internally with a calcareous incrustation. Furthermore, because mytilid borings are formed partly by dissolution rather than a rotational mechanical process, their burrows may tend to be bilaterally symmetrical and non-circular in cross section. Pholadid burrows are circular in cross section. Burrows of Gastrochaenidae, which also bore into soft rock, coral, and other shell, are less easily separated from small pholadid burrows, and extraction and examination of the valves within is the only reliable method of distinguishing between the two families.

GEOLOGIC SIGNIFICANCE

The geologic significance of pholadids has generally been overlooked by field geologists, even though these organisms can be simple and useful tools in stratigraphical and in paleoecological studies.

Most genera of Pholadidae, exclusive of the Xylophagainae, are inhabitants of the intertidal or high inner sublittoral zones. As shallow water indicators, they can be used for postulating ancient shorelines, although not with the precision indicated by the presence of some mytilids.

In discussions on the paleoecology of the Pholadidae, the family should be divided into three general categories, the mud- or soft sediment-borers (generally the Pholadinae), the rock-borers (generally the Martesiinae and Jouannetiinae), and the wood-borers (generally *Martesia*-like forms, and the Xylophagainae). There are exceptions to each of these however. For instance in the Pholadinae, the genus *Zirfaea* will bore into soft rock as well as wood, and *Pholas dactylus* Linné, 1758, has been known to bore into gneiss (MCZ 197105).

The preferred substrates of the first group are sand, mud, peat, clay, and sediments stiffened by settling and compaction rather than by subsequent induration. Often these unconsolidated sediments are being actually deposited, so the pholadid populations would be geologically the same age as the sediments they were inhabiting. In such instances, the resulting filling of the burrow after death of the animal would be indistinguishable from the substrate itself. Collapse of the burrow could cause the internal filling of the burrow to be lithologically identical with the substrate, and would indicate soft sediment.

Since the mud-borers live in habitats which are generally not narrowly restricted

in size, as compared to isolated outcrops of harder rock, or pieces of wood, it would be expected that fossil exposures would yield fewer specimens per locality, but that there would be a greater number of productive outcrops. This is especially true in the Miocene deposits of California where *Zirfaea dentata* is quite common and the rock-boring *Penitella* (subfamily Martesiinae) is rare in comparison.

If a fossil pholadid burrow is filled with matrix that is identical to the surrounding strata, it may be assumed that deposition was contemporaneous with the boring activity of the bivalve, that it occurred in a low energy shallow water environment, that the substrate was non-indurated, and that the surrounding matrix is geologically the same age as the bivalve.

Of the rock-boring species, the subfamilies Martesiinae (except *Martesia*, *Lignopholas* and *Opertochasma*) and Jouannetiinae present a somewhat different picture, though the dividing line between very soft rock and very stiff mud is not well delimited. Most species in this group prefer harder and more indurated substrates than do the Pholadinae. This therefore precludes most of the substrates available to the mud-borers, but leaves isolated exposures of harder rock which are usually found only intertidally on the open coast or in submarine canyons. If the rock surface can be kept clean of finer sediments by currents, rock-borers will inhabit deeper water, such as the pholadids found boring into serpentine between 60 and 100 meters at the mouth of San Francisco Bay (Barrows, 1917: 970).

Because these species necessarily inhabit rock surfaces, their occurrence is virtually restricted to a single non-depositional plane, and do not range throughout a sedimentary sequence as could the mud-boring species. This is in part responsible for the spotty fossil record of the rock-borers. The presence of isolated outcrops of rock will often result in heavy concentrations of pholadids in small areas. Though their actual occurrences *in situ* are few in the fossil record, concentrations are locally greater than that recorded for mud-boring species.

Almost any geologically older unit provides an excellent habitat, and for this reason, rock-boring pholadids, when found, almost always indicate a considerable time differential or unconformable relationship with the surrounding substrata. When overlying strata are deposited, the lithology above is invariably different from that below and often is readily distinguishable. Because sedimentation is slight in the preferred habitats, burrows may not be immediately filled, or if filled before complete inundation by another unit, it is generally with coarser grained sediments.

In summary, the rock-boring pholadids have burrows filled with sediment different from that of the surrounding substrata, are indicative of an unconformable contact, and are geologically the same age as the overlying stratigraphic unit.

Fossil wood-boring pholadids are much rarer than either of the two above mentioned groups. The most significant reason is that suitable habitats, such as floating or waterlogged wood, are much rarer than mud flats or outcrops of rock, and may be more widely distributed in deeper water sediments. They are seldom found in shallow water deposits or normal molluscan death assemblages. Pieces of floating wood, after becoming waterlogged, may settle in deep water. The chance that an isolated piece of fossilized wood containing pholadids will be found is small. Moreover wood, unlike rock and mud, will often decompose and free the valves thereby allowing for further dispersal. The pholadids (and teredinids, if present) would be geologically the same age as the sediments in which they had settled. The piece of wood would be analogous to the hard, but geologically older, substrata inhabited by the rock-borers.

Another aspect in which pholadids are useful as paleoecologic indicators is in determining the relative hardness of fossil substrates. Because substrate hardness is reflected in the sculpture of the anterior slope (see section on Variability; also Evans, 1970), the relative hardness of a fossil sub-

strate at the time of boring, and probably of subsequent deposition of overlying beds, can be estimated by comparing the fossils to Recent specimens taken from rocks of known hardness and rated on any arbitrary scale. Evans (1968a) has described one method for determining relative hardness and figures examples of *Penitella penita* from Coos Bay, Oregon. Variation between and within populations of pholadids prevent their use in determining minute substrate differences, though differences of a certain magnitude are easily detected.

Barrows (1917: 970) suggested that the presence of pholadids in burrows, as the sole remnant of a fossil fauna, may offer the only clue to the age of the formations involved. Unfortunately, too little is known about paleozoogeography and geologic ranges of fossil pholadids before the Neogene and their value as age indicators is only speculative at present. The presence of burrows of rock-boring Pholadidae can pinpoint the exact stratigraphic position of a suspected disconformity, although the time differential cannot be accurately determined.

Pholadids are useful in various phases of stratigraphic and paleoecologic work, but nevertheless have their limitations. Where possible, geologic conclusions based on these borers should be confirmed by other lines of evidence.

GEOLOGIC RECORD

The Pholadidae have left a poor fossil record. In western North America they are common only in Pliocene and Pleistocene strata. Although they supposedly arose in the Jurassic, or questionably even in the Carboniferous (Turner, 1969: 706), the oldest known species on the Pacific slope of North America are Cretaceous in age. Of the 28 genera recognized by Turner (1969), nine are known only from their fossil records; five from the Cretaceous, one from the Cretaceous to the Oligocene, and three from the Eocene. The remaining 19 genera all have living representatives and most have at least short fossil records. The total number of genera may be small, as fossil pholadids have not received as much attention in some parts of the world as they have on the North American and European continents.

SUMMARY OF WEST AMERICAN FOSSIL GENERA

I have been able to document the presence of only three genera in the Cretaceous of the Pacific coast, *Opertochasma* (represented by Gabb's *Martesia clausa*, and other occurrences in the Sacramento Valley), *Turnus* (Gabb's *T. plenus*, and other occurrences in the Sacramento Valley), and *Xylophagella* (from an occurrence in San Diego). *Xylophagella* and *Turnus* are not known in younger rocks, but *Opertochasma* has been found in Paleocene strata in California and Oligocene rocks in Oregon. It is probably this genus that has been incorrectly identified from Cretaceous strata as *Martesia* and *Parapholas*. Paleogene pholadid records are extremely rare, but include the first substantiated record of *Martesia*. Also known are two (or three) forms which can not now be placed in any known pholadid genus. Unfortunately they are poorly preserved and their systematic postion must remain unclear.

The first occurrence of *Penitella* is in the Oligocene of California. It is, however, almost unknown in the Miocene, and the record for *Penitella* through this epoch is so poor that no evolutionary lineages can be traced. *Penitella* is quite common in Pliocene and Pleistocene units, both in numbers of species as well as specimens. Although the fossil record is incomplete, *Ramsetia*, from the Cretaceous of Texas, is similar to *Pholadidea*, which has no fossil record on this coast, and *Penitella*, and could possibly have given rise to both genera. *Ramsetia* is still inadequately defined however.

The genus *Cyrtopleura* has a good fossil record from the Miocene onward in the eastern and Gulf coastal states, but is known only from the Miocene(?) of northwestern Washington and the Pliocene of the Gulf of California trough. The mud-boring genus *Zirfaea* is common in the Miocene of California, but no ancestral form is known. It can be shown, however, that the modern *Zirfaea* is directly related to this Miocene species. A single specimen from the upper Miocene of Oregon appears to represent a link between *Zirfaea*, and the Pliocene to Recent *Chaceia*. Japanese species of *Zirfaea* are characterized by a different type of sculpture, and probably represent a different lineage.

In the Pliocene, *Barnea* (*Anchomasa*)(?), *Chaceia*, *Parapholas*, *Nettastomella*, and *Pholadopsis* make their first appearance on the west coast. *Pholadopsis* has a longer geologic record in other parts of the world (Turner, 1969: 720), and species of *Parapholas* are known from Miocene and possibly Oligocene rocks in Japan. The Cretaceous to Recent range (of authors) for *Parapholas* can not be documented.

The following taxa have representatives living in the tropical eastern Pacific today, but so far are unknown in the fossil record: *Cyrtopleura* s.s., *Thovana*, *Hatasia*, *Diplothyra*, *Particoma*, *Jouannetia*, *Xylophaga*, and *Xyloredo*. This is probably due to the sparsity of late Cenozoic fossil deposits in the tropical eastern Pacific rather than to their real absence in the fossil record. Species of these genera are described and figured by Turner (1954, 1955, 1972), and Knudson (1961).

The geologic ranges of west American Pholadidae are listed under each species in the systematic section, as well as detailed records of all known occurrences in western North America. Geologic ranges of pholadid genera are given in Turner (1969). Many of these do not refer to west American species or occurrences and therefore differ from the ranges of those on this coast. Some of Turner's generic ranges must also be revised, as well as the geologic ranges of most of the species treated herein. Table 1 shows generic ranges as given by Turner compared with generic ranges documented by occurrences only from the eastern Pacific.

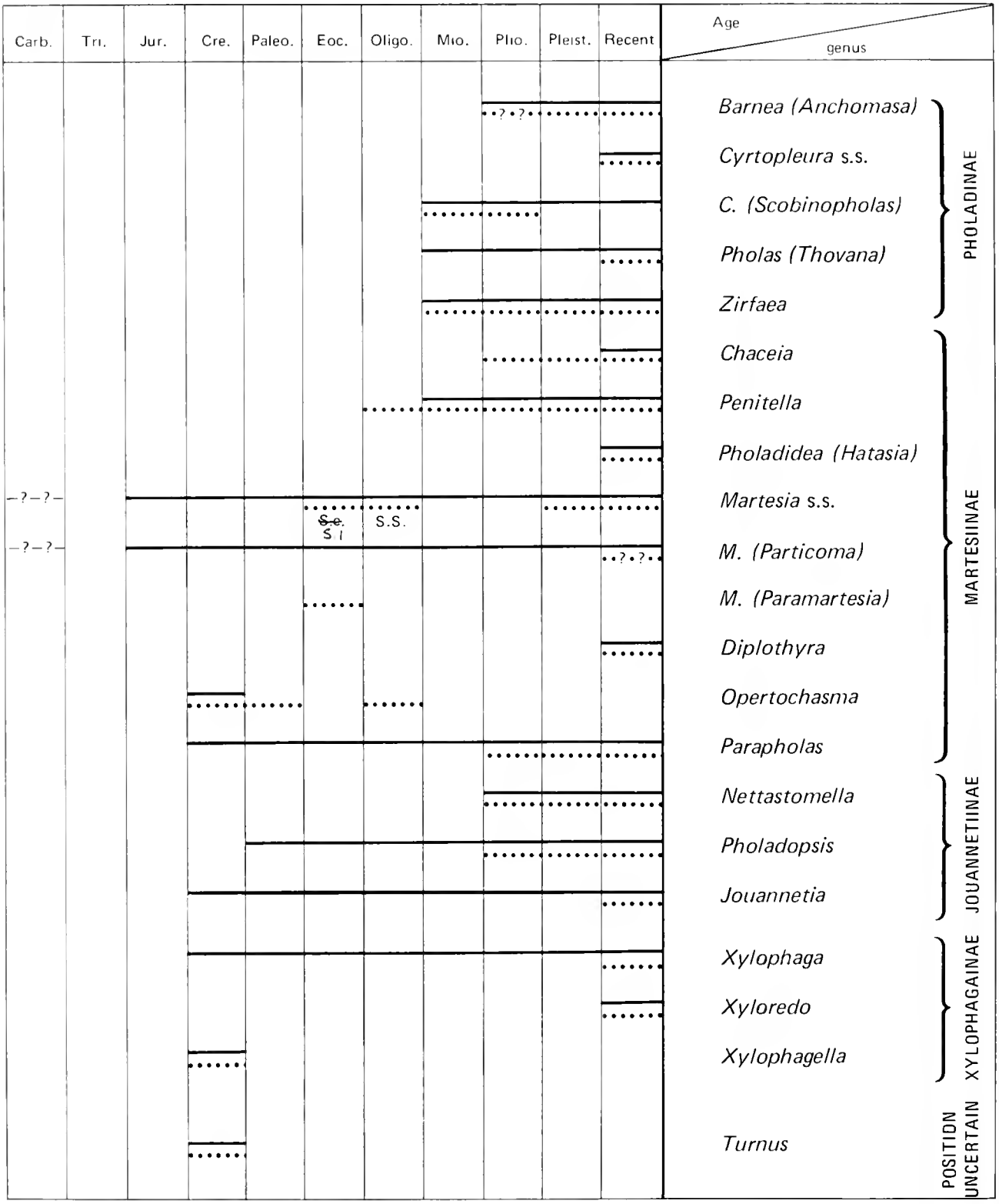
SYSTEMATIC PALEONTOLOGY

The family is divided into four subfamilies, the Pholadinae, Martesiinae, Jouannetiinae, and Xylophagainae. Under each, I include a definition of the subfamily, the type genus, and a list of taxa found in the next lowest taxon. Each genus contains a brief synonomy, a definition of the genus, and how it differs from others in the same subfamily, the type species and its designator, and a list of taxa included within the genus. Subgenera are arranged in the same format. Under each species I have included a synonomy which contains 1) only major objective synonyms, or references of importance in defining ecological or distributional data, and 2) an exhaustive list of references to all known fossil occurrences of this species. These latter references are based almost entirely on my personal examination of the specimens utilized by the original authors, and are at least internally consistant. Following this is a diagnosis of the species (within the genus) and a complete description. The original description of all nominal species described as fossils are also included, if applicable. This in turn is followed by pertinent data on any type specimens and their depositories, the type locality, and the presently known modern distribution of the species.

The Geologic Record is that documented by actual specimens, and is a list of fossil localities with their references (whether by locality number, published account, or both). These are arranged by epoch, and within each, from north to south.

TABLE 1

Geologic ranges of eastern Pacific fossil pholadid genera, taken from Turner (1969; worldwide records, solid lines), and from eastern Pacific fossil records (documented herein, dotted lines). (Periods and epochs not subdivided.)



Phylum MOLLUSCA
Class BIVALVIA Linné, 1758
Subclass HETERODONTA Neumayr, 1884
Order MYOIDA Stoliczka, 1870
Suborder PHOLADINA Adams and Adams, 1858
Superfamily PHOLADACEA Lamarck, 1809
Family PHOLADIDAE Lamarck, 1809

A description of the family was given by Turner (1954: 15; 1969: 706). Closely allied to the Teredinidae, the Pholadidae possess several structures not present in other bivalve groups, including various accessory plates, internal apophysis, callum, siphonoplax, siphonal tube, and chimney. No single genus possesses all these features however. Anatomical comparisons of pholadids with a teredinid and a typical venerid are given in Turner (1966b: 20, fig. 5). Teredinids lack most pholadid features, but possess apophyses, pallets to plug the siphonal entrance, and a large soft body incapable of even slight retraction within the shell. Teredinids also secrete a calcareous lining to their burrow, an extremely rare feature in the Pholadidae (*Xyloredo*).
TYPE GENUS.— *Pholas* Linné, 1758.
TAXA INCLUDED.— The family contains the subfamilies Pholadinae, Martesiinae, Jouannetiinae, and Xylophagainae. Genera are listed under each subfamily. Generic synonomies are given in Turner (1969), and a list of most of the known genus-level taxa is included in Vokes (1967: 326-330).

Subfamily PHOLADINAE Lamarck, 1809

DEFINITION.— Shell beaked or broadly rounded anteriorly, not closed by a callum in the adult stage. Valves not divided by an umbonal-ventral sulcus, except in the genera *Zirfaea* and *Zirlona* (New Zealand Tertiary). All genera possess a protoplax and (or) a mesoplax (a metaplax is also present in *Pholas*), and all lack a callum, hypoplax, and siphonoplax. The foot is well developed and does not atrophy in the adult stage. Animal incapable of complete retraction within the shell.
TYPE GENUS.— *Pholas* Linné, 1758.
TAXA INCLUDED.— Seven genera and seven subgenera (three nominate) are recognized (Turner, 1969) in the Pholadinae, as follows: *Pholas s.s.* Linné, 1758, *Monothyra* Tryon, 1862a, and *Thovana* Gray, 1847; *Barnea s.s.* Risso, 1826 and *Anchomasa* Leach, 1852; *Cyrtopleura s.s.* Tryon, 1862a and *Scobinopholas* Grant & Gale, 1931; *Clavipholas* Conrad, 1868; *Talona* Gray, 1840; *Zirfaea* Gray, 1840; and *Zirlona* Finlay, 1930.

Pholas s.s. (eastern Atlantic), *Monothyra* (Indo-Pacific), *Barnea s.s.* (eastern Atlantic), *Talona* (west Africa), and *Zirlona* (New Zealand) are not represented in the western hemisphere. *Clavipholas* Conrad, 1868, was described from the upper Cretaceous of New Jersey. *Cyrtopleura s.s.* is represented by a single species in the eastern Pacific and *Scobinopholas* by two living species in the western Atlantic, and fossil occurrences on both the east and west coasts. Only *Anchomasa*, *Thovana*, and *Zirfaea* are found living today in both the eastern Pacific and the western Atlantic.

Genus *Barnea* Risso, 1826

Barnea Leach [MS] Risso, 1826:376. Turner, 1954:19.

DEFINITION.— Shell more or less elliptical in outline, beaked or broadly rounded anteriorly. Only accessory plate a calcareous lanceolate protoplax. Umbonal reflection simple, barely reflected anteriorly, closely appressed to or raised slightly above surface of umbo posteriorly. Pedal gape either a narrow slit in anteriorly rounded forms (*Barnea s.s.*), or broadly oval in beaked species (*Anchomasa*).

Barnea differs from other genera in the Pholadinae by having only a single accessory plate, the lanceolate protoplax. The umbonal reflection is not septate, as in *Pholas*, nor are the valves divided by an umbonal-ventral sulcus, as in *Zirfaea*. *Cyrtopleura* has a complicated socket arrangement in the umbonal region (see Fig. 12).

TYPE SPECIES.— *Barnea spinosa* Risso, 1826 (=*Barnea* [*B.*] *candida* [Linné, 1758]), by original monotypy.
TAXA INCLUDED.— The genus contains two subgenera, *Barnea s.s.* and *Anchomasa*. *Barnea s.s.* does not occur in the western hemisphere.

Subgenus *Anchomasa* Leach, 1852

Anchomasa Leach, 1852:253. Turner, 1954:22.

DEFINITION.— Shell beaked anteriorly, rounded to truncate posteriorly with a moderate to large posterior gape. Pedal gape large, oval, and extending about one-third of shell length posteriorly. Umbonal reflection simply, usually closely appressed over umbo, raised anteriorly and barely reflected at beaks.

Anchomasa differs from *Barnea s.s.* by gaping widely anteriorly, and sometimes posteriorly, and by being beaked. *Barnea s.s.* is rounded anteriorly, and has slit-like gapes.
TYPE SPECIES.— *Anchomasa pennantiana* Leach, 1852 (=*Barnea* [*A.*] *parva* [Pennant, 1777]), by original monotypy.
TAXA INCLUDED.— American species of *Anchomasa* are *B. subtruncata* from the eastern Pacific, *B. truncata* (Say, 1822) from the eastern and western Atlantic, and *B. lamellosa* (d'Orbigny, 1846) from the east coast of South America. The type species is from western European waters.

Barnea (*Anchomasa*) *subtruncata* (Sowerby, 1834)
Figures 3-7

Pholas subtruncata Sowerby, 1834:69.
P. [*holas*] *spathulata* Deshayes, 1843:1, pl. 79.
Pholas Pacifica Stearns, 1871:1.
B. [*arnea*] (*Cyrtopleura*) *spathulata*: Lamy, 1925:89.
Barnea pacifica: Cook and Clark, 1943:17. Fitch, 1953:94, fig. 60. Kanakoff and Emerson, 1959:22, in part (*Barnea subtruncata*, in part *Zirfaea pilsbryi*). Valentine, 1961:377.
Barnea (*Anchomasa*) *subtruncata*: Turner, 1954:31, pl. 8 (fig. 1-3), 14-16.
Zirfaea pilsbryi: Kanakoff and Emerson, 1959:25, in part (*Zirfaea pilsbryi*, in part *Barnea subtruncata*). Chace, 1966:170, in part (*Zirfaea pilsbryi*, in part *Barnea subtruncata* and *Chaceia ovoidea*).

DIAGNOSIS.— Shell beaked anteriorly, broadly rounded to truncate posteriorly, not divided by umbonal-ventral sulcus. Sculpture more prominent anteriorly, absent on posterior slope. Umbonal reflection separated from anterior slope by narrow V-shaped furrow. Only accessory plate a narrow lanceolate protoplax.
DESCRIPTION.— Valves thin, light in structure, medium in size, reaching approximately 9 cm in length and 3.5 cm in height. Shell beaked anteriorly, broadly rounded to truncate posteriorly, gaping both anteriorly and posteriorly throughout life. Valves not divided by umbonal-ventral sulcus. Anterior slope and disc regions sculptured with low, thin, usually widely spaced, concentric ridges. Ridges laminated and scalloped anteriorly, weaker on disc, absent on posterior slope except as growth lines. Radial sculpture formed by aligned imbrications of concentric lamellae, stronger on anterior slope, absent on posterior slope.

Umbonal reflections free or barely appressed posteriorly, narrowing abruptly, barely reflected anteriorly. Reflected area separated from anterior slope by narrow V-shaped furrow, which internally exists as narrow ridge extending to beaks.

Protoplax (Fig. 6) only accessory plate, situated above and anterior to umbones, covers anterior dorsal gape, lanceolate, usually rather broad and truncate posteriorly, acuminate anteriorly, sculptured with distinct growth lines and posterior nucleus.

Muscle scars and pallial line faint. Pallial sinus broad, extending anteriorly ⅓ to ½ length of shell. Chondrophore present on knob-like umbo. Apophyses long, narrow for entire length, curved inwardly, ventrally and somewhat posteriorly directed (nearly parallel with external radial sculpture).

Periostracum thin. Siphons incapable of complete retraction within shell. Foot not atrophyed in adult.
HOLOTYPE.— Of *Pholas subtruncata* Sowerby, is lost (Turner, 1954: 33). Insulam Platae, Colombiae Occidentalis (=Isla la Plata, Ecuador). Recent.
HOLOTYPE.— Of *Pholas spathulata* Deshayes, according to Lamy (1925: 89) is in the

Museum National d'Histoire Naturelle in Paris, France. "Seas of Chile" is given by Deshayes (1834), though Lamy notes that the single type is from Payta, Perú, which has subsequently been designated the type locality by Turner (1954: 33). Recent.

LECTOTYPE.— Of *Pholas pacifica* Stearns, USNM 74717, designated by Turner (1954: 33). PARALECTOTYPES.— MCZ 187260 (2 specimens), MCZ 187262 (14 specimens), CAS 10085-10088. Alameda, San Franciso Bay, California, ". . . common in sandy mud between tide marks" (Stearns, 1871: 1). Collected by "Messrs. Harford, Hemphill, Drs. Kellogg and W. P. Gibbons." Recent.

DISTRIBUTION.— Recent; Newport, Oregon (46° 28.5' N. lat.; Turner, 1954: 34) south, including entire Gulf of California, to Atacama Province, Chile (ca. 26-29° S. lat.; Gigoux, 1934: 285 [*fide* Turner]).

GEOLOGIC RECORD.— Pliocene?, Pleistocene to Recent.

Pliocene or **Pleistocene:** Dredged from Oakland Creek, SDSNH loc. 2575.

Pleistocene: Cheviot Vista Place, Palms, Los Angeles, LACMNH loc. 426, Vermont Avenue and Sepulveda Blvd., north of San Pedro (Cook and Clark 1943: 17), LACMNH loc. 147. Below Nob Hill, San Pedro, LACMNH loc. 300. Deadman Island, San Pedro, LACMNH loc. 2. San Pedro Sand, in San Pedro, at high school at 15th and Leland Streets, SDSNH loc. 2138 [=L-2138] (Chace, 1966: 169; as *Zirfaea pilsbryi*, in part), on Harbor Boulevard, opposite old San Pedro Lumber Co., USGS loc. 12628. Palos Verdes Sand, old Bixby Slough, Harbor City, LACMNH loc. 229, near Harbor Boulevard, UCLA loc. 3600 (Valentine, 1961: 377), on Harbor Boulevard, opposite old San Pedro Lumber Co., UCMP loc. B-469, Cherry Avenue in Signal Hill, USGS loc. 12630, on east bluff above Upper Newport Bay, LACMNH loc. 66-2 (Kanakoff and Emerson, 1959: 22), LACMNH locs. 66-10 and 136, SDSC loc. 533.

DISCUSSION.— *Barnea subtruncata* typically lives in heavy muds of bays and estuaries and in other low energy environments. Fitch (1953: 94) reported them living at depths of ten inches or more and in "colonies" of up to twenty individuals. Generally, the sculpture is sparse, and the concentric ridges are rather distantly spaced. Occasional specimens will bore into soft rock or waterlogged wood, but these are usually somewhat stunted, have more pronounced beaks, and a rounded and reduced posterior slope (Turner, 1954: 34).

Because of its preference for muds in protected environments, the valves are usually thin and fragile. This severely limits preservation in detrital deposits (such as predominate in the Pleistocene of California) to heavier shelled specimens, and could explain the poor fossil record for this species. Though its appearance in fossil deposits has only been recorded twice previously, it occurs not uncommonly in the Pleistocene San Pedro Sand and Palos Verdes Sand of San Pedro and Newport Beach. One locality in the San Francisco Bay area has yielded dredged material which appears fossilized, though no definite age assignment can be given at this time.

Fossil specimens boring in soft rock are known from the late Pleistocene Palos Verdes Sand on the east bluff above Upper Newport Bay, California, where they occur with *Chaceia ovoidea*, *Penitella fitchi*, *P. penita*, and *Nettastomella rostrata*. The sculpture of *B. subtruncata* is typical of mud-boring pholadids in hard substrates (see Fig. 3-4). *Chaceia ovoidea* also was adversely affected by the hard substrate, though the *Penitella* and *Nettastomella* were not.

Barnea truncata (Say, 1822) of the western Atlantic is most closely related to *B. subtruncata*, and differs from the eastern Pacific species by its generally smaller size and shorter posterior dorsal margin. The protoplax is also wider in proportion to its length. It is quite probable these two species are derived from a common ancestor, and diverged from each other some time in the early Neogene.

Genus *Cyrtopleura* Tryon, 1862

Cyrtopleura Tryon, 1862a:201. Turner, 1954:34.

DEFINITION.— Shells essentially elliptical in outline, rounded or beaked anteriorly, not divided by umbonal-ventral sulcus. Pedal gape either a narrow slit in anteriorly rounded forms (*Scobinopholas*), or broadly oval in beaked forms (*Cyrtopleura s.s.*). Radial and concentric sculpture especially prominent over anterior slope and disc. Protoplax entirely periostracal or slightly impregnated with aragonite. Mesoplax transverse, in one or two pieces, calcareous, solid. Umbonal reflection simple, barely reflected anteriorly, folded into complicated socket arrangement posteriorly, not septate.

Cyrtopleura differs from *Thovana* by possessing umbonal sockets and a simple, non-septate, umbonal reflection. *Barnea* has a single acuminate protoplax, is less prominently sculptured, and lacks the umbonal sockets.

TYPE SPECIES.— *Ph.*[*olas*] *crucifera*, Sow.[*erby*] (=*Cyrtopleura* [*C.*] *cruciger* [Sowerby, 1834]), by subsequent designation of Stoliczka (1871: xv).

TAXA INCLUDED.— The genus is divided into *Cyrtopleura s.s.* and *Scobinopholas*. The nominate subgenus contains only *C. cruciger* (Sowerby, 1834) which ranges from Guaymas, Sonora, Mexico, to the Gulf of Guayaquil, Ecuador. It has never been reported in the fossil record. *Scobinopholas* occurs today along the Atlantic coasts of North and South America, and in late Cenozoic deposits of both eastern and western North America.

Subgenus *Scobinopholas* Grant and Gale, 1931

Scobina Bayle, 1880:242 [not *Scobina* Lepeletier, 1825 =Hymenoptera].

Scobinopholas Grant and Gale, 1931:431 [new section name]. Turner, 1954:35.

DEFINITION.— Shell rounded at both ends, pedal gape long, narrow, slit-like. Radial and concentric sculpture prominent over anterior slope and disc. Protoplax triangular to T-shaped, thin, largely periostracal. Mesoplax heavy, transverse, calcareous, in one or two pieces. Umbonal reflection appressed to posterior portion of umbo, raised abruptly, narrow, barely reflected anteriorly. Combination of folds in dorsal margin, umbonal reflection, muscle scar pad, and dorsal end of chondrophore forms complicated socket structure in umbonal region. Apophyses large, broad, more or less spoon-shaped, solid or hollow.

Scobinopholas differs from the nominate subgenus by its rounded anterior, and slit-like pedal gape. *Cyrtopleura s.s.* is somewhat beaked anteriorly, has an oval pedal gape, and less pronounced sculpture and umbonal socket structure.

TYPE SPECIES.— *Pholas costatus* Linnaeus, by original designation of Grant and Gale (1931: 431).

TAXA INCLUDED.— The subgenus includes *C. costata*, from the western Atlantic of North and South America and the Neogene of both eastern and western North America, *C. lanceolata* (Orbigny, 1846) from the Atlantic coast of South America, and *C. arcuata* (Conrad, 1841), from the Miocene of the eastern United States.

DISCUSSION.— Fossil specimens referable to *Scobinopholas* are extremely rare on the Pacific slope, the best known occurrence being in the Pliocene of Imperial Co., California. The only other record consists of two partial specimens in the U.S. National Museum (USNM 5913) collected by J. G. Swan from supposedly Miocene strata at "Neeah Bay, Pugets Sound, Oregon" [=Washington]. The more complete of the two specimens is figured (Fig. 11-12).

Cyrtopleura (*Scobinopholas*) *costata* (Linné, 1758) Figures 8-10

[*Pholas*] *costatus* Linné, 1758:669. Gmelin, 1791:3215.

not *Pholas costata*: Tuomey and Holmes, 1857:102, pl. 24 fig. 4 (=*Cyrtopleura arcuata* (Conrad, 1841); *fide* Dall, 1898).

Pholas costata: Holmes, 1860:58, pl. 9, fig. 1, 1a. Plummer, *in* Sellards, Adkins, and Plummer, 1932:794.

C. [*apulus*] *Shreevei* Conrad, 1869:105, pl. 13, fig. 3, 3a (apophysis only; *fide* Turner, 1954).

Pholas (*Barnea*) *costata*: Dall, 1889:274.

Barnea (*Scobina*) *costata:* Dall, 1898:816. Clark, 1906: 192, pl. 52. Mansfield, 1928:130, 131, 140.

Barnea costata: Pugh, 1905:36, 46, 53, 54. Hanna, 1926: 462, pl. 28, fig. 5-6. Richards, 1962:71, pl. 13, fig. 9.
Pholas (aff.) crucigera: Arnold, 1906:22.
Pholas, sp.: Kew, 1914:46. Vaughan, 1917:367.
Pholas (Barnea) costatus: Grant and Gale, 1931:431.
Barnea (Scobinopholas) costata: Turner, 1954:35, pl. 17 (fig. 4-5), 18. DuBar, 1958:182, fig. 14, 34; pl. 9, fig. 2.

DIAGNOSIS.— Shell oval in outline, rounded anteriorly and posteriorly, not beaked. Radial sculpture strong, extending over entire shell. Interior of shell regularly pitted. Umbonal reflection appressed to posterior portion of umbo, raised abruptly, narrowed and barely reflected anteriorly. Complicated umbonal socket structure formed by folds in dorsal margin, umbonal reflection, muscle scar pad, and dorsal end of chondrophore. Protoplax deltoid in outline, largely periostracal. Mesoplax T-shaped, transverse, in one piece, calcareous. Apophyses large, broadly spoon-shaped, hollow at upper end.

DESCRIPTION.— Shell oval in outline, large, approaching 19 cm in length and 7.5 cm in height, light in structure, gibbose, rounded anteriorly and posteriorly. Pedal gape long, narrow. Sculpture of relatively weak concentric ridges interspersed with many fine growth lines, and more pronounced radial "ribs" formed in part by scalloping of the concentric ridges. "Ribs" strong on anterior and posterior slopes, slightly reduced over disc due to differential wear.

Umbones located anteriorly. Umbonal reflection appressed to posterior portion of umbo, abruptly raised, forms part of area of attachment of anterior adductor muscle, then narrows and is barely reflected anteriorly. Combination of folds in dorsal margin, umbonal reflection, muscle scar pad, and dorsal end of chondrophore form complicated socket structure in umbonal region. Mesoplax in one piece, transverse, more or less T-shaped in outline, solid, calcareous, positioned by umbonal sockets. Protoplax large, thin, deltoid in outline, pointed and grooved anteriorly, broad and occasionally slightly lobate posteriorly, largely periostracal, occasionaly impregnated with small amounts of aragonite in larger specimens (Turner, 1954: 36), nucleus centrally located.

External sculpture reflected internally due to thinness of shell, which consists of prominent, regular pits and furrows. Pallial sinus short, extends anteriorly ⅓ length of shell. Pallial line and muscle scars not calcified, barely visible. Occasional specimens have a ventrally protruding ledge below the posterior adductor muscle scar which provides a greater area of attachment for the muscle (Turner, 1954: 36). Apophyses short, broadly spoon-shaped and widened ventrally, hollow dorsally, extending parallel to radial sculpture of shell.

Periostracum thin, deciduous. Foot elliptical in outline, truncate, not resorbed in adult. Siphons not capable of complete retraction within shell. Soft-part anatomy given by Dall (1889).

LECTOTYPE.— Of *Cyrtopleura costata* (Linné), disposition unknown, designated by Turner (1954: 36) as specimen figured by Gualtieri (1742: pl. 105, fig. G). In rocks in southern Europe (Linné, 1758: 669), corrected by Gmelin (1791: 3215) to *"mari americano"*, and subsequently restricted to Charleston, South Carolina by Turner (1954: 36). Recent.

HOLOTYPE.— Of *Capulus shreevei* Conrad, disposition unknown. It is not in the Academy of Natural Sciences in Philadelphia. Long Island, S. Carolina, collected by Lizzie Shreeve. Recent.

DISTRIBUTION.— Recent; Fall River, Massachusetts (41° 42' N. lat.) south to Rio de Janeiro, Brazil (22° 54' S. lat.; Turner, 1954: 38).

GEOLOGIC RECORD.—Pliocene to Recent.

West Coast Pliocene: Imperial Formation, unknown locality, "UC loc. 51" [= W.S.W. Kew loc. no.], Coyote Mountain, CAS loc. 701 (both Hanna, 1926: 462), SDSNH loc. 2532, 3 miles east of Carrizo Stage Station, SDSNH loc. 0051, Carrizo Creek, USGS loc. 3857, Barrett's Oil Well, 20 miles north of Mexican border, USGS loc. 3921, one mile south of Alverson Canyon, USGS loc. 6847 (Hanna, 1926: 462), south of Yuha Buttes, in Baja California, Mexico, SDSC loc. 350.

East Coast Pliocene and **Pleistocene**: From Massachusetts (Dall, 1898: 816) to Texas (Plummer, *in* Sellards, Adkins, and Plummer, 1932: 794).

DISCUSSION.— *Cyrtopleura costata* is the most commonly found fossil pholadid in the Pliocene and Pleistocene formations of the Atlantic and Gulf coastal states.

The fossil occurrence of this species in the eastern Pacific is unusual, though in the Imperial Formation where it is found, there are a number of Atlantic taxa present. None of the specimens here asigned to *C. costata* are well preserved and all are small compared to large living specimens from the east coast. Arnold's (1906: 22) reference to "*Pholas* (*aff.*) *crucigera* Sowerby" is probably based on specimens of *C. costata.* Hanna (1926: 462) remarked that "regarding the identification of the species with the common east coast species, it should be said that they correspond exactly in shape, number of ribs, and form of sculpturing on the inside of the shells." Hanna did not compare his specimens with *C. arcuata*, however, and I have not seen a series of this latter species. According to Dall (1898: 816) *C. costata* differs from the Miocene *C. arcuata* by its uniformly thinner texture, which results in a punctate pattern on the interior of the valves, its larger size, and the different proportions of the umbonal reflection. Further, *Cyrtopleura arcuata* is smaller, has a longer umbonal reflection, is usually more solid and thick, and has more numerous and finer radial "ribs."

According to Turner (1954: 37) *C. costata* typically lives in sandy mud at, and just below, low water mark in protected areas, or well below the tide line on exposed outer beaches. Further, they can burrow to a depth of two feet or more and are capable of moving up and down in their burrows at will, often extending their siphons a short distance out of the burrow.

Cyrtopleura (*C.*) *cruciger* (Sowerby) of the eastern Pacific (Guaymas, Sonora, Mexico and south) differs from *C. costata* by being smaller, somewhat beaked anteriorly, and having less pronounced sculpture. The inside of the shell is not sculptured with little pits, as is that of *C. costata.* To my knowledge it is unknown as a fossil.

Genus *Zirfaea* Gray, 1842

Zirfaea Leach [MS] Gray, 1840:150 [*nomen nudum*]. Gray, 1842:76. Gray, 1847:188. Turner, 1954:54.
Thurlosia Leach [MS] Catlow and Reeve, 1845:3.
Zirphaea Leach, 1852:250, 252.
Zirphoea [error for *Zirphaea*]: Cooper, 1888:270. Ashley, 1895:328.
Zirphaaea [error for *Zirphaea*]: Anderson, 1908:19.
Zirphea [error for *Zirphaea*]: Smith, 1912:174.

DEFINITION.— Shell cylindrical to oval in outline, beaked anteriorly, rounded to truncate posteriorly, widely gaping both anteriorly and posteriorly. Not closed by callum in adult. American species sculptured with overlapping concentric ridges with pointed imbrications. Sulcus weak. Mesoplax only accessory plate, small, more or less V-shaped, situated posterior to umbones. Apophyses solid, strongly curved, broadened, often spoon-shaped ventrally.

Zirfaea differs from other pholadine genera by its transverse V-shaped mesoplax, the presence of an umbonal-ventral sulcus, and the characteristic overlapping concentric ridges. In *Chaceia* a callum is produced in the adult, and the concentric ridges are upturned and more undulate.

TYPE SPECIES.— *Pholas crispata* Linné (= *Mya crispata* Linné, 1758), by subsequent designation of Gray (1847: 188).

TAXA INCLUDED.— The American species are: *Z. crispata* (Linné, 1758) from the western Atlantic and Europe, *Z. pilsbryi* Lowe from the eastern Pacific, and *Z. dentata* Gabb from the Miocene of California.

DISCUSSION.— There are two separate *Zirfaea* lineages, a Japanese, and an American. The American stock contains species characterized by an anterior slope sculptured with overlapping concentric ridges with imbricated "spines." *Zirfaea* sp. of Masuda and Noda (1969: 133, pl. 14, fig. 5-6) from the lower Pliocene of Japan also belongs to this group. The Japanese stock, characterized by an anterior slope sculptured with upturned and undulate concentric ridges (similar to those of *Chaceia ovoidea*), includes the nominal species *Z. subconstricta*

(Yokoyama, 1924) (at least Pleistocene to Recent), *Z. hataii* Masuda and Noda, 1969 (lower Pliocene; probably a thick shelled *Z. subconstricta*), and *Z. subconstricta kotorai* Otuka, 1934 (Miocene).

Zirfaea dentata Gabb, 1866
Figures 13-15

Z. [*irphaea*] *dentata* Gabb, 1866:18, pl. 3, fig. 31, 31a [plate issued 1869].
Zirphoea [*sic*] *dentata*: Cooper, 1888:270, in part (*Zirfaea dentata*, in part. *Z. pilsbryi*).
Zirphoea [*sic*] *gabbi*: Cooper, 1888:270, in part (*Zirfaea pilsbryi*, in part *Z. dentata*).
Zirphaea dentata: Merriam, 1895:3rd p. Anderson, 1905: 176, 177. Osmont, 1905:96. Anderson, 1908:23. Arnold, 1909 [1910]:17, 21, 26[?], 27. pl. 7 fig. 5. Arnold and Anderson, 1910:85, 86, 94, 110[?], 111, pl. 29, fig. 5. Clark, 1912:57. Smith, 1912:174. Clark, 1915: facing 400, 404, facing 408, 421, 426, pl. 63, fig. 1-2. Nomland, 1917b:299. Trask, 1922:142, 144. Clark, [1929]:23, pl. 25, fig. 5 [*Zirphea* on plate]. Stewart, 1930:7. Keen and Bentson, 1944:122. Stewart, 1946:99, 100, table 2. Weaver, 1953:68. Hall, 1958:25. Hall, 1960:292, 295.
? *Zirphaea* sp.: Turner, 1898:494. Watts, 1900 [1901]:219. Anderson, 1905:172. Arnold, 1906:24. Weaver, 1909: 263. Loel and Corey, 1932:71.
? *Zirphaaea* [*sic*] sp.: Anderson, 1908:19.
Zirphaea dentata Conrad [*sic*]: Smith, 1912:67.
Zirphea [*sic*] *gabbi*: Smith, 1912:174, in part (*Zirfaea pilsbryi*, in part *Z. dentata*).
?not *Zirphaea dentata*: Smith, 1919:147 (Pliocene).
?not *Zirphea* [*sic*] *dentata*: Smith, 1919:148 (Pliocene).
Zirphea [*sic*] *dentata*: Smith, 1919:160.
? *Zirfaea*, cf. *dentata*: Nomland, 1916:203.
Zirphaea, aff. *crispata*: Nomland, 1917b:301.
Pholas (*Zirfaea*) *dentatus*: Grant and Gale, 1931:433. Soper, 1938:168.
? *Zirfaea* sp.: Loel and Corey, 1932:66, 76. Addicott, 1966b:646. Adegoke, 1969:40.
? *Zirfaea* n. sp.: Loel and Corey, 1932:130, and, 148, 234 [both as n. sp.?].
Zirfaea dentata: Loel and Corey, 1932:148, 171. Adegoke, 1969:154, "fig." 6A.
Zirfaea cf. *Z. dentata*: Woodring, Stewart, and Richards, 1940 [1941]:143.
Zirfaea pilsbryi: Durham and Addicott, 1965:14, ? in part (*Zirfaea dentata*; ? in part *Z. pilsbryi* [no specimens seen]).

DIAGNOSIS.— Shell beaked anteriorly, broadly rounded posteriorly, gaping widely at both ends. Concentric ridges on anterior slope imbricate, bend sharply and lose imbrications opposite anterior-most contact of valves on ventral margin, exist as low rounded ridges which parallel sculpture of posterior ventral margin, exist only as growth lines posterior to sulcus. Sulcus intersects ventral margin half the distance along line of contact of valves. Muscle scar pad on umbonal reflection large, heavy, extends two thirds distance to beaks.

ORIGINAL DESCRIPTION.— Shell large, subcylindrical, thin; ends broadly gaping; beaks [=umbones] anterior to the middle; covered by the dorsal plate [=umbonal reflection]; posterior dorsal margin of valves thin and sharply reflexed. Surface of anterior third of shell marked by serrated, squamose plates, as in *Z. crispata;* a faint line or rib passes between the middle and posterior third of the width, from the beaks [=umbones] obliquely down to the base; dorsal plate [=umbonal reflection] heavy, compressed, and divided into two concave surfaces by a sharp, angular ridge, commencing at the posterior end, and running forwards, slightly curved, ending in a tooth at a point about a third of the length of the plate from the anterior extremity.

SUPPLEMENTARY DESCRIPTION.— Shell large, long, cylindrical for diameter, reaching 14 cm in length. Siphonal and pedal gapes wide. Valves divided by weak umbonal-ventral sulcus, intersecting ventral margin near its midpoint. Anterior portion often larger than posterior, sculptured with heavy, knobby, or imbricate, occasionally spinose, concentric ridges, and radial pattern created by aligned imbrications. Concentric ridges of anterior slope bend sharply, lose imbrications opposite foremost point of contact of valves, then run posteriorly, parallel to sculpture of posterior ventral margin, as low rounded ridges, vanish at sulcus, then existing only as growth lines.

Umbonal reflection heavy, longitudinally symmetrical, appressed for much of length. (That of *Z. pilsbryi* is lighter, wider above the umbonal region, and usually not appressed except over the umbo.) Muscle scar pad large, part of umbonal reflection, commonly extends nearly two thirds distance to beaks.

Umbonal-ventral ridge low, prominent, occasionally ornamented with little bumps, corresponding to intersection of sulcus with concentric ridges on exterior of shell.

Muscle scars, pallial line and sinus, and apophysis unknown. Mesoplax unknown, probably similar to that of *Z. pilsbryi*.

HOLOTYPE.— Of *Zirphaea dentata* Gabb, once in the University of California Museum of Paleontology (Merriam, 1895: 3rd p.), it appears now to be lost (Stewart, 1930: 7). (See also Discussion remarks.) Pliocene beds at the east end of Kirker's Pass, Contra Costa Co., California (Gabb, 1866: 18). Grant and Gale (1931: 433) however suggest an age of 'possibly Miocene.'

GEOLOGIC RECORD.— Miocene to lower Pliocene.

Miocene: Lake County, USGS loc. 93. Martinez, USGS loc. 104. East end of Kirker's Pass (Gabb, 1866: 18; type locality). Briones Sandstone, east, and west limbs of the Pacheco Syncline, UW locs. 3415 and 3414 (both Weaver, 1953: 68), northeast side of Shell Ridge, UCMP loc. 305. San Pablo Group, east of Riggs Canyon north of Tassajara, UCMP loc. 492 (Clark, 1915: facing 408), south of Rodeo, UCMP loc. 1600, near Tormey, UCMP loc. 1607, south of Pittsburg, UCMP loc. 1891. Temblor Formation, near Cantua Creek, UCMP loc. B-8609, 4.5 miles southeast of Ciervo Mountain, USGS loc. 5802. Santa Margarita Formation, Big Blue Hills, USGS loc. 5828, Cantua Creek, USGS loc. 5829, near Domengine Creek, UCMP loc. A-9731. Vaqueros Formation, in the Oil City-Oilfields region, UCMP locs. 2300, 2309, and 2313, USGS locs. 4633, and 4803 (both Arnold, 1909 [1910]: 17; and Arnold and Anderson, 1910: 85, 86). Temblor Formation, in the Oil City-Oilfields region, UCMP locs. B-7085, B-7086, D-115, D-116, D-1072, D-1073, D-1076, and D-1078 (all Adegoke, 1969: 154), CAS locs. 2087, 2088, and 28485, UCMP locs. A-1306, and A-3345. Santa Margarita Formation, northwest of San Joaquin Valley Coal Mine, USGS loc. 4632 (Arnold, 1909 [1910]: 21; and Arnold and Anderson, 1910: 94). Vaqueros Formation, Sulphur Spring Canyon below Garza Creek, USGS loc. 4625, west of Big Tar Canyon, USGS loc. 4627 (both Arnold, 1909 [1910]: 17; and Arnold and Anderson, 1910: 85). Temblor Formation, vicinity of Reef Ridge, UCMP locs. B-6518 and D-1059 (both Adegoke, 1969: 154), near Garza Creek, UCMP loc. B-6511 (Adegoke, 1969: 154), UCMP loc. A-7583, east of Big Tar Canyon, UCMP locs. A-9739, and D-1048 (both Adegoke, 1969: 154), UCMP loc. A-9742, south of Big Tar Canyon, UCMP loc. B-4339, west of Little Avenal Creek, UCMP loc. D-1066 (Adegoke, 1969: 154), Reef Ridge northwest of Garza Peak, USGS loc. 14397, near Betram Creek, USGS loc. 14408, Arroyo Pinoso, USGS loc. 14409, and west side of Zapato Canyon, USGS loc. 14410 (all USGS locs. Stewart, 1946: table 2). Escudo Formation, south side of Escudo Mountain, USGS-M loc. 3779 (cf.). ?Vaqueros Formation, Neason's Flat in the Pleito Hills, UCMP loc. 7180. Bacon Hills, USGS loc. 18740. West of El Tranquillon Peak, CAS loc. 27871A. Temblor Formation, Santa Rosa Island, CAS loc. 1154 (? Loel and Corey, 1932: 66). Vaqueros Formation, Santa Clara Valley west of mouth of Wiley Canyon, UCMP loc. A-252, and Santa Monica Mountains west of Ensenal Canyon, UCMP loc. A-551 (both Loel and Corey, 1932: 66, 76). Temblor Formation, upper Malibu Canyon, UCMP loc. A-557. Topanga Formation, two miles south of Calabasas, LACMNH loc. 2905, Dry Canyon, UCLA loc. L-167 (Soper, 1938: 168), Old Topanga Canyon, LACMNH locs. 32 and 317-J, USGS loc. 18732, ridge north of Mesa Peak in Santa Monica Mountains, USGS-M loc. 1071. Southwest of Irvine Lake Reservoir, USGS loc. 18459.

Pliocene: Jacalitos Formation, Coalinga area, on ridge south of Garcas Creek, USGS loc. 4745 (Arnold, 1909 [1910]: 26; and Arnold and Anderson, 1910: 110. [= *Zirfaea* sp. indet.]), on or near Jacalitos Creek (Nomland, 1916: 203). Etchegoin Formation [Jacalitos "stage," faunizone E, zonule 8], near Shell Oil well 155-15, Domengine Ranch quad., UCMP loc. B-6534 (Adegoke, 1969: 154). Pancho Rico Formation, east of Peachtree Valley, UCMP loc. A-3241, south side of Pancho Rico Creek, USGS-M loc. 1966 [?], and north side of Powell Canyon, USGS-M loc. 979 [?] (all Durham and Addicott, 1965: 14; as *Zirfaea pilsbryi*; no

specimens seen for last two localities).

DISCUSSION.— *Zirfaea dentata* was the first extinct species of Pholadidae described from Cenozoic deposits of the Pacific slope. It is restricted to the Miocene and lowermost Pliocene of California, where it is often locally abundant.

The holotype of *Z. dentata* Gabb was reported to be in the University of California Museum of Paleontology by Merriam (1895), but missing by Stewart (1930: 7). A specimen in the UCMP collections, no. 31180, matches Gabb's original figure (1869: pl. 3, fig. 31), but is a mirror image. If the figure was *not* reversed, the type is probably lost. No other specimens matching the figure could be found in the Miocene collections in the University of California Museum of Paleontology.

Zirfaea dentata can be recognized by its sculpture on the anterior slope, which distinguishes it from its Pliocene to Recent descendent, *Z. pilsbryi*. The imbricated concentric ridges of *dentata* bend sharply at the central part of the anterior slope, lose their imbrications, and then (still anterior to the sulcus) run parallel to the sculpture of the posterior ventral margin. The sulcus itself intersects the ventral margin one half way along the line of contact of the valves, thus differing from *pilsbryi* in which the sulcus intersects the margin near the anterior point of contact. Though not well shown on the figures, this feature is distinct on fossil specimens.

Zirfaea dentata is conspicuously absent in strata outside of central and southern California. It is not known to occur in the Miocene of Oregon or Washington, though suitable habitats existed. Since *Z. pilsbryi* occurs today on the Arctic coast of Alaska, the slightly colder waters of the northwest coast was probably not the limiting factor. *Zirfaea dentata* is especially common in the Coalinga-Kettleman Hills region of the western San Joaquin Valley. The southernmost occurrence of the species is in Orange County, southwest of Irvine Lake reservoir.

Zirfaea dentata has often been characterized as a typically Miocene species, though it also ranges into the lowermost Pliocene (Jacalitos "stage" of authors). Both Arnold (1909 [1910]: 26) and Arnold and Anderson (1910: 110) reported *Z. dentata* from the Jacalitos Formation near Coalinga (USGS loc. 4745), but the specimen cannot be identified to species. More recently, Durham and Addicott (1965: 14) cited specimens, as *Z. pilsbryi*, from the lower Pliocene (Jacalitos "stage") Pancho Rico Formation in the Salinas Valley. Specimens from only one locality of three could be located, and these were representative *Z. dentata*. They were originally catalogued as Miocene, Santa Margarita Formation, from UCMP loc. A-3241. Adegoke (1969: 154) also cited one lot of specimens, of good *Z. dentata*, from the Pliocene Etchegoin Formation from the Coalinga region (UCMP loc. B-6534). These are from his lowest Pliocene faunizone E, zonule 8, equivalent to the Jacalitos "stage" of authors. This faunizone is transitory, and includes strata with the highest occurrences of some Miocene species, as well as the lowest occurrences of several Pliocene species. The name Jacalitos was dropped because it could not be properly distinguished on a purely lithologic basis from the Etchegoin (Adegoke, 1969: 26-27). Unfortunately, this is likely to cause confusion with those who associate the Etchegoin Formation with Middle Pliocene, or Etchegoin "stage" of past authors.

Zirfaea pilsbryi Lowe, 1931
Figures 16-18, 19

Z. [*irphaea*] *Gabbii*: Gabb, 1869:52, 88, in part; not pl. 15, fig. 10 (*Penitella gabbii*, in part *Zirfaea pilsbryi* and *Chaceia ovoidea* [pl. 15, fig. 10].

Zirphoea [*sic*] *dentata*: Cooper, 1888:270, in part (*Zirfaea dentata*, in part *Z. pilsbryi*).

Zirphoea [*sic*] *gabbi*: Cooper, 1888:270, in part (*Zirfaea pilsbryi*, in part *Z. dentata*).

Zirphoea [*sic*] *crispata*: Orcutt, 1889:71. Osmont, 1905:95.

Zirphaea crispata: Diller, 1896:482. Newcombe, 1914:109. Nomland, 1917a: facing 230. Wagner, 1959:37, 38, 40.

Zirphaea orispata [*sic*]: Watts, 1900 [1901]:224.

Zirphaea gabbi: Arnold, 1903:23, 25, 27, 31, 38. Arnold, 1906:27, 34. Arnold, 1908:354, 355. Arnold, 1909 [1910]:35, 39. Arnold and Anderson, 1910:129, 132. Martin, 1916:243, 245. Smith, 1919:143, 144. Waterfall, 1929: facing 78. Crickmay, 1924:631. Natland, 1957: facing 548. Glen, 1959:158. Faustman, 1964:105.

Zirphaea gabbii: Arnold, 1903:184. Martin, 1916:229, 255.

not? *Zirphea* [*sic*] *gabbi*: Smith, 1912:174 (?=*Zirfaea dentata*).

? *Zirphaea*, species: Gester, 1917:224.
Zirphea [*sic*] *gabbi*: Smith, 1919:145.
Zirfaea gabbi: Orcutt, 1921:24. Jordan, 1926:245 (of "Dall" [=Orcutt], 1921). Manger, 1934:283, 293. Wagner, 1959:40. Valentine, 1960b:19. Adegoke, 1969:154, "fig." 6A.
? *Zirphaea* sp.: Santillán and Barrera, 1930:26.
Zirfaea gabbi?: Hoots, 1931:122.
Zirfaea pilsbryi Lowe, 1931:53, pl. 3, fig. 1-2. Willett, 1937 [1938]:106, in part (*Z. pilsbryi*, in part large *Penitella*). Putnam, 1942:699. Wilson, 1943:246. Burch, 1947:9. Emerson, 1951:89, pl. 31. Fitch, 1953:95, fig. 61. Emerson and Addicott, 1953:434, 441. Turner, 1954:58, pl. 30 (fig. 4-9), 31-34. Valentine, 1956:196, in part (*Z. pilsbryi*, in part *Chaceia ovoidea*). Valentine, 1957:297. Emerson and Addicott, 1958:8. Addicott and Emerson, 1959:17. Valentine, 1959:54. Kanakoff and Emerson, 1959:25, in part (*Z. pilsbryi*, in part *Barnea subtruncata*). Emerson and Chace, 1959:338. Emerson, 1960:5. Valentine, 1961:357. Addicott, 1964a:658. Addicott, 1966a:4, pl. 4, fig. 18. Chace, 1966:170, in part (*Zirfaea pilsbryi*, in part *Barnea subtruncata* and *Chaceia ovoidea*). Thompson, 1967 MS:22. McLean, 1969:90, fig. 53.2. Wright, 1972:691. Kennedy, 1973:122.
Pholas (*Zirfaea*) *gabbi*: Grant and Gale, 1931:432, pl. 24, fig. 2. Wilson, 1966:108.
Pholas pilsbryi: Willett, 1937:391.
Zirfaea gabbi var.: Woodring, Stewart, and Richards, 1940 [1941]:33, 68, opposite 78, 96.
Zirfaea gabbii var.: Woodring, Stewart, and Richards, 1940 [1941]: opposite 35.
Zirfaea cf. *Z. gabbi*: Woodring, Stewart, and Richards, 1940 [1941]:54.
Zirfaea sp.: Woodring, Stewart, and Richards, 1940 [1941]: opposite 67, 70.
Pholas gabbi: Delong, 1941:242, facing 244.
Zirfea [*sic*] *gabbi*: Cook and Clark, 1943:17.
Zirfaea pilsbryi (Tryon) [*sic*]: Bruff, 1946:233.
Zirfaea cf. *Z. pilsbryi*: Woodring and Bramlette, 1950 [1951]: facing 49. Hertlein and Grant, 1972:331.
not *Zirfaea*? sp.: Valentine, 1958:691 (=*Chaceia ovoidea*?).
Pholas (*Zirfaea*) cf. *P.* (*Z.*) *gabbi*: Glen, 1959:157, 177.
Pholas (*Z.*) *gabbi*: Glen, 1959:160.
? *Zirphaea* aff. *gabbi*: Hall, 1960:295.
Pholadidea penita: Valentine, 1961:370, in part (*Penitella penita*, in part *Zirfaea pilsbryi* and *Chaceia ovoidea*).
not *Zirfaea*? cf. *Z. pilsbryi*: Valentine, 1961:376 (=*Chaceia ovoidea*).
not *Zirfaea pilsbryi*: Addicott, 1963a:344 (=*Penitella turnerae*). Durham and Addicott, 1965:14, in part ? (*Zirfaea dentata*; ? in part *Z. pilsbryi* [no specimens seen]).
Parapholas californica: Vedder and Norris, 1963:46, 50, in part (*P. californica*, in part *Zirfaea pilsbryi* and *Chaceia ovoidea*).
Penitella gabbi: Adegoke, 1967:16, in part (*Penitella gabbii*, in part *Zirfaea pilsbryi* [all fossil references]).
Zirfaea gabbi (Tryon) *femii* Adegoke, 1967:17 (*nomen nudum*). Adegoke, 1969:154, "fig." 6A; pl. 9, fig. 2, 8, 11-12; pl. 10, fig. 3, 5-6, 13.
Zirfaea? species: Addicott, 1969:63, 74, pl. 2, fig. 9.
? *Zirfaea* sp.: Masuda and Noda, 1969:133, pl. 14, fig. 5-6 [Pliocene of Japan].
Zirfae [*sic*] *pilsbryi*: Human, 1972:9.

DIAGNOSIS.— Sculpture on anterior slope not parallel to the ventral margin posterior to the sulcus. Shell beaked anteriorly, broadly rounded to truncate posteriorly, gaping widely at both ends. Valves usually in contact on the ventral margin only posterior to the sulcus. Apophyses spoon-shaped.

DESCRIPTION.— Shell reaching 14 cm in length and 10 cm in height, beaked anteriorly, broadly rounded or truncate posteriorly. Pedal and siphonal ends widely gaping throughout life. Valves in contact only at umbones and ventral margin posterior to sulcus.

Anterior slope sculptured with moderately spaced, laminate, often spinose, imbricate, concentric ridges, and weak radial pattern imparted by the radial alignment of imbrications on the concentric ridges. In heavy-shelled specimens, concentric ridges are closely spaced, more undulate and up-turned, giving the appearance of thickness. Shell divided by weak umbonal-ventral sulcus, more conspicuous in juvenile specimens, almost disappearing near the ventral margin in older specimens. Disc and posterior slope ornamented only with concentric growth lines.

Umbonal reflections only appressed to anterior slope near umbones, becoming narrower and less appressed anteriorly. The reflection is always worn at the point of contact of the valves. Mesoplax only accessory plate, transverse, small for size of valves, more or less triangular in outline, commonly with a well-developed basal flange (Turner, 1954: 60), situated posterior to umbones.

Pallial line well-marked, muscle scars indistinct. Ventral muscle scar barely differentiated from widened, often calcified pallial line. It is quite different from the ventral muscle scar of *Chaceia ovoidea*. Pallial sinus broad, deep, extending anteriorly about one-half the length of the shell. Umbonal-ventral ridge distinct, beaded in juveniles, lacking entirely in older specimens. Apophyses large, strong, curved, and moderately to strongly spoon-shaped.

Periostracum thin, usually persistent on posterior slope. Siphons large, incapable of retraction within shell. Foot truncate and nearly circular in outline.

HOLOTYPE.— Of *Zirfaea pilsbryi* Lowe, ANSP 50809. PARATYPES: Once in the Lowe collection (Lowe, 1931: 53), and thought to be in the San Diego Natural History Museum (Turner, 1954: 60), they are not recognizable as such, if at all present (cf. Wilson and Kennedy, 1967). A search was made for them and they were not found. Bolinas, California, collected by Henry Hemphill. Recent.

HOLOTYPE.— Of *Zirfaea gabbi femii* Adegoke, UCMP 36795. PARATYPES: UCMP 36796-36798. South slope of hill, in sec. 22, T. 22 S., R. 16 E., MDBM, Kings County, California, UCMP loc. B-6538. Collected ? by O. S. Adegoke, 1963. Pliocene, Etchegoin Formation.

DISTRIBUTION.— Recent; Point Lay, Arctic coast of Alaska (69° 44' N. lat.; USGS-M loc. 2069 [fragment] to Magdalena Bay, Baja California, Mexico (ca. 24° 30' N. lat.; SDSNH 50645 [beachworn]).

GEOLOGIC RECORD.— Pliocene to Recent.

Pliocene: Merced Formation, three-fourths of a mile southeast of Mussel Rock, UCMP loc. 1722 (Martin, 1916: 229; cf.), Moss Beach, UCMP loc. B-4793 (Glen, 1959: 157), northwest corner of Santa Clara Co., UCMP loc. B-8348. Merced(?) Formation, Arastradero Road, city of Los Altos Hills, USGS-M loc. 1715 (Addicott, 1969: 61, 63, 74; as *Zirfaea*? species). Purisima Formation, sea cliffs south of Halfmoon Bay (Martin, 1916: 243), west of Sargent on north side of Pescadero Creek, UCMP loc. 1905 (Martin, 1916: 245), Santa Cruz quadrangle (Arnold, 1906: 27; and Arnold, 1908: 354). ?Paso Robles Formation, northwest of Jolon, UCMP loc. B-4928. Etchegoin Formation, east side of San Benito River southeast of San Benito, USGS loc. 18558 (cf.), Gabilan Range, NNW of Pinnacles, UCMP loc. B-2178, northeast side of Bitterwater Valley, LACMNH loc. 1204, hills northeast of Priest Valley, UCMP loc. 3016 (Nomland, 1917a: facing 230), near Jacalitos Creek, UCMP locs. 2668 (cf.) and A-650, northwest of Zapato Creek, USGS loc. 4710, and near Henry Spring, SSW of Coalinga, USGS loc. 4758 (both Arnold, 1909 [1910]: 35, 39; and Arnold and Anderson, 1910: 129, 132). San Joaquin Formation, Coalinga region, CAS loc. 509, west of Oilfields, UCMP loc. D-1203 (Adegoke, 1969: "fig." 6A), southwest slope of Kreyenhagen Hills, UCMP locs. B-6537 and B-6538 (both Adegoke, 1969: 155; as *Zirfaea gabbi femii*). Etchegoin Formation, North Dome of Kettleman Hills (all [USGS locs.] Woodring, Stewart, and Richards, 1940 [1941]), on ridge north of El Chichon, USGS loc. 12421 (p. 68), southwest of Discovery Ridge, USGS loc. 12818 (opp. p. 67), east slope of La Tusa, USGS loc. 14119 (p. 70), La Cuesta, UCMP loc. A-9738, southeast slope of El Serrijon, USGS loc. 12424 (p. 68), west side of La Paredes, USGS loc. 14113 (p. 70), on branch of Arroyo Doblegado southeast of Las Paredes, USGS loc. 12426 (p. 70), and on Arroyo Murado southeast of La Clavija, USGS loc. 14122 (p. 70). Cascajo Conglomerate member of San Joaquin Formation (all Woodring, Stewart, and Richards 1940 [1941]: 54), North Dome of Kettleman Hills, on south slope of Cerro Ultimo, USGS loc. 14087, South Dome, at El Arco, USGS loc. 12653, north of Oyster Hill, USGS locs. 12657, 12793, and 12794, west of Oyster Hill, USGS loc. 12656, ESE of Oyster Hill, USGS loc. 12660, Cascajo Hill, USGS loc. 12645. San Joaquin Formation, Kettleman Hills, UCMP loc. B-7727, on North Dome, ridge above fork of Arroyo Murado, UCMP loc. B-8589, near El Rascador, UCMP loc. D-330, along west branch of Arroyo Hondo, USGS loc. 12336, and (all Woodring, Stewart, and Richards, 1940 [1941]) Arroyo del Camino, USGS locs. 12372 (p. 33) and 12370a (opp. p. 35), Arroyo Somero, USGS loc. 12373 (opp. p. 35). Northeast flank of Caliente Mountain, USGS loc. 12956. Etchegoin Formation, from oil well near McFarland, SDSNH 00201 (Grant and Gale, 1931: 433). Graciosa Member of Careaga Sandstone, north slope of Casmalia Hills, northwest of Schuman's Siding, USGS loc. 14609 (Woodring, Stewart and Richards, 1940 [1941]: facing 49). Sisquoc Formation,

Pennsylvania asphalt mine southeast of Orcutt, USGS loc. 4472 (cf.). "Pico" Formation, south of Santa Paula on south side of South Mountain, UCMP loc. 7098 (Waterfall, 1929: facing 78). San Diego Formation, southwest of Goat Canyon, LACMNH loc. 305 (Hertlein and Grant, 1972: 331).

Pliocene or Pleistocene: Cujije [?] Arroyo, San Antonio Rancho, Baja California, Mexico, USGS loc. 9156.

Pleistocene: Near Cook Street, between Spring Ridge and Protestant Orphanage, Victoria, British Columbia (Newcombe, 1914: 109 ; as *Zirphaea crispata*). Saanich Formation, Bay Street and Cedar Hill Road, Victoria, British Columbia (Wagner, 1959: 38). Hinton Point, Yaquina Bay, LACMNH loc. 3952, USGS-M loc. 4622. North of jetty, Yaquina Bay State Park, Oregon, USGS-M loc. 3026. Cliff near "Newport Point," Oregon (Diller, 1896: 482; as *Zirphaea crispata*). Cape Blanco, Oregon, UCMP loc. A-8712 (Addicott, 1964a: 658), and .5 miles southeast, CAS loc. 20 (aff.). Crannell Road and Highway 101 south of Trinidad, LACMNH loc. 3936. Point Año Nuevo, USGS-M locs. 1690 (aff.) and 2147 (both Addicott, 1966a: 4), SDSNH loc. 2670 (aff.). Southeast of Lions Head, USGS loc. 15052. Isla Vista, near Goleta (Wright, 1972: 691; *Z. p.* and *Z.* sp. aff. *Z. p.*), LACMNH locs. 416 and 2694. West of Goleta Point, SDSNH loc. 0040. Santa Barbara (Cooper, 1888: 270). Near Ventura, on ridge between Javon and Madranio Canyons (Putnam, 1942: 299). Potrero Canyon, Pacific Palisades (Hoots, 1931: 122), UCLA loc. 3225 (Valentine, 1956: 196; in part). Cheviot Vista Place, Palms, Los Angeles, LACMNH loc. 426. Palos Verdes Sand, Lincoln Avenue, near Venice, LACMNH 59 (Willett, 1937: 391). Undifferentiated Pleistocene at San Pedro (Gabb, 1869: 52, 88), LACMNH loc. 1, SDSC loc. 736, UCMP loc. 2112, Deadman Island, LACMNH loc. 17, San Pedro RR cut, SDSNH loc. 1899, new San Pedro lumberyard, SDSC loc. 648, SDSNH loc. 1960, Wilmington and San Pedro Road, USGS loc. 12141 (cf.), First Street and [old] Harbor Boulevard, UCMP loc. A-218, "San Pedro Bluffs" at Second and Beacon Streets, UCMP loc. D-1627. San Pedro Sand, in San Pedro, at Nob Hill, LACMNH loc. 300, Pacific Avenue, LACMNH loc. 131, Third and Mesa Streets, LACMNH loc. 98, corner of Bonita Street and Pacific Avenue, ANSP [no locality number], high school at 15th and Leland Streets, SDSNH loc. 2138 [= L-2138] (Chace, 1966: 170; in part), LACMNH loc. 2687, Peck Park, USGS loc. 13125. Palos Verdes Sand, in San Pedro, CAS loc. 91, south of Union Oil refinery in Harbor District Sanitation yard, LACMNH locs. 427 and 1210, opposite San Pedro Lumber Company, UCMP loc. B-469, Pacific Avenue and Hards Street, LACMNH loc. 440, Pacific Avenue and Bonita Street, USGS loc. 12132, Second and Mesa Streets, UCMP loc. D-390, Third and Mesa Streets, SDSNH loc. 2660, USGS loc. 13779, Palos Verdes Avenue between Eighth and Ninth Streets, UCLA loc. 3440 (Valentine, 1961: 370; as *Pholadidea penita*, in part), Third Street and Palos Verdes Avenue, USGS loc. 12134, Deadman Island (Crickmay, 1929: 631), old Crawfish George's, and San Pedro Bluff (last three Arnold, 1903: 23, 25, 27), 22nd and Mesa Streets, USGS loc. 12138, outfall sewer at Lomita and Main Streets in Wilmington, LACMNH loc. 77, Cherry Avenue in Long Beach, LACMNH loc. 424, Cherry Avenue in Signal Hill, USGS loc. 12630, USGS-M loc. 2011, Raymond Avenue in Signal Hill, CIT loc. 1348 (Delong, 1941: facing 244), Signal Hill, UCMP locs. A-221 and A-1483, Los Cerritos Hill [= Signal Hill] (Arnold, 1903: 31), Huntington Beach mesa, UCLA loc. 3657 (Valentine, 1957: 297), west facing bluff of Santa Ana River channel, UCMP loc. A-3129, west bluff of Upper Newport Bay, UCMP loc. A-3101 (both Bruff, 1946: 233), west bluff of "middle" Newport Bay, LACMNH loc. 68-A, and east bluff of Upper Newport Bay, LACMNH loc. 66-2 (both Kanakoff and Emerson, 1959: 25; in part), LACMNH loc. 136, SDSC locs. 531, 532, 534, and 535, CAS loc. 38432, USGS-M loc. 1722, Newport Beach, ANSP [no locality number], Corona del Mar (Human, 1972: 9). Capistrano Beach, LACMNH loc. 58 (Willett, 1937 [1938]: 106; in part). San Nicolas Island, USGS loc. 21664 (Vedder

and Norris, 1963: 46; as *Parapholas californica*, in part). Torrey Pines Beach State Park. UCLA loc. 2410. Lindavista Formation, east of Murphy Canyon, San Diego, SDSNH loc. 0325 (Kennedy, 1973: 122). Bay Point Formation, Tecolote Canyon, San Diego (Kanakoff, *in* Emerson and Chace, 1959: 338), Glorietta Bay, Coronado, SDSC loc. 71 or 118 (Thompson, 1967 MS: 22), LACMNH loc. 2658. Coronado Beach, SDSNH loc. 2528, CAS (HH 12008). Two miles south of Ocean Beach, San Diego (Orcutt, 1889: 71). Border locality in southwestern San Diego County, UCMP locs. A-9003, A-9004, A-9005, and A-9006 (all Emerson and Addicott, 1953: 434, 441), UCLA loc. 3175 (Valentine, 1961: 357), LACMNH loc. 4556, SDSNH loc. 0120. In Baja California, Mexico, at Rosarito Beach, UCLA loc. 2720 (Valentine, 1957: 297); Punta San José (Emerson, 1960: 5); Punta Cabras and vicinity, UCMP locs. A-9589 ("?"), A-9587, A-9713, and A-9917 (all Addicott and Emerson, 1959: 17); San Quintin (Orcutt, 1921: 24; Manger, 1934: 283), USGS locs. 7498, 7499, and 11729; immediately east of Punta Baja, UCMP locs. A-9590 and A-9591 (both Emerson and Addicott, 1958: 8); Bahía San Bartolomé [= Bahía Tórtolo], UCMP locs. B-3027 and B-3050; near San Juanica and Punta Pequeña, LACMNH loc. 2719.

DISCUSSION.— *Zirfaea pilsbryi* was long known under the trivial name *gabbi*. Though actually a *Penitella*, *gabbii* was construed to be the living west coast *Zirfaea* until Lowe described it as *Z. pilsbryi* in 1931. Unfortunately Lowe's description was published too late to be included in Grant and Gale's (1931) "Catalogue of the marine Pliocene and Pleistocene Mollusca of California," and thus the older name remained in common use in paleontological literature.

Zirfaea pilsbryi is readily distinguished from other Pholadinae by its umbonal-ventral sulcus. It can be separated from *Z. dentata*, a Miocene to lowermost Pliocene species, by the sculpture on the anterior slope, which does not parallel that of the posterior slope, and the umbonal-ventral sulcus, which intersects the ventral margin near the anterior-most point of contact of the valves, rather than near the midpoint as in *Z. dentata*.

Zirfaea gabbi femii described by Adegoke (1969: 154) from the Pliocene San Joaquin Formation is only a young *Z. pilsbryi*. Many specimens utilized by Adegoke (from UCMP locs. B-6537, B-6538, and D-1203) in his description were not given type designations.

Typically a soft-sediment borer, *Z. pilsbryi* inhabits heavy muds, clay, or soft rock, in bays, estuaries, and other low energy environments, though it may also bore into soft rock on the open coast (Fitch, 1953: 95). Burrows in mud may reach a depth of 40 cm (Fitch, 1953: 95). Emerson (1951: 89, pl. 31) reported *Z. pilsbryi* in waterlogged wood, though the occurrence seems to be fortuitous.

Zirfaea pilsbryi is the most common fossil pholadid on the Pacific slope of North America and is well known from detrital Pleistocene deposits of California and northern Baja California. Known Pleistocene occurrences *in situ* are uncommon, though it has been found at Point Año Nuevo (Addicott, 1966a: 3), in the low late Pleistocene terrace near Goleta, both places associated with *Penitella turnerae*, at the border locality of Emerson and Addicott (1953), and on the terrace platform at Punta San José, Baja California (Emerson, 1960: 5). The few occurrences of paired valves in the Pleistocene are due to the soft nature of the preferred habitat, which does not well withstand erosive action.

Except for a locality of questionable age in Baja California, *Z. pilsbryi* is known from Pliocene deposits only in California, commonly with both valves together. Masuda and Noda (1969: 133, pl. 14, fig. 5-6) however have cited incomplete specimens of *Zirfaea* sp. from the early Pliocene Tatsunokuchi Formation near Sendai, Japan, which in all respects are identical to living *Z. pilsbryi*, and unlike *Z. subconstricta* of Japan or *Z. dentata* of the California Miocene.

A variant of *Z. pilsbryi*, cited throughout as *Zirfaea* sp. aff. *Z. pilsbryi* (see Fig.

19), also occurs in the Pleistocene of northern California and Oregon. The type of anterior sculpture does not closely resemble that of the nominal species, but is more like that of *Chaceia ovoidea*, with separated undulating concentric ridges. More work needs to be done on this form, which is also known from living specimens (e.g., Buhne Point in Humboldt Bay, MCZ 195915).

Subfamily MARTESIINAE Grant and Gale, 1931

DEFINITION.— Shell beaked and gaping anteriorly in the young stage, closed in the adult by a callum, a dorsal extension of which usually encloses the anterior adductor muscle. Number of accessory plates variable, but always possessing a mesoplax and lacking a protoplax. Apophyses always present. Valves divided into two regions by an umbonal-ventral sulcus, and into three regions in some genera. Foot well-developed in the young stage, atrophied in the adult. Siphons capable of complete retraction within the shell except in the genus *Chaceia*.

TYPE GENUS.— *Martesia* Sowerby, 1824.

TAXA INCLUDED.— Fourteen genera and four subgenera are recognized (Turner, 1969) in the Martesiinae, as follows: *Aspidopholas* Fischer, 1887, *Chaceia* Turner, 1955, *Diplothyra* Tryon, 1862b, *Eutylus* Vincent, 1891, *Goniochasma* Meek, 1864, *Heteropholas* Fischer, 1887, *Lignopholas* Turner, 1956, *Martesia s.s.* Sowerby, 1824, and *Particoma* Bartsch & Rehder, 1945, *Opertochasma* Stephenson, 1952, *Parapholas* Conrad, 1848, *Penitella* Valenciennes, 1846, *Pholadidea s.s.* Turton, 1819 and *Hatasia* Gray, 1851, *Ramsetia* Stephenson, 1941, and *Xylophomya* Whitfield, 1902. Olsson (1961) considers *Hatasia* to be of full generic rank. A new subgenus of *Martesia*, *Paramartesia* is described later in this paper.

The type species of *Aspidopholas*, *Eutylus*, *Goniochasma*, *Heteropholas*, *Opertochasma*, *Paramartesia*, *Ramsetia*, and *Xylophomya* are fossils. The genera occurring today in the eastern Pacific are *Chaceia*, *Diplothyra*, *Martesia s.s.* (and ? *Particoma*), *Parapholas*, *Penitella*, and *Hatasia*. *Opertochasma* and *Paramartesia* are known from fossils in the same region.

Genus *Chaceia* Turner, 1955

Chaceia Turner, 1954:3, 16, 17; [*nomen nudum*]. Turner, 1955:66.

not *Chaceia* (?): Adegoke, 1966:233 (=*Penitella*).

DEFINITION.— Shell oval, moderate to large in size, widely gaping anteriorly and posteriorly in young stage. Pedal gape only partially closed by callum in adult, siphonal gape remaining wide. Umbonal-ventral sulcus pronounced. Valves in contact only at umbones and ventral condyles. Dorsal extension of calum extends from beaks to umbones. Mesoplax only accessory plate, transverse, single, small and V-shaped in juvenile, covered and U-shaped in adult. Siphons incapable of complete retraction within shell.

The genus *Chaceia* differs from other morphologically similar genera by gaping widely at both ends of the shell, and by possessing only a partial callum.

TYPE SPECIES.— *Pholas ovoidea* Gould, by original designation of Turner (1955: 66).

TAXA INCLUDED.— The genus only includes *Chaceia ovoidea* from the eastern Pacific. "*Pholadidea* (*Penitella*) *chishimana* Habe, 1955," of Japan, may possibly belong to either *Chaceia* or *Zirfaea* rather than to *Penitella*.

DISCUSSION.— The genus *Chaceia* was proposed for *Pholas ovoidea* Gould, a species not easily accommodated in either *Pholadidea* in its revised and restricted sense, or in *Penitella*. It is most closely related to *Zirfaea* (subfamily Pholadinae) and there is little doubt that it did not evolve from this latter genus sometime in the early Neogene. A single specimen of ?*Zirfaea* sp. collected from the basal portion of the Miocene Montesano Formation of Canyon River, Washington (USGS-M loc. 3073), may represent an ancestral *Chaceia*. The poorly preserved specimen has a short anterior dorsal margin similar to *C. ovoidea*, and an anterior slope quite unlike that of *Zirfaea dentata*. Additional specimens are

needed before its systematic position can be clarified.

Chaceia is definitely known only from the Pliocene to Recent. Siliceous mud filled burrows from the late Miocene Pismo Formation of San Luis Obispo Co., California, questionably attributed to *Chaceia* by Adegoke (1966) belong to *Penitella.* One specimen (UCMP 32523) possesses a complete callum (see Adegoke, 1966: pl. 21, fig. 1) and others resemble *Penitella* in size and anterior slope sculpture, though these are not diagnostic features. Evans (1967b) has refuted the generic assignment of Adegoke's specimens to *Chaceia* (?) on the basis of shell morphology and burrow shape. See also Discussion under *Nettastomella rostrata.*

Chaceia ovoidea (Gould, 1851)
Figures 20-27, 103

Pholas ovoidea Gould, 1851:87. Gould, 1853:388, pl. 15, fig. 1a-c. Johnson, 1964:121.

Z.[irphaea] Gabbii: Gabb, 1869:52, pl. 15, fig. 10, in part (*Penitella gabbii*, in part *Chaceia ovoidea* [pl. 15, fig. 10], and *Zirfaea pilsbryi*).

not? *Pholadidea ovoidea:* Dall, 1878a:11. Dall, 1878b:28. Cooper, 1888:259. Arnold, 1909 [1910]:39. Arnold and Anderson, 1910:132. Smith, 1912:174, 182. Burch and Burch, 1943:9. Clark, 1943:4. Burch, 1947:9.

not? *Pholadidea* (aff.) *ovoidea:* Watts, 1900 [1901]:224 (? *Penitella penita*).

not *Pholadidea ovoidea* Conrad [*sic*]: Arnold, 1907:423, pl. 55, fig. 1a-b (=*Penitella turnerae*). Arnold and Anderson, 1907:59, pl. 22 fig. 1a-b (=*Penitella gabbii, P. penita,* and *P. turnerae* [pl. 22, fig. 1a-b]).

Pholadidea (Pholadidea) ovoidea: Grant and Gale, 1931: 434, in part (*Chaceia ovoidea*, in part *Zirfaea pilsbryi* and *Penitella* spp.).

not *Pholadidea ovoidea* (Gould), short var.: Woodring, Stewart, and Richards, 1940 [1941]: facing 78, pl. 14, fig. 6 (=*Pholadopsis pectinata*).

Pholadidea ovoidea: Fitch, 1953:93, fig. 59. Kanakoff and Emerson, 1959:24, in part (*Chaceia ovoidea*, in part *Penitella penita*).

Chaceia ovoidea: Turner, 1955:66, pl. 36-38, 39 (fig. 1-3). McLean, 1969:91, fig. 53.3.

Zirfaea pilsbryi: Valentine, 1956:196, in part (*Zirfaea pilsbryi*, in part *Chaceia ovoidea*). Chace, 1966:170, in part (*Zifaea pilsbryi*, in part *Barnea subtruncata* and *Chaceia ovoidea*).

Pholadidea? sp.: Valentine, 1960a:163, in part (*Penitella* sp. and *Chaceia ovoidea*). Valentine, 1962:95.

Pholadidea penita: Valentine, 1961:370, in part (*Penitella penita*, in part *Zirfaea pilsbryi* and *Chaceia ovoidea*).

Zirfaea? cf. *Z. pilsbryi:* Valentine, 1961:376.

Parapholas californica: Vedder and Norris, 1963:46, 50, in part (*P. californica*, in part *Zirfaea pilsbryi* and *Chaceia ovoidea*).

not *Chaceia ovoidea:* Addicott, 1964b:147 (=*Penitella* sp. cf. *P. conradi*). Wright, 1972:691 (=*Penitella* gabbii).

not *Chaceia*(?) sp. indet.: Adegoke, 1966:234 (=*Penitella* sp. indet.).

DIAGNOSIS.— Shell large, widely gaping anteriorly and posteriorly. Valves in contact only at umbones and ventral condyles. Callum only partial, infolded between beaks, not protruding anteriorly. Apophyses often channeled, not spoon-shaped. Mesoplax broadly V-shaped (like that of *Zirfaea*), or in old specimens, covered dorsally and widely U-shaped.

DESCRIPTION.— Shell reaching approximately 12 cm in length, 8 cm in height, broadly oval in outline, inflated, usually light in structure. Immature specimens strongly beaked anteriorly, pedal gape nearly circular, posterior broadly rounded, widely gaping, closed by partial callum in adult.

Anterior slope sculptured with moderately to tightly spaced, up-turned, undulate concentric ridges, supplemented by radial pattern formed by alignment of undulations of these ridges. Umbonal-ventral sulcus prominent, variable in width. Disc and posterior slope ornamented with distinct, low rounded concentric ridges (more reduced posteriorly), which are extensions of ridges of anterior slope.

Umbonal reflections broad, closely appressed over umbones and upper part of anterior slope, immediately narrowing anteriorly, barely reflected and free at beaks. Callum only partial, sculptured with fine concentric growth lines, and with radial depressions near the anterior margin in heavy shelled specimens. Callum extends dorsally, flush or posterior (but never anterior) to tips of beaks, forms a narrow dorsal extension of callum on umbonal reflection.

Umbonal-ventral ridge pronounced, ornamented with beads in thin-shelled specimens. Muscle scars usually not apparent, but often heavily calcified in older specimens. Ventral muscle scar distinctive, short, high, extends antero-dorsally for

short distance. Pallial sinus deep, extends beyond umbonal-ventral ridge. Apophyses narrow, often channeled, but not large or broadened ventrally, extend from beneath umbones nearly parallel to umbonal-ventral ridge.

Periostracum thin, persistent. Siphons very large, not capable of retraction within shell. Foot large, broadly oval in outline and truncate, atrophied in adult (Turner, 1955: 69).

HOLOTYPE.— Of *Pholas ovoidea* Gould, according to Johnson (1964: 121) is missing. Monterey, California, collected by Major William Rich. Recent.

DISTRIBUTION.— Recent; Santa Cruz, Santa Cruz Co., California (37° N. lat.) to Bahía San Bartolomé [= Bahía Tórtolo], Baja California, Mexico (27° 39' N. lat.; Fitch, 1953: 93).

GEOLOGIC RECORD.— Pliocene to Recent.

Pliocene: One mile southeast of Oil City, Fresno Co., CAS loc. 28485 [see text].

Pleistocene: San Nicolas Island, USGS loc. 21664 (Vedder and Norris, 1963: 46; as *Parapholas californica*, in part), SDSNH loc. 0702. Potrero Canyon, Pacific Palisades, UCLA loc. 3225 (Valentine, 1956: 196; as *Zirfaea pilsbryi*, in part). Fourth terrace, Fort MacArthur Upper Reservation, San Pedro, UCLA loc. 4243 (Valentine, 1962: 95; as *Pholadidea?* sp.). Seventh terrace, Palos Verdes Hills, LACMNH loc. 1307. San Pedro Sand, at high school at 15th and Leland Streets, San Pedro, SDSNH loc. 2138 [= L-2138] (Chace, 1966: 169; as *Zirfaea pilsbryi*, in part). Palos Verdes Sand, Western Avenue, San Pedro, UCLA loc. 3602 (Valentine, 1961: 376; as *Zirfaea?* cf. *Z. pilsbryi*), near Palos Verdes Avenue between Eighth and Ninth Streets, UCLA loc. 3440 (Valentine, 1961: 370; as *Pholadidea penita*, in part), Los Angeles Harbor District sanitation yard, San Pedro, LACMNH loc. 1210, on west bluff of "middle" Newport Bay, LACMNH loc. 68-A (Kanakoff and Emerson, 1959: 24 [specimens not seen]), on east bluff above Upper Newport Bay, LACMNH loc. 66-2 (Kanakoff and Emerson, 1959: 24; in part *Penitella penita*), LACMNH locs. 66-10 and 136, SDSC locs. 533 and 537. Torrey Pines Beach State Park, UCLA locs. 3457 (in part) and 3458 (in part) (both Valentine, 1960a: 163; as *Pholadidea?* sp.). On west side of Point Loma, SDSNH loc. 2631. Bahía Tórtolo, Baja California, Mexico, UCMP loc. B-3007.

DISCUSSION.— *Chaceia ovoidea* has never been properly interpreted in paleontological literature. Over a hundred years ago Gabb (1869: 52, pl. 15, fig. 10) figured a Recent juvenile specimen of *C. ovoidea* under the name *Zirphaea gabbi* in his "Palaeontology of California." In reality Gabb's reference included three species (in three genera); the name and unique type refer to *Penitella gabbii*, the figure to *C. ovoidea*, and the fossil record of large valves in the San Pedro Pleistocene to *Zirfaea pilsbryi*. Grant and Gale (1931: 434) placed Gabb's whole citation under their *Pholadidea ovoidea* because of the figure. Adegoke (1966: 235) called attention to Grant and Gale's "error" and placed the reference in his over-inclusive "*P.* [*enitella*] *gabbii*."

Many authors (see synonomy) have repeatedly cited specimens of *Penitella gabbii* and *P. turnerae* together as "*Pholadidea ovoidea*." In addition, Woodring, Stewart, and Richards (1940 [1941]: facing 78) have cited and figured the very ovoid and globose *Pholadopsis* from the Kettleman Hills of California as a short variety of *Pholadidea ovoidea*. Most recently Addicott (1946b: 147) cited a specimen of *Penitella* sp. cf. *P. conradi* as *C. ovoidea*.

Chaceia ovoidea can be recognized by its large size, broad pedal and siphonal gapes, partial and non-protruding callum, small V-shaped mesoplax, and narrow dorsal extension of the callum. Confusion may occur in identification between juvenile and (or) fragmentary *C. ovoidea* and old, heavy shelled *Zirfaea pilsbryi* (subfamily Pholadinae). Although there are no good criteria for separating fragmented specimens, the nature of the concentric ridges of the anterior slope, the more prominent umbonal-ventral sulcus, and the umbonal reflection of *C. ovoidea* may be useful. The ventral muscle scar of *C. ovoidea* (see Fig. 23) is distinctly different from that of *Z.*

pilsbryi, which is not well distinguished from the pallial line.

Though individuals of *C. ovoidea* have been known to bore into waterlogged wood (MCZ 251345), the species is usually found boring into clay, shale, sandstone, or other soft rock on the open coast to a depth of twenty inches, the burrows tapering to an inch in diameter at the surface (Fitch, 1953: 93). Specimens of this species normally do not cease boring and produce a callum until they are 70-90 mm in length and 40-50 mm in height, but may reach 120 mm in longitude and 82 mm in altitude (USNM 612116).

The fossil record of *C. ovoidea* is rather meager. In the Pleistocene, the species is most abundant in the Palos Verdes Sand of Upper Newport Bay, in Orange Co., where many articulated specimens have been found. The only known specimen with a preserved mesoplax (a juvenile) came from this region (SDSC loc. 533).

Only one known specimen has been found in rocks which might be Pliocene in age. The specimen (see Fig. 103) was associated with several *Zirfaea dentata* and supposedly was from the same general Miocene locality (CAS loc. 28485). The matrix and type of preservation are so entirely different however, there can be no doubt they were collected at another locality, the *Chaceia* most probably coming from nearby Pliocene strata.

Genus *Penitella* Valenciennes, 1846

Penitella Valenciennes, *in* du Petit-Thouars, 1846: pl. 24, legend [no description]. Turner, 1955:70. Adegoke, 1967:9.
Navea Gray, 1851:385.

DEFINITION.— Shell oval in outline, distinctly divided by umbonal-ventral sulcus, small to large, reaching 12 cm in length. Anterior beaked, widely gaping in young stage, closed by partial or complete callum in adult; posterior rounded to truncate, and closed. Umbonal reflection usually appressed to anterior slope, but may be free anterior to umbones. Mesoplax only accessory plate, transverse, situated posterior to umbones, circular or V-shaped in juvenile, covered dorsally in adult. Siphonoplax noncalcareous, presence variable. Siphons capable of complete retraction within shell.

Penitella differs from other genera in the Martesiinae by its single accessory plate, a dorsally covered mesoplax situated posterior to the umbones. The umbonal reflection is generally appressed to the anterior slope, and the dorsal extension of the callum extends from thhe beaks to the umbones. The mesoplax of *Pholadidea* is longitudinally divided into two pieces. *Chaceia* is larger, has a partial callum, nonretractable siphons, and a wide posterior gape.

TYPE SPECIES.— *P.*[*enitella*] *conradi* Valenciennes, by subsequent designation of Grant and Gale (1931: 433).

TAXA INCLUDED.— There are at least eight species from the eastern Pacific alone, two of which are known only from their fossil records (*P. lorenzana* and *P. durhami*). *Penitella conradi*, *P. fitchi*, *P. gabbii*, *P. penita*, and *P. turnerae* are all found both living and as fossils. *Penitella kotakae* (Kanno and Matsuno, 1960) is known from the upper Oligocene of Japan, and *P. kamakurensis* (Yokoyama, 1922) from both Pleistocene and Recent faunas of Japan and Alaska. *Pholadidea* (*Penitella*) *chishimana* Habe, 1955, also of Japan, may belong to *Zirfaea* or *Chaceia* rather than to *Penitella*.

DISCUSSION.— The genus *Penitella*, as is true of most Martesiinae, characteristically bores into finer grained soft rock, shales, and mudstones (all in various stages of induration), usually on the open coast or in situations where the burrow entrance will not be occluded by sedimentation. Because of this habitat preference, species of *Penitella* are geologically younger than the rocks in which they inhabit, and are found *in situ* in outcrops or in cobbles in detrital deposits. Representatives of this genus are probably responsible for most of the mud filled burrows found in Neogene formations on the Pacific slope.

The genera *Penitella* and *Zirfaea* (subfamily Pholadinae) constitute the bulk of known fossil pholadid specimens in the west coast Cenozoic. Whereas there are only two species of *Zirfaea*, there are at least eight

species of *Penitella* in North America, ranging from the Oligocene to the present. Because specific differences are minor, and there were misunderstandings about the genus for many years, the number of species was considered small. Consequently the trivial name *penita* was often used indiscriminately for any fossil *Penitella*. When Turner (1955) monographed the genus, it was then possible to clear up the many years of accumulated mis-citations in the paleontologic literature, a task not accomplished by Adegoke (1967) in his brief review of the fossil and Recent species of *Penitella*.

The "sudden occurrence" in the Oligocene of California of two species of *Penitella* leaves no doubt that the group is older than middle Oligocene. Though Eocene records of *Penitella* are unknown, this may be due to the thicker sections of continuous deposition, which would not provide suitable substrates. Miocene occurrences of *Penitella* are so rare, and specimens so poorly preserved, that tracing specific lineages from the Oligocene to the Pliocene is difficult.

It has not be possible to identify to species a fair number of specimens of *Penitella*, and although they are not listed here for reasons of brevity, they may be found in the Register of Localities.

Penitella conradi Valenciennes, 1846
Figures 41-45

Penitella conradi Valenciennes, *in* du Petit-Thouars, 1846: pl. 24, fig. 1, 1a-b [no description]. Lamy, 1921: 179. Turner, 1955:75, pl. 43-46. Adegoke, 1967:15. Meredith, 1968:281, pl. 42. McLean, 1969:92, fig. 53.7. Smith, 1969:869 *et seq.* Hertlein and Grant, 1972:332, pl. 57, fig. 5, 13.

N.[*avea*] *subglobosa* Gray, 1851:385.

P.[*enitella*] *parva* Tryon, 1965:39, pl. 2, fig. 4-5.

P.[*enitella*] *conradi:* Grant and Gale, 1931:433 [in text].

Pholadidea (*Pholadidea*) *penita:* Willett, 1937:391.

Pholadidea parva: Willett, 1937 [1938]:106.

not? *Navea*? cf. *N. subglobosa:* Valentine, 1960a:163 (=*Penitella* sp. indet.).

Penitella penita: Vedder and Norris, 1963:46, 50, in part (*P. penita*, in part *P. conradi* and *P. gabbii*). Wright, 1972:691, in part (*P. turnerae* and *P.* sp. cf. *P. conradi*).

Chaceia ovoidea: Addicott, 1964b:147 (*Penitella* sp. cf. *P. conradi*).

DIAGNOSIS.— Small, globose *Penitella*. Umbonal reflections broad, closely appressed their entire length. Dorsal extension of callum anteriorly lobate. Mesoplax semicircular in outline, broadly rounded or truncate posteriorly, bluntly pointed anteriorly, lacking any lateral wings. Posterior muscle scar roughened. Siphonoplax heavy, lined with aragonitic or calcitic granules. Small deformed specimens found in abalones (*Haliotis*).

DESCRIPTION.— Shell generally globose, oval in outline, small, reaching about 3 cm in length and 2 cm in height. Beaked, widely gaping anteriorly in young specimens, closed by complete callum in adult; rounded and closed posteriorly. Anterior slope about one third size of combined disc and posterior slope, sculptured with very fine, tightly-spaced, upturned, undulate concentric ridges and weak supplementary radial pattern expressed mainly by alignment of concentric undulations. Umbonal-ventral sulcus prominent, not incised. Disc and posterior slope sculptured with concentric growth lines.

Umbonal reflection wide, closely appressed its entire length. Callum heavy (in *Haliotis*) or thin and light (in shale), extends dorsally anterior to beaks. Dorsal extension of callum low, anteriorly lobate.

Mesoplax only accessory plate, thin, nearly flat, more or less semicircular in outline in young specimens (Turner, 1955: 76), covered dorsally in adult, posteriorly broadly rounded to truncate, anteriorly bluntly pointed, lacking any lateral wings.

Umbonal-ventral ridge barely visible. Muscle scars large, pronounced, usually roughened. Muscle scar pad large, semicircular, present immediately above umbo on umbonal reflection. Pallial sinus broad, deep, extends anteriorly beyond umbonal-ventral ridge. Apophyses very narrow, fragile, often broken in fossil specimens, occasionally rather deformed and irregular when boring in *Haliotis*.

Siphonoplax lined internally with white calcareous granules. Periostracum persistent, heavy on posterior slope. Siphons capable of complete retraction within the shell. Foot large, nearly circular in outline,

truncate, in young specimens, atrophied in adult (Turner, 1955: 73).

TYPES.— Of *Penitella conradi* Valenciennes, are in the Museum National d'Histoire Naturelle in Paris (Lamy, 1921: 179). Monterey, California, is on the type label, though no locality was published by Valenciennes (Lamy, 1921: 179). Recent.

LECTOTYPE.— Of *Navea subglobosa* Gray, selected by R.D. Turner and to be published at a later date, is in the British Museum (Natural History). California, in a hole in a shell. Recent.

LECTOTYPE.— Of *Penitella parva* Tryon, ANSP 50999, designated by Turner (1955: 78). PARALECTOTYPES: ANSP 136741 (six valves). Lower California, from a *Haliotis*. Collected by Wesley Newcomb. Recent.

DISTRIBUTION.— Recent; Canon Beach, Clatsop Co., Oregon (45° 53' N. lat.; Meredith, 1968: 281) south at least as far as Bahía San Bartolomé [= Bahía Tórtolo], Baja California, Mexico (27° 39' N. lat.; Turner, 1955: 79).

GEOLOGIC RECORD.— ?Miocene, Pliocene to Recent.

Miocene: East side of El Toro Valley, southwest of Salinas, UCMP loc. A-2549. ?Monterey Formation, near end of road leading north from Klondike Canyon (north off of Carmel Valley), UCMP loc. A-2550 (cf.).

Pliocene: Saugus Formation, south of Piru, CAS loc. 90 (cf.). Fernando Formation, Crocker Citizens Plaza excavation at Sixth and Hope, LACMNH loc. 466, ARCO Plaza excavation at Sixth and Flower, both downtown Los Angeles, LACMNH loc. 1219, on the east bluff above Upper Newport Bay, LACMNH loc. 471. San Diego Formation, in San Diego, at Arroyo Drive, SDSNH loc. 2454, quarry at end of Arroyo Drive, LACMNH loc. 107, Laural Canyon, SDSNH loc. 2455, northeast corner of Upas and India Streets, SDSNH loc. 2529 (cf.), on hill between Goat Canyon and U.S.-Mexican border, LACMNH locs. 305 (in shell) and 305C (both Hertlein and Grant, 1972: 332).

Pleistocene: Isla Vista near Goleta, USGS-M (cf.) (Wright, 1972: 691; as *Penitella penita*, in part). Lincoln Avenue, northeast of Playa del Rey, LACMNH loc. 59 (Willett, 1937: 391; as *Pholadidea penita*). Point Dume terrace, near Escondido Beach, USGS-M loc. 1710 (cf.) (Addicott, 1964b: 147; as *Chaceia ovoidea*). Lomita Marl, San Pedro, northeast corner of Coralmount Drive and Park Western Drive, LACMNH loc. 435, SDSNH loc. 2669, fourth ravine west of Hawthorne Avenue on north border of Palos Verdes Hills, USGS loc. 12259. Undifferentiated formations on Palos Verdes Peninsula, on second terrace, immediately east of Flatrock Point, USGS loc. 12192, below Nob Hill, LACMNH loc. 300 (cf.), Third and Mesa Streets, LCAMNH loc. 98, Eighth and Palos Verdes Streets, LACMNH loc. 226. Palos Verdes Sand, on Deadman Island (zone 7 of Arnold), CAS loc. 1479. Calle Fortuna, Capistrano Beach, LACMNH loc. 58 (Willett, 1937 [1938]: 106). San Nicolas Island, USGS locs. 21653 and 21655 (Vedder and Norris, 1963: 46; as *Penitella penita*, in part).

DISCUSSION.— *Penitella conradi* was long known under the names *Penitella parva* and *Navea subglobosa*. Active boring specimens without a callum and covered in the mantle cavity of an abalone with patches of black conchin (= conchiolin) were cited as *N. subglobosa*, while those adults which had produced the callum and siphonoplax, and were thereafter covered with nacre in the inside of the *Haliotis*, were called *P. parva*. The affinities of these were recognized by Turner (1955) and were synonomized. When the active boring pholadid breaches the nacreous layer in the mantle cavity of the abalone, the abalone begins depositing a heavy layer of conchin over the active irritation, keeping pace with boring, but nacre is not deposited over the active animal. This continues until the pholadid has ceased boring and produces a callum and siphonoplax, at which time the no longer active irritation can be covered over with the nacreous layer. Smith (1969: 869) believes the boring process in *P. conradi* is mainly through dissolution, but whether the effect is on the organic matrix or the crystals themselves is still unknown. This may be the key to discovering why nacre is not

deposited over an active borer. Smith further notes that "mechanical abrasion helps remove loosened crystals and/or organic matrix."

Penitella conradi is also known to bore into other marine mollusks (*Mytilus californianus* Conrad, *Astraea* sp., *Pododesmus* sp.), as well as the abalones *Haliotis fulgens* Philippi, *H. rufescens* Sowerby, and *H. sorenseni* Bartsch (Turner, 1955: 79; Meredith, 1968: 281), *H. cracherodii* (SDSNH 53172), and the hybrid *H. kamtschatkana assimilis* x *H. sorenseni* (cf. Owen, McLean, and Meyer, 1971: fig. 17, upper right). Abalone borers are often deformed (see Turner, 1955: pl. 44-45; McLean, 1969: fig. 53.7) and have large adductor muscles, a roughened posterior muscle scar, and a disproportionately large mesoplax and dorsal extension of the callum. Specimens boring into soft rock are often perfectly formed, though uncommon. In the fossil record a reverse situation exists and only a single valve is known from a fragment of unidentified shell material, the remainder coming from soft rock *in situ*, or from detrital deposits.

Recent specimens of *P. conradi* boring into shale or soft rock are easily separated from the quite similar *P. penita*, and other species of *Penitella*. The semicircular mesoplax of *P. conradi* plus the granular and cup-shaped siphonoplax are sufficient for positive identification. *Penitella penita* has a posteriorly pointed mesoplax and a periostracal siphonoplax. In detrital fossil specimens however, these are lost or typically not preserved and identification is more difficult. Fossil occurrences of the mesoplax are uncommon, and I have seen but a single siphonoplax preserved (from LACMNH loc. 435).

Fossil specimens boring into shale are often mistaken for short ovoid forms of *P. penita*. The more difficult the substrate is to penetrate, the greater is the similarity of *P. penita* to *P. conradi*. Both the overall shell outline and nature of the anterior ornamentation are extremely similar. In *P. conradi* however, the posterior muscle scar is usually more deeply impressed and quite roughened, while a muscle scar pad is often produced above each umbo. Further, the posterior dorsal margin is humped, the beaks are slightly blunter, the beak to umbo distance is usually shorter, and the apophyses thinner and more fragile in *P. conradi* than in *P. penita*.

The fossil record of *P. conradi* is more extensive than previously realized, ranging back into the Miocene with two occurrences in the Salinas-Carmel Valley area east of Monterey. Both lots were collected in 1936 and exact age or formational assignments are not known. One locality was questionably assigned to the Monterey Formation, but may only have been boring into that formation, and thus would be geologically younger. Considering the habitat preference of *P. conradi*, *i.e.*, shell and harder substrates, it is doubtful that the animals were living at the time of deposition, but more probably that they lived some time after the underlying formation had consolidated into a more indurated substrate.

The greatest abundance of Pliocene *P. conradi* is in the San Diego Formation on Arroyo Drive in the city of San Diego. Identified from the shape of the mesoplax, many are short and globose, though some seem almost too elongate and would not have been assigned to *conradi* without the accessory plate, which eliminates assignment to any other known species.

Of Pleistocene occurrences, the specimens collected from the Lomita Marl in San Pedro (LACMNH loc. 435, SDSNH loc. 2669) are remarkedly well preserved; one specimen still had its calcareously lined siphonoplax intact. This locality is the richest Pleistocene locality for *P. conradi*. The Pleistocene specimen cited by Valentine (1960: 163) as *Navea?* cf. *N. subglobosa* may possibly be *P. penita*, but it is too small and poorly preserved for positive identification. The specimen was collected from Torrey Pines Beach State Park in San Diego Co. (UCLA loc. 2410, not UCLA loc. 3457 as cited).

Penitella durhami Adegoke, 1967
Figures 33-35

Pholadidea (Penitella) lorenzana: Weaver, 1953:60.
Penitella durhami Adegoke, 1967:12, fig. 12, 16-17, 20-26.

DIAGNOSIS.— Valves well inflated. Umbonal reflection only loosely appressed anteriorly, free at beak. Callum not extending beyond beaks. Mesoplax unknown.

ORIGINAL DESCRIPTION.— Shell small to large, with elongate oval outline; immature specimens gaping wide anteriorly and posteriorly; umbonal-ventral sulcus conspicuously depressed, flanked by two narrow but prominently elevated ridges which are further delineated from the rest of shell by shallow broad depressions; umbonal-ventral sulcus divides valves into two distinct and very unequal parts; anterior portion small, about half length of posterior portion, remarkably robust, inflated, and rounded, with subcircular cross-sectional outline; sharp ventral concave flexure coincides with ventral portion of umbonal-ventral sulcus, further delimiting rounded anterior from the less high, laterally compressed posterior; protoplax [= dorsal extension of callum] strongly developed, separated from beak and callum by narrow, depressed umbonal reflection; callum well developed, protrudes beyond beaks, closes pedal gape in adults; anterior slope ornamented by numerous wavy concentric ridges with poorly defined, radially arranged spines; posterior region of shell longer than anterior region, flattened laterally, not as high as anterior region; posterior dorsal margin prominently ridged, and convex; posterior ventral margin keeled, markedly concave; posterior slope and disc ornamented by wide concentric ribs with narrow interspaces; posterior extremity sharply truncated, with wide subcircular siphonal gape.

SUPPLEMENTARY DESCRIPTION.— Shell robust, well inflated, small to large, reaching 7 cm in length and 3 cm in height, producing a callum in the adult stage. The valves may be widely gaping posteriorly (Adegoke), but I have not seen any specimens with the posterior slope complete. Immature specimens very strongly beaked, the anterior margin being strongly angulate.

Anterior slope sculptured with moderately spaced undulate, upturned, concentric ridges, not spinose. Umbonal-ventral sulcus distinct. Disc and posterior slope ornamented with conspicuous smooth rounded concentric ridges which are extensions of the ridges of the anterior slope.

Umbonal reflection appressed near umbo, looser anteriorly, free at beaks, widest just posterior to widest point of dorsal extension of callum (= "protoplax" of Adegoke), appears only where the two do not overlap. The callum does *not* extend anterior to the beaks, though it may be flush with them. A simlar situation exists in *P. gabbii* and any protrusion is less than a fraction of a mm. Normal callum almost hemispherical, occasionally so reduced as to be almost recessed.

Mesoplax only accessory plate, so poorly preserved on available specimens that little can be said of it. Apophyses, pallial sinus, and pallial line unknown. Posterior muscle scar symmetrically oval in outline. Umbonal-ventral ridge beaded, quite distinct, flanked by slight depressions.

HOLOTYPE.— Of *Penitella durhami* Adegoke, UCMP 30108. PARATYPES: UCMP 30102-30105, 30108, 32493-32497, 32503-32508. East limb of Pacheco Syncline, in road cut on California State Highway 4, Contra Costa Co., California, UCMP loc. A-4296 (here corrected). Collected by Univ. Calif. Paleontology 103 class, 1947, J.H. Peck and J.W. Durham, 1951, and O.S. Adegoke, 1966. Late Oligocene, basal San Ramon Formation.

GEOLOGIC RECORD.— Oligocene.

Oligocene: Along California State Highway 4 (= Arnold Industrial Highway) on the east limb of the Pacheco Syncline, UW loc. 1238 (Weaver, 1953: 60; as *Pholadidea lorenzana* [specimens not seen]), UCMP loc. A-7762 (Adegoke, 1967: 13), UCMP loc. A-4296 (holotype collected here).

DISCUSSION.— *Penitella durhami* was the second Oligocene *Penitella* to be described from California. Based on poorly preserved

specimens, it is difficult to characterize, though it probably is distinct. The most useful distinguishing character, the mesoplax, cannot be adequately described from the available material. *Penitella durhami* can be separated from the other Oligocene species, *P. lorenzana*, by its more robust shape and the callum which does not protrude anterior to the beaks.

At the type locality on the east limb of the Pacheco Syncline, the basal San Ramon Formation (Oligocene) is disconformable with the uppermost Pereira Shale Member of the Eocene Alhambra Formation (Weaver, 1953: 50). At this locality *P. durhami* is associated with *Platyodon pecki* Adegoke, 1967, and both are found boring into the underlying Eocene strata.

The holtype of *P. durhami* was collected from UCMP loc. A-4296, not UCMP loc. A-7762 as cited by Adegoke (1967: 13), and is here designated the type locality. The two localities are supposed to be equivalent however. Several of the "paratype" specimens, UCMP 32503-32508 are only mud filled burrows and specific determinations are not possible. Other specimens from UCMP loc. A-4296 are better preserved than much of the type material, and were available to Adegoke (the holotype was selected from this lot), but were not cited. Much of the supplementary description herein is based on these specimens.

Penitella fitchi Turner, 1955
Figures 55-59

Penitella fitchi Turner, 1955:71, pl. 40-42. Adegoke, 1967:15.
Pholad sp.?: Chace, 1956:178.
Pholadidea penita Carpenter [*sic*]: Chace, 1966:170, in part (*Penitella penita*, in part *P. fitchi*).

DIAGNOSIS.— Anterior-dorsal margin short, dorsally convex, giving beaks a blunt appearance. Mesoplax large, subcircular, broader than long, with or without primary lateral wings. Umbonal reflection longitudinally symmetrical, tightly appressed for entire length. Callum only partial, extends dorsally anterior to beaks. Siphonoplax composed of numerous periostracal leaves.

DESCRIPTION.— Shell oval in outline, solid in structure, moderate in size, reaching about 6 cm in length and 3.5 cm in height. Beaked and widely gaping anteriorly in young specimens, closed by partial callum in adult, rounded and closed posteriorly. Anterior slope small, about one third size of combined disc and posterior slope, tapering to point on ventral margin, sculptured by very close-set, upturned, undulate concentric ridges, and by secondary radial pattern formed by alignment of the undulations. Umbonal-ventral sulcus pronounced. Posterior slope broadly rounded in young specimens, proportionately longer and more tapered in adult, sculptured with fine growth lines. Umbones located near anterior third of shell. Dorsal margin just posterior to umbones "humped" in adults.

Umbonal reflection longitudinally symmetrical, tightly appressed for entire length. Callum partial (see Turner, 1955: pl. 40, fig. 1), rather heavy, solid, extends dorsally anterior to beaks, sculptured with growth lines and slight indication of forward extension of radial sculpture of anterior slope.

Mesoplax only accessory plate, broad, thin, nearly flat, rounded posteriorly in young specimens (Turner, 1955: 72), large, heavy, subcircular to nearly laterally ellipsoidal in outline, bluntly pointed anteriorly, covered dorsally in adult. Lateral wings, when present, fragile, only remnant extensions of juvenile mesoplax. Mesoplax figured by Turner (1955: pl. 40, fig. 2, and pl. 42).

Umbonal-ventral ridge broad, smooth. Muscle scars large, pronounced, roughened in adult. Pallial sinus broad, deep, extends anteriorly beyond umbonal-ventral ridge. Apophyses solid, expanded, very blade-like ventrally, extend in direction anterior to umbonal-ventral ridge.

Periostracum thin and deciduous. Siphonoplax periostracal, composed of numerous leaf-like layers. Siphons capable of complete retraction within shell. Foot large, nearly circular in outline, truncate in young specimens, atrophied in the adult (Turner, 1955: 73).

HOLOTYPE.— Of *Penitella fitchi* Turner,

MCZ 189413. PARATYPES: MCZ 189414 (15 specimens), MCZ 189741 (11 specimens), USNM 701539 (3 specimens), ANSP 191715 (2 specimens), LACMNH 1444 (2 specimens), SDSNH types 4183 and 4184, SU 10059 (2 specimens), Berry collection (? part of SU 10059). North side of Bahía San Bartolomé, Baja California, Mexico, in sedimentary rocks. Holotype and paratypes collected by J.E. Fitch, November 21, 1952; paratypes by E. Dwyer and D.C. Joseph, January 6, 1954. Recent.

DISTRIBUTION.— Recent; Redondo Beach, Los Angeles Co., California (33° 15.4' N. lat.; LACMNH A.2777) south to Punta Pequeña, Baja California, Mexico (26° 14' N. lat.; LACMNH 71-181).

GEOLOGIC RECORD.— Pleistocene to Recent.

Pleistocene: San Pedro Sand, at high school at 15th and Leland Streets, San Pedro, SDSNH loc. 2138 [= L-2138] (Chace, 1966: 170; as *Pholadidea penita*, in part). Palos Verdes Sand, on east bluff above Upper Newport Bay, SDSC loc. 537, SDSNH loc. 2561. In hills opposite southwest corner of Turtle Bay, Baja California, Mexico, SDSNH loc. 0624 (Chace, 1956: 178; as Pholad sp.?).

DISCUSSION.— Recent specimens of *Penitella fitchi* are rare in collections and are restricted to the Californian and Surian (overlap area of the Californian and Panamic) Provinces of the eastern Pacific. Though it has been found in greatest abundance at the type locality, Bahía San Bartolomé, the waters of this bay are known to be cool and near the temperature of those in southern California (E.C. Allison, pers. comm.). Other occurrences are few, but specimens are known from Redondo Beach (LACMNH A.2777), San Diego (USNM 111401), La Jolla (author's collection), and from Baja California near Isla San Geronimo (LACMNH 71-91), San Cristobal Bay (LACMNH 71-172), and at Punta Pequeña (LACMNH 71-181).

At the type locality, J.E. Fitch (Turner, 1955: 74) found *P. fitchi* associated with equal numbers of *P. penita* and *Chaceia ovoidea*. The dead specimen collected from La Jolla was found intertidally in a large mudstone cobble with *P. gabbii*, *P. penita*, *Nettastomella rostrata*, and *Lithophaga plumula* (Hanley, 1843).

Penitella fitchi is even rarer in the fossil record, and is known from only three localities in the Pleistocene and not at all in the Pliocene. Several specimens of *P. fitchi* are known from the late Pleistocene Palos Verdes Sand on the east bluff above Upper Newport Bay, California. One, a juvenile collected in loose sandy-shelly detrital material, has both valves present, and is in perfect condition. Another, represented by fragments of both valves of an adult, was collected *in situ*, and associated with relatively large numbers of *Chaceia ovoidea* and *Nettastomella rostrata*, and lesser numbers of *P. penita* and *Barnea subtruncata*. *Penitella fitchi* also occurs in the Pleistocene deposits of San Pedro, and Turtle Bay, Baja California.

Penitella fitchi is not closely related to any west American *Penitella*, though in some respects it appears similar to *P. conradi*. Both have a rounded mesoplax, roughened muscle scars, and a little hump on the posterior-dorsal margin in the adult. *Penitella fitchi* however has a partial callum, very blade-like apophyses, and a shorter convex anterior-dorsal margin, which gives the beaks a blunt, rounded appearance.

Penitella gabbii (Tryon, 1863)
Figures 36-40

Zirphaea Gabbii Tryon, 1863:144, pl. 1, fig. 1.

Z. [irphaea] Gabbii: Gabb, 1869:52, 88, in part; not pl. 15, fig. 10 (*Penitella gabbii*, in part *Zirfaea pilsbryi*, and *Chaceia ovoidea* [pl. 15, fig. 10]).

Pholadidea ovoidea Conrad [*sic*]: Arnold, 1907:423, in part; not pl. 55, fig. 1a-b (*Penitella gabbii*, *P. penita*, and *P. turnerae* [fig. 1a-b]). Arnold and Anderson, 1907:59, in part; not pl. 22, fig. 1a-b (ibid). [Author on plates is Gould.]

not *Pholas (Zirfaea) gabbi:* Grant and Gale, 1931:433, pl. 24, fig. 2. Wilson, 1966:108. (Both =*Zirfaea pilsbryi*).

Pholadidea penita: Bruff, 1946:232, in part (*Penitella penita*, in part *P. gabbii*). Woodring and Bramlette, 1950 [1951]: facing 34, 41, facing 48, 66, 91, in part; not p. 54, pl. 8, fig. 6, nor pl. 14, fig. 3 (*Penitella penita*, in part *P. gabbii*, and *P. turnerae* [figures]).

Penitella gabbi: Turner, 1955:85, pl. 52-54. Turner, 1962: 306. Adegoke, 1967:16, in part (*Penitella gabbii* [Re-

cent], in part *Zirfaea pilsbryi* [all fossil references]).
Penitella penita: Vedder and Norris, 1963:46, 50, in part (*Penitella penita*, in part *P. conradi* and *P. gabbii*).
not *Zirfaea gabbi* (Tryon) *femii* Adegoke, 1967:17 (*nomen nudum*, introduced manuscript name). Adegoke, 1969: 154, "fig." 6A, pl. 9, fig. 2, 8, 11-12; pl. 10, fig. 3, 5-6, 13. (Both = *Zirfaea pilsbryi*).
Chaceia ovoidea: Wright, 1972:691.

DIAGNOSIS.— Callum not protruding beyond beaks. Umbonal reflections narrow, lightly appressed over umbones, free anteriorly. Mesoplax with blunt, ventrally directed point and broad lateral wings posteriorly. Periostracum not present inside siphonal opening. Siphonoplax lacking.

DESCRIPTION.— Shell oval in outline, solid in structure, reaching 10 cm in length and 5 cm in height (Turner, 1962: 306) (though rarely even one-half these dimensions). Immature specimens beaked, widely gaping anteriorly, closed by complete callum in adult; rounded and closed posteriorly. Anterior slope sculptured by close-set, upturned, undulating, concentric ridges, and radial "ribs" formed by aligned undulations of the ridges. Umbonal-ventral sulcus prominent. Disc and posterior slope sculptured with concentric growth lines and obscure, low, rounded ridges. Umbones prominent, located near anterior third of shell.

Umbonal reflection narrow, lightly appressed over umbo, free centrally and anteriorly. Callum sculptured by weak radial ribs (foreward extensions of radial sculpture of anterior slope), does not protrude anterior to beaks. Dorsal extension of callum narrow, not lobate.

Mesoplax transverse, situated posterior to umbones, truncate or pointed anteriorly, rounded posteriorly with a blunt, ventrally directed point, and with two wide lateral wings posteriorly.

Umbonal-ventral ridge low, prominent, terminating ventrally in small circular condyle in active boring specimens, but inconspicuous in adult. Muscle scars visible, not roughened. Ventral muscle scar long, narrow, overlaps umbonal-ventral ridge. Posterior muscle scar elongate-oval in outline. Pallial sinus broad, extends beyond umbonal-ventral ridge, sometimes to anterior margin. Apophyses flattened, not blade-like, rotated 1/8 turn from long axis of shell, wider ventrally, protruding at angle slightly anterior to that of umbonal ridge.

Periostracum moderately heavy, persistent (Turner, 1955: 86), exists inside shell at siphonal opening only as narrow marginal band. Siphons capable of complete retraction within shell. Foot in young specimens nearly circular in outline, truncate (Turner, 1955: 86), atrophied in the adult.

HOLOTYPE.— Of *Zirphaea gabbii* Tryon, ANSP 51085. Tryon (1863: 144) cites "?coast of Japan," but according to Gabb (1869: 53), Tryon believed it to be a California shell. Turner (1955: 87) has subsequently restricted the type locality to Monterey, California. Recent.

DISTRIBUTION.— Recent; Drier Bay, Knight Island, Prince William Sound, Alaska (60° 18.5' N. lat.; Turner, 1955: 88), south to Sacramento Reef, just south of Isla San Geronimo, Baja California (29° 43.7' N. lat.; LACMNH 71-91).

GEOLOGIC RECORD.— Pliocene to Recent.

Pliocene: Etchegoin Formation, east of Priest Valley in Hans Grieve Canyon, USGS loc. 9393. Foxen Mudstone, at Waldorf asphalt mine, 3 miles SSE of Guadalupe, USGS loc. 4473 (Arnold, 1907: 423; Arnold and Anderson, 1907: 59; both as *Pholadidea ovoidea*, in part), and USGS loc. 14879 (both localities, Woodring and Bramlette, 1950 [1951]: 41; as *Pholadidea penita*, in part), CAS loc. 76, USGS loc. 23621. Graciosa Member of Careaga Sandstone, Howard Canyon, Solomon Hills, USGS loc. 14722 (Woodring and Bramlette, 1950 [1951]: facing 48; *ibid.*). Cebada Member of Careaga Sandstone, on Graciosa Ridge, 3.7 miles southeast of Orcutt, USGS loc. 14648 (Woodring and Bramlette, 1950 [1951]: facing 48; *ibid.*), at Fugler Point asphalt mine, one mile NNE of Garey, USGS loc. 4475 (Arnold and Anderson, 1907: 59; as *Pholadidea ovoidea*, in part). Sisquoc Formation, at the Pennsylvania asphalt mine, 3½ miles southeast of Orcutt, USGS loc. 4472 (Arnold and Anderson, 1907: 59; *ibid.*), NTU asphalt mine, NNW of Casmalia,

UCMP loc. D-2845 (cf.).

Pleistocene: North side of Fivemile Point near Bandon, Oregon, LACMNH loc. 3950. Isla Vista, near Santa Barbara (Wright, 1972: 691; as *Chaceia ovoidea*). Palos Verdes Sand, on north side of Newport Bay proper, opposite Lido Isle, UCMP loc. A-3132 (Bruff, 1946: 232; as *Pholadidea penita*, in part). San Nicolas Island, USGS loc. 21655 (Vedder and Norris, 1963: 46; as *Penitella penita*, in part). Rosarito Beach, Baja California, Mexico, SDSNH loc. 2531.

DISCUSSION.— The description of *P. gabbii* was based on a unique battered specimen without a callum sent to Tryon by W.M. Gabb, who noted (1869: 52-53) that he obtained it from Japan with a collection of miscellaneous shells, though Tryon himself believed it to be a California shell. Further confusion about the species was perpetrated by Gabb (1866-1869) who, in his treatise on the paleontology of California, actually included three separate species in his discussion of *P. gabbii*. In the citation, the unique specimen (holotype) referred to is *Penitella gabbii*, the figure is of a juvenile *Chaceia ovoidea*, and the fossil reference to large valves in the San Pedro Pleistocene can only be *Zirfaea pilsbryi*. Both Tryon and Gabb thought *gabbii* was a *Zirfaea*, which led to subsequent common usage of the name for the west coast species of *Zirfaea*. Over sixty years passed before Lowe (1931: 52) recognized the type of *gabbii* as a *Penitella*, and described *Z. pilsbryi*. Lowe however put *gabbii* in synonomy with *Penitella penita concamerata* (Deshayes), itself a synonym of *P. penita*. The validity of *P. gabbii* (Tryon) was generally not accepted until recognized by Turner (1955: 85).

Penitella gabbii is not easily confused with other species of *Penitella*, and may be readily identified by its narrow and anteriorly free umbonal reflection, the callum which does not extend beyond the tips of the beaks, and the characteristic mesoplax (see Fig. 37-38). The apophyses are also flattened, gently curving, and are unlike the stouter, weakly blade-like apophyses of *P. penita*.

Penitella gabbii lives in the same substrates as *P. penita*, *i.e.*, in "soft" rock on the open coast. At Coos Bay it is found in abundance closely associated with *P. penita* and *P. turnerae*, which has led some workers to believe that together with *P. penita*, it is responsible for the existence of the "hybrid" *P. turnerae*. Without further evidence this is not accepted, although there are some suspicious records of these species occurring together.

The geologic record of this species has long been confused. With the specific name *gabbii* "occupied" by a *Zirfaea*, there can be little wonder that workers had to find other names for this *Penitella*, and both *penita* and *ovoidea* [= *Chaceia*] have been used. This latter name, thought incorrect, is appropriate because of the usual perfectly ovoid shape of *P. gabbii*'s callum filled anterior.

Although Adegoke (1967: 16) was correct in citing the geologic range of *P. gabbii* as Pliocene to Recent, his conclusion was based on two Pliocene records of "*Zirfaea gabbi*" (= *Zirfaea pilsbryi* Lowe) and not on the true *Penitella*. *Zirfaea gabbi* (Tryon) *femii* Adegoke, introduced as "a small variety of *P.* [*enitella*] *gabbi*," is also *Zirfaea pilsbryi*. *Penitella gabbii* is abundant as a fossil only in the asphalt mines in the Pliocene Foxen Mudstone, Cebada Member of the Careaga Sandstone, and in the Sisquoc Formation, all exposed in the Santa Maria district of California. Here *P. gabbii* and equal numbers of *P. turnerae* are commonly found *in situ*, with accessory plates preserved, and together have been variously reported under the specific names *ovoidea* and *penita*. It is unusual that *P. gabbii* is not better represented in the Pleistocene of California, especially in the San Pedro region. The only known Pleistocene occurrences are from Isla Vista, the Palos Verdes Sand of Newport Beach, San Nicolas Island, and Rosarito Beach in northwestern Baja California, Mexico.

Penitella kamakurensis (Yokoyama, 1922)
Figure 60

Jouannetia kamakurensis Yokoyama, 1922:120, pl. 6, fig. 10. Hanzawa, Asano, and Takai, 1961:247.
"Jouannetia" kamakurensis: Sieverts, 1933:292.
Pholadidea penita: MacNeil, *in* MacNeil, Mertie, and Pilsbry, 1943: 73, 75, 76, 94, pl. 16, fig. 4-6. Hopkins, 1967:66, 78. McCulloch, 1967:108.
Ph.[oladidea] (P.[enitella]) kamakurensis: Habe, 1952: 243, fig. 665-666.
Pholadidea (Penitella) kamakurensis: Taki and Oyama, 1954: pl. 26, fig. 10. Taki and Habe, 1955:11, pl. 2, fig. 14-15. Kira, 1965:183, pl. 63, fig. 18. Masuda and Matsushima, 1969: pl. 4, fig. 3.
P.[holadidea] (P.[enitella]) kamakurensis: Habe, 1955: 24 [in text], pl. 7, fig. 5-6.
Pholadidea kamakurensis: Itoigawa, 1963:110 [in text], pl. 3, fig. 3.

DIAGNOSIS.— Anterior dorsal margin short for genus. Umbonal reflection narrow, not appressed anteriorly. Mesoplax longitudinally ellipsoidal to rectangular, bluntly pointed posteriorly, with small lateral wings. Callum complete, flush with tips of beaks, does not protrude beyond. Posterior dorsal margin humped in adult.

ORIGINAL DESCRIPTION.— Shell small, roughly four-sided in outline, with surface divided into two parts by a mesial groove. The anterior half is very convex with the dorsal margin very short and slightly concave, and the ventral margin steeply ascending, almost twice as long as the dorsal, and at first straight, but excavated near the upper end, so that the front border of the shell becomes pointed, though blunt at apex. The sculpture consists of concentric and radiating riblets. The radiating riblets are unequal, rather distant, about ten in number, alternately large and small in the middle portion of the surface and quite absent in a small space immediately bordering the mesial groove. The concentric riblets are close, rounded and going over the radiating ones, giving them a crenate appearance. The margin is also crenate. The dorsal margin of the posterior half of the shell is double the length of that of the anterior half, scarcely convex, sloping, the meeting point with the ascending, somewhat undulatory ventral margin being subtruncate. Margin smooth.

LECTOTYPE.— Of *Jouannetia kamakurensis* Yokoyama, is in the Geological Institute, University of Tokyo, no. CM 21154, here designated. PARALECTOTYPE: In the Institute, no. CM 21155. The lectotype, a "living shell [was] picked up on the coast of Kamakura" (Yokoyama, 1922: 120) on Sagami Bay, Island of Honshu, Japan, here designated the type locality. Recent.

DISTRIBUTION.— Recent; Island of Kyushu, Japan (ca. 31-34° N. lat.; Kira, 1965: 183), north into the Gulf of Alaska (Middleton Island, 59° 27' N. lat.; USGS-M loc. 3852).

GEOLOGIC RECORD.— Pleistocene to Recent.

Pleistocene: Upper Musashino [?=Narita Formation] Formation, Shito, Chiba Pref., Honshu, Japan (Yokoyama, 1922: 120). Second beach, Peluk Creek, near Nome, Alaska, USGS loc. 3752 (MacNeil, *in* MacNeil, Mertie, and Pilsbry, 1943: 94; as *Pholadidea penita*), USGS loc. 3751. Yakatat Bay, Gulf of Alaska, USGS loc. 15864.

DISCUSSION.— *Penitella kamakurensis* has not previously been reported, either living or fossil, outside of Japan. The species however occurs at least as far north as the Gulf of Alaska (Chirikof Island and Middleton Island). Pleistocene specimens also are known from Alaska in the Second Beach deposits near Nome, and in the vicinity of Yakatat Bay, Gulf of Alaska.

The type specimens of *Jouannetia kamakurensis* are now in the Geological Institute of the University of Tokyo. Unfortunately, Yokoyama did not indicate either a type specimen nor a type locality. The single specimen figured by Yokoyama (1922: pl. 6, fig. 10; see Taki and Oyama, 1954: pl. 26, fig. 10), said to be the Pleistocene specimen from Shito, is actually the Recent one from the coast of Kamakura (K. Chinzei, *in litt.*). This specimen (CM 21154) is designated the lectotype, and the Pleistocene specimen (CM 21155) is designated a paralectotype. The "Holotype" listings in Taki and Oyama (1954: facing pl. 26) and in Hanzawa, Asano, and Takai (1961: 247) are confusing because of Yokoyama's error in his original plate description, and are considered invalid.

Penitella lorenzana (Clark, 1925)
Figures 28-32

Pholadidea aff. *penita:* Clark, 1918:162.
Pholadidea (Penitella) lorenzana Clark, 1925:107, pl. 18, fig. 5 [holotype], 6 [paratype]. Keen and Bentson, 1944:98.
Pholadidae lorenzana: Clark, 1925:107 (text).
not *Pholadidea (Penitella) lorenzana:* Weaver, 1953:60 (=*Penitella durhami*).
Penitella aff. *P. penita:* Addicott, 1966b:646.
Penitella lorenzana: Adegoke, 1967:11, fig. 14, 27.

DIAGNOSIS.— Shell narrow, flattened, somewhat spindle-shaped. Posterior extremity subacutely pointed, closed. Callum prominently protruded beyond beaks. Umbonal reflection narrow, free anteriorly. Mesoplax more or less rectangular, bluntly flattened posteriorly with lateral wings.

ORIGINAL DESCRIPTION.— Shell elongate subovate; beaks [= umbones] in anterior third of shell, each covered by a callus which stands out very prominently on anterior dorsal edge. Anterior portion of shell separated from posterior portion by a fairly deep transverse furrow, between beaks [= umbones] and above the middle of ventral edge. Anterior end bluntly pointed. On specimens at hand, siphonal gap [= anterior pedal gape] is filled by a callus plate; posterior end subacutely rounded, not gapping, as on shells belonging to the Recent species, *P. penita* Conrad. Surface of shell anterior to transverse furrow covered by concentric spinose wavy lamellae; the spines of the different lamellae are in line, and so give the effect of a number of fairly distinct radiating lines crossing the wavy lamellae. Surface of shell posterior to transverse lamellae smooth, except for somewhat irregular, fairly heavy incremental lines; a rather narrow, elongate quadrate metaplax [= mesoplax] with upper surface rather strongly concave, hinge plate not exposed.

SUPPLEMENTARY DESCRIPTION.— Shell narrow, laterally compressed, somewhat spindle-shaped, small to medium in size, reaching 6.5 cm in length, and 2 cm in height. Anterior gaping in juvenile, closed by callum in adult. Callum complete, protrudes prominently beyond beaks. Posterior compressed, conspicuously closed in both young and adult stages. Anterior slope sculptured with narrow low, slightly undulate concentric ridges with an inconspicuous radial pattern. Umbonal-ventral sulcus narrow, distinct. Disc and posterior slope ornamented with indistinct concentric ridges.

Umbonal reflections appressed above umbones, loose, free anteriorly. Callum thin, protruding anterior to beaks, sculptured with prominent concentric growth lines. Dorsal extension of callum longitudinally symmetrical, reasonably narrow, not lobate.

Mesoplax [= metaplax of Clark] only accessory plate, situated posterior to umbones, quadrate, posteriorly truncate, medianly and centrally constricted, and with posterior lateral wings.

On specimens from CAS loc. 36499 the posterior muscle scar is nearly circular in outline, and is situated high near the dorsal margin at the posterior end of the shell. Periostracum attachment scars extend only a short distance within the siphonal end of the valves.

HOLOTYPE.— Of *Pholadidea (Penitella) lorenzana* Clark, UCMP 30323 (not 30612, as cited by Clark, 1925: 107). A cast is in the California Academy of Sciences, no. 6253 (Keen and Bentson, 1944: 98). PARATYPE: UCMP 33491. Collected from UCMP loc. 1131, one half mile southwest of the town of Walnut Creek, in creek bed about 100 yards east of the Oakley-Antioch Bridge, Contra Costa Co., California. 37° 53' 07" N. lat., 122° 04' 08" W. long. Oligocene, basal San Lorenzo [= San Ramon] Formation.

GEOLOGIC RECORD.— Oligocene to Miocene.

Oligocene: San Ramon Formation, southwest of town of Walnut Creek, UCMP loc. 1131 (type locality; Clark, 1918: 162; and Clark, 1925: 107), and in large highway cut at Carquinez, CAS loc. 36499.

Miocene: Basal Montesano Formation, Canyon River, Washington, USGS-M locs. 3117 and 1542 (both Addicott, 1966b: 646; as *Penitella* aff. *P. penita*). "Monterey Formation," near Crockett, UCMP loc. D-599 (cf.).

DISCUSSION.— *Penitella lorenzana*, a

little known Oligocene to Miocene species, has not been reported since its initial discovery. The specimens which Clark (1925) used in his description are probably those which he had cited seven years earlier as *Pholadidea* aff. *penita* Conrad from the same locality (Clark, 1918: 162). At that time he noted that it was probably new, but declined to describe it due to the poor preservation of the specimens.

At the type locality, *P. lorenzana* was associated with the following mollusks (Clark, 1925: 107; Adegoke, 1967: 11): *Acila muta* (Clark), *Anomia inconspicua* Clark, *Antigona mathewsonii* (Gabb), *Anadara* (*Anadara*) *mediaimpressa* (Clark), *Glycymeris tenuimbricata* Clark, *Mytilus mathewsonii* Gabb, *Yoldia cooperi supramontereyensis* Arnold, *Bruclarkia gravida* (Gabb), and *Molopophorus biplicatus* Gabb. The two specimens of *P. lorenzana* collected by Clark were boring from the basal Oligocene beds "into beds that were presumably Tejon [Eocene], though no Tejon fossils were found at this locality [UCMP loc. 1131]" (Clark, 1918: 162). The thinness of the valves and the elongate shape indicate the substrate must have been relatively soft at the time of penetration by *P. lorenzana*.

Penitella lorenzana is presently known only from the Oligocene, and possibly Miocene, of central California, and the Miocene of Washington. Four specimens from CAS loc. 36499 from the San Ramon Formation at Carquinez resemble *P. lorenzana* in all respects, unless there are differences in the mesoplax, which is imperfectly preserved on the type specimens. The mesoplax of at least one of these specimens appears different from the rest, but too little is known of the species to validate any differences. Specimens from the Miocene "Monterey Formation" near Crockett (UCMP loc. D-599) are internal molds and are only questionably assigned to *P. lorenzana* on the basis of outline and the prominently protruded callum. The specimens cited by Addicott (1966b: 646) as *Penitella* aff. *penita* from the Miocene Montesano Formation, Canyon River, Washington (USGS-M locs. 3117 and 1542) very closely match the type specimens of *P. lorenzana*.

Penitella lorenzana is easily separated from the only other Oligocene *Penitella*, *P. durhami* Adegoke, by the callum which protrudes anterior to the beaks.

Penitella penita (Conrad, 1837)
Figures 46-54

P.[*holas*] *penita* Conrad, 1837: 237, pl. 18, fig. 7.
Pholas concamerata Deshayes, 1839: 357.
Penitella speloeum Conrad, 1855: 7 (*nomen nudum*). Blake, 1856: 55. Blake, 1857: 186.
P.[*enitella*] *speloeum* Conrad, 1855: 16.
Penitella spelaeum: "Conrad," 1856: 270.
Penitella spelaea: Conrad, 1857: 319. Carpenter, 1864: 590. Schuchert, 1905: 492.
P.[*enitella*] *spelaea:* Conrad, 1857: 326, pl. 5, fig. 43, 43a-b.
P.[*enitella*] *curvata* Tryon, 1865:40, pl. 2, fig. 6-8.
P.[*enitella*] *penita:* Gabb, 1869: 88, in part (*P. penita*, in part *P. turnerae*).
Pholadidea penita: Cooper, 1888: 259, in part (*Penitella penita*, in part *P. turnerae*). Bowers, 1890: 408. Arnold, 1903: 15, 23, 25, 27, 31, 37. Arnold, 1906: 31, 34. Moody, 1916: 45. Jordan, 1924: 154. Oldroyd, 1925: 8. Crickmay, 1929: 631. Willett, 1937 [1938]: 106. Putnam, 1942: 699. Weaver, 1942 [1943]: 265, in part (*Penitella penita*, in part *P. turnerae*). Bruff, 1946: 232, in part (*Penitella penita*, in part *P. gabbii*). Burch, 1947: 9. Woodring and Bramlette, 1950 [1951]: 54, 91, in part; not pl. 8, fig. 6, nor pl. 14, fig. 3 (*Penitella penita*, in part *P. gabbii*, and *P. turnerae* [figures]). Valentine, 1957: 297, in part (*Penitella penita*, in part *Parapholas californica*). Valentine, 1958:691, in part. Valentine, 1960a: 163. Orr, 1960: 1117. Valentine, 1961: 407; 370, in part (*Penitella penita*, in part *Zirfaea pilsbryi* and *Chaceia ovoidea*). Valentine and Meade, 1961: 19; 10, in part (*Penitella* sp. cf. *P. penita*, *Parapholas californica* and *Nettastomella rostrata*). Orr, 1968: 22.
?*Pholadidea* (aff.) *ovoidea:* Watts, 1900 [1901]: 224.
Pholadidea (*Penitella*) *penita:* Arnold, 1903: 184.
Pholadidea ovoidea Conrad [*sic*]: Arnold and Anderson, 1907: 59, in part; not pl. 22, fig. 1a-b (*Penitella penita*, *P. gabbii*, and *P. turnerae* [fig. 1a-b]) [author on plate is Gould].
? *Pholadidea* cf. *penita:* Eldridge, 1907: 27.
not? *Pholadidea penita:* Arnold, 1908: 355 (?=*Penitella turnerae*). Soper, 1938: 168 (Miocene). Weaver, 1945: 56 (?=*Penitella turnerae*). Woodring and Bramlette, 1950 [1951]: facing p. 49 (specimens not seen, likely *Penitella gabbii* and/or *P. turnerae*).
not *Pholadidea penita:* Dall, 1909: 134. Howe, 1922: facing 92. (Both =*Penitella turnerae*). Hertlein and Crickmay, 1925: 274. MacNeil, *in* MacNeil, Mertie, and Pilsbry, 1943: 75, 94, pl. 16, fig. 4-6 (=*Penitella kamakurensis*). Hopkins, 1967: 66, 78. McCulloch, 1967: 108. (Both=*Penitella kamakurensis*).
Pholadidea sagitta (Stearns Ms) Dall, 1916b: 417.
not *Pholadidea* aff. *penita:* Clark, 1918: 162 (=*Penitella*

lorenzana).
Pholadidea penita ?: Hoots, 1931: 120.
Pholadidea (*Pholadidea*) *penita:* Grant and Gale, 1931: 434, in part; not pl. 24, fig. 1a-b (*Penitella penita*, in part *P. conradi*, and *P. turnerae* [figures]). Soper and Grant, 1932: 1060.
not *Pholadidea* (*Pholadidea*) *penita:* Willett, 1937: 391 (=*Penitella conradi*). Wilson, 1966: 108 (=*Penitella turnerae*).
Pholadidae [*sic*] *penita:* Upson, 1951: 430.
Penitella penita: Fitch, 1953: 97, fig. 63. Turner, 1954: pl. 5. Turner, 1955: 80, pl. 47-51. Emerson, 1960: 5. Vedder and Norris, 1963: 46, 50, in part (*P. penita*, *P. conradi*, and *P. gabbii*). Evans, 1967a: 148. Adegoke, 1967: 17, fig. 11. Evans, 1968a: 271. Evans, 1968b: 111, pl. 1-4. Evans, 1968c: 156. Evans, 1968d: 619, fig. 2, 4-5. Zullo, 1969: 350, fig. 4. Human, 1972: 9. Bishop and Bishop, 1972: 6. Hertlein and Grant, 1972: 333, in part; pl. 56, fig. 8-9, 16; pl. 57, fig. 1-2 (*P. penita*, not Miocene record).
Pholadidea ovoidea: Kanakoff and Emerson, 1959: 24, in part (*Chaceia ovoidea*, in part *Penitella penita*).
Pholadidea? sp.: Valentine, 1961: 360.
not *Pholadidea* cf. *P. penita:* Valentine, 1961: 389 (*Penitella turnerae* and *Parapholas californica*).
Pholadidea penita Carpenter [*sic*]: Chace, 1966: 170, in part (*Penitella penita*, in part *P. fitchi*).
not *Penitella penita:* Addicott, 1966a: 4, pl. 4, fig. 1 (=*P. turnerae*). Bradley and Addicott, 1968: 1204 (=*P. turnerae*). Wright, 1972: 691 (=*P. turnerae* and *P. conradi*).
not *Penitella* aff. *P. penita:* Addicott, 1966b: 646 (=*P. lorenzana*).
Pholas penita: Keen, 1966: 171.

DIAGNOSIS.— Mesoplax sharply pointed posteriorly with anteriorly swept-back wings. Umbonal reflection wide, appressed entire length. Dorsal extension of callum low, often lobate. Posterior dorsal margin not "humped." Apophyses short, solid, thick, weakly blade-like.

DESCRIPTION.— Shell oval in outline, solid in structure, medium to large in size, reaching 9.5 cm in length, and 5 cm in height. Anteriorly beaked, widely gaping in young stage, closed with complete callum in adult; posteriorly rounded and closed. Anterior slope sculptured with moderately to tightly spaced, upturned, undulate, concentric ridges. Aligned undulations create a distinct radial pattern. Umbonal-ventral sulcus distinct, variable in width. Disc and posterior slope sculptured with growth lines, or weak low ridges in thin shelled specimens. The posterior-dorsal margin is relatively straight with no bump.

Umbones prominent, situated anterior to middle of shell. Umbonal reflection variable, appressed for entire length, usually broader anteriorly. Callum protrudes slightly beyond beaks, heavy, ornamented with weak concentric growth lines. Dorsal extension of callum extends anteriorly around beaks, dorsally over umbonal reflections, doubles upon itself, forms enclosure for anterior part of anterior adductor muscle, anteriorly very low and lobate in thick shelled specimens, moderately narrow and longitudinally symmetrical in thin-shelled specimens.

Mesoplax only accessory plate, situated posterior to umbones, covered dorsally, truncate anteriorly, keeled ventrally, sharply pointed posteriorly with anteriorly swept-back lateral wings. Juvenile mesoplax transverse, V-shaped.

Umbonal-ventral ridge low, distinct, beaded in thin-shelled specimens. Ventral condyle present in active boring specimens. Muscle scars and pallial line visible. Pallial sinus broad, extends anteriorly past umbonal-ventral ridge. Apophyses short, thick, solid, weakly blade-like, extending anterior to direction of umbonal ridge.

Siphonoplax entirely periostracal, widely diverging. Periostracum usually heavy on posterior slope. Siphons capable of complete retraction within shell. Foot in immature specimens large, oval in outline, truncate, atrophied in adult (Turner, 1955: 82).

The original description of *Penitella speloeum* Conrad is: Ovate, ventricose, anteriorly inflated with fine radiating lines and transverse wrinkles, transverse furrow medial, angular, slightly oblique; posterior side cuneiform, truncated at the extremity, which is direct, and with prominent, acute, wrinkled concentric lines; from dorsal margin widely recurved, trisulcate; cardinal plate broad, sulcated process slender.

TYPES.— Of *Pholas penita* Conrad, are missing (Turner, 1955: 83), though perhaps in the Gould collection (see Carpenter, 1857: 194, and Keen, 1966: 171). Conrad (1837: 237 [236]) notes the specimens were from "the vicinity of Sta. [San] Diego and Sta. Barbara," California although often cited by

authors as San Diego. Carpenter (1857: 194) however suggested the specimens were from Sta. Barbara. Recent.

TYPES.— Of *Pholas concamerate* Deshayes, are missing (Turner, 1955: 83). They are not in the British Museum (Natural History) (J.D. Taylor, *in litt.*). "Californie, dans les marnes calcaires des rivages," Monterey, California. Recent.

LECTOTYPE [?HOLOTYPE].— Of *Penitella speloeum* Conrad, USNM 1868, here designated. San Pedro, California (Conrad, 1855: 16). In accordance with Blake (1856: 55) the type locality is here redefined as the summit of 30 foot high bluffs near the mouth of the Los Angeles River, and south of the landing, Bay of San Pedro [now Los Angeles Harbor, California], collected by W.P. Blake, 1853. "Recent Formation" [= late Pleistocene, Palos Verdes Sand].

LECTOTYPE.— Of *Penitella curvata* Tryon, ANSP 51004, designated by Turner (1955: 83). PARALECTOTYPES: ANSP 316742 (eight valves). Strait of San Juan de Fuca, collected by W.M. Gabb. Recent.

HOLOTYPE.— Of *Pholadidea sagitta* Dall, USNM 63312. Monterey, California. Recent.

DISTRIBUTION.— Recent; at least from the Gulf of Alaska (Montague Island, ca. 60° N. lat.; USGS-M loc. 3601), south to Punta Pequeña, Baja California, Mexico (26° 14' N. lat.; LACMNH 71-181, and 71-179).

GEOLOGIC RECORD.— Pliocene to Recent.

Pliocene: "Merced" Formation, Moss Beach, CAS loc. 34437. Etchegoin Formation, Reef Ridge quad., UCMP loc. D-1124 (Adegoke, 1969: 155; "cf. *P. penita*" [not seen]). ?Careaga Sandstone, 3 miles southeast of Orcutt, USGS lco. 4476 (Arnold and Anderson, 1907: 59; as *Pholadidea ovoidea*, in part). Fernando Formation, southeast flank of Mt. San Cayetano (Eldridge, 1907: 27; specimen not seen), in Los Angeles on Fourthh Street between Broadway and Hill, UCMP loc. 3030 (cf.) (Moody, 1916: 45; Soper and Grant, 1932: 1060), Interstate 405 and Cherry Avenue, Long Beach, LACMNH loc. 423. San Diego Formation, "quarry" at end of Arroyo Drive, San Diego, LACMNH loc. 107 (cf.) (Hertlein and Grant, 1972: facing pl. 57), in southwest corner of San Diego County, SDSNH loc. 0417 and UCLA loc. 312 (both Hertlein and Grant, 1972: 333), SDSNH loc. 0429, on hill southwest of Goat Canyon, LACMNH loc. 305. South end of San Quintin Valley, Baja California, Mexico, LACMNH loc. 453.

Pliocene or Pleistocene: South of Cape Blanco, Oregon, UCMP loc. A-8709 (cf.). In bluff near beach, San Juan Capistrano, LACMNH loc. 1144. In bluff near beach between San Quintin and Rancho Socorro, Baja California, Mexico, SDSNH loc. 2658. [Neogene], southwest of Rosario, Baja California, Mexico, USGS loc. 10058 (cf.).

Pleistocene: Fivemile Point, near Bandon, LACMNH locs. 3950 and 3951, USGS-M loc. 4623. Coquille Point, Bandon, Oregon, USGS-M loc. 2798 (Zullo, 1969: 350). Cape Blanco, Oregon, LACMNH loc. 2641. Three miles north of Cayucos, CAS loc. 31832. One half, 1½, and 2½ miles west of Cayucos Creek, UCLA locs. 3393 (in part), 3448, and 3445, and at Cayucos, UCLA loc. 3447 (all Valentine, 1958: 691). Southeast of Point Sal Landing, USGS loc. 14966 (Woodring and Bramlette, 1950 [1951]: 54; cf.). West of Tajiguas Creek, near Gaviota, USNM (field no. NT-37) (Upson, 1951: 430). West of Punta Gorda (Putnam, 1942: 699). Near Sea Cliff RR station, north of Ventura City, SDSNH loc. 0078 (cf.). North end of Santa Rosa Island (Orr, 1960: 1117). Mouth of Potrero Canyon (Hoots, 1931: 120). Redondo Beach, LACMNH loc. 14. Los Angeles City, community of Watts, LACMNH loc. 2690, Vermont and Sepulveda, north of San Pedro (Cook and Clark, 1943: 17). Timms Point Silt, north border of the Palos Verdes Hills, UCLA loc. 3460 (Valentine, 1961: 407). Undifferentiated Pleistocene, in San Pedro (Arnold, 1906: 34), LACMNH loc. 5, SDSNH loc. 1883, northwest of Whites Point, USGS loc. 13130, San Pedro RR cut, SDSNH loc. 1899, Nob Hill, SDSNH loc. 1885, and below, LACMNH loc. 300, lumberyard near Timm's Point, LACMNH loc. 1203, Deadman Island, CAS loc. 495, LACMNH locs. 17 and 1206. Lomita Marl, northeast corner of Host Place, and Park Western and Coralmount Drives, San

Pedro, SDSNH loc. 2669. San Pedro Sand, in San Pedro, at the "Chiton Bed" [of Chace and Chace, 1919] on Point Firmin, SDSNH loc. 0625, Peck Park, USGS loc. 13125, at High School at 15th and Leland Streets, SDSNH loc. 2138 [=L-2138] (Chace, 1966: 170; in part), Nob Hill cut (Oldroyd, 1925: 8), Second and Beacon Streets, UCLA loc. 1824 (Valentine and Meade, 1961: 19), southeast corner of Third and Mesa Streets, LACMNH loc. 98, SDSNH loc. 2660, Eighth Street and Palos Verdes Avenue, LACMNH loc. 226, Deadman Island (Arnold, 1903: 15, 37; and Arnold, 1906: 31), CAS loc. 94. Palos Verdes Sand, old Bixby Slough, Harbor City, LACMNH loc. 229, in San Pedro, at Southern Pacific RR depot, CAS loc. 91 (cf.), at southeast corner of Pacific Avenue and Hards Street, LACMNH loc. 440, Pacific Avenue and Bonita Street, USGS loc. 12132, southeast corner of Pacific Avenue and Oliver Street, USGS-M loc. 2017, Palos Verdes Avenue between Eighth and Ninth Streets, UCLA loc. 3440 (Valentine, 1961: 370; in part), old Crawfish George's (Arnold, 1903: 25), Deadman Island (Arnold, 1903: 23; Crickmay, 1929: 631), CAS locs. 90 and 92, north end of San Pedro Bluff (Arnold, 1903: 27; =lumberyard locality, p. 37), "Arnold's lumberyard," on Harbor Boulevard, USGS-M loc. 1728, south of Union Oil refinery, in Harbor District Sanitation Yard, LACMNH loc. 1210, bluff east of Gaffey Street, USGS loc. 12139, Los Cerritos Hill [=Signal Hill] (Arnold, 1903: 31), Cherry Avenue, Signal Hill, USGS-M loc. 2011, Pacific Coast Highway and Newport Bay, LACMNH loc. 241, on west bluff of "middle" Newport Bay, UCMP loc. A-3104 (Bruff, 1946: 232), on east bluff above Upper Newport Bay, LACMNH loc. 66-2 (Kanakoff and Emerson, 1959: 24; as *Pholadidea ovoidea*, in part), SDSC loc. 533. San Joaquin Bay [=Newport Bay], CAS (CSMB 11896) (?Bowers, 1890: 408). Corona del Mar (Human, 1972: 9). Near Calle Fortuna, Capistrano Beacch, LACMNH loc. 58 (Willett, 1937 [1938]: 106), LACMNH loc. 137. San Nicolas Island, USGS loc. 21655 (Vedder and Norris, 1963: 46; in part). Torrey Pines Beach State Park, UCLA loc. 2410 (Valentine, 1960a: 163; as UCLA loc. 3457). Pacific Beach, San Diego, UCLA loc. 3606 (Valentine, 1961: 360; as *Pholadidea*? sp.). Foot of Tourmaline Street, Pacific Beach, SDSNH loc. 0289 (Bishop and Bishop, 1972: 6), UCMP loc. 5092. West side of Point Loma, UCLA loc. 3605 (cf.) (Valentine and Meade, 1961: 10; in part), SDSNH locs. 2530 and 2668. In Baja California, Mexico, 10 miles south of the U.S. border, SDSNH loc. 2576; 8, and 5.2 miles north of Rosarito Beach, UCLA locs. 3161 and 3160 (both Valentine, 1957: 297); Rosarito Beach, UCLA loc. 2720 (Valentine, 1957: 297), SDSNH loc. 2531; 2.2, 5.7, 6.4, and 8.5 miles south of Rosarito Beach, UCLA locs. 2719, 2718, and 2717 (all Valentine, 1957: 297), and SDSNH loc. 2629; El Descanso, SDSC loc. 109; immediately south of Punta San José (Emerson, 1960: 5); south of Punta Cabras, UCMP loc. A-9587 (Addicott and Emerson, 1959: 17; "cf. *P. penita*" [not seen]); northwest, and southwest sides of Turtle Bay, UCMP locs. B-3027, and B-3007.

DISCUSSION.— *Penitella penita* is the commonest and best known of all Pacific coast pholadids. It is widely distributed geographically and, due mostly to the variety of substrates it can and will inhabit, is extremely variable in form. It will bore into clay, shale, mudstone, sandstone (all in various stages of induration), though only rarely into other shell (in *Haliotis rufescens*, SDSNH 50959). Usually found on the open coast, it frequents intertidal and subtidal habitats, with burrows as deep as 13 cm (Fitch, 1953: 97). *Penitella penita* is often associated with *Chaceia ovoidea*, *Penitella fitchi*, *P. gabbii*, *P. turnerae*, *Parapholas californica*, *Nettastomella rostrata*, *Lithophaga plumula* (Hanley, 1843), *Adula falcata* (Gould, 1851) and *Platyodon cancellatus* (Conrad, 1837).

Complete specimens of *Penitella penita* are easily distinguished from other species of *Penitella* by the sharp posteriorly-pointed mesoplax with "swept-back" wings. Loose valves of *P. penita* are readily separated from those of *P. fitchi* by the pointed beaks and the long, narrow, anterior-dorsal

margin of the shell, and from *P. gabbii* (and juvenile *Chaceia ovoidea*) by the wider and fully appressed umbonal reflection. From *P. conradi* and *P. turnerae*, it is less easily separated. Specimens of *P. conradi* that bore into soft rock are small (up to 3 cm in length), very perfectly formed, globose, have roughened posterior muscle scars, and usually thin and fragile apophyses and callum. The dorsal margin posterior to the umbo is humped, not straight as in *P. penita*. *Penitella turnerae* has the anterior margin immediately ventral to the beaks strongly angled, a longitudinally symmetrical umbonal reflection and a high and longitudinally symmetrical, not lobate, dorsal extension of the callum. The apophyses are usually flattened and gently curving, unlike the stout, weakly blade-like apophyses of *P. penita*.

Because of the relative abundance of *P. penita* in the living fauna of California, it has often been assumed, though incorrectly, that any fossil *Penitella* was *P. penita*, and the name has served for many years in this capacity as a junk-basket term. In reported literature, none of the Miocene or older records can be substantiated with actual specimens of *P. penita*, and the verified geologic range is accordingly restricted to Pliocene through Recent. In fact, actual Pliocene occurrences are few, and the species is not known from the lower Pliocene at all. Known occurrences, in the "Merced," Fernando, and San Diego formations, all are upper Pliocene or later.

Penitella penita, however, is quite abundant in Pleistocene deposits of California and northern Baja California. Most were associated with a large number of molluscan species collected from detrital death assemblages representing a wide range of habitats. Only a few instances of *P. penita* occurring abundantly *in situ* have been reported, although it is not uncommon to find single specimens in cobbles in detrital deposits.

Penitella turnerae Evans and Fisher, 1966
Figures 61-64

Pholadidea penita: Cooper, 1888: 259, ? in part (*Penitella penita*? or *P. turnerae*?). Dall, 1909: 134. Arnold and Hannibal, 1913: 594. Howe, 1922: facing 92. Hertlein and Crickmay, 1925: 274. Weaver, 1942 [1943]: 265, 639. Woodring and Bramlette, 1950 [1951]: facing 34, 41, 48, facing 48, 66, 91, in part; pl. 8, fig. 6, and pl. 14, fig. 3 (*Penitella penita* [Pleistocene, p. 54], in part *P. gabbii* and *P. turnerae* [figures]).

Pholadidea ovoidea Conrad [*sic*]: Arnold, 1907: 423, in part; pl. 55, fig. 1a-b. Arnold and Anderson, 1907: 59, in part; pl. 22, fig. 1a-b. (*Penitella gabbii*, *P. penita*, and *P. turnerae* [figures]). [Author on plates is Gould].

? *Pholadidea penita:* Arnold, 1908: 355 [cf. Addicott, 1966a: 4]. Weaver, 1945: 56.

? *Parapholas californica:* Arnold and Hannibal, 1913: 590.

Pholas borings: Arnold and Hannibal, 1913: 603. Howe, 1922: 89. Schenck, 1927: 454. Schenck, 1928: 19, 20.

? *Parapholas californica* Hinds [*sic*]: Howe, 1922: facing 92.

Pholadidea californica: Oldroyd and Grant, 1931: 91.

Parapholas californica: Oldroyd and Grant, 1931: 92.

Pholadidea (*Pholadidea*) *penita:* Grant and Gale, 1931: 434, in part; pl. 24, fig. 1a-b (*Penitella penita*, in part *P. conradi* and *P. turnerae* [pl. 24, fig. 1a-b]). Wilson, 1966: 108.

Pholadidea cf. *P. penita:* Woodring, Stewart, and Richards, 1940 [1941]: 70. Valentine, 1961: 389, in part (*Penitella turnerae* and *Parapholas californica*).

? *Pholadidea californica:* Weaver, 1942 [1943]: 265, 639. Weaver, 1945: 56 (as "?").

Pholas sp.: Weaver, 1945: 50, 51.

Zirfaea pilsbryi: Addicott, 1963: 344.

Penitella turnerae Evans and Fisher, 1966: 222, pl. 31 [in part].

Penitella penita: Addicott, 1966a: 4, pl. 4, fig. 1. Bradley and Addicott, 1968: 1204. Wright, 1972: 691, in part (*P. turnerae* and *P. conradi*).

DIAGNOSIS.— Very prominently beaked in young stage, anterior margin strongly angulate. Umbonal reflection longitudinally symmetrical, not wide, appressed to anterior slope except right near beaks. Dorsal extension of callum usually high, longitudinally symmetrical, and not lobate. Mesoplax subacuminate to broadly crescent-shaped posteriorly, with lateral wings, anterior portion usually narrower than posterior portion. Apophyses flattened their entire length, gently curving, not blade-like.

DESCRIPTION.— Shell large, reaching 12 cm in length and 5 cm in height, somewhat pear-shaped in outline, solid in structure, and producing a callum in adult stage. Immature specimens very strongly beaked,

anterior margin near beaks sharply angulate.

Anterior slope sculptured with widely to narrowly spaced, upturned, undulate concentric ridges, supplemented by radial pattern formed by alignment of undulations of the ridges. These "radial ribs" may be arranged in pairs. Anterior slope separated from disc by prominent umbonal-ventral sulcus. Undulating ridges of anterior slope give sulcus ladder-like appearance as they cross it, continue on disc as narrow, low rounded, smooth ridges (or heavy growth lines).

Umbonal reflection somewhat longitudinally symmetrical, appressed to anterior slope for entire length except near beaks. Pedal gape large, sub-oval in young stage, closed by complete callum in adult. Callum sculptured by concentric growth lines parallel to anterior margin, and by slight radial ridges which are extensions of radial pattern of anterior slope. The central part of the callum is elevated above general surface, probably due to vestigial presence of foot. Callum protruded anterior to beaks, dorsal extension of which is high, somewhat longitudinally symmetrical.

Mesoplax only accessory plate, situated posterior to umbones, somewhat V-shaped in young stage, covered, semipointed with lateral wings (remnants of juvenile plate) in adult. The posterior end is almost crescent-shaped in some specimens, centrally constricted, or narrowed anteriorly.

Umbonal-ventral ridge prominent, either beaded in thin specimens or smooth in heavy shelled ones. Pallial line and muscle scars well calcified and readily apparent. Pallial sinus extends anteriorly past umbonal-ventral ridge, sometimes almost to mid-point of anterior margin. Ventral muscle scar sausage-shaped. Posterior muscle scar oval to sub-oval. Anterior muscle scar pad not prominently calcified. Apophyses extend anteriorly away from umbonal-ventral ridge, usually flattened their entire length, just barely spooned, gently curving, not blade-like.

Periostracum thin, found primarily on posterior slope, extends internally into siphonal end of shell. Foot well developed, oval and truncate (Evans and Fisher, 1966: 222). Siphons capable of complete retraction within shell.

HOLOTYPE.— Of *Penitella turnerae* Evans and Fisher, CAS 12445. PARATYPES: CAS 12445a, MCZ 170898 (4 specimens), RM 16284 (2 specimens), and UO 1334 (3 specimens). North end of Fossil Point in Coos Bay, Coos Co., Oregon, "in soft muddy sandstone at zero foot tide level." 43° 22' N. lat., 124° 15' W. long. Recent.

DISTRIBUTION.— Recent; at least from Newport, Oregon (46° 38.5' N. lat.; ANSP 130970, SDSNH 7046) south to Waddell Beach, Santa Cruz Co., California (37° 06' N. lat.; LACMNH 67-95).

GEOLOGIC RECORD.— Pliocene to Recent.

Pliocene: Empire Formation, Coos Bay and vicinity, Oregon, USGS loc. 2954 (USNM 153957; Dall, 1909: 134 [as Miocene]; Weaver, 1942 [1943]: 265, 639), UCMP locs. 3321 [not seen] and 3322 (both Howe, 1922: facing 92; as *Parapholas californica* and *Pholadidea penita*), UCMP loc. A-87, USGS loc. 18284, east side of South Slough, UW loc. 719 ("?" as *Pholadidea californica*), Fossil Point, UW loc. 725 (both Weaver, 1945: 56 [specimens not seen]), east of Tunnel Point, UW loc. 752 (Weaver, 1945: 50, 51; as Oligocene, *Pholas* sp.), CAS loc. 243. Arroyo Murado, northwest of El Pulgar, North Dome of Kettleman Hills, USGS loc. 14118 (Woodring, Stewart, and Richards, 1940 [1941]: 70; as *Pholadidea penita*). Sisquoc Formation, Pennsylvania asphalt mine, southeast of Orcutt, USGS loc. 4472 (Arnold and Anderson, 1907: 59; as *Pholadidea ovoidea*, in part; also Woodring and Bramlette, 1950 [1951]: 91; as *Pholadidea penita*, in part), NTU asphalt mine, NNW of Casmalia, UCMP loc. D-2845 (cf.). Foxen Mudstone, Waldorf asphalt mine, SSE of Guadalupe, USGS loc. 4473 (Arnold, 1907: 423; and Arnold and Anderson, 1907: 59; both as *Pholadidea ovoidea*, in part), USGS loc. 14879 (both locs. Woodring and Bramlette, 1950 [1951]: 41; as *Pholadidea penita* [specimens not seen]), CAS loc. 76. Careaga Sandstone (Cebada Member), at Fugler Point, north of Garey, USGS loc.

14768 ("cf."), on Graciosa Ridge, southeast of Orcutt, USGS loc. 14648 (both Woodring and Bramlette, 1950 [1951]: facing 48; as *Pholadidea penita*). "Bracket Mesa," Arroyo Santa Catarina, Baja California, Mexico, SDSNH loc. 2646 (cf.).

Pleistocene: Crescent City, USGS-M loc. 1449 (Addicott, 1963: 344; as *Zirfaea pilsbryi*), LACMNH locs. 3944 and (all cf.) 3943, 3945, and 3946. Point Año Nuevo, USGS-M locs. 1690 and 2147, and Point Santa Cruz, USGS-M loc. 1691 (all Addicott, 1966a: 3, 4; as *Penitella penita*). RR cut west of Tajiguas Creek, near Gaviota, UCLA loc. 3597 (Valentine, 1961: 389; as *Pholadidea* cf. *P. penita*, in part). Isla Vista, near Goleta (Oldroyd and Grant, 1931: 91, 92; Wright, 1972: 691; as *Penitella penita*), SDSNH loc. 0074, LACMNH locs. 416 and 2694, ANSP [no locality number].

DISCUSSION.— *Penitella turnerae* is a recently described species which was not recognized until a large series of living specimens was collected by Evans and Fisher from Fossil Point in Coos Bay, Oregon. Though morphologically distinct, it is similar in certain aspects to both *P. gabbii* and *P. penita*, and has often been cited as the latter species, or as *Parapholas californica*.

There is some disagreement as to the validity of this species. Turner (pers. comm. and in Evans and Fisher, 1966: 224) believed that, because of its similarity to the above mentioned species, and its described occurrence from a single locality, it should be treated as an infertile hybrid, and cited as *Penitella gabbii* x *Penitella penita*. I have seen Recent specimens from a number of different localities on the coasts of northern California and Oregon which extend the range considerably, and prove the areal extent beyond the type locality. Noteworthy is the fact that *P. turnerae* frequently occurs with *P. gabbii* and *P. penita*. At the type locality all three species occur together, and at Duxbury Reef at Bolinas, California, *P. gabbii* and *P. penita* are abundant, and beach worn specimens of *P. turnerae* are not uncommon. Whether *P. turnerae* is really a distinct species or a hybrid needs to be investigated, though both schools of thought recognize it as morphologically distinct. In the light of fossil evidence, I recognize *P. turnerae* as a valid species.

Penitella turnerae can usually be separated from *P. penita* by its large size, the high and longitudinally symmetrical dorsal extension of the callum, the strongly angulate anterior margin ventral to the beaks, and the umbonal reflection which is not appressed at its anterior extremity. Further, the mesoplax is not sharply pointed posteriorly and the apophyses are flattened and gently curving and unlike the sharp blade-like apophyses of *P. penita*.

In the fossil record, *P. turnerae* is rather common in certain localities in California and Oregon. It is the large *Penitella* which is found *in situ* on the low late Pleistocene terrace at Isla Vista, near Santa Barbara, California. Grant and Gale (1931: pl. 24, fig. 1a-b) figured one of these specimens as *Pholadidea penita*, which has caused confusion in subsequent paleontological literature. Outside of the questionable occurrence in Baja California at Arroyo Santa Catarina, Santa Barbara, California, is the most southerly occurrence of this species in the Pleistocene, and Recent specimens are known only from Santa Cruz Co., California, to Newport, Oregon.

Two localities on a late Pleistocene marine terrace in the vicinity of Point Año Nuevo in San Mateo Co., California (Addicott, 1966a: 3; cited as *Penitella penita*) contain large numbers of *P. turnerae in situ*. On the south side of the Point (at USGS-M loc. 1690) *P. turnerae* is found inhabiting steeply inclined burrows and associated with *Zirfaea* sp. aff. *Z. pilsbryi*, *Saxidomus giganteus* (Deshayes, 1839) and *Protothaca staminea ruderata* (Deshayes, 1853). The substrate at this locality is the Miocene Monterey Formation. At another locality (USGS-M loc. 2147) north of Pt. Año Nuevo, a terrace platform (cut into the Pliocene Purisima Formation) is extensively pitted with holes of *P. turnerae*, many of which are still *in situ*.

In the Santa Maria district of Califor-

nia, *P. turnerae* is quite common in the asphalt mines in the Guadalupe-Orcutt area, where it is associated with approximately equal numbers of *P. gabbii*, and only rarely with *P. penita*. The species occurs in a succession of formations (Foxen Mudstone, Cebada Member of the Careaga Sandstone, and the Sisquoc Formation) without any apparent change.

Poorly preserved specimens are not uncommon in the Pliocene Empire Formation of the Coos Bay region of Oregon, and it is the only fossil pholadid known from this area. The reports of Dall and Weaver of *Penitella penita* in the Empire Formation refer to *P. turnerae*. It is quite probable also that the references to occurrences of *Parapholas californica* in the "Miocene" and Pliocene of Coos Bay (Arnold and Hannibal, 1913: 590; Howe, 1922; facing 92; Weaver, 1942 [1943]: 265, 639; and Weaver, 1945: 56) refer to these large bulbous specimens common to that area. *Parapholas californica* is the only species which might be confused with *P. turnerae* on size alone, though no specimens of *Parapholas* from here have ever been figured, or are present in numerous fossil collections examined.

Genus *Martesia* Sowerby, 1824

Martesia Leach [MS] Sowerby, 1824: no pagination [2nd p. of *Pholas*]. Bartsch and Rehder, 1945: 2. Turner, 1955: 101.

DEFINITION.— Shells pear shaped, light in structure, small, usually not over 3.5 cm in length, divided into two regions by umbonal-ventral sulcus. Beaks sinuously to sharply truncate, widely gaping anteriorly in young stage, closed by complete callum in adult. Valves narrowly to broadly rounded posteriorly and closed. Umbones prominent, nearly centrally located in young shells, near anterior end in adult due to disproportionate growth of posterior portion of shell. Umbonal reflection closely appressed over umbo, raising abruptly anteriorly to form distinct funnel-shaped pit.

Mesoplax covered dorsally, broadly circular to ellipsoidal, situated anterior to umbones. Metaplax and hypoplax long, narrow and pointed anteriorly, pointed, truncate, or divided posteriorly. Dorsal margin of shell posterior to umbo may be reflected upon itself to form a narrow enclosure (in *Paramartesia*). Umbonalventral ridge distinct, narrow, usually beaded. Chondrophore and internal ligament present, but small. Apophyses long, thin, and fragile. Siphons capable of complete retraction within shell.

Martesia differs from closely related genera in the Martesiinae by the presence of the mesoplax, metaplax, hypoplax, funnel-shaped pit below the umbonal reflection, and complete callum. There is no dorsal extension of the callum. The posterior slope is not covered with periostracal flaps and the umbonal-ventral sulcus (and corresponding ridge) is the only radial division of the shell. Species of *Martesia* are wood-borers.

TYPE SPECIES.— *Pholas clavata* Lamarck (=*Martesia* [*M.*] *striata* [Linné, 1758]), by original monotypy.

TAXA INCLUDED.— Recent species of *Martesia* are divided into two subgenera, *Martesia s.s.* and *Particoma* Bartsch and Rehder, on the basis of umbonal and accessory plate morphology. The subgenus *Paramartesia*, on the basis of shell morphology alone, is described herein.

The two living species of *Martesia* found in the eastern Pacific are *M.* (*M.*) *striata* (Linné, 1758), and *M.* (*M.*) *fragilis* Verrill and Bush, 1898, both occurring in the warm waters of the tropics and subtropics. *Martesia striata* occurs as far north as the mangrove swamps of Magdalena Bay on the outer coast of Baja California. Neither species has been identified from fossil deposits in western North America, though both have occasionally been reported in the Neogene of the eastern and Gulf coastal states.

DISCUSSION.— *Martesia s.s.* is distinguished from *Particoma* by the presence of a non-bifurcate metaplax and hypoplax, and by the shape of the mesoplax. In the former it is broadly circular, and in the latter it is ellipsoidal. The anterior adductor muscle scar pad in *Martesia s.s.* is

sickle-shaped and attached anteriorly, while that of *Particoma* is thicker and oval-shaped. The nature of the sculpture on the mesoplax, as well as the shapes of the ends of the long dorsal and ventral plates are useful in specific determination. The number of concentric ridges or shape of the valves in general are not however.

Reportedly, *Martesia* is the oldest known genus of Pholadidae, occurring in the Carboniferous (questionably), and from Jurassic to Recent (see Turner, 1969: 711). Some of these early occurrences may acutally belong to *Opertochasma* Stephenson, 1952, a wood boring genus not uncommon in the Cretaceous of North America. I have seen no specimens of true *Martesia* older than early Tertiary. References to nominal species of *Martesia* in the Paleocene and Eocene of the eastern and southeastern United States are listed in Palmer and Brann (1965: 191).

Fossil specimens of *Martesia* are rare in Cenozoic deposits of western North America. Burrows in fossil wood figured by MacNeil (1957: pl. 12, fig. 1; USNM 561882) as possibly belonging to a *Martesia* with Atlantic affinities were made by teredinids. Besides *M. meganosensis* Clark and Woodford, and *M. (Paramartesia) tolkieni* Kennedy, subgen. et sp. nov., the only occurrences of *Martesia* which can be documented by specimens are:

1) One small, poorly preserved specimen from the upper Eocene or lower Oligocene Keasey Formation from Rock Creek, south of the Keasey Post Office, Keasey, Oregon (UCMP loc. 4194). No accessory plates are preserved.

2) Forty-two specimens of "*Martesia* sp." cited by Hickman (1969: 69, pl. 8, fig. 4, 6) from the middle Oligocene Eugene Formation, near Eugene, Oregon (UO locs. 80, 2544, 2553, and 2554). Several specimens are still preserved in a fragment of fossil wood (UO 27326) with the mesoplax present. They belong to *Martesia s.s.*

3) Two single valves belonging to *Martesia* have been collected from Pleistocene deposits at Puerto Libertad, Sonora, Mexico, by T.E. Stump and R.J. Dowlen in 1972 [field no. S2-SD-5]. The specimens represent the only known fossil pholadids from the Gulf of California region.

Subgenus indet.
Martesia meganosensis Clark and Woodford, 1927
Figures 65-66

Martesia meganosensis Clark and Woodford, 1927: 103, pl. 18, fig. 7-8. Keen and Bentson, 1944: 65.

DIAGNOSIS.— No features considered distinctive below the generic level are present on the poorly preserved types. Further recognition of the species can only be speculative.

ORIGINAL DESCRIPTION.— Shell somewhat variable in length, roughly elongate, ovate in outline; umbones broad, fairly prominent, strongly inturned, and slightly prosogyrous. Anterior edge sloping rather abruptly down to the anterior end; posterior dorsal margin long, straight to slightly convex; ventral margin straight. Anterior end with a sharp V-shaped notch which shows very decidedly in the concentric lines of growth. Surface sculptured by heavy, broadly rounded concentric ribs or undulations on and between which are finer incremental lines; the interspaces between these undulations are about half their width. A very distinct umbonal groove extends obliquely and posteriorly from the umbones to the ventral edge.

SUPPLEMENTARY DESCRIPTION.— Anterior gape and (or) callum rhomboidal, upper two sides shortened, slightly concave. Both the type and paratype are small, poorly preserved, and in matrix. The accessory plates are absent and the umbonal regions are obscured.

HOLOTYPE.— Of *Martesia meganosensis* Clark and Woodford, UCMP 31297. PARATYPE: UCMP 31298. Casts of each are in the California Academy of Sciences, type nos. 6206 and 6207. Northeast of Mt. Diablo, on ridge immediately east of hill 392, near margin of Byron quadrangle, Contra Costa Co., California (UCMP loc. 3577). Elevation 375 feet. Early Eocene, Meganos Formation (division D).

GEOLOGIC RECORD.— Eocene.

Eocene: Meganos Formation (division D), northeast of Mt. Diablo, on ridge immediately east of hill 392 near western margin of Bryon quadrangle, UCMP loc. 3577 (holotype), on top of ridge in NW cor. of SW ¼ sec. 21, T. 1 N., R. 2 E., MDBM, UCMP loc. 3159 (paratype; both Clark and Woodford, 1927:103).

DISCUSSION.— This species is not placed subgenerically because characters presently used in the definition of subgeneric and specific taxa rely essentially on the morphology of the umbonal region and of the three accessory plates, and these are not preserved. Both specimens of *M. meganosensis* are in matrix and represent detrital valves. Neither is associated with any woody material. The dimensions of the holotype (juvenile, "a small specimen") and the paratype (adult) are, respectively: length 4.5 mm, height 3.2 mm, and length 14 mm, height 6 mm; length to height ratios are 1.4 and 2.34 respectively.

Clark and Woodford (1927:103) compared *M. meganosensis* with *"M." clausa* Gabb, 1864 (see Fig. 94) from the Cretaceous of California. Gabb's species however belongs to *Opertochasma* (*q.v.*) and differs from *Martesia* in a number of subtle ways.

Paramartesia n. subgen.

DEFINITION.— Shell martesia-form, pear-shaped, small, ranging to 3 cm in length. Dorsal margin posterior to umbo folded upon itself to form elongate enclosure. Mesoplax quadrate to broadly circular, metaplax and hypoplax present. Anterior margin with V-shaped notch. Umbonal reflection appressed to anterior slope, raised at beaks to form funnel-shaped pit. Posterior adductor muscle scar long, relatively narrow.

Paramartesia differs from other subgenera of *Martesia* by the folded dorsal margin and the long posterior muscle scar, both similar to those of *Parapholas*. *Paramartesia* however is smaller, has the distinguishing pit below the umbonal reflection, the V-shaped notch in the anterior margin, and a wood-boring habit. *Parapholas* and *Opertochasma* have periostracal flaps on the posterior slope, and a divided mesoplax.

TYPE SPECIES.— *Martesia* (*Paramartesia*) *tolkieni* Kennedy, sp. nov.

TAXA INCLUDED.— The type species is the only representative of the group known to me.

ETYMOLOGY.— The name *Paramartesia* is derived from the generic names *Parapholas* and *Martesia*, to both of which it bears similarities.

Martesia (Paramartesia) tolkieni n. sp.
Figures 67-70: frontispiece

DIAGNOSIS.— Dorsal margin folded upon itself to form an elongate enclosure. Mesoplax roughly quadrate to broadly circular, sculptured with irregular wrinkles. Metaplax and hypoplax non-bifurcate, pointed anteriorly and posteriorly. Umbonal reflection folded over beaks to form funnel-shaped pit. Posterior adductor muscle scar long, narrow.

DESCRIPTION.— Shell pear-shaped, laterally compressed posteriorly, thin, light in structure, ranging to approximately 3 cm in length and 1.2 cm in height. Anterior gape rhomboidal, two dorsal sides shorter, closed in adult with complete hemispherical, smooth callum. Posterior gape narrow, slit-like, if present. Shell divided by umbonal-ventral sulcus, anterior portion one third to one fourth size of posterior. Anterior slope sculptured with thin, closely spaced concentric ridges, minutely denticulated but too fine to form a radial pattern. Concentric ridges constricted by broad V-shaped notch in anterior margin, widening, smoother posterior to constriction, approaching size and shape of posterior ridges where cross sulcus. Umbonal-ventral sulcus manifested as change in type of sculpture between anterior slope and disc. Disc and posterior slope sculptured with broad, low rounded, smooth ridges.

Dorsal margin immediately posterior to umbo reflected back, doubled upon itself, forms an elongate enclosure, wide, broadly rounded anteriorly, narrowing posteriorly, disappearing approximately halfway be-

tween umbo and posterior extremity, similar to that of *Parapholas californica* (Conrad).

Umbonal reflection covered by adult mesoplax posteriorly, folded anteriorly to form distinct funnel-shaped pit. Mesoplax situated above and anterior to umbones, roughly quadrate to broadly circular, sculptured with irregular wrinkles. There are no lateral wings. Metaplax rests on or between dorsal reflection of valves, divided longitudinally by growth line, pointed posteriorly, centrally widened, curved, and ventrally pointed anteriorly. Hypoplax narrow, divided longitudinally by growth line, pointed anteriorly and posteriorly.

Umbonal-ventral ridge narrow, pronounced, either smooth, or in thin-shelled specimens ornamented with little bumps corresponding externally to intersection of concentric ridges with sulcus. Posterior adductor muscle scar long, narrow, resembling that of *Parapholas*. Internal morphology surrounding umbo, including apophyses, unknown.

HOLOTYPE.— Of *Martesia* (*Paramartesia*) *tolkieni*, USNM 163803. PARATYPES: USNM 163804. In foothills on west side of San Joaquin Valley, between Ortigalito and Little Panoche Creeks, near top of hill on east side of small strike valley at center of north line of sec. 19, T. 12 S., R. 11 E., MDBM, Merced Co., California (USGS loc. 5712). Collected by R. W. Pack and E. L. Ickes, July, 1910. "Eocene gray sandstone overlying Cantua Shale member of the Lodo Formation."

GEOLOGIC RECORD. — Eocene.

Eocene: Lodo Formation, at the type locality, USGS loc. 5712.

DISCUSSION.— The type lot of *P. tolkieni* is in a piece of fossilized wood (see frontispiece) approximately 12 by 10 by 5 cm in size, and it contains at least 25 specimens exposed solely on its surfaces. It was broken off a much larger piece, probably in the field, and has had one end trimmed with a rock saw, exposing a single specimen. The burrows average 2.5 cm in length, though the animals themselves are a little shorter. The burrows are filled with a fine dark brown sediment which has completely surrounded and filled the shells, which in turn have been leached away leaving a large number of internal and external molds. The wood has also been infested with teredinids, and many calcareous lined burrows are present below the level of the *Martesia*, and are generally boring in a direction perpendicular to the pholadids. The wood was presumably penetrated first by the *Martesia*, since none of the pholadid burrows intersect those of the teredinids. From submerged test boards it has been found that Recent *Martesia* will not avoid teredinid burrows if encountered, though teredinids will make every effort to avoid any obstruction or other tube, even to the point of completely reversing the direction of boring (Turner, 1955:65).

Except for the folded dorsal margin, the similarity of *M. tolkieni* to true *Martesia* is striking, and there can be no doubt that it evolved from the typical genus.

The name *tolkieni* honors the late J.R.R. Tolkien, creator of *The Hobbit*, *The Lord of the Rings*, and many delightful creatures of long ago in the time of Middle-earth.

Genus *Opertochasma* Stephenson, 1952

Opertochasma Stephenson, 1952: 139. Turner, 1969: 715.

DEFINITION.— Shell divided by two radial "sulci" in anterior slope-disc region. Mesoplax quadrate to broadly circular, divided into two pieces, situated above and anterior to umbones, perhaps actually only a dorsal extension of the callum. Metaplax and hypoplax present. Concentric ridges conspicuously narrow. Posterior slope covered by periostracal flaps, often not preserved in fossil specimens. Umbonal reflection may form funnel-shaped pit at anterior end. Anterior margin notched with sharp V-shaped indentation. Callum complete except for small ellipsoidal gape. Radial internal ridge (not the umbonal-ventral ridge) broad, follows just dorsally of external disc-posterior slope division.

Opertochasma differs from similar genera by its periostracal flaps, divided "meso-

plax," double radial division of the shell, and the broad internal ridge which parallels the external division of disc and posterior slope.
TYPE SPECIES.— *Opertochasma venustum* Stephenson, by original designation, Stephenson (1952:139).
TAXA INCLUDED.— The following nominal taxa belong to the genus: *Martesia clausa* Gabb, 1864, *Parapholas mersa* Stoliczka, 1870, *Turnus sphenoideus* White, 1876, *O. venustum* Stephenson, 1952, *O. subconicum* Stephenson, 1952, and *Martesia turnerae* Hickman, 1969.
DISCUSSION.— Except for *Martesia turnerae* from the Oligocene all of the nominal species assigned to *Opertochasma* are known only from the Cretaceous. There is, however, a single poorly preserved specimen, possibly assignable to *Opertochasma*, known from the Eocene of the southern Simi Valley in Ventura Co. (UCMP loc. 3776) (Nelson, 1925: facing 402; as "*Martesia* (?) species"). The relationships of these species to one another is unknown, though all are wood borers.

The original description of *Opertochasma* (Stephenson, 1952:139) suggested the absence of a hypoplax, the lack of which has subsequently been used by Turner (1969:715) to partially characterize the genus. Examination of the types and paratypes of Stephenson's two nominal species, *O. venustum* and *O. subconicum*, reveal that both species have both a metaplax, and a hypoplax, as do *Martesia turnerae*, *Turnus sphenoideus*, and *Martesia clausa*.

Opertochasma turnerae (Hickman, 1969)
Figures 71-72

Martesia turnerae Hickman, 1969: 68, 13, 16, 66, pl. 8, fig. 10-11, 13-14, 16.

DIAGNOSIS.— Shell small, less than 1 cm in length. Posterior slope covered with periostracal plates, separated from disc by slight angular change, present internally as broad ridge. Shell divided by two radial sulci in anterior slope-disc region, manifested internally as double or bifurcate ridge. Anterior slope very finely sculptured. Narrow ellipsoidal gape present between halves of callum. Metaplax and hypoplax present. "Mesoplax" divided longitudinally, quadrate to circular, situated above and anterior to umbones, perhaps actually only a dorsal extension of the callum. Inhabits wood.
ORIGINAL DESCRIPTION.— Shell more or less pear-shaped and small, the largest specimen reaching 9 mm; twice as long as high; callum present in adults, unsculptured; umbones prominent and recurved, forming funnel-shaped pits anteriorly; metaplax and hypoplax thin and elongate, undivided, pointed anteriorly and bluntly rounded posteriorly; protoplax lacking; mesoplax unusually small and subrectangular, divided longitudinally into two parts by median groove, notched posteriorly, somewhat pointed anteriorly; valves divided into two distinct areas by moderately incised umbonal-ventral sulcus; surface without raised concentric ribs, covered with extremely fine concentric lines of growth, over 100 counted on holotype; sculpture slightly denticulate on anterior portion of shell; shell interior not exposed. Dimensions of holotype: length 8.5 mm, altitude 4.5 mm, convexity 4.5 mm.
HOLOTYPE.— Of *Martesia turnerae* Hickman, UO 27314. PARATYPES: UO 27315-27319, 27732-27733; (=47 specimens). Roadcuts along Interestate 5, in NW ¼ sec. 3, T. 18 S., R. 3 W., WBM, Eugene quadrangle, Lane Co., Oregon, UO loc. 2553. Oligocene, Eugene Formation.
GEOLOGIC RECORD.— Oligocene.

Oligocene: Eugene Formation, at the type locality, UO loc. 2553 (Hickman, 1969:69).
DISCUSSION.— This is the only positive known occurrence of *Opertochasma* from strata younger than Cretaceous. *Opertochasma* is a wood boring genus, and the type lot of 48 specimens were all contained in a single piece of fossilized wood (from UO loc. 2553).

Genus *Parapholas* Conrad, 1848

Parapholas Conrad, 1848: 121. Turner, 1955: 123.

DEFINITION.— Shell moderate to large in size, reaching 15 cm in length, beaked and gaping anteriorly in young stage, closed by a complete callum in the adult. Shells closed, broadly rounded to acuminate posteriorly. Valves divided into three distinct regions in living specimens, though not readily apparent on fossils. Posterior slope covered by series of regularly spaced periostracal plates, separated from disc by a slight groove (in very young shells) or ridge extending from umbones to posterior ventral extremity. Posterior dorsal margin reflected upon itself to form an elongate enclosure. Mesoplax, metaplax, and hypoplax present. Posterior end of burrow filled with chimney of cemented sediment.

Parapholas differs from other Martesinae in having the valves divided into three distinct areas, and in having periostracal flaps on the posterior slope. There are three accessory plates, and the dorsal margin posterior to the umbo is folded upon itself to form an elongate enclosure. *Aspidopholas* differs by having a bare posterior slope. *Martesia s.l.*, and *Lignopholas* have a funnel shaped pit under the umbonal reflection, and *Opertochasma* has a double radial division of the shell and a small ellipsoidal opening between the opposing halves of the callum.

TYPE SPECIES.— *Pholas californica* Conrad, by original monotypy.

TAXA INCLUDED.— *Parapholas* is not divided subgenerically. The genus occurs worldwide, and is represented in the eastern Pacific by *P. californica* (Conrad) in temperate waters of California, and by *P. calva* (Sowerby, 1834) and *P. acuminata* (Sowerby, 1834) in tropical and semitropical waters of the Panamic Province.

DISCUSSION.— The geologic range of *Parapholas* is often cited as Cretaceous to Recent (Oldroyd, 1924:210; Turner, 1969: 715). Records of *Parapholas* in the Cretaceous (White, 1879; Stanton, 1893; and Schuchert, 1905) are referable to *Opertochasma* Stephenson. *Parapholas kneiskerni*, described by Whitfield (1885:241, pl. 30, fig. 22-24), from the Eocene Greensand marls of Shark River, New Jersey, is an unidentifiable internal mold probably not that of a *Parapholas* (R. D. Turner, pers, comm.). The oldest fossil occurrence of *Parapholas* in western North America is from the Pliocene, and in Japan, from the Miocene, or possibly Oligocene.

Besides *P. californica*, the only other known fossil *Parapholas* from western North America is one poorly preserved specimen (see Fig. 93) collected from near La Purisima, Baja California, Mexico (USGS loc. 9330). It resembles both *P. calva* and *P. acuminata* in size and shape, but cannot be specifically identified.

Parapholas californica (Conrad, 1837)
Figures 73-75

P. [*holas*] *Californica* Conrad, 1837: 236, pl. 18, fig. 5-6.
Pholas Janellii Deshayes, 1839: 557.
Pholas californica: Conrad, 1848: 121.
Parapholas californica: Cooper, 1888: 257, in part, ? not fossil. Bowers, 1890: 407, 408. Bruff, 1946: 232. Fitch, 1953: 96, fig. 62. Turner, 1955: 124, pl. 73-77. Kanakoff and Emerson, 1959: 23. Valentine, 1960a: 163. Valentine, 1961: 364. Vedder and Norris, 1963: 46, 50, in part (*P. californica*, in part *Zirfaea pilsbryi* and *Chaceia ovoidea*). McLean, 1969: 92, fig. 53.6. Wright, 1972: 691.
not? *Parapholas californica:* Arnold and Hannibal, 1913: 590. Oldroyd and Grant, 1931: 92. (?=*Penitella turnerae*).
not? *Parapholas californica* Hinds [*sic*]: Howe, 1922: facing 92 (?=*Penitella turnerae*).
Pholadidea (*Parapholas*) *californica:* Grant and Gale, 1931: 435, in part (*Parapholas californica* [Recent], in part *Penitella turnerae* [fossil occurrences]).
Pholadidea penita: Valentine, 1957: 297, in part (*Penitella penita*, in part *Parapholas californica*). Valentine and Meade, 1961: 10, in part (*Penitella* sp. cf. *P. penita*, *Parapholas californica* and *Nettastomella rostrata*).
not? *Pholadidea californica:* Oldroyd and Grant, 1931: 91. Weaver, 1942 [1943]: 265, 639. Weaver, 1945: 56. (?=*Penitella turnerae*).
Pholas sp. *indet.*: Glen, 1959: 177.
Pholadidea cf. *P. penita:* Valentine, 1961: 389, in part (*Penitella turnerae* and *Parapholas californica*).

DIAGNOSIS.— Shell large, divided into three regions. Concentric ridges on anterior slope closely spaced. Umbonal reflection reflected over, but not appressed to, anterior

slope. Dorsal margin posterior to umbo reflected upon itself to form an elongate enclosure. Mesoplax divided longitudinally, not readily distinguishable from umbonal reflection and dorsal extension of callum, to which it is often fused. Metaplax pointed posteriorly, blunt, abutting mesoplax anteriorly. Hypoplax broadly rounded posteriorly, pointed anteriorly.

DESCRIPTION.— Shell solid in structure, pear-shaped, divided into three well defined regions, reaching about 15 cm in length, and just over 7 cm in height. Immature specimens long for height (see Turner, 1955: pl. 76), prominently beaked, widely gaping anteriorly. Anterior slope sculptured with very close-set, upturned, undulate, concentric ridges. Umbonal-ventral sulcus prominent. Disc sculptured only by pronounced growth lines. Disc separated from posterior slope in very young specimens by a thin furrow near the umbo, and in subsequent life, by an angular change from disc to posterior slope. Posterior slope sculptured with prominent growth lines representing the regular attachment of rounded and overlapping periostracal plates found on living specimens. These are attached to an aragonitic layer which deteriorates readily on fossil specimens, thus disguising the tripartite division of the valve.

Umbonal reflection simple, reflected back over the anterior-dorsal margin, but not appressed to it. Callum complete, heavy, slightly ribbed by forward extensions of the radial pattern of the anterior slope, extends dorsally between the beaks, but only over the anterior half of the umbonal reflection.

Mesoplax broadly oval, divided longitudinally into two pieces, covers posterior half of umbonal reflection, not readily distinguishable from dorsal extension of callum, from which it is separated by a suture. In older specimens this suture line becomes fused. Juvenile mesoplax small, thin, more or less U-shaped, enlarged and produced anteriorly in adult, when dorsal portion is added (Turner, 1955:125).

Dorsal margin posterior to umbo reflected back and appressed to valve, extending one half the distance to the posterior extremity. Presumably at, or near, cessation of active boring, a dorsal portion is added, forming an enclosure, usually widest at its central part, upon which the metaplax will lie. The reflections do not extend to the line of commissure, but leave a narrow dorsal gape.

Metaplax long, narrow, covers gape left between dorsal reflections, butts against posterior end of mesoplax, truncate and bent sharply down anteriorly, tapered to narrow point posteriorly. Hypoplax pointed anteriorly, widening posteriorly to broadly rounded extremity, covers narrow ventral gape.

Posterior adductor muscle scar narrow, elongate, situated near the posterior-dorsal margin. Ventral muscle scar sausage-shaped, situated on ventral margin and superimposed on umbonal-ventral ridge. Umbonal-ventral ridge often prominent, condyle present at ventral extremity in young specimens. Pallial sinus nearly as broad as shell is high, extends anteriorly about one third length of shell, nearly intersects umbonal-ventral ridge. Apophyses heavy, strong, broad, spoon-shaped, truncated ventrally, extend anteriorly away from the umbonal-ventral ridge.

Posterior slope covered by large semicircular, and overlapping periostracal flaps. On large specimens they may be spaced at regular 2 to 3 mm intervals, though their point of juncture with the valve are only evident as pronounced, barely curved, "growth" lines, and not indicative of the shape of the flaps. Siphons capable of complete retraction within shell. Foot in young specimens more or less ellipitical in outline, rounded anteriorly, pointed posteriorly and truncate, atrophied in the adult (Turner, 1955:127).

"SYNTYPE?".— Of *Pholas californica* Conrad, BM(NH) 61.5.21.157 (Keen, 1966:171). "Sta. Diego and Sta. Barbara in soft rocks" (Conrad, 1837:237). Carpenter (1857:194), however, suggested Sta. Barbara for the type locality after examining the Nuttall collection. Recent.

TYPES.— Of *Pholas janellii* Deshayes, are not known to still exist, though they may be

in the British Museum (Natural History) (Turner, 1955:128). The type locality is the shores of California.

DISTRIBUTION.— Recent; Bodega Bay, Sonoma County, California (38° 18' N. lat.; Turner, 1955:128) south to Punta Pequeña, Baja California, Mexico (26° 14' N. lat.; LACMNH 71-181).

GEOLOGIC RECORD.— Pliocene to Recent.

Pliocene: Merced Formation, Capitola Beach, LACMNH loc. 314. "Merced" Formation, Moss Beach, UCMP loc. B-4793 (Glen, 1959:177, as *Pholas* sp. *indet.*).

Pleistocene: Near mouth of Tajiguas Creek, near Gaviota, UCLA loc. 3597 (Valentine, 1961:389; as *Pholadidea* cf. *P. penita*, in part). Isla Vista, near Santa Barbara (Wright, 1972:691), LACMNH loc. 2694. Terrace seven, Palos Verdes Hills, LACMNH loc. 1307. Gaffey Street Bridge, San Pedro, USGS [no locality number]. San Joaquin Bay [?=Newport Bay] (Bowers, 1890:407, 408). Palos Verdes Sand, on east bluff above Upper Newport Bay, LACMNH loc. 66-2 (Kanakoff and Emerson, 1959:23), on west bluff of Upper Newport Bay, UCMP loc. A-3101, and in north bluff of Newport Bay proper, opposite Lido Isle, UCMP loc. A-3132 (both Bruff, 1946:232). San Nicolas Island, east of hill 818, USGS loc. 21655, and at east end of island, USGS loc. 21664 (both Vedder and Norris, 1963:46, in part). San Clemente, UCLA loc. 2774 (Valentine, 1961:364). Torrey Pines Beach State Park, UCLA loc. 2410 (Valentine, 1960a:163; as UCLA loc. 3457), CAS loc. 102. On west side of Point Loma, UCLA loc. 3605 (Valentine and Meade, 1961:10, as *Pholadidea penita*, in part), SDSNH loc. 2419. In Baja California, 4½ miles south of Rio Morro, UCLA loc. 3569 (Valentine, 1957:297; as *Pholadidea penita*), and at Campo del Arroyo, Cedros Island, SDSNH loc. 2630.

DISCUSSION.— Fossil specimens of *Parapholas californica* can be identified by their distinctive anterior sculpture, reflected posterior-dorsal margin, and by the dorsal extension of the callum which extends only half the distance to the umbo.

Although this species is quite common in the living fauna of California and northern Baja California, it is not common in the fossil record, even though it inhabits the same substrates as does *Penitella penita*. It lives in clay, shale, or sandstone (all in various stages of induration), usually on the open coast, and may burrow 20 cm or more in the substrate (Fitch, 1953:96).

Pliocene occurrences of *P. californica* are rare. The specimens upon which the record of Arnold and Hannibal (1913:590) is based have not been found, although one specimen used by Howe (1922: facing 92) is *Penitella turnerae*. There are no other species with which *P. californica* may be confused. However, it is probable that Arnold and Hannibal had large bulbous and poorly preserved *Penitella turnerae* which are quite common in the Empire Formation of the Coos Bay region of Oregon. Both *P. turnerae* and *P. californica* are similarly shaped, and specimens of *Parapholas* from this area have never been figured, nor are they present in any of the numerous collections examined.

The specimen cited by Glen (1959:177) as *Pholas* sp. *indet.* from the Pliocene "Merced" Formation at Moss Beach, San Mateo Co., is poorly preserved, but the distinctive anterior-dorsal margin serves to clarify its affinities, although it is not evident that the shell is divided into three regions.

Pleistocene occurrences of *P. californica* are surprisingly few in number. Only one specimen has ever been collected *in situ* (from the late Pleistocene Palos Verdes Sand of Upper Newport Bay, UCMP loc. A-3132 [see Fig. 74]). The other known fossil specimens are from detrital deposits and are either worn or fragmentary.

Parapholas californica is most closely related to *P. minoensis*, described by Itoigawa (1960:273, pl. 3, fig. 1) from the middle Miocene Shukunohora Sandstone member of the Oidawara Formation, from central Japan. *Parapholas acuminata* (Sowerby) and *P. calva* (Sowerby) from tropical west American waters are smaller than *P. californica*, and each have a large mesoplax which envelops the entire anterior dorsal region of the shell.

Subfamily JOUANNETIINAE Tryon, 1862

DEFINITION.— Shell pholadiform, beaked, and widely gaping anteriorly in young stage. Gape partially or completely closed by a callum in adult. In *Nettastomella* the callum is a peripheral band of calcareous material with the large central region being periostracal; in *Pholadopsis* and *Jouannetia* it is entirely calcareous and very large. Anterior adductor muscle housed by a dorsal extension of the callum. Accessory plates lacking except in *Pholadopsis* which possesses a mesoplax. The siphonoplax may be paired, or present only on the right valve. Shells divided into two distinct areas by an umbonal-ventral sulcus. Apophyses lacking. Foot well developed in the young stage, atrophied in the adult. Animal capable of complete retraction within the shell.
TYPE GENUS.— *Jouannetia* Des Moulins, 1828.
TAXA INCLUDED.— The subfamily includes *Nettastomella*, *Pholadopsis*, and *Jouannetia*. All three are found in, though not restricted to, the eastern Pacific. They occur in both modern and fossiliferous sediments. A fourth genus, *Scyphomya* Dall, 1898, may be of questionable validity (R.D. Turner, pers. comm.).

Genus *Nettastomella* Carpenter, 1865

Netastoma Carpenter, 1864: 637. Vokes, 1956: 768.
Nettastomella Carpenter, 1865: 202. Turner, 1955: 141. Turner, 1962: 291.

DEFINITION.— Shell small, fragile, light in structure. Bilaterally symmetrical in young stage, widely gaping anteriorly, closed posteriorly, adult shell equivalve or slightly inequivalve. Callum partial, sculptured with growth lines or thin vertical lamellae, produced equally on both valves as peripheral band on anterior margin, or much wider on left valve. Periostracum encloses portion of adult pedal gape not closed by callum. Valves constricted considerably at umbonal-ventral sulcus. Anterior slope triangular in outline, sculptured by imbricate, concentric ridges. Disc and posterior slope sculptured with concentric ridges and (or) growth lines. Umbonal reflection free anterior to umbo, which it just touches. Siphonoplax calcareous, present on both valves or only on right, short or long, straight or divergent at base. Accessory plates and apophyses lacking. Chrondrophore small, present on left valve.

Nettastomella differs from the larger *Pholadopsis*, to which it is most closely related, by the absence of both a mesoplax, and a very large, unequal callum. In addition, the siphonoplax of the right valve of *Pholadopsis* is serrated on its posterior margin.
TYPE SPECIES.— "*Nettastomella darwinii*, Sby." of Carpenter, 1865 (= *Nettastomella rostrata* [Valenciennes, 1846], not *Pholas darwinii* Sowerby, 1849), by original monotype (see discussion in Turner, 1955: 141).
TAXA INCLUDED.— The genus is not divided subgenerically. There are three known living species; *N. darwinii* (Sowerby, 1849) from southern South America, *N. rostrata* (Valenciennes) from the northern eastern Pacific, and *N. japonica* (Yokoyama) from the northern Pacific. The last two are also known as fossils.
DISCUSSION.— The genus *Netastoma* was described by Carpenter in 1864. Because the procedure at that time dictated his original name a homonym of *Nettastoma* Rafinesque, 1810, a genus of fish, he proposed the new name *Nettastomella* Carpenter, 1865, which has been in constant use since. The latter name is here used for the sake of uniformity with existing literature.

Nettastomella is most closely related to *Pholadopsis* and the juvenile stages are quite similar, including the characteristic umbonal reflection. Although the two genera are morphologically similar, they differ in their geographic distribution. *Pholadopsis* is known only from tropical and semitropical areas, while *Nettastomella* inhabits more temperate and boreal waters. The ranges of the two genera meet, with little overlap, in the vicinity of Cedros Island, Baja California, Mexico. *Nettastomella japonica* (Yokoyama) of the northern Pacific, morphologically resembles both genera by possessing features of each in the adult stage.

Nettastomella rostrata (Valenciennes, 1846)
Figures 76-78

Pholas rostrata Valenciennes, *in* du Petit-Thouars, 1846: pl. 24, fig. 4, 4a [no description]. Lamy, 1921: 182.
Nettastomella darwinii: Carpenter, 1865: 202.
Nettastomella rostrata: Dall, 1916a: 43. Turner, 1955: 143, pl. 87. Turner, 1962: 298, pl. 48 (fig. 1), 49-50. Evans, 1967b: 175, in part, pl. 17, fig. 2 (*N. rostrata* [Recent], not fossil reference to Adegoke, 1966). Addicott and Galehouse, 1973: 510, fig. 3e, j.
Pholadidea rostrata: Hertlein and Grant, 1944: 68. Chace, 1966: 170.
Pholadidea penita: Valentine and Meade, 1961: 10, in part (*Penitella* sp. cf. *P. penita*, *Parapholas californica*, and *Nettastomella rostrata*).
Netastoma rostrata: McLean, 1969: 92, fig. 53.7.

DIAGNOSIS.— Shell small, equivalve. Callum partial, exists as peripheral band along anterior margin. Siphonoplax long, narrow, paired, reflected outward at base. Umbonal reflection free, not appressed to anterior slope.

DESCRIPTION.— Shell reaching about 2 cm in length (excluding the siphonoplax) and 1 cm in height, equivalve in both juvenile and adult stages. Shell beaked, widely gaping anteriorly in young stage, closed posteriorly. Anterior slope sculptured with moderately spaced, thin, high, undulate, concentric ridges. Shell strongly constricted at umbonal-ventral sulcus. Posterior slope and disc sculptured with thin, high, concentric ridges which are continuations of ridges of anterior slope. Umbones located near anterior third of shell. Umbonal reflections narrow, barely touching at umbo, free anterior to point of contact. Callum partial, equal on both valves, exists as narrow peripheral band along anterior margin, fragile, sculptured with thin, high, undulate ruffles paralleling anterior margin. Central portion of anterior gape not enclosed by callum is periostracal. Calcareous dorsal extension of callum only partially covers anterior-dorsal gape. Siphonoplax calcareous, length and width dependent on size of burrow (from which it takes its shape), reflected outward at its base.

Posterior adductor muscle scar elongate-oval in outline, positioned near posterior-dorsal margin. Pallial sinus extends anteriorly to umbonal-ventral ridge. Siphons capable of complete retraction within shell. Foot large, rounded and truncate in young specimens, atrophied in adult. Soft part morphology given in Turner (1962: 303, pl. 51).

HOLOTYPE.— Of *Pholas rostrata* Valenciennes, in the Museum National d'Histoire Naturelle in Paris (Lamy, 1921: 182). Monterey, California is given on the original label, although not published by Valenciennes (Lamy, 1921: 182). Recent.

DISTRIBUTION.— Recent; Puget Sound (ca. 48° N. lat.; Dall, 1916a: 43) and vicinity, to San Cristobal Bay, Baja California, Mexico (27° 17' 35" N. lat.; LACMNH 71-173).

GEOLOGIC RECORD.— Pliocene to Recent.

~~**Pliocene**: San Joaquin Formation, Kettleman Hills, UCMP loc. B-7727~~.

Pliocene: San Joaquin Formation, Kettleman Hills, UCMP loc. B-7727. Paso Robles Formation, east of Atascadero USGS-M loc. 4621 (Addicott and Galehouse, 1973: 510).

Pleistocene: Lomita Marl, in San Pedro at northeast corner of Coralmount Drive and Park Western Drive, LACMNH loc. 435. San Pedro Sand, in San Pedro, at high school at 15th and Leland Streets, SDSNH loc. 2138 [=L-2138] (Chace, 1966: 170), "Chiton Bed" [of Chace and Chace, 1919] on Point Firmin, SDSNH loc. 0625, and corner of 8th and Palos Verdes Streets, LACMNH loc. 226. Palos Verdes Sand, on east bluff above Upper Newport Bay, LACMNH loc. 487, SDSC locs. 533 and 537. West side of Point Loma, UCLA loc. 3605 (Valentine and Meade, 1961: 10, as *Pholadidea penita*, in part). Spanish Bight, San Diego (Hertlein and Grant, 1944: 68).

DISCUSSION.— Though known to occur as deep as 100 m (Turner, 1955: 145), *N. rostrata* is commonly found in the intertidal zone, often associated with species of *Penitella* and other rock boring bivalves. The burrows are usually short and not often straight.

The occurrence of *N. rostrata* in the fossil record is rare, having been reported three times (from San Diego by Hertlein and Grant, 1944: 68, from San Pedro by Chace, 1966: 170, and from near Atascadero by

Addicott and Galehouse, 1973: 510). The species occurs, however, most abundantly in the late Pleistocene Palos Verdes Sand on the east bluff above Upper Newport Bay in California. The molluscan fauna of this formation includes seven species of pholadids, and specimens of *N. rostrata* have been found in association with numerous *Chaceia ovoidea*, and lesser numbers of *Penitella fitchi*, *Barnea subtruncata*, and *P. penita*. In addition to Pleistocene records, *N. rostrata* occurs in the Pliocene Paso Robles Formation of San Luis Obispo Co., and the Kettleman Hills of central California. The single specimen from the Kettleman Hills is an internal-external mold-pair from which all shell material has been leached away. It was associated with several specimens of an *Adula*.

Recently, Evans (1967b), in a reinterpretation of silicified mud filled pholadid burrows described by Adegoke (1966) from the Miocene Pismo Formation of San Luis Obispo Co., California, attributed one specimen, an unusually bulbous burrow (UCMP 31410), to *N. rostrata* on the basis of the similarity in shape of the burrow with those of that species. The specimen is not nearly so full-bottomed as it seems, and the larger size is caused by a conchoidal fracture in the cherty matrix surrounding and paralleling the surface of the burrow. This feature does not show in Adegoke's figure (1966: pl. 21, fig. 8) and is difficult to discern even on the specimen itself. The burrows were made by an unidentified species of *Penitella* and are discussed further under *Chaceia*.

The fossil distribution of *N. rostrata* is considerably less extensive than that of Recent specimens, and it should be expected to occur both north and south of known fossil occurrences.

Nettastomella japonica (Yokoyama, 1920)
Figures 79-81, 85

Jouannetia japonica Yokoyama, 1920: 105, pl. 7, fig. 1a-c. Hanzawa, Asano, and Takai, 1961: 247.
N.[ettostomella] japonica: Habe, 1952: 244. Taki and Oyama, 1954: 50, pl. 8, fig. 1a-c.
Nettastomella japonica: Habe, 1955: 24, pl. 4 (fig. 9), 7 (fig. 3). Taki and Habe, 1955: 14, pl. 2, fig. 3-4. Turner, 1962: 292, pl. 47, 48 (fig. 2), 50.
Netastomella [sic] japonica: Hanna, 1966: 71, 78, fig. 82.

DIAGNOSIS.— Slightly inequivalve, callum on left valve larger than on right, only partial. Siphonoplax on right valve longer than on left, not serrated posteriorly or reflected outward at base.

ORIGINAL DESCRIPTION.— Shell small, thin, fragile, globose, widely gaping in front, with the anterior end bluntly pointed and smooth, and the posterior end rounded. Surface divided into two parts by a deep groove running from beak [=umbo] to antero-ventral angle, whence the margin which is crenate, ascends obliquely upward anteriorly. The sculpture consists of distant concentric laminae which in the anterior portion are wavy, the crests of the waves forming about eight radiating ribs whose interspaces are unequal, being broader in the anterior portion. Accessory plates not preserved.

SUPPLEMENTARY DESCRIPTION.— Shell reaching about 2.5 cm in length, widely gaping anteriorly, closed posteriorly, equivalve in juvenile, inequivalve in adult. Callum greater near ventral margin, larger on left valve than on right. Siphonoplax of right valve longer than that of left, not reflected outward at base. Callum of right valve greatly reduced, as is siphonoplax of left valve.

Anterior slope sculptured with widely spaced, high, weakly undulate concentric ridges, supplemented by radial pattern formed by alignment of undulations or projections on ridges. Umbonal-ventral restriction prominent. Posterior slope ornamented with concentric growth lines and occasionally by thin low, plain or ruffled, ridges.

Umbonal reflection narrow, equally produced on both valves, barely touching above umbones, but free anterior to them. Dorsal extension of callum extends anterior to and around beaks, greater on left valve, only partially covers anterior-dorsal gape.

Posterior muscle scar deeply impressed, situated close to the posterior-dorsal margin.

Ventral muscle scar only lightly impressed, situated at base of umbonal-ventral ridge (Turner, 1962: 294). Pallial sinus not marked. Apophyses and accessory plates absent. Foot large, rounded, truncate in young specimens, atrophhied in adult (Turner, 1962: 294).

LECTOTYPE.— Of *Jouannetia japonica* Yokoyama, in the Geological Institute, University of Tokyo, no. CM20333, here designated. This is the specimen figured by Yokoyama (1920: pl. 7, fig. 1a-c). PARALECTOTYPES: In the Geological Institute, no. CM20334 (3 specimens [?valves]). Otsu on the Miura Peninsula, Ishikawa Prefecture, Honshu, Japan. Pliocene [= middle Pleistocene], Lower Musashimo Formation, Yokosuka Zone (zone 5).

DISTRIBUTION.— Recent; From Noto Peninsula, on the north coast of Honshu (ca. 37.5° N. lat.; Taki and Habe, 1955: 14), north, perhaps around the Aleutian Island Arc, and on the west coast of Canada to the Strait of Juan de Fuca and vicinity (48° 27' N. lat.; Turner, 1962: 298).

GEOLOGIC RECORD.— Pleistocene to Recent.

Pleistocene: Lower Musashimo Formation, Yokosuka zone, at Otsu on the Miura Peninsula, Honshu, Japan (type locality; Yokoyama, 1920: 106).

DISCUSSION.— This is a Japanese species which has only recently been recognized living on the west coast of British Columbia, Canada (Turner, 1962: 289). Described from the middle Pleistocene Otsu Shell Bed (J. Itoigawa, *in litt.*), on the island of Honshu, Japan, it has been reported living off the coasts of Honshu and Hokkaido. Though little is known of the ecology of this species, specimens have been recorded from 305 m off the Noto Peninsula (Honshu) and 117 m off Sado Island (both Taki and Habe, 1955: 14). Specimens taken at Masset Inlet, British Columbia were collected alive in soft friable sandstone at the low tide line (Turner, 1962: 295). Although the species is known from only a few Recent localities in Japan and British Columbia, it may range northward and around the Aleutian Island Arc.

Nettastomella japonica is interesting because it possesses the inequivalve condition previously considered peculiar to *Pholadopsis* and *Jouannetia*. The callum on the left valve is enlarged, though not to the extent that it is in the other two genera. Furthermore, the siphonoplax on the right valve is longer than that of the left, and is not reflected outward at the base as in other species of *Nettastomella*.

Aside from the type specimens from the middle Pleistocene Otsu Shell Bed, no other fossil specimens of *N. japonica* are known from any Japanese Tertiary or Quaternary deposits. It certainly has not been recorded as fossil from the eastern Pacific, though this may be due to the scarcity of appropriate late Cenozoic deposits along the Canadian and Alaskan coasts.

In recent years there has been some confusion about the types of *Jouannetia japonica* Yokoyama, and the following information was kindly offered by Dr. Junji Itoigawa, Nagoya University, who inquired about the type material. According to Dr. Kiyotaka Chinzei (Itoigawa, *in litt.*) of the Geological Institute, University of Tokyo, Yokoyama described *J. japonica* from four specimens [?valves], one of which he figured. Yokoyama did not designate a type or assign catalogue numbers to any of his specimens, nor did he indicate how many specimens were in the type lot. The specimens, now in the Geological Institute, are registered as no. CM20333 (figured specimen) and no. CM20334 (3 remaining specimens [?valves]). The "Holotype" designation of Taki annd Oyama (1954: 50), opposite a reproduction of Yokoyama's original plate, and the "Syntype" listing in Hanzawa, Asano, and Takai (1961: 247) are considered invalid. The figured specimen is here designated the lectotype, and the three remaining specimens considered paralectotypes.

Genus *Pholadopsis* Conrad, 1849

Pholadopsis Conrad, 1849: 156. Turner, 1955: 136.
Triomphalia Sowerby [II], 1849: 500.

DEFINITION.— Shell small to moderate in size, globose or pear-shaped, juvenile beaked anteriorly, rounded and closed posteriorly, adult closed anteriorly by callum, gaping posteriorly. Umbonal-ventral sulcus prominent. Callum large, globose, that of left valve larger than that of right valve. Siphonoplax of right valve serrated posteriorly, lacking on left valve, replaced by ventral and posterior growth of callum material. Mesoplax only accessory plate, small, fused to dorsal extension of callum in adult. Umbonal reflection high and free, not appressed to anterior slope. Chondrophore present, apophyses lacking.

Pholadopsis differs from other Jouannetiinae by possessing a mesoplax. The umbonal reflection of *Jouannetia* is appressed to the anterior slope. *Pholadopsis* differs from *Nettastomella* by its mesoplax, very large callum, gross inequivalve shape, and the serrated right siphonoplax.

TYPE SPECIES.— *Pholadopsis pectinata* Conrad, by original monotypy.

TAXA INCLUDED.— The known living representatives of *Pholadopsis* are: *P. quillingi* (Turner, 1955), from the western Atlantic and the Gulf of Mexico, *P. pectinata* Conrad from the tropical eastern Pacific, *P. globulosa* (Quoy and Gaimard, 1834) from the Indo-Pacific, and *P. vignoni* Fischer, 1862, from the eastern Atlantic of Africa.

DISCUSSION.— *Pholadopsis* has long been placed as a subgenus of *Jouannetia* des Moulins. Though both genera have a large bulbous callum, the juvenile shells are less similar, and *Pholadopsis* appears more closely related to *Nettastomella*. *Pholadopsis* also possesses a mesoplax which neither of the other two have. The inequivalve adult condition, distinctive of *Jouannetia* and *Pholadopsis*, is also present in *N. japonica* to a lesser degree, and should not be used as a generic character.

Pholadopsis pectinata Conrad, 1849
Figures 82-84, 86-90

P.[holadopsis] pectinata Conrad, 1849: 156.
Triomphalia pulcherrima Sowerby, 1849: 501, pl. 106, fig. 58-59.
Pholadidea ovoidea (Gould), short var.: Woodring, Stewart, and Richards, 1940 [1941]: facing 78, pl. 14, fig. 6.
Jouannetia (Triomphalia) pectinata: Hertlein and Strong, 1950: 248, pl. 2, fig. 6.
Jouannetia (Pholadopsis) pectinata: Turner, 1955: 137, pl. 83. Olsson, 1961: 451, pl. 80, fig. 3, 3a. Turner, 1962: pl. 53. Keen, 1971: 276, fig. 704.
Jouannetia pectinata: Keen, 1958: 216, fig. 549.

DIAGNOSIS.— Shell globose or pear-shaped. Callum very large, bulbous, irregularly sculptured, that of left valve much larger, overlapping that of right valve, fused to mesoplax. Umbonal reflection free anterior to umbo. Siphonoplax of right valve finely serrated posteriorly, greatly reduced on left valve.

DESCRIPTION.— Adult shell about 5 cm in length, 3 cm in height, inequivalve, globose, pear-shaped in outline. Juvenile shell equivalve, beaked, widely gaping anteriorly, closed posteriorly. Anterior slope sculptured by numerous wavy concentric ridges, and weak radial pattern formed by rows of undulations of these ridges. Umbonal-ventral sulcus prominent, posterior margin indefinite, especially on right valve. Disc and posterior slope sculptured with sharp, precise, growth striae which are continuations of concentric ridges of anterior slope.

Umbonal reflection narrow, high, and free, touches just anterior to umbo. Callum very large, globose, complete, that of right valve nearly typical, greatly enlarged on left valve and overlapping that of right. Callum extends prominently anteriorly and ventrally to beaks. Dorsal extension of callum not distinguishable from callum proper, that of left valve very much enlarged, covers anterior adductor muscle. Ventrally, callum of right valve stops at umbonal-ventral sulcus, on left valve additional material is added along ventral margin of the disc and posterior slope (Turner, 1955: 137). Siphonplax present only on right valve, finely serrated posteriorly, replaced on left valve by callum material, margin smooth.

Mesoplax only accessory plate, small, deltoidal, sculptured with concentric growth lines, fused to dorsal extension of callum in adult. Enlargement of callum displaces mesoplax at an angle to longitudinal axis of

shell (Turner, 1955: 137).

Umbonal-ventral ridge low, distinct. Chondrophore on left valve small, apophyses lacking. Posterior adductor muscle scar small, elongate-oval in outline, located internally high on posterior slope. Pallial sinus broad, extends only to umbonal-ventral ridge.

HOLOTYPE.— Of *Pholadopsis pectinata* Conrad, ANSP 51075. PARATYPE: ANSP 136743 (*ex* 51075). No specific locality is cited by Conrad (1849: 155), though the several species described by him were "from the coasts of Lower California and Peru." Hertlein and Strong (1950: 249) have subsequently restricted the type locality to the east coast of Lower [Baja] California. Recent.

HOLOTYPE.— Of *Triomphalia pulcherrima* Sowerby, in the British Museum (Natural History) (Turner, 1955: 138). West Columbia, in soft stone at low water, collected by Hugh Cuming. Recent.

DISTRIBUTION.— Recent; Off Cedros Island, Baja California, Mexico (28° 05' N. lat.; Turner, 1955: 138), into the Gulf of California, and south to Peru (Olsson, 1961: 451).

GEOLOGIC RECORD.— Pliocene, Pleistocene?, Recent.

Pliocene: San Joaquin Formation, in the Kettleman Hills, UCMP loc. B-7727 (cf.), on the North Dome, at La Lomica, USGS loc. 12365, and Arroyo Conchoso, USGS loc. 12374 (both Woodring, Stewart, and Richards, 1940 [1941]: facing 78).

Pleistocene or Recent: Southwest of San Carlos Bay, near Guaymas, Sonora, Mexico, MCZ 228109.

DISCUSSION.— *Pholadopsis pectinata* is a rare species and living examples are uncommon even in large collections of Recent mollusks. Although Hertlein and Strong (1950) restricted the type locality of *P. pectinata* to the east coast of Lower California, they did not include Baja California in their distribution for the species. If the specimens from San Carlos Bay are Recent, rather than Pleistocene, this would establish a known northern limit for the species in the Gulf of California.

The fossil record of *P. pectinata* almost does not exist. One lot of specimens (MCZ 228109) from a small peninsula directly southwest of San Carlos Bay, near Guaymas, Sonora, Mexico, can only tentatively be assigned an age older than Recent, since it is not known if the pholadids were really collected from land. High oxidation of the extrusive volcanic rock in which they were boring, and lack of any organic matter or marine life on the rocks suggest they are not Recent, but to assign a Pleistocene age to them would also be speculative.

The Pliocene record of *P. pectinata* is based on specimens cited by Woodring, Stewart, and Richards (1940 [1941]) as *Pholadidea ovoidea* (Gould), short var. The specimens have slightly thicker shells than some Recent specimens, but fall in the range of variation expected by different substrates. They were collected from two separate localities in the Pliocene San Joaquin Formation in the Kettleman Hills of California. Another specimen from the same general area is an internal mold of the anterior portion of a left valve, and is only tentatively referred to *P. pectinata*.

Subfamily XYLOPHAGAINAE Purchon, 1941

DEFINITION.— Shell beaked and gaping anteriorly throughout life. Beaks nearly rectangularly truncate, giving shells a teredo-like appearance. Valves rounded and closed posteriorly. Anterior slope sculptured with numerous rows of finely denticulate ridges as in the Teredinidae. Disc and posterior slope separated from anterior slope by umbonal-ventral sulcus, sculptured only by growth lines. Umbonal reflection narrow, simple, barely reflected. Only accessory plate a small divided mesoplax. Callum and apophyses absent. Umbonal-ventral ridge pronounced, usually possessing a ventral condyle. Posterior adductor muscle scar large, generally oval in outline, placed near the posterior-dorsal margin. The foot does not atrophy in the adult. The animal is usually capable of complete retraction within the shell. *Xyloredo* deposits a calcar-

eous lining in its burrow similar to that produced in the Teredinidae.

Xylophagainae differ from Teredinidae in that they possess an accessory plate while lacking apophyses and pallets.

TYPE GENUS.— *Xylophaga* Turton, 1822.

TAXA INCLUDED.— Only three genera are known in the Xylophagainae: *Xylophaga* Turton, 1822, *Xylophagella* Meek, 1864 [*in* Meek and Gabb], and *Xyloredo* Turner, 1972. Three Recent species of *Xylophaga* were recognized by Turner (1955; see also Knudsen, 1961: 203) in the eastern Pacific. They are: *X. globosa* Sowerby, 1835 (Panama to Chiloe Island, Chile), *X. mexicana* Bartsch, 1921 (California [33° 29' N.] to off Acapulco, Mexico [16° 47' N.]), and *X. washingtona* Bartsch, 1921 (Washinton [48° 31' N.] to California [33° 31' N.]). Subsequently, Knudsen (1961) described six new species, all from deep water in the Gulf of Panama. They are: *X. aurita*, *X. concava*, *X. duplicata*, *X. obtusata*, *X. panamensis*, and *X. turnerae*. In addition, one species of *Xyloredo*, *X. naceli*, was described from deep water off San Miguel Island, California by Turner (1972: 6).

DISCUSSION.— A description of the subfamily has been added for reference although no Xylophagainae have ever been found in Cenozoic rocks in western North America. *Xylophagella*, described from the Cretaceous of Idaho, is however known from Campanian strata in La Jolla, San Diego Co., California.

Good accounts of the taxonomy, variation, reproduction, and distribution of *Xylophaga* are given in Knudsen (1961). The Xylophagainae are essentially deeper water inhabitants and usually bore into wood or other plant debris, though they are known to occur in other substrates. Species of *Xylophaga* appear to have unusually restricted geographic ranges (Turner, 1966a: 444; Knudsen, 1961: 201) and only rarely occur in shallow water, and then only in temperate regions. (*Xylophaga washingtona* Bartsch is the only species from the eastern Pacific recorded from shallow depths.) The rarity of *Xylophaga s.l.* in shallow marine sediments (which predominate in the west American Cenozoic record) and similarity to teredinids in habitat, small size, and superficial morphology would probably disguise their true relationship even if found.

INCERTAE SEDIS

"*Zirphaea*" *plana* White, 1889
Figure 101

Zirphaea plana White, 1889: 15, pl. 4, fig. 22. Schuchert, 1905: 704.

Z.[*irfaea*] *plana:* Dall, 1898: 818, 820.

HOLOTYPE.— Of *Zirphaea plana* White, USNM 20129. Martinez, Contra Costa Co., California, collected by H. W. Turner. Cretaceous or Eocene, "Chico-Tejon series."

DISCUSSION.— White's (1889: 15) comments on the species are: "Among the fossils collected by Mr. H.W. Turner from the Chico-Tejon strata at Martinez, Contra Costa Co., is a single valve of a shell which seems to possess the essential characters of *Zirphaea*. The shell is small, irregularly suboval in marginal outline; the anterior portion inflated, larger than the posterior portion, from which it is separated by a well-defined depression that extends from near the beak to the base of each valve, and also by the abrupt inflation of the anterior portion; cardinal border of the anterior portion somewhat reflexed. The shell substance of the specimen is mostly exfoliated, but remains of narrow, concentric, raised striae are observable, which are separated by rather wide interspaces and which seem to have covered the whole surface. Length, 14 mm; height, 11 mm."

The actual age of the species is in doubt. Dall (1898: 818) referred it to the Eocene Tejon Formation, though Schuchert (1905: 704) considered it to belong to the Cretaceous Chico Formation.

The specimen somewhat resembles the genus *Pholadopsis*, but because of the poor preservation and greater antiquity, it seems best not to place it systematically at this time. It is not a *Zirfaea*. The species may be synonomous with "*Jouannetia*" sp. of Clark and Woodford (1927: 102; see Figs. 91-92) from the Eocene Meganos Formation.

"*Jouannetia*" sp. Clark and Woodford, 1927
Figures 91-92

Jouannetia sp. Clark and Woodford, 1927: 102, pl. 18, fig. 6. Keen and Bentson, 1944: 55.

HYPOTYPE.— Of *Jouannetia* sp. Clark and Woodford, UCMP 31340. Mt. Diablo quadrangle, on top of ridge at middle of north edge of SE ¼ sec. 20, T. 1 N., R. 2 E., MDBM, Contra Costa Co., California (UCMP loc. 3158). Lower Eocene, Meganos Formation [division D].

DISCUSSION.— Among the molluscan species reported from the Eocene Meganos Formation by Clark and Woodford (1927) was an indetermined pholadid tentatively assigned to the genus *Jouannetia* on the basis of its outline and sculpturing, though too poorly preserved to be named. The specimen (UCMP 31340) upon examination shows very little sculpture, is composed of indurated sand, and is either a cast or internal mold with no shell remaining. It is globose and pear-shaped, with a prominent constriction running from the umbones to the ventral margin. The species somewhat resembles the genus *Pholadopsis*, but the type of sculpture on the anterior slope (see Fig. 91) differs remarkedly from that genus, and so is not placed systematically. "*Zirphaea*" *plana* White (1889: 15; see Fig. 101) may be synonomous with "*Jouannetia*" sp. of Clark and Woodford.

"*Martesia* (?)" sp. Dickerson, 1914
Figure 99

Martesia (?), sp. Dickerson, 1914: 96, 140.

HYPOTYPE.— Of *Martesia* (?) sp. Dickerson, UCMP 10607. About one-fourth to one-half mile east and a little south of Lower Lake on Knoxville Road, Lake Co., California (UCMP loc. 784). Paleocene, Martinez Formation.

DISCUSSION.— Dickerson (1914: 140) described the species as: "Shell elongate with thin test; beaks [=umbones] anterior, incurved, approximate; posterior dorsal margin concave and undulating; anterior dorsal margin short, rounded; anterior end rounded; posterior end slightly flaring; ventral margin nearly straight. One beaded umbonal groove diverges from the beak [=umbo]. A posterior groove, which indicates the position of an internal rib, makes a very obtuse angle with the ventral margin. Tube unknown. Height, 13 mm; length unknown."

"*Martesia*(?) sp." was based on a unique specimen (Fig. 99), which does not closely resembly any known west American pholadid, though the family in the Paleogene is still inadequately known. The specimen is an internal mold with only little shell remaining, though not enough to make out any sculpture. A callum appears to be present. Posterior to the umbonal-ventral sulcus another groove runs from the posterior side of the umbo to the center edge of the posterior margin, vaguely suggesting the genus *Turnus* Gabb (see Fig. 98), though actually quite different. The posterior margin, from the umbonal-ventral sulcus to near the umbo, is flared outward slightly and fused to what may have been a calcareous tube, only remnants of which are preserved. This condition parallels that found in the Cretaceous to middle Miocene genus *Teredina* Lamarck, 1818 (see Turner, 1969: 717) in which a calcareous tube is fused simultaneously to both valves of the shell. The "tube" on this specimen appears to be fused separately to each valve (only one is present), or is divided dorsally and (?) ventrally. This division may only be an artifact however. Further description of this species must await better preserved material.

INCONCLUSIVE RECORDS

Below are records, listed chronologically by date of publication, of Pholadidae whose taxonomic position is not posible to determine at the present. Some are literature citations for specimens which could neither be found or recognized in the various collections examined, and some are only casual references to borings attributed to pholadids. Still others are from early

paleontologic literature and, generic concepts being broader than now, can not be positively identified without the aid of comparative material. Additional records of unidentifiable pholadids, here noted for the first time, are included in the Register of Localities.

Antisell (1856: 44, 45, 199) noted the presence of beds "pierced by pholadines" in the Santa Margarita Valley of California.

Blake (1857: 186, 187) reported finding rock "perforated in every direction by boring mollusks", Pholadidae "undisturbed in their self-excavated domicils" from San Pedro, and rock perforated by boring shells and by "*Pholas*" at Monterey.

Newberry (1857: 14, 15) reported "*Pholas*" on a twenty foot terrace on the south shore of San Pablo Bay, California.

Newberry (1861: 12) reported finding "stones bored by *Pholas*" on the road from San Pedro to Los Angeles and "in the ancient sea bottoms at San Pedro, San Luis Obispo, and the bay of San Pablo." Also cited (Newberry, 1861: 133) were: "Infusorial rock with *Pholas*, St. Luis Obispo," "Shale with Entomostraca and *Pholas*, Monterey," and "infusorial clays bored by *Pholas*" from a "raised sea bottom, Monterey" and from a place "eighty feet above sea, San Pedro."

Gabb (1869: 175, 233) recorded *Martesia clausa* Gabb "from the Martinez Group at Martinez, and from the Tejon Group at Martinez, ten miles west of Griswold's and Tejon." *Martesia clausa* Gabb, described from the Cretaceous Chico Group of California (Gabb, 1864: 145, pl. 22, fig. 115), belongs to the genus *Opertochasma*. Dall (1898: 820), however, followed Gabb in this range extension, though Anderson and Hanna (1925: 147) in their study of the type Tejon, could find no material or justification of this age assignment and thought it best to consider it erroneous. The possible poor preservation of Gabb's specimens, the whereabouts of which are unknown, may be responsible for Gabb's inability to separate his Eocene and Cretaceous specimens, and it is now impossible to determine what the Eocene specimens were in reference to.

Cooper (1888: 250) reported "*Martesia intercalata* Carpenter" from the Quaternary at Santa Barbara, California. Though Carpenter's species is considered to be *Penitella conradi* by Turner (1955: 75), what Cooper had must remain unknown until the specimen is recognized.

Bowers (1890: 407) reported finding, on the west side of San Joaquin Bay (=Newport Bay), "The soft underlying rock [of the terrace] contains vast quantities of *Pholas* in a vertical position. The stratum . . . is about a foot thick, and the cavities are filled with inspissated bitumen, leaving casts of the rock-boring shells." Some of these Bowers reported were of the chimney building *Parapholas californica*.

Arnold (1907: 423) reported "*Pholadidea* (?) species indeterminate" from the Pliocene Fernando Formation from the Santa Maria district of California. This is probably one of several species of *Penitella* found in this area.

Arnold and Anderson (1907: 59) also report "*Pholadidea* (?) sp. indet." from the same region. Two fragments in the U.S. National Museum may also be the same ones referred to by Arnold (1907: 423) above. They are from USGS loc. 4506, Pliocene Fernando Formation, Lompoc quadrange, Santa Barbara Co., and represent a species of *Penitella*.

Dickerson (1911: 175, 177) suggested "*Zirphaea* (?)" as being responsible for pholadid burrows in boulders in a basal conglomerate of the Eocene Tejon Formation north of Mount Diablo, and for borings in the Cretaceous Chico "Formation" along the Chico-Martinez contact south of Stewartville. The burrows are filled with material entirely different from the rock penetrated (Dickerson, 1911: 177), which suggests a rock-boring genus rather than the mud-boring *Zirfaea* (see section on Burrows in this paper).

Clark (1915: facing 408) reported "*Pholas*, sp. indt." from four localities (UCMP locs. 481, 482, 490, and 1485) near Tassajara, Contra Costa Co., from the Miocene San Pablo "Group." Since *Zirfaea dentata* was also identified from the same area, the specimens may be a *Penitella*, but

they could not be found in the collections of the University of California Museum of Paleontology.

Dickerson (1916: facing 372) reported "*Pholadidea*, sp." from four localities (UCMP locs. 143, 476, 709, and 1430) in the basal Tejon strata south of Mt. Diablo, Contra Costa Co. "*Pholadidea*, sp." was also reported (p. 446) from north of Mt. Diablo, and in the *Turbinolia* zone of the California Eocene. None of the specimens have been seen and no guess as to the proper systematic placement can be made.

Nomland (1917b: 303) reported "*Pholas* (?), sp." and "*Pholas* (?) borings" at the base of the mapped "Monterey Shale." The numerous borings are in a Mesozoic serpentine in the San Luis quad., near the north boundary of sec. 18, T. 29 S., R. 11 E., MDBM.

Gester (1917: 225) found shell "fragments, with Pholas borings" in the Etchegoin Formation at a depth of 928 feet, from Well #9 of the United Oil Co., west of Fellows, San Luis Obispo Co. (?).

Howe (1922: 89) quoted an earlier reference to Arnold and Hannibal (1913: 602) which probably refer to *Penitella turnerae*: "An angular unconformity marked by Pholas borings may be observed in a niche of the sea cliffs which form the type section of the Tunnel Point beds." He however believed the borings to be within the Oligocene beds, and not between them and the overlying Pliocene Empire Formation.

Berry (1922: 413, footnote) recorded a "*Pholad* sp." from the "coal mine" on the Pleistocene terrace on the west side of Point Loma, San Diego Co.

Clark and Arnold (1923: 156, pl. 16, fig. 2) cited a small pholad as *Zirfaea* sp. from the Oligocene Sooke Formation from west of Otter Point, Sooke, Vancouver Island, British Columbia. The small specimen appears similar to, and may represent, a *Zirfaea pilsbryi*. The specimen (SU 295, not UCMP 30065 as cited) is from SU loc. N.P. 129.

Nelson (1925: facing 402) reported "*Martesia* (?) species" from the Eocene "Martinez Marine Member of the Martinez Group" [see Keroher, *et al.*, 1966: 2404] on the south side of the Simi Valley (UCMP loc. 3776), Ventura Co., California. The single left valve is too poorly preserved to be identified, although it may be an *Opertochasma* rather than a *Martesia*.

Hanna (1926: 462) in his discussion of "*Barnea*" *costata* suggested either *Lithophaga* (Mytilidae) or *Pholadidea* for holes in coral from Alverson Canyon, Coyote Mountain, Imperial Formation (CAS loc. 701). All holes examined to date from this formation in both coral and oyster shell have had the characteristic shape of rock-boring mytilids (such as *Lithophaga*).

Santillán and Barrera (1930: 25) reported "*Pholadidea* sp." from the late Pliocene Cantil Costero Formation from between El Rosario and San Antonio del Mar on the northwest coast of Baja California, Mexico.

Weaver (1953: 58, 62) reported finding "Pholad borings at [the] contact with [the] Sobrante formation" on the east limb of the Pacheco syncline, and, also in the Sobrante Formation, a "shale containing Pholad borings at top" on the west limb of the same structure.

Hertlein and Allison (1959: 21) repeat Santillán and Barrera's (1930) record of "*Pholadidea* sp." from northwestern Baja California.

Higgins (1960: 199, 204, 208, 214, 221, fig. 5, pl. 20, fig. a) used holes bored in the Franciscan Formation in Sonoma Co., California, and associated with the Ohlson Ranch Formation of Pliocene age, to map and delimit the extent of this latter formation. These holes were only referred to as "mollusk borings" by Higgins. However, Peck (1960: 238), in reference to the same, noted that "sea stacks containing many "pholad" borings are locally abundant on the Franciscan-Ohlson Ranch contact."

Stanton (1966: fig. 2, p. 31) reported "boring pelecypods" from seven localities (CIT locs. 234, 1849, 2069, 2083, 2099, 2105, and 2106) in the upper Miocene Castaic Formation near Castaic, Ventura Co., California. Most may possibly be mytilid

borings since they "are lined with a variable number of carbonate layers." However, "At loc. 2069, a rounded tuff pebble is pitted by several shallow borings about three mm. in diameter. The borings resemble those made by Recent pholads." None of the specimens have been seen.

Frazier (1968 [1967]: 13, and 1968: 25) reported finding both *Zirfaea* and *Parapholas* on the "large terrace exposed at Newport Beach. This is about a mile back from the coast overlooking Upper Newport Bay." This is from the late Pleistocene Palos Verdes Sand. The specimens were not available for examination and may be the large *Chaceia ovoidea* common to this area.

Evans (1968a: 277) notes that "Fossil pholad beds . . . of rather recent origin can be seen as a horizontal foot deep layer running for many miles south along the coastal cliffs . . . in the Coos Bay area" of Oregon. "This bed ranges from about 7 to 50 feet above high tide level." Apparently no shell material has ever been found in the cavities along the three mile extent of discontinuous occurrences of the borings, which are thought to be late Pleistocene in age (J.M. Armentrout, *in litt.*).

Zullo (1969: 350) recorded a "Pholadid species" as rare in a Pleistocene terrace deposit at Grave Point, near Bandon, Coos Co., Oregon (UCMP loc. B-7493). The specimen could not be found at the University of California Museum of Paleontology.

Rowland (*in* Anon., 1970: 147) records "*Penitella*" from the Pliocene San Diego Formation in northwestern Baja California, 10.2 miles south of the U.S.-Mexican border. This may be from UCD loc. A-249.

Kennedy (1973: 122) recorded "*Penitella* sp." from the lower Pleistocene Lindavista Formation in San Diego, California, from SDSNH locs. 0325 ("?") and 0326. The umbonal regions of the small specimens are too damaged for specific identification.

Inconclusive Records, Addenda

Addicott and Galehouse (1973: 514) report "exposures of the basal Paso Robles in the vicinity of Santa Margarita are characterized by angular boulders of Monterey Shale and Vaqueros Sandstone bored by moderately large marine pholadid bivalves (E.W. Hart, written commun., Oct. 2, 1972). A specimen collected from one of these borings on Chalk Hill, about a mile northeast of Santa Margarita, appears to be a small *Zirfaea.*" The specimens have not been seen.

Edwards (1934: 796, 803, 804) has reported several occurrences of "*Pholad* borings" from conglomerates and sedimentary breccias in the Los Angeles basin, "immediately east of the corner of Fourth and Flower, Streets" [Los Angeles], "about a mile north of Newport and Balboa", and from the "Santa Monica Mountains". Also reported (p. 806) were broken pieces of Miocene Modelo Formation "attacked by *Pholads* and other burrowing invertebrates . . . until . . . buried in the Pliocene sediments."

Bowers (1901: 8) noted that in a wash on the southeast side of Table Mountain in Carrizo Valley [Imperial Co.], he found "crystallized limestone containing the burrows of pholads, or rock-borers." All burrows seen by me from this area have been made by rock-boring mytilids.

REGISTER OF LOCALITIES

The fossil localities cited in this report to which institutional numbers have been assigned are given below. All localities are from the State of California unless otherwise noted. Geological age assignments are generally those recognized by Keroher (1966, U.S. Geol. Surv. Bull. 1200) in the Lexicon of Geologic Names of the United States. Formational assignments usually follow those of the original collector, although many of these have since been restricted in time and space.

Specific names in quotation marks are identifications from the literature which are doubtful, and for which specimens could not be found. A few specimens cannot readily be assigned to any presently known pholadid genus, and these are also cited in quotation marks.

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CAS loc. 20.— Pleistocene. Near the top of the sea cliff one half mile southeast of Cape Blanco, Curry Co., Oregon. *Zirfaea* sp. aff. *Z. pilsbryi*, *Penitella turnerae*.

CAS loc. 76.— Pliocene, Foxen Mudstone. At the Waldorf asphalt mine three miles SSE of Guadalupe, Santa Barbara Co. *Penitella gabbii*, *P. turnerae*, *P.* sp. indet.

CAS loc. 90.— Pliocene, Saugus Formation. On the point of a prominent ridge approximately one mile south of the head of Torrey Canyon, south of Piru, Ventura Co. Formation is composed of light gray sand and gravel. Fossils quite abundant. *Penitella penita*, *P.* sp. cf. *P. conradi*.

CAS loc. 91.— Pleistocene, Palos Verdes Sand. One quarter mile north of the Southern Pacific Railroad Depot, San Pedro, Los Angeles Co. Fossils occur abundantly in nearly horizontal beds a foot or more in thickness. *Zirfaea pilsbryi*, *Penitella* sp. cf. *P. penita*.

CAS loc. 92.— Pleistocene, Palos Verdes Sand. On Deadman Island, San Pedro, Los Angeles Co. Four to six foot horizon six or eight feet below the top of the island, and four feet stratigraphically below a *Pecten* bed. *Penitella penita*.

CAS loc. 94.— Pleistocene. Deadman Island, San Pedro Island, Los Angeles Co. Boring into the horizon immediately underlying the Lower San Pedro Series. Brown and gray medium grained sandstone. *Penitella penita*.

CAS loc. 102.— Pleistocene. On terrace in sea cliff in Torrey Pines Beach State Park, three miles south of Del Mar, San Diego Co. Fossils were obtained from a coarse gravel bed. *Parapholas californica*.

CAS loc. 243.— Pliocene, Empire Formation. In the sea cliff about 200 yards east of Tunnel Point and about one half mile southwest of Coos Head, Coos Co., Oregon. *Penitella turnerae*.

CAS loc. 495.— Pleistocene. Deadman Island, San Pedro, Los Angeles Co. Collected by F.M. Anderson. *Penitella penita*.

CAS loc. 509.— Pliocene. Northhwest [? ESE] of Alcade, in NE 1/4 sec. 25, T. 21 S., R. 15 E., MDBM, Fresno Co. "Kreyenhagen, Coalinga." [V.A. Zullo, *in litt.*, notes this locality is in error and that "The associated fauna is characteristic of the latest Pliocene San Joaquin Formation, and is very probably from the *Pecten* zone."] *Zirfaea pilsbryi*.

CAS loc. 701.— Pliocene, Imperial Formation. "Fossils received from the California State Mining Bureau without locality data, but probably from Alverson Canyon, Imperial Co. Collected by Dr. Stephen Bower." *Cyrtopleura costata*.

CAS loc. 1154.— Miocene, Temblor Formation. About 9.6 km south of ranch house on Santa Rosa Island, Santa Barbara Co., California. From oyster bed and beds on slope of ridge down to San Augustine Canyon between spring on top of ridge, to *Turritella inezana* bed at CAS loc. 1153. Collected by L.G. Hertlein and E.L. Rixford, July 13 and 15, 1927. *Zirfaea dentata*.

CAS loc. 1479.— Pleistocene, Palos Verdes Sand. Deadman Island, San Pedro, Los Angeles Co. Zone 7 of Arnold. Collected by C.H. Crickmay, 1928. *Penitella conradi*.

CAS loc. 1841.— Miocene, Temblor Formation. At the base of Temblor Reef, Jasper Canyon, Fresno Co. Collected by G D. Hanna, September, 1929. Unidentified pholadid.

CAS loc. 2087.— Miocene, Temblor Formation. Reef bed north of Coalinga, Fresno Co. Collected by F.M. Anderson. *Zirfaea dentata*.

CAS loc. 2088.— Miocene, Temblor Formation. "Reef beds" north of Coalinga, on south side of sec. 20, T. 19 S., R. 15 E., MDBM, Fresno Co. *Zirfaea dentata*.

CAS loc. 27871A.— "Eocene." Tranquillon Mtn. 7-1/2" quad., 924 feet N. 81° W. of El Tranquillon Peak, Santa Barbara Co. Collected June, 1934. [Miocene; ? boring into Eocene strata "through" an uncomformity. *Zirfaea dentata*].

CAS loc. 28485.— Miocene, Temblor Formation [only in part]. One mile southeast of Oil City in Fresno Co. Collected by Joe Knowles, 1915-1935. "(Possibly the Temblor and Santa Margarita fossils were slightly mixed in locs. 28485 . . .)". *Zirfaea dentata*. [This "locality" represents at least two different time periods, one of which is probably Pliocene. *Chaceia ovoidea*.]

CAS loc. 31832.— Pleistocene. About ten to twelve feet above high tide, three miles north of Cayucos, San Luis Obispo Co. Collected by A.G. Smith, 1932-1933. *Penitella penita*.

CAS loc. 34437.— Pliocene, "Merced" Formation. Moss Beach, San Mateo Co. Collected by Don and Kelly Castleberry, Feb. 22, 1955. *Penitella penita*, *P.* sp. cf. *P. penita*, cast of pholadid burrow.

CAS loc. 36499.— Oligocene, San Ramon Formation. Large highway cut at Carquinez, Contra Costa Co. Collected just below the pebbly conglomerate which

appears to be slightly disconformable with the silty shale of probable Eocene age. Received from E.H. Drew, April 10, 1959. *Penitella lorenzana.*

CAS loc. 38432.— Pleistocene, Palos Verdes Sand. East side of Upper Newport Bay, city of Newport Beach, Orange Co. "From a large canyon since filled." Collected by E.V. Coan, "probably 1961." *Zirfaea pilsbryi.*

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[Material not seen]

CIT loc. 234.— Miocene, Castaic Formation. Near Castaic, Los Angeles Co. E 1/2 sec. 32, T. 5 N., R. 16 W., SBBM. "Boring pelecypods."

CIT loc. 1348.— Pleistocene, Palos Verdes Sand. Southwest slope of Signal Hill, 500 feet north and a litle east of intersection of Raymond Avenue and 21st Street, city of Signal Hill, Los Angeles Co. Collected by J.H. DeLong, Jr., summer, 1938. *Zirfaea pilsbryi.*

CIT loc. 1849.— Miocene, Castaic Formation. On ridge west of junction of Reynier and Sand Canyons, near Castaic, Los Angeles Co. SW 1/4 SE 1/4 sec. 35, T. 4 N., R. 15 W., SBBM. "Boring pelecypods."

CIT loc. 2069.— Miocene, Castaic Formation. South edge of Humphreys quadrangle, near Castaic, Los Angeles Co. W 1/4 NW 1/4 SW 1/4 sec. 27, T. 4 N., R. 15 W., SBBM. "Shallow borings" which "resemble those made by Recent pholads."

CIT loc. 2083.— Miocene, Castaic Formation. On a broad flat ridge northwest of Castaic Creek, near Castaic, Los Angeles Co. "Boring pelecypods."

CIT loc. 2099.— Miocene, Castaic Formation. 3750 feet N. 72° E. from Cordova Ranch, in sec. 36, T. 6 N., R. 17 W., SBBM, near Castaic, Los Angeles Co. "Boring pelecypods."

CIT loc. 2105.— Miocene, Castaic Formation. East of junction of Castaic and Fish Creeks, near Castaic, Los Angeles Co. "Boring pelecypods.",

CIT loc. 2106.— Miocene, Castaic Formation. Ridge crest north of Elderberry Canyon, near Castaic, Los Angeles Co. "Boring pelecypods."

LOS ANGELES COUNTY
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LACMNH loc. 1.— Pleistocene. San Pedro, Los Angeles Co. Mrs. Burton Williamson collection. *Zirfaea pilsbryi.*

LACMNH loc. 2.— Pleistocene. Deadman Island, Los Angeles Harbor, Los Angeles Co. Mrs. Burton Williamson collection. *Barnea subtruncata.*

LACMNH loc. 5.— No data; possibly from the Pleistocene of San Pedro, Los Angeles Co. *Penitella penita.*

LACMNH loc. 14.— Pleistocene. Redondo, Los Angeles Co. Mrs. Burton Williamson collection. Collected February 1892. *Penitella penita.*

LACMNH loc. 17.— Pleistocene. Deadman Island, San Pedro, Los Angeles Co. Williamson collection. *Zirfaea pilsbryi, Penitella* sp. cf. *P. penita.*

LACMNH loc. 32.— Miocene, Topanga Formation. Topanga Canyon, Los Angeles Co., on a hillside north of bend in Old Topanga Canyon Road, 1/4 mile north of the Hiram Montgomery Ranch and 1/2 mile south of the summit and junction with Dry Canyon Road. South of middle of sec. 35, T. 1. N., R. 17 W., SBBM. Collected by H.R. Hill and U.S. Grant, IV, August 13, 1930. *Zirfaea dentata.*

LACMNH loc. 58.— Pleistocene. Just east of Calle Fortuna, between Camino Estrella and Avenida de las Palmas, Capistrano Beach, Orange Co. Collected by George Willett, 20-21 September, ? 1936. *Zirfaea pilsbryi, Penitella penita, P.* sp. indet.

LACMNH loc. 59.— Pleistocene, Palos Verdes Sand. Just south of outfall sewer as it crosses Lincoln Avenue, about 2 miles northeast of community of Playa del Rey, Los Angeles Co. Fossiliferous stratum 8 to 12 inches thick and from 2 to 4 feet below surface, at an elevation of 50 feet. Collected by George Willett, 1935-1936. *Zirfaea pilsbryi, Penitella conradi.*

LACMNH loc. 66-2.— Pleistocene, Palos Verdes Sand. One half mile southeast of the salt reducing plant at the head of Upper Newport Bay, Orange Co. North facing exposure in second erosion channel cut into the surface of the lower of two terraces, near the base of the second. Richly fossiliferous sand 20 to 36 feet thick, immediately overlying a 1 to 2 foot thick basal conglomerate. 33° 38' 37" N., 117° 52' 37" W. Collected by G.P. Kanakoff. *Barnea subtruncata, Zirfaea pilsbryi, Chaceia ovoidea, Penitella penita, Parapholas californica.*

LACMNH loc. 66-10.— Pleistocene, Palos Verdes Sand. On east bluff above Upper Newport Bay, near LACMNH loc. 66-2, city of Newport Beach, Orange Co. Collected by Jack Schwartz, March, 1966. *Barnea subtruncata, Chaceia ovoidea.*

LACMNH loc. 68-A.— Pleistocene, Palos Verdes Sand. Exposure in cliff face of Newport Mesa, on west side of "middle" Newport Bay, city of Newport Beach, Orange Co. Sediments 12 to 18 feet thick. Collected by G.P. Kanakoff. *Zirfaea pilsbryi, Chaceia ovoidea;*[not seen].

LACMNH loc. 77.— Pleistocene, Palos Verdes Sand. "Outfall Sewer" ditch at corner of Lomita Boulevard and Main Street, Wilmington, Los Angeles Co. Collected by Chester Stock and G.P. Kanakoff, February 19, 1947. *Zirfaea pilsbryi.*

LACMNH loc. 98.— Pleistocene, San Pedro Sand. Southeast corner of 3rd and Mesa Streets, San Pedro, Los Angeles Co. Fossiliferous strata 2 to 10 feet thick and 20 to 30 feet above street level. *Zirfaea pilsbryi, Penitella* sp. cf. *P. conradi, P. penita.*

LACMNH loc. 107.— Pliocene, San Diego Formation. Quarry at end of Arroyo Drive, city of San Diego, San Diego Co. Exposure 40 to 50 feet high. Scattered boulders (clay concretions) contain molluscan material. Collected by G.P. Kanakoff. *Penitella conradi, Penitella* sp. cf. *P. penita.*

LACMNH loc. 131.— Pleistocene, San Pedro Sand. Street cut on north side of 500 block of N. Pacific Avenue, San Pedro, Los Angeles Co. Sand stratum 2 to 10 feet thick and 10 to 20 feet above street level. Collected by Museum's junior paleontology class. *Zirfaea pilsbryi.*

LACMNH loc. 136.— Pleistocene, Palos Verdes Sand. On east bluff above Upper Newport Bay, Orange Co.

"*Anomia* Bed" 15 feet below level of airfield at elevation of 87 feet. Collected by G.P. Kanakoff, October 16, 1947. *Barnea subtruncata, Zirfaea pilsbryi, Chaceia ovoidea.*

LACMNH loc. 137.— Pleistocene. Just east of Calle Fortuna, between Camino Estrella and Avenida de las Palmas, Capistrano Beach, Orange Co. Collected by G.P. Kanakoff, 24 October 1947, and thereafter. *Penitella penita.*

LACMNH loc. 147.— Pleistocene, Palos Verdes Sand. Near intersection of Vermont Avenue and Sepulveda Boulevard, west of Carson and north of San Pedro in an unincorporated part of Los Angeles Co. *Barnea subtruncata.*

LACMNH loc. 226.— Pleistocene, Palos Verdes Sand. Area of 8th and Palos Verdes Streets, San Pedro, Los Angeles Co. Collected by G.P. Kanakoff, December 29, 1951. *Penitella* sp. cf. *P. conradi, P. penita, Nettastomella rostrata.*

LACMNH loc. 229.— Pleistocene, Palos Verdes Sand. Deposit on south side of Anaheim St., east of intersection with Normandie Ave., Harbor Lake [= old Bixby Slough], community of Harbor City, city of Los Angeles, Los Angeles Co. Collected by G.P. Kanakoff, 29 December 1951. *Barnea subtruncata, Penitella* sp. indet.

LACMNH loc. 241.— Pleistocene, Palos Verdes Sand. A one mile exposure 40 to 60 feet thick, one mile west of the bridge over Newport Bay, on present Highway 1 (Pacific Coast Highway), city of Newport Beach, Orange Co. Collected by G.P. Kanakoff, October 1952, and thereafter. *Penitella penita.*

LACMNH loc. 300.— Pleistocene, San Pedro Sand. Below "Nob Hill," San Pedro, Los Angeles Co. Collected by G.P. Kanakoff, November 4, 1955. *Barnea subtruncata, Zirfaea pilsbryi, Penitella* sp. cf. *P. conradi, P. penita.*

LACMNH loc. 305.— Pliocene, San Diego Formation. On hill southwest of Goat Canyon, 290 feet north of the U.S.-Mexican border, southwestern San Diego Co. Sixty foot exposure from 1 to 2 feet thick. Collected by G.P. Kanakoff, July 20, 1956. *Zirfaea pilsbryi, Penitella conradi, P. penita.*

LACMNH loc. 305-C.— Pliocene, San Diego Formation. In small amphitheater on south side of Goat Canyon, southwestern San Diego Co. 100' west and 440' south of NE cor. sec. 8, T. 19 S., R. 2 W., SBBM. Collected by G.P. Kanakoff. *Penitella conradi.*

LACMNH loc. 314.— Pliocene, Merced Formation. Two mile stretch of outcrop at Capitola Beach, Santa Cruz Co. Collected by G.P. Kanakoff, July 2, 1958. *Parapholas californica* [chimneys only].

LACMNH loc. 317-J.— Miocene, Topanga Formation. "Same as [LACMNH loc.] 32 but with stratigraphic positions." Collected by G.P. Kanakoff, "3-10-59." *Zirfaea dentata.*

LACMNH loc. 416.— Late Pleistocene. Exposures between the University of California at Santa Barbara and Devereaux School, Isla Vista, near Goleta, Santa Barbara Co. Collected by G.P. Kanakoff. *Zirfaea pilsbryi, Penitella turnerae.*

LACMNH loc. 423.— Pliocene, Fernando Formation. Excavation 35' below freeway level, near the intersection of Interstate 405 and Cherry Avenue, Long Beach, Los Angeles Co. Collected by Roger Reimer, 26-29 July 1963. *Penitella penita.*

LACMNH loc. 424.— Pleistocene. About 1/4 mile west of intersection of Interstate 405 and Cherry Avenue, Long Beach, Los Angeles Co. Collected by Roger Reimer, July 23, 1963. *Zirfaea pilsbryi.*

LACMNH loc. 426.— Pleistocene. North facing bank on south side of Interstate 405 at north end of Cheviot Vista Place, Palms, city of Los Angeles, Los Angeles Co. Collected by G.P. Kanakoff. *Barnea subtruncata, Zirfaea pilsbryi.*

LACMNH loc. 427.— Pleistocene, Palos Verdes Sand. Hillside 1/4 mile from San Pedro end of Harbor Freeway, immediately after the Union Oil Co. refinery, San Pedro, Los Angeles Co. Collected by G.P. Kanakoff, J.E. Fitch, Jr., and N. Furjaner, August 1, 1964. *Zirfaea pilsbryi.*

LACMNH loc. 435.— Pleistocene, Lomita Marl. Forty foot exposure on south side of gully at intersection of 1200 Park Western Drive, 1200 West Coralmount Drive, and 1100 Host Place, San Pedro, Los Angeles Co. Collected 35 feet below Host Place level by G.P. Kanakoff. *Penitella conradi, Nettastomella rostrata.*

LACMNH loc. 440.— Pleistocene, Palos Verdes Sand. Excavation at southeast corner of Pacific and Hards Streets, San Pedro, Los Angeles Co. Collected at the approaches to Vincent Tomas Bridge between San Pedro and Wilmington, by G.P. Kanakoff, April 6, 1965. *Zirfaea pilsbryi, Penitella penita.*

LACMNH loc. 452.— Pleistocene. 100 yard exposure along RR tracks from San Clemente RR station and south, 30 feet up cliff, San Clemente, Orange Co. Collected by James Ingle and William Meisalis, 30 July 1960. *Penitella* sp. indet.

LACMNH loc. 453.— Pliocene. About 100 miles south of Ensenada, at south end of San Quintin Valley, Baja California, Mexico. On east side of highway in sandstone cliffs just below top of mesa. Collected by M.L. Webster and David Hyatt, September, 1965. *Penitella penita.*

LACMNH loc. 466.— Pliocene, Fernando Formation. Excavation for Crocker Citizens Plaza Building, corner of Sixth and Hope Streets, downtown Los Angeles, Los Angeles Co. *Penitella conradi.*

LACMNH loc. 471.— Pliocene, Fernando Formation. On east bluff above Newport Bay, Orange Co. Approximately 800 feet south and 50 feet west of NE cor. sec. 24, T. 6 S., R. 10 W., SBBM. Highly fossiliferous gray unconsolidated silt exposed over an area of several hundred square yards by bulldozers excavating housing sites. Collected in 1966 or 1967. *Penitella conradi.*

LACMNH loc. 482.— Pleistocene, Norfolk Formation. Virginia Beach, Princess Anne Co., Virginia. *Cyrtopleura costata.*

LACMNH loc. 487.— Pleistocene, Palos Verdes Sand. On east bluff above Upper Newport Bay, city of Newport Beach, Orange Co. Collected by Boris Savic and J.A. Sutherland. *Nettastomella rostrata.*

LACMNH loc. 1144.— Pliocene or Pleistocene. Bluff near beach, San Juan Capistrano, Orange Co. *Penitella penita.*

LACMNH loc. 1203.— Pleistocene. Lumberyard near Timm's Point, San Pedro, Los Angeles Co. Collected by E.J. Post. *Penitella penita.*

LACMNH loc. 1204.— Pliocene, Etchegoin Formation. On northeast side of Bitterwater Valley, San Benito Co. NE 1/4 sec. 13, T. 18 S., R. 9 E., MDBM. Collected by Carl Bleifus, November, 1956. *Zirfaea pilsbryi.*

LACMNH loc. 1205.— Miocene, Monterey Formation. Pinole, Contra Costa Co. "From contact between Monterey and Chico." *Penitella* sp. indet.

LACMNH loc. 1206.— Pleistocene. Deadman Island, San Pedro, Los Angeles Co. *Penitella penita.*

LACMNH loc. 1210.— Pleistocene, Palos Verdes Sand. North end of the Los Angeles Harbor District Sanitation Yard, in middle of low bluff parallel to and immediately south of the Union Oil Company refinery, between the communities of San Pedro and Wilmington, Los Angeles Co. Locality is west of the Harbor Freeway and from 2/5 to 1 mile due east of the intersection of Gaffey Street and Westmount Drive. Collected by E.C. Wilson, and 603 helpers, October 4, 5, 11, 12, and 18, 1969. *Zirfaea pilsbryi, Chaceia ovoidea, Penitella penita.*

LACMNH loc. 1219.— Pliocene, Fernando Formation. Excavation 60 feet below surface for Atlantic-Richfield Plaza basement, north corner of intersection of Sixth and Flower Streets, downtown Los Angeles, Los Angeles Co. Collected by P.I. LaFollette, J. Marr, B. Savic, and S. Geldman, 30 December 1969 to 4 January, 1970. *Penitella conradi.*

LACMNH loc. 1307.— Pleistocene, Terrace 7. Palos Verdes Peninsula, Los Angeles Co. "Building excavation 582 m . . . N4W from bench mark 832. Elevation 192 m. W.H. Easton and L.N. Marincovich [loc. 7-1], collectors." *Chaceia ovoidea, Parapholas californica.*

LACMNH loc. 2636.— Pleistocene. South face of gentle slope on Coquille Point, southwest of benchmark on point, Bandon, Oregon. SE 1/4 SE 1/4 sec. 26, T. 28 S., R. 15 W., WBM. Collected by G.L. Kennedy and G.G. Sphon, 9 August 1972. *Penitella* sp. indet.

LACMNH loc. 2641.— Pleistocene. In cliff face of natural amphitheater on southeast side of Cape Blanco, Oregon. Center of S 1/2 NE 1/4 sec. 2, T. 32 S., R. 16 W., WBM. Collected by G.L. Kennedy and G.G. Sphon, 10 August 1972. *Penitella penita.*

LACMNH loc. 2658.— Pleistocene, Bay Point Formation. Rear of building cut on Pomona Street, Coronado, 20 to 40 m west of entrance to the Coronado Yacht Club on Glorietta Bay in San Diego Harbor, San Diego Co. Lithology: detrital shell layers and unconsolidated beach sand. Collected by G.L. Kennedy. *Zirfaea pilsbryi.*

LACMNH loc. 2687.— Pleistocene, Second Terrace. Excavation for High School at 15th and Leland Streets, San Pedro, city of Los Angeles, Los Angeles Co. Collected by E.P. Chace, 1937. *Zirfaea pilsbryi.*

LACMNH loc. 2690.— Pleistocene. Storm drain ditch south of railroad tracks, crossing 103rd Street, Watts, city of Los Angeles, Los Angeles Co. *Penitella penita.*

LACMNH loc. 2694.— Pleistocene. Deposit above the beach at Isla Vista, near Goleta, Santa Barbara Co. Collected by E.V. Coan. *Zirfaea pilsbryi, Penitella turnerae, Parapholas californica.*

LACMNH loc. 2719.— Pleistocene. Conflicting data, but somewhere in the vicinity of San Juanica and Punta Pequeña, Baja California, Mexico. 26° 15' 35" N., 112° 26' 20" W. Collected by P.I. LaFollette, 25-27 October 1971. *Zirfaea pilsbryi.*

LACMNH loc. 2905.— Miocene, Topanga Formation. Head of Topanga Canyon, two miles south of Calabasas P.O., Los Angeles Co. *Zirfaea dentata.*

LACMNH loc. 3936.— Pleistocene. Flat on southeast corner of Crannell Road and Highway 101 frontage road, .2 miles south of Crannell offramp, Humboldt Co. 2200 feet west and 1350 feet south of NE cor. sec. 7, T. 7 N., R. 1 E., HBM. Collected by G.L. Kennedy, 31 July and 28 August, 1973. *Zirfaea pilsbryi.*

LACMNH loc. 3944.— Pleistocene, Battery Formation. Beach cliff just below southeast corner of intersection of Pebble Beach Drive and Murphy Drive, Crescent City, Humboldt Co. Pholads boring into underlying Pliocene mudstone. Collected by G.L. Kennedy, 4 August 1973. *Penitella turnerae.*

LACMNH loc. 3950.— Pleistocene. Terrace deposit on south side of Fivemile Point, between Bandon and Coos Bay, Coos Co., Oregon. 450 feet W. and 1500 feet S. of NE cor. sec. 19, T. 27 S., R. 14 W., WBM. Collected by G.L. Kennedy, 9 August 1973. *Penitella gabbii, P. penita.*

LACMNH loc. 3951.— Pleistocene. Terrace deposit on north side of Fivemile Point, between Bandon and Coos Bay, Coos Co., Oregon. 400 feet W. and 1150 feet S. of NE cor. sec. 19, T. 27 S., R. 14 W., WBM. Collected by G.L. Kennedy, 9 August 1973. *Penitella penita.*

LACMNH loc. 3952.— Pleistocene. Base of bluff on west side of road on very eastern tip of Hinton Point, opposite corrugated metal buildings, Yaquina Bay, near Newport, Lincoln Co., Oregon. Collected by G.L. Kennedy, 12 August 1973. *Zirfaea pilsbryi.*

LACMNH loc. 4556.— Pleistocene. "Border locality" (supposedly =SDSNH loc. 118) in southwesternmost San Diego Co. Collected by Mark Roeder. *Zirfaea pilsbry, Penitella* sp. indet.

SAN DIEGO NATURAL HISTORY MUSEUM

SDSNH loc. 0040.— Pleistocene. About 1-1/2 miles west of Goleta Point and 4 miles WSW of Goleta, Santa Barbara Co. At Campbell's Ranch, in bank of soft clay shale overlain by a very rich fossiliferous sandy layer. Collected by U.S. Grant, IV, 1927. *Zirfaea pilsbryi, Penitella turnerae.*

SDSNH loc. 0051.— Pliocene, Imperial Formation. Carrizo Creek, loc. B, about 3 miles east of Old Carrizo Creek Stage Station and one mile south of the road, western Imperial Co. Collected ? by Frank Stephens. *Cyrtopleura costata.*

SDSNH loc. 0074.— Pleistocene. Fossiliferous deposit near top of embankment about 1 to 1-1/4 miles west of Goleta Point, Santa Barbara Co. Same as SDSNH loc. 0040 but about 1/4 mile east along beach. Collected by U.S. Grant, IV, September 19, 1928. *Penitella turnerae.*

SDSNH loc. 0078.— Pleistocene. Terrace 1/2 mile south of Sea Cliff Station on Southern Pacific Railroad and 8 miles north of Ventura City, Ventura Co. At north end of sea wall south of an evergreen grove. Collected by Lynn Farish, July 3, 1926. (Deposit obscured by widening of state highway; (s) U.S. Grant, 1928.) *Penitella* sp. cf. *P. penita.*

SDSNH loc. 0120.— Pleistocene. About 125 yards north of U.S.-Mexican border and 1/2 to 1/3 mile from the ocean, southwestern San Diego Co. Mixed clay, sand and boulders at 30 feet elevation on the west side of a ravine heading across the border. Collected by Frank Stephens, September 17, 1929. [Locality description on label differs somewhat from that in locality book.] *Zirfaea pilsbryi.*

SDSNH loc. 0289.— Pleistocene. Terrace material collected around mouth of Tourmaline Street canyon (Tourmaline Street Surfing Park), Pacific Beach, city of San Diego, San Diego Co. Collected by M.J. Bishop and S.J. Bishop. *Penitella penita.*

SDSNH loc. 0325.— Pleistocene, Lindavista Formation. North-facing bank on south side of residence at 10735 Montego Drive (in southeast corner of first cul-de-sac on Montego Drive west of El Noche Way), San Diego, San Diego Co. Fossiliferous unconsolidated conglomeratic sandstone. Altitude 131 m. Approximate coordinates, 32° 49.7' N., 117° 5.8' W. Collected by G.L. Kennedy, September 1971. *Zirfaea pilsbryi, Penitella* sp. indet.

SDSNH loc. 0326.— Pleistocene, Lindavista Formation. West-facing bank on east side of residence at 10735 Montego Drive (in southeast corner of first cul-de-sac on Montego Drive west of El Noche Way), San Diego, San Diego Co. Approximate coordinates, 32° 49.7' N., 117° 5.8' W. Collected by G.L. Kennedy, September 1971. *Penitella* sp. indet.

SDSNH loc. 0417.— Pliocene, San Diego Formation. About 1/4 mile and fifth ravine north of U.S.-Mexican border, and 3/4 mile east of ocean on west face of terrace, southwestern San Diego Co. Collected by E.H. Quayle, August 28, 1932. *Penitella penita.*

SDSNH loc. 0429.— Pliocene, San Diego Formation. About 250 yards north of the U.S.-Mexican border and 1/2 mile from the ocean in a small gulch in the cliff bordering the Tia Juana River, southwestern San Diego Co. Collected by Frank Stephens, July 20 and August 12, 1932. *Penitella penita.*

SDSNH loc. 0624.— Pleistocene. Southwest corner of Turtle Bay, Baja California, Mexico, at south end of hills on the peninsula between the bay and the Pacific Ocean. Collected by E.P. Chace, 16 July 1954. *Penitella fitchi.*

SDSNH loc. 0625.— Pleistocene. "Chiton Bed," on Point Firmin, a few yards west of the western boundary of the picnic grounds around Peck's Pavillion, San Pedro, Los Angeles Co. Gray sand, sometimes considerably indurated, about 10 feet below the upper edge of the bluff. Collected by E.P. Chace and E.M. Chace, 1918. *Penitella penita, Nettastomella rostrata.*

SDSNH loc. 0702.— Pleistocene. San Nicolas Island, Channel Islands, Ventura Co. Collected ? by Malcolm Rogers. *Chaceia ovoidea.*

SDSNH loc. 1883.— Pleistocene. San Pedro, Los Angeles Co. Collected ? by Ralph Arnold. *Penitella penita.*

SDSNH loc. 1885.— Pleistocene. Nob Hill, San Pedro, Los Angeles Co. *Penitella penita.*

SDSNH loc. 1899.— Pleistocene. San Pedro Railroad Cut, San Pedro, Los Angeles Co. Collected by Kate Stephens. *Zirfaea pilsbryi, Penitella penita.*

SDSNH loc. 1960.— Pleistocene. New San Pedro Lumber Yard, San Pedro, Los Angeles Co. Collected by E.P. Chace. *Zirfaea pilsbryi.*

SDSNH loc. 2138 [= L-2138].— Pleistocene, San Pedro Sand. In foundation hole, two feet below surface, for the San Pedro High School, 15th and Leland Streets, San Pedro, Los Angeles Co. 33° 43' 52.5" N. lat., 118° 17' 42" W. long. Collected by E.P. Chace, 1936. *Barnea subtruncata, Zirfaea pilsbryi, Chaceia ovoidea, Penitella fitchi, P. penita, Nettastomella rostrata.*

SDSNH loc. 2419.— Pleistocene. Below California Western University campus of the U.S. International University, west side of Point Loma, San Diego, San Diego Co. Collected by R.C. Schwenkmeyer and Museum paleontology class. *Parapholas californica.*

SDSNH loc. 2454.— Pliocene, San Diego Formation. Arroyo Drive, city of San Diego, San Diego Co. *Penitella conradi.*

SDSNH loc. 2455.— Pliocene, San Diego Formation. Laural Canyon, city of San Diego, San Diego Co. Collected ? by O.H. Reinhold. *Penitella conradi.*

SDSNH loc. 2528.— Pleistocene. Coronado Beach, San Diego Co. Collected by C.L. Hubbs. *Zirfaea pilsbryi.*

SDSNH loc. 2529.— Pliocene, San Diego Formation. Northeast corner of Upas and India Streets, city of San Diego, San Diego Co. *Penitella* sp. cf. *P. conradi.*

SDSNH loc. 2530.— Pleistocene. Point Loma, San Diego Co. Collected by C.H. Hubbs. *Penitella penita.*

SDSNH loc. 2531.— Pleistocene. Rosarito Beach, Baja California, Mexico. Collected ? by Kate Stephens. *Penitella gabbii, P. penita,* unidentified pholadid burrow.

SDSNH loc. 2532.— Pliocene, Imperial Formation. Coyote Mountain, Imperial Co. Collected by Frank Stephens. *Cyrtopleura costata.*

SDSNH loc. 2561.— Pleistocene, Palos Verdes Sand. On the east bluff above Upper Newport Bay, approximately 140 meters north of north corner of bridge on Vista del Oro Street, city of Newport Beach, Orange Co. Richly fossiliferous, unconsolidated detrital sand. 33° 38' 26" N. lat., 117° 53' 02" W. long. Collected by L.M. Kennedy, June 5, 1966. *Penitella fitchi.*

SDSNH loc. 2575.— Pliocene or Pleistocene. Dredged in Oakland Creek [?San Francisco Bay], California. Collected by Henry Hemphill. *Barnea subtruncata.*

SDSNH loc. 2576.— Pleistocene. "At the ocean beach" about 10 miles south of the U.S.-Mexican border, Baja California, Mexico. *Penitella penita.*

SDSNH loc. 2629.— Pleistocene. Approximately 8.4 miles south of Rosarito Beach, Baja California, Mexico. About 4-5 feet below the surface of old Highway 1, "200 yards south of Happy's Club." Collected by Arnold Ross and J.R. Jehl, Jr., November 7, 1968. *Penitella penita.*

SDSNH loc. 2630.— Pleistocene. Pavement on bluffs at Campo del Arroyo, Cedros Island, Baja California,

Mexico. Collected by F.H. Wolfson, January, 1968. *Parapholas californica.*

SDSNH loc. 2631.— Late Pleistocene. Terrace deposit on west side of Point Loma, San Diego Co. Collected by G.D. Webster, April, 1968. *Chaceia ovoidea.*

SDSNH loc. 2646.— Pliocene or Pleistocene. "Bracket Mesa," Arroyo Santo Catarina, Baja California, Mexico. Pholadids boring into Paleocene strata with a "Martinez" fauna. Collected by M.L. Webster. *Penitella* sp. cf. *P. turnerae.*

SDSNH loc. 2658.— Pliocene or Pleistocene. From a shallow cave near the top of the bluff that parallels the coast between San Quintin and Rancho Socorro, Baja California, Mexico. Collected by M.L. Webster. *Penitella penita.*

SDSNH loc. 2660.— Pleistocene. Corner of Third and Mesa Streets, San Pedro, Los Angeles Co. Collected by E.P. Chace. *Zirfaea pilsbryi, Penitella penita.*

SDSNH loc. 2669.— Pleistocene, Lomita Marl. Near bottom of northeast facing slope below Coralmount and Park Western Drives, San Pedro, Los Angeles Co. Collected *in situ* in cobbles, by G.L. Kennedy and R.P. Battelle, 13 September, 1970. *Penitella conradi, P. penita.*

SDSNH loc. 2670.— Pleistocene. From south-facing cove on south side of Point Año Nuevo, San Mateo Co. Collected by G.L. Kennedy, 21 June 1970. *Zirfaea* sp. aff. *Z. pilsbryi.*

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SDSC loc. 71 (=**SDSC loc. 118**).— Pleistocene, Bay Point Formation. Glorietta Bay, 100 yards north of corner of U.S. Highway 75 and Pomona Street, Coronado, San Diego Co. Fine gray sandstone with cross bedded coquina. Elevation nine feet. 32° 41' 15" N., 117° 10' 15" W. *Zirfaea pilsbryi.*

SDSC loc. 109.— Pleistocene. El Descanso, northwestern Baja California, Mexico. *Penitella penita.*

SDSC loc. 350.— Pliocene, Imperial Formation. South of Yuha Buttes [Imperial County, California] in Baja California, Mexico. Collected by R.G. Gastil and J.A. Minch, December, 1963. *Cyrtopleura costata.*

SDSC loc. 531.— Pleistocene, Palos Verdes Sand. On the east bluff above Upper Newport Bay, 170 meters NNW of north corner of bridge on Vista del Oro Street, city of Newport Beach, Orange Co. Richly fossiliferous detrital layer 1-1/2 to 2 feet thick, intermixed with coarse friable sand. Collected by G.L. Kennedy, fall, 1966. *Zirfaea pilsbryi.*

SDSC loc. 532.— Pleistocene, Palos Verdes Sand. On the east bluff above Upper Newport Bay, 230 meters northwest of north corner of bridge on Vista del Oro Street, city of Newport Beach, Orange Co. Same lithology as SDSC loc. 531. Collected by G.L. Kennedy, fall, 1966. *Zirfaea pilsbryi.*

SDSC loc. 533.— Pleistocene, Palos Verdes Sand. On the east bluff above Upper Newport Bay, 183 meters NNW of north corner of bridge on Vista del Oro Street, city of Newport Beach, Orange Co. Exposure of paleobottom in outcrop of massive fine grained sandstone. Collected by G.L. Kennedy, fall, 1966. *Barnea subtruncata, Chaceia ovoidea, Penitella penita, Nettastomella rostrata.*

SDSC loc. 534.— Pleistocene, Palos Verdes Sand. On the east bluff above Upper Newport Bay, 166 meters northwest of north corner of bridge on Vista del Oro Street, city of Newport Beach, Orange Co. Same lithology as SDSC loc. 531 but somewhat indurated with lime. Collected by G.L Kennedy, fall, 1966. *Zirfaea pilsbryi.*

SDSC loc. 535.— Pleistocene, Palos Verdes Sand. On the east bluff above Upper Newport Bay, 163 meters northwest of north corner of bridge on Vista del Oro Street, city of Newport Beach, Orange Co. Very coarse sand and cobbles, highly stained with iron oxide. Two feet stratigraphically above SDSC loc. 534. Collected by G.L. Kennedy, fall, 1966. *Zirfaea pilsbryi.*

SDSC loc. 537.— Pleistocene, Palos Verdes Sand. On the east bluff above Upper Newport Bay, 170 meters NNW of north corner of bridge on Vista del Oro Street, city of Newport Beach, Orange Co. Same lithology as SDSC loc. 533. Collected by G.L. Kennedy, fall, 1966. *Chaceia ovoidea, Penitella fitchi; Nettastomella rostrata* [not collected].

SDSC loc. 648.— Pleistocene. New San Pedro Lumberyard, on San Pedro and Wilmington Road, San Pedro, Los Angeles Co. Collected by E.P. Chace. *Zirfaea pilsbryi.*

SDSC loc. 736.— Pleistocene. San Pedro, Los Angeles Co. *Zirfaea pilsbryi.*

STANFORD UNIVERSITY

SU loc. N.P. 129.— Oligocene, Sooke Formation. Sea cliffs of Kirby (formerly Coal Creek) and Muir Creeks, west of Otter Point, Sooke, Vancouver Island, British Columbia, Canada. "*Zirfaea* sp." [The specimen appears similar to, and may represent, a Pliocene to Recent *Zirfaea pilsbryi.*]

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UCD loc. A-249.— Pliocene, San Diego Formation. North end of a steep east-west trending canyon which begins just north of the village of La Gloria, on Route 1, past Escuela Amando Nervo, to the coast, northwestern Baja California, Mexico. The canyon head is approximately 4.2 road miles from Highway 1. Gray sandstone with large cobbles. Collected by R.W. Rowland, spring 1968. Burrow with *Penitella* sp. indet.

UNIVERSITY OF CALIFORNIA AT LOS ANGELES

UCLA loc. 167.— Miocene, Topanga Formation. "On" road, Old Topanga Canyon, Los Angeles Co. About 2200 feet east and 250 feet north of the southwest corner of sec. 35, T. 1 N., R. 17 W., SBBM, Dry Canyon quadrangle. Greenish-brown, medium to fine-grained sandstone with interbedded gray shale cut by basalt

intrusions. *Zirfaea dentata*, *"Pholadidea penita"*; [not seen].

UCLA loc. 312.— Pliocene, San Diego Formation. Fifth ravine north (about 1/4 mile) of the U.S.-Mexican border, at west face of terrace 3/4 mile east of the coast, southwestern San Diego Co. *Penitella penita.*

UCLA loc. 1824.— Pleistocene, San Pedro Sand. Southeast corner of Second and Beacon Streets, San Pedro, Los Angeles Co. *Penitella penita.*

UCLA loc.2410.— Pleistocene. Marine terrace deposit about 100 feet (?) above strand, at mouth of staircase canyon, Torrey Pines State Park, south of Del Mar, San Diego Co. Collected by G. Weir. *Zirfaea pilsbryi, Penitella penita, P.* sp. indet., *Parapholas californica.*

UCLA loc. 2717.— Pleistocene. Sandy rubble in sea cliff approximately 6.4 miles south of the radio tower at Rosarito Beach, and about 0.3 miles south of kilometer 36 on [old] Highway 1, Baja California, Mexico. Collected by J.S. Cunningham and J. W. Valentine, February, 1952. *Penitella penita.*

UCLA loc. 2718.— Pleistocene. Sandy rubble exposed in sea cliff approximately 5.7 miles south of the radio tower at Rosarito Beach, at kilometer 36 on [old] Highway 1, Baja California, Mexico. Collected by J.S. Cunningham and J.W. Valentine, February, 1952. *Penitella penita.*

UCLA loc. 2719.— Pleistocene. Unconsolidated pebble conglomerate exposed in sea cliff approximately 2.2 miles south of the radio tower at Rosarito Beach, at kilometer 30 on [old] Highway 1, Baja California, Mexico. Collected by J.W. Valentine, December, 1952. *Penitella penita.*

UCLA loc. 2720.— Pleistocene. Sandy rubble exposed in sea cliff at the second small re-entrant in first sea cliffs south of the radio tower at Rosarito Beach, Baja California, Mexico. Collected by J.W. Valentine, December, 1952. *Zirfaea pilsbryi, Penitella penita.*

UCLA loc. 2774.— Pleistocene. Terrace near San Clemente, Orange Co. Coarse-grained sands with cobbles in lenses, about 5 feet thick, exposed in gully west of U.S. Highway 101 about 150 feet on a line projecting from the end of Magdalena Avenue. Collected by R.J. Smith, 1953. *Parapholas californica.*

UCLA loc. 3160.— Pleistocene. Unconsolidated cobble conglomerate exposed in low sea cliff approximately 5.2 miles north of the radio tower at Rosarito Beach, Baja California, Mexico. Collected by J.S. Cunningham and J.W. Valentine, January, 1952. *Penitella penita.*

UCLA loc. 3161.— Pleistocene. Unconsolidated cobble conglomerate exposed in sea cliff approximately 8 miles north of the radio tower at Rosarito Beach, Baja California, Mexico. Collected by J.S. Cunningham and J.W. Valentine, January, 1952. *Penitella penita.*

UCLA loc. 3175.— Pleistocene. Terrace near the U.S.-Mexican border, southwestern San Diego Co. Fine grained sandstone about 1 foot thick, locally cemented, exposed in the first north-south trending gully cutting the terrace and draining into the Tia Juana River valley east of the ocean, along road running to the International Boundary Monument. Collected by J.S. Cunningham and J.W. Valentine, winter, 1951. *Zirfaea pilsbryi.*

UCLA loc. 3225.— Pleistocene. At the head of Potrero Canyon, Pacific Palisades, Los Angeles Co. Collected by F.C. Clark. *Zirfaea pilsbryi, Chaceia ovoidea.*

UCLA loc. 3393.— Pleistocene. Sea cliffs approximately 1/2 mile west of the mouth of Cayucos Creek, and 75 feet west of intersection of frontage road with California State Highway 1, near Cayucos, San Luis Obispo Co. Collected by J.W. Valentine. *Chaceia ovoidea, Penitella penita.*

UCLA loc. 3440.— Pleistocene, Palos Verdes Sand. Near Palos Verdes Street, between 8th and 9th Streets, San Pedro, Los Angeles Co. Medium grained sand. *Zirfaea pilsbryi, Chaceia ovoidea, Penitella penita.*

UCLA loc. 3445.— Pleistocene. Sea cliffs approximately 2-1/2 miles west of mouth of Cayucos Creek, just west of the headland which is west of Cayucos Point, San Luis Obispo Co. Collected by J.W. Valentine. *Penitella penita.*

UCLA loc. 3447.— Pleistocene. Sea cliffs at small point nearly opposite intersection of frontage road and Highway 1, Cayucos, San Luis Obispo Co. Collected by J.W. Valentine. *Penitella penita.*

UCLA loc. 3448.— Pleistocene. Sea cliffs approximately 1-1/2 miles west of mouth of Cayucos Creek, just west of first stream gully east of Cayucos Point, San Luis Obispo Co. Collected by J.W. Valentine. *Penitella penita.*

UCLA loc. 3457.— Pleistocene. Terrace in hanging valley approximately 1/2 mile south of the parking lot on the beach at Torrey Pines Beach State Park, San Diego Co. Collected by J.W. Valentine, April 19, 1958. *Chaceia ovoidea.*

UCLA loc. 3458.— Pleistocene. Terrace in hanging valley approximately 7/8 mile south of the parking lot on the beach at Torrey Pines Beach State Park, San Diego Co. Collected by J.W. Valentine, April 19, 1958. *Chaceia ovoidea, Penitella* sp. indet.

UCLA loc. 3460.— Pleistocene, Timms Point Silt. On the northern border of the Palos Verdes Hills, Los Angeles Co. Exposure is 1,000 feet east of Crenshaw Boulevard and 2,250 feet slightly west of south of the intersection of Crenshaw and U.S. Highway 101, at about 345 feet elevation, in the second ravine east of Crenshaw cutting the north slope of 400 foot hill. Collected by Carl Helms and J.W. Valentine. *Penitella penita.*

UCLA loc. 3569.— Pleistocene. Unconsolidated cobble conglomerate exposed in gully 20 feet inland from sea cliff, approximately 4-1/2 miles south of the mouth of Rio Morro, and about 150 yards north of kilometer 45 on [old] Highway 1, Baja California, Mexico. Collected by J.W. Valentine, November, 1952. *Parapholas californica.*

UCLA loc. 3597.— Pleistocene. On platform surface on north side of the first railroad cut west of Tajiguas Creek, near Gaviota, Santa Barbara Co. In sands above sea cliffs. Collected by J.W. Valentine, spring, 1956. *Penitella turnerae, Parapholas californica.*

UCLA loc. 3600.— Pleistocene, Palos Verdes Sand. South side of ravine opposite loading platform on siding of Western Oil and Refining Co., 2,200 feet southwest of intersection of Harbor Boulevard and Frigate Avenue, Torrance quadrangle, Los Angeles Co. Medium grained sand. Collected by J.W. Valentine, spring, 1956. *Barnea*

subtruncata.

UCLA loc. 3602.— Pleistocene, Palos Verdes Sand. Near top of cut on east side of Western Avenue, 900 feet south of valley of lower George F Canyon, Torrance quadrangle, Los Angeles Co. *Ostrea lurida-Anomia peruviana* association in sand, overlying San Pedro Sand. Collected by J.W. Valentine, spring, 1956. *Chaceia ovoidea.*

UCLA loc. 3605.— Pleistocene. Terrace sands exposed in a building site cut at the end of Sunset Cliffs Street, 1/4 mile south of Ladera Street, Point Loma, San Diego Co. *Penitella* sp. cf. *P. penita, Parapholas californica, Nettastomella rostrata.*

UCLA loc. 3606.— Pleistocene. Sand at northeastern-most end of fossiliferous Pleistocene beds at Pacific Beach, San Diego Co. Collected by R.F. Meade and J.W. Valentine, winter, 1957. *Penitella penita.*

UCLA loc. 3657.— Pleistocene. Sand and gravel pit on west face of ridge north of oil sumps in N 1/2 NE 1/4 sec. 34, T. 5 S., R. 11 W., SBBM, Huntington Beach Mesa, Orange Co. Two foot pebble conglomerate in northeast corner of pit. Collected by P.U. Rodda and J.W. Valentine, spring, 1957. *Zirfaea pilsbryi.*

UCLA loc. 4243.— Pleistocene, fourth terrace. Cut along Fort McArthur Upper Reservation on the west side of Gaffey Street, 50 feet north of 38th Street, San Pedro, Los Angeles Co. Collected by R.F. Meade and J.W. Valentine. *Chaceia ovoidea* [fragment].

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UCMP loc. 51.— Error by Hanna, 1926; =W.S.W. Kew locality number.

UCMP loc. 305.— Miocene, Briones Sandstone. On northeast side of Shell Ridge about 1 mile west of east edge of Concord quadrangle. Elevation 700 feet. Collected by J.C Merriam [loc. 305]. *Zirfaea dentata.*

UCMP loc. 143.— Eocene, Tejon Group. South of Mt. Diablo, Mt. Diablo quad., NE 1/4 sec. 4, T. 1 S., R. 1 W., MDBM, Contra Costa Co. Near contact of Chico and Tejon "Formations." "*Pholadidea*, sp." [not seen].

UCMP loc. 360.— Miocene. Two-thirds of a mile southwest of Vallejo Junction, in bluff close to the railroad tracks at the lowest Miocene contact with the Martinez Formation. Collected by J.C. Merriam [loc. 408]. *Penitella* sp. indet.

UCMP loc. 476.— Eocene, Tejon Group. South of Mt. Diablo, Mt. Diablo quad., SW 1/4 NW 1/4 sec. 22, T. 1 S., R. 1 W., MDBM, Contra Costa Co. Elevation 1200 feet, in little wash near creek, below 1250 foot hill. Collected by W.S.W. Kew, 1912. "*Pholadidea*, sp." [not seen].

UCMP loc. 481.— Miocene, San Pablo group. In small gully leading southeast into Riggs Canyon, Black Hills, north of Tassajara, Contra Costa Co. *Astrodapsis whitneyi* zone, near center of NE 1/4 sec. 28, T. 1 S., R. 1 E., MDBM. "*Pholas*, sp. indt." [not seen].

UCMP loc. 482.— Miocene, San Pablo group. Near Alamo Creek, northwest of Tassajara, Contra Costa Co. Near center of south side of NW 1/4 sec. 28, T. 1 S., R. 1 E., MDBM. Elevation 1200 feet. "*Pholas*, sp. indt." [not seen].

UCMP loc. 490.— Miocene, San Pablo group. East of Riggs Canyon and north of Tassajara, Contra Costa Co., a little to east of center of south side of sec. 21, T. 1 S., R. 1 E., MDBM. "*Pholas*, sp. indt." [not seen].

UCMP loc. 492.— Miocene, San Pablo group. East of Riggs Canyon and north of Tassajara, Contra Costa Co., in SW 1/4 SE 1/4 sec. 21, T. 1 S., R. 1 E., MDBM. Elevation 1750 feet. *Zirfaea dentata.*

UCMP loc. 709.— Eocene, Tejon Group. On east side of Cave Point, Mt. Diablo quad., Contra Costa Co. Collected by R. E. Dickerson, 1912. "*Pholadidea*, sp." [not seen].

UCMP loc. 784.— Eocene, Martinez Group. Well at old brickyard, about 1/4 to 1/2 mile east and a little south of Lower Lake on Knoxville road, 1000 feet (horizontal) above the Chico-Martinez contact, Lake Co. NW 1/4 NE 1/4 sec. 11, T. 12 N., R. 7 W., MDBM. "*Martesia*(?), sp." [see *INCERTAE SEDIS*].

UCMP loc. 1131.— Oligocene, San Ramon Formation. One half mile southwest of the town of Walnut Creek, Contra Costa Co. In creek bed about 100 yards east of Oakley-Antioch Bridge. Elevation 150 feet. 37° 53' 07" N., 122° 04' 08" W. Collected by B.L. Clark [loc. 72]. *Penitella lorenzana.*

UCMP loc. 1430.— Eocene, Tejon Group. South of Mt. Diablo, Mt. Diablo quad., SE 1/4 sec. 11, T. 1 S., R. 1 W., MDBM, Contra Costa Co. On north side near top of 2018 foot hill. Collected in 1911. "*Pholadidea*, sp." [not seen].

UCMP loc. 1485.— Miocene, San Pablo group. On south side of Black Hawk Ridge, near Mt. Diablo, Contra Costa Co., near west edge of SE 1/4 NW 1/4 sec. 19, T. 1 S., R. 1 E., MDBM. Elevation about 1250 feet. "*Pholas*, sp. indet." [not seen].

UCMP loc. 1600.— Miocene, San Pablo group. About 2-1/2 miles east and a little south of Rodeo, Contra Costa Co., on south side of 700 foot hill near the head of a deep north-south gulch. *Zirfaea dentata.*

UCMP loc. 1607.— Miocene, San Pablo group. Near Tormey, Contra Costa Co., on hill over tunnel just south of Tormey railroad station, in coarse sandstone on north side of a quarry, and just west of a big oil tank. *Zirfaea dentata.*

UCMP loc. 1722.— Pliocene, Merced Formation. In a gulch a few yards east of the main coast road about 3/4 of a mile due southeast of Mussel Rock, San Mateo Co. Near the south side of NE 1/4 sec. 23, T. 3 S., R. 6 W., MDBM. *Zirfaea* sp. cf. *Z. pilsbryi.*

UCMP loc. 1891.— Miocene, San Pablo group. South of Pittsburg, on south side of 594 foot hill, very near the top, near center of SW 1/4 sec. 29, T. 2 N., R. 1 E., MDBM. *Zirfaea dentata.*

UCMP loc. 1905.— Pliocene, Purisima Formation. Sargent Oil Field, on slope of hill north of Pescadero Creek, west of Sargent, Santa Clara Co. *Zirfaea pilsbryi.*

UCMP loc. 2112.— Pleistocene, Palos Verdes Sand. "Cornwall. Arnold. San Pedro," Los Angeles Co. *Zirfaea pilsbryi.*

UCMP loc. 2300.— Miocene, Vaqueros Formation. North of Coalinga, near Oilfields, in canyon west of red cliffs in the NW cor. of SW 1/4 NE 1/4 sec. 10, T. 19 S., R. 15 E., MDBM, Fresno Co. Elevation 1250 feet. Collected by B.L. Clark [loc. 19]. *Zirfaea dentata.*

UCMP loc. 2309.— Miocene, Vaqueros Formation. Near Oil City, Fresno Co. Near section line on side of creek above SE corner of NE 1/4 NE 1/4 sec. 4, T. 19 S., R. 15 E., MDBM. Collected by B.L. Clark [loc. 51]. *Zirfaea dentata.*

UCMP loc. 2313.— Miocene, Vaqueros Formation. West of Oil City and north of Oilfields, in reef beds somewhat below the middle of the Vaqueros in NW 1/4 SE 1/4 sec. 16, T. 19 S., R. 15 E., MDBM, Fresno Co. Collected by B.L. Clark [loc. 205]. *Zirfaea dentata.*

UCMP loc. 2388.— Pleistocene. San Pedro, including Terminal Island, and Deadman Island, Los Angeles Co.

UCMP loc. 2668.— Pliocene, Etchegoin Formation. Southwest of Coalinga, in hills to north of Jacalitos Creek, near middle of north line of NE 1/4 SW 1/4 sec. 34, T. 21 S., R. 14 E., MDBM, Fresno Co. *Zirfaea* sp. cf. *Z. pilsbryi.*

UCMP loc. 3016.— Pliocene, Etchegoin Formation. Bank of creek in hills on northeast side of Priest Valley, Fresno Co. Southeast cor. NE 1/4 NE 1/4 sec. 14, T. 20 S., R. 12 E., MDBM. *Zirfaea pilsbryi.*

UCMP loc. 3030.— Pliocene, Fernando Formation. Thirty-four feet below surface in excavation for department store on 4th Street between Broadway and Hill Streets, Los Angeles, Los Angeles Co. Collected by J.G. Gilbert. *Penitella* sp. cf. *P. penita.*

UCMP loc. 3158.— Eocene, Meganos Formation. On top of ridge in the middle of north edge of SE 1/4 sec. 20, T. 1 N., R. 2 E., MDBM, Contra Costa Co. "*Jouannetia* sp." [see *Incertae sedis.*]

UCMP loc. 3159.— Eocene, Meganos Formation. On top of ridge in the NW cor. of SW 1/4 sec. 21, T. 16 N., R. 2 E., MDBM, Contra Costa. *Martesia meganosensis.*

UCMP loc. 3321.— Pliocene, Empire Formation. Basal beds of formation 150 yards east of Tunnel Point, Coos Bay, Coos Co., Oregon. Collected by H.V. Howe. "*Parapholas californica*" [not seen; probably *Penitella turnerae*].

UCMP loc. 3322.— Pliocene, Coos Conglomerate, Empire Formation. Three miles southwest of Empire, on South Slough, Coos Bay, Coos Co., Oregon. *Penitella turnerae.*

UCMP loc. 3577.— Eocene, Meganos Formation. On ridge immediately east of Hill 392, northeast of Mount Diablo. At west edge of Byron quadrangle, 1/4 mile southwest of L in Los Meganos. Collected by A.O. Woodford [loc. 458A]. *Martesia meganosensis.*

UCMP loc. 3776.— Eocene, "Martinez Formation." In SW 1/4 SE 1/4 sec. 23, T. 2 N., R. 18 W., SBBM, about 5300 feet N. 3° W. of 2150 foot hill in the Simi Hills, Ventura Co. About 900 feet north of main fork in creek, on west side of bottom of canyon, a little northeast of mouth of small canyon coming southeast. Elevation 1145 feet. *?Opertochasma* sp.

UCMP loc. 4194.— Oligocene, Keasey Formation. In shaley sandstone bluffs along Rock Creek, 1-1/2 miles below the Keasey Post Office, Keasey, Columbia Co., Oregon. Sec. 33, T. 5 N., R. 5 W., WBM. Collected by H.G. Schenck. *Martesia* sp.

UCMP loc. 5092.— Pleistocene. Bluffs at mouth of Tourmaline Street Canyon, Pacific Beach, city of San Diego, San Diego Co. Elevation 20 feet. Collected by Vorge and Hanna, summer, 1922 [loc. 255]. *Penitella penita.*

UCMP loc. 7098.— Pliocene, "Pico" Formation. South Mountain, about 500 feet north of an artificial cut in low ridge in SW cor. sec. 34, T. 3 N., R. 21 W., SBBM, Ventura Co. Collected by L.N. Waterfall. *Zirfaea pilsbryi.*

UCMP loc. 7180.— Miocene, ?Vaqueros Formation. On east side of small ridge in N center of SE 1/4 sec. 35, T. 10 N., R. 21 W., SBBM, just northwest of farthest southern spring in Neason's Flat, Kern Co. Collected by T.B. Stewart. *Zirfaea dentata.*

UCMP loc. A-87.— Pliocene, Empire Formation. In the vicinity of Coos Bay, Coos Co., Oregon. Sec. 3, T. 26 S., R. 14 W., WBM. Collected by H.G. Schenck [loc. S 110]. *Penitella turnerae.*

UCMP loc. A-218.— Pleistocene. Excavation in lot behind Seamen's Church Institute, E. First Street and Harbor Boulevard, San Pedro, Los Angeles Co. Collected by Simpson and Winterer. *Zirfaea pilsbryi.*

UCMP loc. A-221.— Pleistocene, Palos Verdes Sand. Large excavation on southern flank of Signal Hill, 1200 feet S. of summit and 500 feet NE of Junipero Avenue, city of Signal Hill, Los Angeles Co. Collected by Simpson and Winterer, January, 1927. *Zirfaea pilsbryi.*

UCMP loc. A-252.— Miocene, Vaqueros Formation. Along NE-SW ridge west of mouth of Wiley Canyon, Santa Clara Valley, Ventura Co. In alternating hard and soft sandstones and shaley sandstones of lower *Turritella inezana* zone, near south center of SE 1/4 sec. 34, T. 4 N., R. 19 W., SBBM. *Zirfaea dentata.*

UCMP loc. A-551.— Miocene, Vaqueros Formation. Between Ensenal Canyon and unnamed canyon to west, on abut 600-700 foot contour, Santa Monica Mountains, Los Angeles Co. Near south boundary line of SW 1/4 sec. 28, T. 1 S., R. 19 W., SBBM. Collected by W.H. Corey. *Zirfaea dentata.*

UCMP loc. A-557.— Miocene, Temblor Formation. Quarry at end of trail, east side of upper Malibu Canyon, 1/2 mile north of entrance to creek [?], Los Angeles Co. Collected ? by W.H. Corey. *Zirfaea* sp. cf. *Z. dentata.*

UCMP loc. A-649.— Pliocene, Etchegoin Formation. In NW 1/4 SW 1/4 sec. 24, T. 22 S., R. 15 E., MDBM, Fresno Co. *Zirfaea* sp. indet.

UCMP loc. A-650.— Pliocene, Etchegoin Formation. In west central part of NE 1/4 sec. 22, T. 21 S., R. 15 E., MDBM, Fresno Co. *Zirfaea pilsbryi.*

UCMP loc. A-1036.— Miocene, Temblor Formation. "Button Bed" on hill to east of Oil Canyon, just above southern boundary line of sec. 20, T. 19 S., R. 15 E., MDBM, Fresno Co. *Zirfaea dentata.*

UCMP loc. A-1483.— Pleistocene, [? Palos Verdes Sand]. Signal Hill, city of Signal Hill, Los Angeles Co. *Zirfaea pilsbryi.*

UCMP loc. A-2549.— Miocene. In small narrow gully just east of Union Oil Service Station [in 1936], on east

side of El Toro Valley, southwest of Salinas, Monterey Co. Just above northern boundary of T. 16 S., in SW 1/4 sec. 35, T. 15 S., R. 2 E., MDBM. Collected by A.G. Bennison [loc. 99], fall, 1936. *Penitella conradi.*

UCMP loc. A-2550.— Miocene, ?Monterey Formation. Near end of road leading north from Klondike Canyon (north off of Carmel Valley), Monterey Co. In sec. 1, T. 17 S., R. 2 E., MDBM. Collected by A.G. Bennison [loc. 101], fall, 1936. *Penitella* sp. cf. *P. conradi.*

UCMP loc. A-3101.— Pleistocene, Palos Verdes Sand. On west bluff of Upper Newport Bay, Orange Co. About 10-20 feet below brow of palisade in gray, loosely consolidated and cross bedded coarse sand, and below a buff-brown sandy clay. Collected by S.C. Bruff [loc. 75a]. *Zirfaea pilsbryi, Parapholas californica.*

UCMP loc. A-3104.— Pleistocene, Palos Verdes Sand. On west bluff of "middle" Newport Bay, Orange Co. Exposure of sands containing shells down to 50 feet below brow of cliff and unconformably overlying exposed anticline in the Monterey Shale. Collected by S.C. Bruff [loc. 80]. *Penitella penita.*

UCMP loc. A-3129.— Pleistocene, Palos Verdes Sand. Gully in westward facing escarpment on the Santa Ana River channel, 2 miles from the ocean, Costa Mesa, Orange Co. Fossils from a horizon 45 feet above the flood-plain and 30 feet below the terrace. Collected by S.C. Bruff [loc. 108], December, 1938. *Zirfaea pilsbryi.*

UCMP loc. A-3132.— Pleistocene, Palos Verdes Sand. In cliff opposite and north of Lido Isle, Newport Bay proper, Orange Co. Fossils in basal conglomerate below cross-bedded sand; saturated with oil and tar. Collected by S.C. Bruff [loc. 78], December, 1938. *Penitella gabbii, Parapholas californica.*

UCMP loc. A-3241.— Miocene, Santa Margarita Formation. East of Peachtree Valley, Monterey Co. Center of sec. 1, T. 21 S., R. 11 E., MDBM. Collected by N.L. Taliaferro and geology field class, June 10, 1937. *Zirfaea dentata.*

UCMP loc. A-3345.— Miocene, Temblor Formation. Near Oil City, in reef beds at top of hill running N-S in center of W 1/2 sec. 21, T. 19 S., R. 15 E., MDBM, Fresno Co. Collected by Paleontology 103 class, April 15, 1940. *Zirfaea dentata.*

UCMP loc. A-3415.— Miocene, Pismo Formation. Frazer property, about one mile southeast of the Huasna school house, San Luis Obispo Co. Near west central part of sec. 29, T. 23 S., R. 15 E., MDBM. Collected by J.O. Nomland and G.C. Gester, 1916. *Penitella* sp. indet.

UCMP loc. A-4261.— Miocene, Monterey Formation. In cliffs south of railroad tracks and 100 yards west of the Selby Railroad Station, Selby, Contra Costa Co. Collected by S.P. Welles, August, 1947. Unidentified small pholadid.

UCMP loc. A-4296.— Oligocene, San Ramon Formation. In facing roadcuts, 1-1/4 miles east of Muir Station on California State Highway 4 (Arnold Industrial Highway), Contra Costa Co. Collected by Paleontology 103 class, fall, 1947. *Penitella durhami.*

UCMP loc. A-7583.— Miocene, Temblor Formation. In reef beds paralleling Garza Creek in SE 1/4 SE 1/4 sec. 3, T. 23 S., R. 16 E., MDBM, Kings Co. From hard calcareous sandstones containing *Turritella ocoyana.* Collected by Paleontology 137 class, October 3, 1951. *Zirfaea dentata.*

UCMP loc. A-7762.— Oligocene, San Ramon Formation. On north side of California State Highway 4 (Arnold Industrial Highway) about 1/2 mile northeast of Atchison, Topeka, and Santa Fe Railroad tunnel (west of the turnoff to Avon), Contra Costa Co. Pholadids boring 1-3" below contact between Eocene Alhambra Formation and San Ramon Formation. Collected by J.W. Durham and J.H. Peck, Jr., December 8, 1951, and O.S. Adegoke, 1966. *Penitella durhami.*

UCMP loc. A-8709.— Pliocene or Pleistocene. Two miles southeast of Cape Blanco, SW 1/4 NE 1/4 sec. 12, T. 32 S., R. 16 W., WBM, Curry Co., Oregon. Poorly consolidated 12 foot conglomerate between massive sands in cliffs about 30 feet above sea level. Collected by Paleontology 137 class, September, 1952. *Penitella* sp. cf. *P. penita.*

UCMP loc. A-8712.— Pleistocene. About 200 feet south of access road to Cape Blanco Light House, Curry Co., Oregon. Fossils in basal 2 to 3 feet, conglomerate truncating steeply dipping older sediments. In center of NE 1/4 sec. 2, T. 32 S., R. 16 E., WBM. Collected by Paleontology 137 class, September, 1952. *Zirfaea pilsbryi.*

UCMP loc. A-9003.— Pleistocene. Small gully in terrace 250 feet along shore line north of the U.S.-Mexican border, southwestern San Diego Co. Soft poorly sorted sands with occasional cobbles and boulders overlying channeled Pliocene (?) sediments. Elevation 35 feet. 32° 32' 05.7" N., 117° 07' 19.5" W. Collected by R.O. Fox, J.W. Emerson, W.K. Emerson, and W.O. Addicott. *Zirfaea pilsbryi* [*in situ*].

UCMP loc. A-9004.— Pleistocene. North face of terrace, 700 feet north of U.S.-Mexican Boundary Monument 258, southwestern San Diego Co. Gray, fine grained, unconsolidated sand from 1 to 3 inches thick overlying sandy siltstone of the Pliocene San Diego Formation. Elevation 20-25 feet. Collected by R.O. Fox, J.W. Emerson, and W.K. Emerson [loc. E305]. *Zirfaea pilsbryi.*

UCMP loc. A-9005.— Pleistocene. Northwest face of terrace, 700 feet north and 600 feet east of U.S.-Mexican Boundary Monument 258, southwestern San Diego Co. Highly fossiliferous, gray, well sorted, fine grained sand, 6-12 inches thick, exposed in cut along road to Boundary Monument. 32° 32' 10.6" N. lat., 117° 07' 11.5" W. long. Elevation 30 feet. Collected by R.O. Fox, J.W. Emerson, W.K. Emerson [loc. E-307], and W.O. Addicott. *Zirfaea pilsbryi.*

UCMP loc. A-9006.— Pleistocene. North face of terrace immediately east of 250 foot wide, north trending ravine and 1,750 feet inland from the ocean, southwestern San Diego Co. Poorly sorted sand with occasional cobbles, from 4-8 inches thick, and overlying a boulder conglomerate. 32° 32' 09.4" N. lat., 117° 07' 06.3" W. long. Collected by R.O. Fox, J.W. Emerson and W.K. Emerson [loc. E-306]. *Zirfaea pilsbryi.*

UCMP loc. A-9587.— Pleistocene. Terrace remnant 1200 feet south from shore line angle from Punta Cabras,

Baja California, Mexico. White coquina strata, four feet thick, forming a broad bench about 12 feet above sea level and overlying an alternating brown sandstone and pebble conglomerate of late Cretaceous age. 31° 19' 03" N. lat., 116° 26' 25" W. long. Collected by W.O. Addicott, February 7, 1953, and W.K. Emerson, June, 1953. *Zirfaea pilsbryi*, "*Penitella* cf. *P. penita*" [not seen].

UCMP loc. A-9589.— Pleistocene. Sea cliff approximately 3/4 of a mile north of Punta Cabras, Baja California, Mexico. Fossils from pockets of fine grained sand in well indurated, four foot thick, basal conglomerate overlying Cretaceous sandstone and underlying 30 feet of unfossiliferous sands. 31° 19' 45" N. lat., 116° 27' 05" W. long. Collected by W.O. Addicott [loc. 227], February 7, 1953. "*?Zirfaea pilsbryi*" [not seen].

UCMP loc. A-9590.— Pleistocene. First rocky point NNE of Punta Baja, Baja California, Mexico. Poorly sorted, unconsolidated, sandy gravel with small boulders, 4 feet thick, and overlying a well indurated upper Cretaceous conglomerate. 29° 57' 32" N. lat., 115° 44' 35" W. long. Collected by W.O. Addicott [loc. 229], February 9, 1953. *Zirfaea pilsbryi.*

UCMP loc. A-9591.— Pleistocene. Sea cliff at intersection of sea cliff and mouth of small south trending ravine about 1-1/2 miles east of Punta Baja, and on north shore of Bahia del Rosario, Baja California, Mexico. Outcrop from 1 to 4 feet thick, exposed 12 feet above sea level in face of cliff. Lithology same as at UCMP loc. A-9590. 29° 57' 35" N. lat., 115° 47' 15" W. long. Collected by W.O. Addicott [loc. 228] and W.K. Emerson, February 9, 1953. *Zirfaea pilsbryi.*

UCMP loc. A-9713.— Pleistocene. Terrace deposit 4700 feet south from shore line angle from Punta Cabras, Baja California, Mexico. Abundantly fossiliferous calcareous sandstone containing well-rounded cobbles and boulders of upper Cretaceous sandstone at the base. Collected by W.K. Emerson, November, 1953. *Zirfaea pilsbryi.*

UCMP loc. A-9731.— Miocene, Santa Margarita Formation. Bed of Domengine Creek, Fresno Co. NW 1/4 SW 1/4 sec. 34, T. 18 S., R. 15 E., MDBM. Orange to buff sand and clay with abundant filled borings. Collected by Paleontology 137 class, September, 1953. *Zirfaea dentata.*

UCMP loc. A-9738.— Pliocene, ? Etchegoin Formation. Down embankment in north fork in road in SE 1/4 NE 1/4 SW 1/4 sec. 7, T. 22 S., R. 18 E., MDBM, La Cuesta, Kettleman Hills, Kings Co. Lower *Mulinia* zone? Collected by Paleontology 137 class, September, 1953. *Zirfaea pilsbryi.*

UCMP loc. A-9739.— Miocene, Temblor Formation. From the gullies east of Big Tar Canyon Road, Kings Co. *Turritella* zone 500 feet north of north edge of prominent rock spine of Reef Ridge. NE 1/4 NE 1/4 NE 1/4 sec. 18, T. 23 S., R. 17 E., MDBM. Collected by Paleontology 137 class, September, 1953. *Zirfaea dentata.*

UCMP loc. A-9742.— Miocene, Temblor Formation. From gullies east of Big Tar Canyon Road, Kings Co. Mixed zone 800 feet north of north edge of prominent rock spine of Reef Ridge. Collected by Paleontology 137 class, September, 1953. *Zirfaea dentata.*

UCMP loc. A-9917.— Pleistocene. Marine terrace 3700 feet south along coast from Punta Cabras, Baja California, Mexico. Subheadlands on 30 foot terrace, in 1/2-1 foot poorly consolidated sandstone bed. Collected by W.K. Emerson [loc. E-1002], November 12, 1953. *Zirfaea pilsbryi.*

UCMP loc. B-469.— Pleistocene, Palos Verdes Sand. Gaffey Street anticline, opposite the San Pedro Lumber Co., 4300 feet northeast of intersection of Harbor Boulevard and Pacific Avenue, San Pedro, Los Angeles Co. Eight foot thick fossiliferous layer of gray silty sand. Collected by E.P. Chace, and by Chace and W.K. Emerson, December, 1953. *Barnea subtruncata, Zirfaea pilsbryi.*

UCMP loc. B-2178.— Pliocene, Etchegoin Formation. Gabilan Range about 7 miles NNW of Pinnacles, San Benito Co. Center of east boundary line of SW 1/4 SW 1/4 sec. 21, T. 15 S., R. 7 E., MDBM. Collected by I.E. Wilson, July 22, 1940. *Zirfaea pilsbryi.*

UCMP loc. B-3007.— Pleistocene. Terrace deposit at about 40 foot elevation N. 30° E. of peak on south side of entrance to Turtle Bay, Baja California, Mexico. Collected by E.C. Allison, June 18, 1956. *Chaceia ovoidea, Penitella penita.*

UCMP loc. B-3027.— Pleistocene. Terrace immediately behind long sandy beach along southwest portion of peninsula northwest of Turtle Bay, Baja California, Mexico. Elevation 15 to 20 feet. Collected by E.C. Allison, June 27, 1956. *Zirfaea pilsbryi, Penitella penita.*

UCMP loc. B-3033.— Miocene. Along east side of air field at summer camp site east and northeast of the village at Turtle Bay, Baja California, Mexico. Megafossils from sandy horizons at base of white shale, and immediately overlying Cretaceous-Miocene unconformity. Collected by E.C. Allison, June 28, 1956. Small sand filled pholadid burrows.

UCMP loc. B-3050.— Pleistocene. Terrace along shore on northeast side of Turtle Bay, Baja California, Mexico. Elevation 15 to 20 feet. Collected by E.C. Allison, July 3, 1956. *Zirfaea pilsbryi.*

UCMP loc. B-4339.— Miocene, Temblor Formation. "Button Bed" near ridge on steep hill south of Big Tar Canyon, Kings Co. 700 feet south of BM 1307, in NE 1/4 NE 1/4 NE 1/4 sec. 18, T. 23 S., R. 17 E., MDBM. Collected by Paleontology 137 class, September, 1956. *Zirfaea dentata.*

UCMP loc. B-4793.— Pliocene, "Merced" Formation. Intertidal zone on Moss Beach, 200 feet S. 28° [W.] from mouth of first unnamed intermittant stream north of San Vicente Creek, Moss Beach, San Mateo Co. Collected by William and Marilyn Glen, fall, 1956. *Zirfaea pilsbryi, Parapholas californica.*

UCMP loc. B-4928.— Pliocene, ? Paso Robles Formation. Northwest of Jolon, Monterey Co. SW 1/4 SW 1/4 sec. 9, T. 22 S., R. 7 E., MDBM. Collected by Robert Weidman, ? 1955. *Zirfaea pilsbryi.*

UCMP loc. B-6511.— Miocene, Temblor Formation. Highest two (of four) *Turritella* ledges cropping out along north bank of Garza Creek, Kings Co. Sec. 3, T. 23 S., R. 16 E., MDBM. Collected by O.S. Adegoke.

Zirfaea dentata.

UCMP loc. B-6518.— Miocene, Temblor Formation. Ledges conspicuously exposed from slope of hill west of Baby King Canyon westward to hill that flanks the east bank of Garza Creek, Kings Co. Hard, coarse, gray sandstone ledges overlying main "Reef Beds" and containing *Turritella*. Sec. 11, T. 23 S., R. 16 E., MDBM. Collected by O.S. Adegoke, ? 1963. *Zirfaea dentata.*

UCMP loc. B-6534.— Pliocene, Etchegoin Formation [Jacalitos "stage"]. In cut in road to Shell Oil well 155-15, in sec. 15, T. 19 S., R. 15 E., MDBM, Fresno Co. Collected ? by O.S. Adegoke, 1963. *Zirfaea dentata.*

UCMP loc. B-6537.— Pliocene, San Joaquin Formation. Reef Ridge quadrangle, sec. 22, T. 22 S., R. 16 E., MDBM, 2310 feet north, 870 feet east. From coarse, brown, gravelly sandstone bed cropping out along crest of hill. *Zirfaea pilsbryi.*

UCMP loc. B-6538.— Pliocene, San Joaquin Formation. South slope of hill, 10 feet below crest, in sec. 22, T. 22 S., R. 16 E., MDBM, Kings Co. Collected by O.S. Adegoke, ? 1963. *Zirfaea pilsbryi.*

UCMP loc. B-7085.— Miocene, Temblor Formation. Near Oil Canyon, Oil City — Oilfields region, Fresno Co. "Button Bed" near top of hill in center of NW 1/4 SW 1/4 sec. 21, T. 19 S., R. 15 E., MDBM. Collected by Paleontology 137 class, October, 1959. *Zirfaea dentata.*

UCMP loc. B-7086.— Miocene, Temblor Formation. Float on hillside below UCMP loc. B-7085, and about 75 yards west of the NE corner of NW 1/4 SW 1/4 sec. 21, T. 19 S., R. 15 E., MDBM, Fresno Co. Collected by Paleontology 137 class, October, 1959. *Zirfaea dentata.*

UCMP loc. B-7493.— Pleistocene. Sea cliff on south side of Grave Point, three-fourths of a mile southwest of Bandon, Coos Co., Oregon. 10-20 foot thick bed of poorly sorted unconsolidated sandstone with subrounded pebbles. Collected in 1960. "Pholadid species" [not seen].

UCMP loc. B-7727.— Pliocene, San Joaquin Formation. Kettleman Hills, Fresno [? Kings] Co. Collected by A.C. Hall. *Zirfaea pilsbryi, Nettastomella rostrata, Pholadopsis* sp. cf. *P. pectinata*, unidentified pholadid burrows.

UCMP loc. B-8348.— Pliocene, Merced Formation. Road cut about 1/4 mile west of Page Mill Road on Arastradero Road, Santa Clara Co. Conglomeratic sands with abundant fossil material at the base of the Merced. 37° 23' 08" N., 122° 10' 09" W. Collected by R.J. Fleck, October 7, 1963. *Zirfaea pilsbryi.*

UCMP loc. B-8579.— Miocene, Temblor Formation. Near Gres Canyon, N 1/2 NE 1/4 NW 1/4 sec. 12, T. 14 S., R. 11 E., MDBM, Fresno Co. Fine grained sandstone, near contact of basal Temblor. Collected by Paleontology 237 class, September, 1964. *Zirfaea* sp. indet., *Penitella* sp. indet.

UCMP loc. B-8589.— Pliocene, San Joaquin Formation. Crest of ridge paralleling the eastern tributary to Arroyo Murado, North Dome, Kettleman Hills, Kings Co. In SE 1/4 sec. 6, T. 22 S., R. 18 E., MDBM. *Pecten coalingaensis* zone. Collected by Paleontology 237 class, September, 1964. *Zirfaea pilsbryi.*

UCMP loc. B-8605.— Miocene, Santa Margarita Formation. South bank of Salt Creek, 1000 feet west of east boundary of sec. 11, T. 18 S., R. 14 E., MDBM, Fresno Co. Massive fine grained sandstone. Collected by William Read, October 27, 1960. *Zirfaea* sp. indet.

UCMP loc. B-8609.— Miocene, Temblor Formation. West bank of stream 2000 feet NNW of SE corner of sec. 32, T. 17 S., R. 14 E., MDBM, Fresno Co. Light grained, resistant sandstone. Collected by William Read, October 4, 1960. *Zirfaea dentata.*

UCMP loc. D-115.— Miocene, Temblor Formation. Oil City — Oilfield region north of Coalinga, Fresno Co. In SW 1/4 NW 1/4 sec. 21, T. 19 S., R. 15 E., MDBM, 500 feet southwest of hill 2021. Collected by Paleontology 237 class, September, 1962. *Zirfaea dentata.*

UCMP loc. D-116.— Miocene, Temblor Formation. Float below UCMP loc. D115. *Zirfaea dentata.*

UCMP loc. D-330.— Pliocene, San Joaquin or Etchegoin formations. Near El Rascador, 1250 feet ESE of hill 1054, North Dome, Kettleman Hills, Kings Co. SE 1/4 SE 1/4 SE 1/4 NE 1/4 NE 1/4 sec. 17, T. 22 S., R. 18 E., MDBM. Coarse blue sandstone below Cascajo Conglomerate (*s.s.*). Collected by C.T. Williams, October, 1967. *Zirfaea pilsbryi.*

UCMP loc. D-390.— Pleistocene, Palos Verdes Sand. Second and Mesa Streets, San Pedro, Los Angeles Co. Collected ? by J.W. Durham, 1961. *Zirfaea pilsbryi.*

UCMP loc. D-599.— Miocene, "Monterey Group." From a bank on the southeast side of Interstate Highway 80, near the turn off to Crockett, Contra Costa Co. Pholadid borings from irregular contact 150 feet above present road bed. T. 2 N., R. 3 W., MDBM. Collected by J.W. Durham and D. Alsip, 1958. *Penitella* sp. cf. *P. lorenzana.*

UCMP loc. D-1048.— Miocene, Temblor Formation. East of Big Tar Canyon Road, in sec. 18, T. 23 S., R. 17 E., MDBM, Kings Co. Brown indurated sandstone ledge overlying UCMP loc. A-9739. Collected by O.S. Adegoke, ? 1963. *Zirfaea dentata.*

UCMP loc. D-1059.— Miocene, Temblor Formation. From the lowest two of four *Turritella* beds that crop out on north bank of Garza Creek, Reef Ridge quadrangle, sec. 3, T. 23 S., R. 16 E., MDBM, 1085 feet north, 1390 feet west. Collection was made intermittently for about 200 feet downstream below the eastward bend in the creek. *Zirfaea dentata.*

UCMP loc. D-1066.— Miocene, Temblor Formation. Northwest of Dirty Spring, on east slope of hill 2168, Reef Ridge, Fresno Co. Sec. 33, T. 22 S, R. 16 E., MDBM, 650 feet north, 3,400 feet west. Conglomeratic sandstone ledge. Collected by O.S. Adegoke, ? 1963. *Zirfaea dentata.*

UCMP loc. D-1072.— Miocene, Temblor Formation. Domengine Ranch quadrangle, in sec. 20, T. 19 S., R. 15 E., MDBM, 850 feet north, 2130 feet east. Collected from top of loc. D-1071 to base of white diatomaceous shale ("Indicator" bed). Lateral extent of collection about 400 feet. *Zirfaea dentata.*

UCMP loc. D-1073.— Miocene, Temblor Formation. 800 feet laterally along slope of hill east of Oil Canyon, Fresno Co. Sec. 20, T. 19 S., R. 15 E., MDBM, 600 feet north, 2,400 feet east. Stratigraphically above white diatomaceous shale. Collected by O.S. Adegoke, ? 1963.

Zirfaea dentata.

UCMP loc. D-1076.— Miocene, Temblor Formation. From the lowest three gray-white calcareous sandstone ledges cropping out on the west slope of hill 2021, Domengine Ranch quadrangle, in sec. 21, T. 19 S., R. 15 E., MDBM, 1800 feet south, 1100 feet east. Lateral extent of collection about 300 feet. *Zirfaea dentata.*

UCMP loc. D-1078.— Miocene, Temblor Formation. Oil City — Oilfield region north of Coalinga, Fresno Co. Sec. 21, T. 19 S., R. 15 E., MDBM, 2200 feet south, 1080 feet east. From very prominent reddish-brown sandstone ledges. Collected by O.S. Adegoke, ? 1963. *Zirfaea dentata.*

UCMP loc. D-1124.— Pliocene, Etchegoin Formation. Reef Ridge quadrangle, in sec. 6, T. 23 S., R. 17 E., MDBM, 1510 feet north, 1400 feet west. Buf colored concretionary mudstone overlying coarse blue sandstone bed, poorly exposed on northeast slope of hill. Fossil bed about 125 feet below base of basal San Joaquin Formation. "*Pholadidea* sp. cf. *P. penita*" [not seen].

UCMP loc. D-1203.— Pliocene, San Joaquin Formation. Domengine Ranch quadrangle, in sec. 24, T. 19 S., R. 15 E., MDBM, 1975 feet north, 2130 feet west. From northwest slope of hill, about 50 feet above creek bed. Fossils in hard concretions, "exposures" of which are rather poor. *Zirfaea pilsbryi.*

UCMP loc. D-1627.— Pleistocene. San Pedro Bluffs, Second and Beacon Streets, San Pedro, Los Angeles Co. Collected by Ralph Arnold. *Zirfaea pilsbryi.*

UCMP loc. D-2845.— Pliocene, Sisquoc Formation. NTU asphalt mine, 3-1/3 miles NNW of Casmalia, Santa Barbara Co. Throughout quarry, but mostly from talus slope at base of southern cliff. Outcrop of tar sands. 34° 53' 28" N., 120° 33' 20" W. Collected by J.C. Holden, September 26, 1965. *Penitella* sp. cf. *P. gabbii*, *P.* sp. cf. *P. turnerae.*

UNIVERSITY OF OREGON (EUGENE)

UO loc. 80.— Oligocene, Eugene Formation. Beneath the cemetery in a prominent cut on the main line of the Southern Pacific Railroad in SW 1/4 sec. 34, T. 17 S., R. 3 W., WBM, Eugene quadrangle, Lane Co., Oregon. *Martesia* sp.

UO loc. 2544.— Oligocene, Eugene Formation. Excavation for Science II Annex, University of Oregon campus, Eugene, Lane Co., Oregon. S 1/2 sec. 32, T. 17 S., R. 3 W., WBM. *Martesia* sp.

UO loc. 2553.— Oligocene, Eugene Formation. Roadcuts along Interstate Freeway 5 in NW 1/4 sec. 3, T. 18 S., R. 3 W., WBM, Eugene quadrangle, Lane Co., Oregon. *Martesia* sp., *Opertochasma turnerae.*

UO loc. 2554.— Oligocene, Eugene Formation. At base of hill on east side of Interstate Freeway 5 in NW 1/4 sec. 3, T. 18 S., R. 3 W., WBM, Eugene quadrangle, Lane Co., Oregon. Gray tuffaceous siltstone with layers of concentrated fossil shells. *Martesia* sp.

UNITED STATES GEOLOGICAL SURVEY (WASHINGTON, D.C.)

[A number of the following collections are now housed at the Menlo Park Branch.]

USGS loc. 93.— Miocene. Lake Co. Collected ? by H.W. Turner, December 14, 1882. *Zirfaea dentata.*

USGS loc. 104.— Miocene. "Locality 13. Martineze. California (See old register). H.W. Turner coll.". *Zirfaea dentata.*

USGS loc. 2463.— Pleistocene. San Pedro, Los Angeles Co. Collected by R.E.C. Stearns, 1892. *Zirfaea pilsbryi*, *Penitella penita.*

USGS loc. 2954.— Pliocene, Empire Formation. Near Empire City, Coos Bay, Coos Co., Oregon. *Penitella turnerae.*

USGS loc. 3751.— Pleistocene. Peluche [Peluk] Creek, Seward Peninsula, Alaska. Collected ? by A.H. Brooks. *Penitella kamakurensis.*

USGS loc. 3752.— Pleistocene, "Second Beach." Mine dump on claim 2, Peluk Creek, near Nome, Seward Peninsula, Alaska. Collected by F.L. Hess, 1903. *Penitella kamakurensis.*

USGS loc. 3857.— Pliocene, Imperial Formation. Carrizo Creek, San Diego Co. Collected by Stephen Bowers, 1903. *Cyrtopleura costata.*

USGS loc. 3921.— Pliocene, Imperial Formation. Barrett's Oil Well, about 20 miles north of the U.S.-Mexican border, Imperial Co. Sec. 11, T. 15 S., R. 9 E., SBBM. Collected by Stephen Bowers, 1904. *Cyrtopleura costata.*

USGS loc. 4472.— Pliocene, Sisquoc Formation. Pennsylvania asphalt mine, 3-1/2 miles southeast of Orcutt, Santa Barbara Co. Collected by Ralph Arnold, 1906. *?Zirfaea pilsbryi, Penitella turnerae, P. gabbii.*

USGS loc. 4473.— Pliocene, Foxen Mudstone. Waldorf asphalt mine, 3 miles SSE of Guadalupe, Santa Barbara Co. Collected by Ralph Arnold, 1906. *Penitella gabbii, P. turnerae.*

USGS loc. 4475.— Pliocene, Careaga Sandstone, Cebada Member. Fugler Point asphalt mine, 1 mile NNW of Garey, Santa Barbara Co. Collected by Ralph Arnold, 1906. *Penitella gabbii, P.* sp. indet.

USGS loc. 4476.— Pliocene. Asphaltum layer above Monterey Shale near Folsom well no. 3, Santa Maria oil fields, 3 miles southeast of Orcutt, Santa Barbara Co. Collected by Ralph Arnold, 1906. *Penitella penita.*

USGS loc. 4500.— Pleistocene [?]. In Miocene shale in asphalt mine at Carpinteria, Santa Barbara Co. Collected by Ralph Arnold. *Penitella* sp. indet.

USGS loc. 4506.— Pliocene, Fernando Formation. One mile southeast of summit of Redrock Mountain, along ridge near 1700 foot knob, Santa Barbara Co. Collected by Robert Anderson, October, 1906. *Zirfaea* sp. indet.

USGS loc. 4625.— Miocene, Vaqueros Formation. "Reef beds" in Sulphur Spring Canyon, Kings Co. Sec. 23, T. 22 S., R. 16 E., MDBM. *Zirfaea dentata.*

USGS loc. 4627.— Miocene, Vaqueros Formation. "Reef beds" just west of Big Tar Canyon, Kings Co. North part of sec. 18, T. 23 S., R. 16 E., MDBM. *Zirfaea dentata.*

USGS loc. 4632.— Miocene, Santa Margarita Formation. At, and northwest of the San Joaquin Valley Coal Mine, near the Miocene-Eocene contact, Fresno Co. Sec. 26, T. 20 S., R. 14 E., MDBM. Collected by Ralph Arnold, 1907. *Zirfaea dentata.*

USGS loc. 4633.— Miocene, Vaqueros Formation. *Turritella* bed about 11 miles north-northeast of Coalinga, Fresno Co. On ridge, just below "Big Blue" in sec. 10, T. 19 S., R. 15 E., MDBM. Collected by Ralph Arnold, 1907. *Zirfaea dentata* [not seen].

USGS loc. 4710.— Pliocene, Etchegoin Formation. North side of ravine, 3/4 miles northwest of BM 806 on Zapato Creek, Fresno Co. *Pecten coalingaensis* zone, in west central part of NE 1/4 sec. 5, T. 22 S., R. 16 E., MDBM. *Zirfaea pilsbryi.*

USGS loc. 4745.— Pliocene, Jacalitos Formation. "Big *Trophon* bed" on ridge south of Garcas Creek, Kings Co. Sec. 2, T. 23 S., R. 16 E., MDBM. Collected by Ralph Arnold, 1905. *Zirfaea* sp. indet.

USGS loc. 4750.— Pliocene, Etchegoin Formation. On ridge south of Garcas Creek, Kings Co., 2700 feet stratigraphically above USGS loc. 4745. Collected by Ralph Arnold. *Penitella* sp. indet.

USGS loc. 4758.— Pliocene, Etchegoin Formation. East side of 1900 foot hill near Henry Spring, 4 miles SSW of Coalinga, Fresno Co. SW 1/4 sec. 18, T. 21 S., R. 15 E., MDBM. *Zirfaea pilsbryi.*

USGS loc. 4803.— Miocene, Vaqueros Formation. On Laval grade, 8-1/2 miles north of Coalinga, Fresno Co. "Button bed" 200± feet above Eocene unconformity in SW 1/4 sec. 21, T. 19 S., R. 15 E., MDBM. *Zirfaea dentata.*

USGS loc. 5718.— Eocene, Lodo Formation. Foothills between Ortigalito and Little Panoche Creeks, west side of the San Joaquin Valley, Merced Co. Near top of hill on east side of strike valley, at center of north line of sec. 19, T. 12 S., R. 11 E., MDBM. Basal part of Eocene gray sandstone overlying the Cantua Shale. Collected by R.W. Pack and E.L. Ickes, July, 1910. *Martesia tolkieni.*

USGS loc. 5802.— Miocene, Temblor Formation. Cantua district, 4.5 miles southeast of Ciervo Mountain, Ciervo Hills, in SE 1/4 sec. 12, T. 17 S, R. 13 E., MDBM. Collected by R.W. Pack, September, 1909. *Zirfaea dentata.*

USGS loc. 5828.— Miocene, Santa Margarita Formation. Cantua district, Big Blue Hills, 2-1/2 miles northwest of Domengine place, on east face of blue serpentine conglomerate hills west of longitudinal valley of Martinez Creek, Fresno Co. Collected by R. Anderson and Olaf Jenkins, August, 1909. *Zirfaea dentata.*

USGS loc. 5829.— Miocene, Santa Margarita Formation. Cantua district, about 1-1/2 miles up Cantua Creek from the San Joaquin Valley, 1/3 mile up stream from where creek turns from southeast to northeast, Fresno Co. Near center of west line of SE 1/4 sec. 34, T. 17 S., R. 14 E., MDBM. Collected by R.W. Pack, September, 1909. *Zirfaea dentata.*

USGS loc. 6847.— Pliocene, Imperial Formation. Ravine about 1 mile south of Alverson Canyon, Carrizo Mountain, Imperial Co. Collected by Stephen Bowers and W.C. Mendenhall, ? January 20, 1904. *Cyrtopleura costata.*

USGS loc. 7498.— Pleistocene. San Quintin, Baja California, Mexico. Collected by C.R. Orcutt, November, 1887. *Zirfaea pilsbryi.*

USGS loc. 7499.— Pleistocene. "*Turritella* bed, south side of wharf," San Quintin, Baja California, Mexico. Collected by C.R. Orcutt, November, 1887. *Zirfaea pilsbryi.*

USGS loc. 9156.— ? Pliocene. Bluffs opposite San Antonio Ranch, "Cudije" [?] Arroyo, Baja California, Mexico. Collected by W.S.W. Kew, 1920. [Two modes of preservation are represented.] *Zirfaea pilsbryi, Penitella* sp. indet.

USGS loc. 9330.— Neogene. Arroyo 11 miles north and 5 miles west of La Purisima, Baja California, Mexico. *Parapholas* sp. indet.

USGS loc. 9393.— Pliocene. About 2 miles north of pump station #3, on spur ridge on south side of ridge east of canyon road, Priest Valley quadrangle, Fresno Co. In center of SW 1/4 sec. 24, T. 20 S., R. 12 E., MDBM. Basal bed of formation above the Etchegoin. Collected by R.W. Pack, "9/11/13." *Penitella gabbii.*

USGS loc. 10057.— Pliocene or Pleistocene. Rosario, Baja California, Mexico. Collected by J.B. Orynski, 1920. *Penitella penita.*

USGS loc. 10058.— Pliocene or Pleistocene. Fine conglomerate and float on beach southwest of Rosario, Baja California, Mexico. Collected by J.B. Orynski, 1920. *Penitella* sp. cf. *P. penita.*

USGS loc. 10460.— Pleistocene. Near top of sea cliff about 150 feet above sea level, near Resort Point, city of Palos Verdes Estates, Los Angeles Co. Thin layer of rocks, gravel, and sand, lightly indurated in spots. Collected by E.P. Chace, May 6, 1923. *Penitella* sp. indet.

USGS loc. 11729.— Pleistocene. San Quintin Bay, Baja California, Mexico. Collected by C.R. Orcutt. *Zirfaea pilsbryi.*

USGS loc. 12132.— Pleistocene, Palos Verdes Sand. Cut on west side of Pacific Avenue, midway between Oliver and Bonita Streets, San Pedro, Los Angeles Co. Collected by W.P. Woodring, July 14, 1930. *Zirfaea pilsbryi, Penitella penita.*

USGS loc. 12134.— Pleistocene, Palos Verdes Sand. East side of Palos Verdes Street, 75 feet north of Third Street, San Pedro, Los Angeles Co. Collected by W.P. Woodring, July 21, 1930. *Zirfaea pilsbryi.*

USGS loc. 12138.— Pleistocene, Palos Verdes Sand. In Fort McArthur Lower Reservation, on north side of ravine 350 feet SE of [old] foot of 22nd Street [now intersection of 22nd and Mesa Streets], San Pedro, Los Angeles Co. Collected by W.P. Woodring, July 26, 1930. *Zirfaea pilsbryi.*

USGS loc. 12139.— Pleistocene, Palos Verdes Sand. On south side of deep ravine in bluff east of Gaffey Street, 2350 feet N. 4° E. of [old] intersection of Harbor Boulevard and Gaffey Street, San Pedro, Los Angeles Co. Collected by W.P. Woodring, August 2, 1930. *Penitella penita.*

USGS loc. 12141.— Late Pleistocene. Bluff along Harbor Boulevard [now Wilmington and San Pedro Road], 4400

feet N. 55° E. of the [old] intersection of Harbor Boulevard and Gaffey Street, midway between entrance to San Pedro Lumber Co., San Pedro, Los Angeles Co. Collected by W.P. Woodring, August 2, 1930. [?] *Zirfaea pilsbryi.*

USGS loc. 12192.— Pleistocene. Top of sea cliff 300 feet north of Flatrock Point, city of Palos Verdes Estates, Los Angeles Co. Collected by W.P. Woodring, September 18, 1930. *Penitella conradi.*

USGS loc. 12257.— Pleistocene, Lomita Marl. Foot of waterfall in ravine north of Hawthorne Street, community of Walteria, city of Torrance, Los Angeles Co. 2600 feet W. 7° S. of intersection of Hawthorne Street and Pacific Coast Highway. Collected by W.P. Woodring, August 25, 1930. *Penitella* sp. indet.

USGS loc. 12327.— Pliocene, San Joaquin Formation. North fork of Arroyo Bifido, North Dome, Kettleman Hills, Kings Co. Sec. 35, T. 21 S., R. 17 E., MDBM. *Pecten* zone. Collected by Ralph Stewart. Unidentified pholadid burrow.

USGS loc. 12328.— Pliocene, San Joaquin Formation. Across small gully (200 feet east of USGS loc. 12327), north fork of Arroyo Bifido, North Dome, Kettleman Hills, Kings Co. Sec. 35, T. 21 S., R. 17 E., MDBM. *Pecten* zone. Collected by Ralph Stewart. Unidentified small pholadid in burrow.

USGS loc. 12336.— Pliocene, San Joaquin Formation. Near west fork of Arroyo Hondo, North Dome, Kettleman Hills, Kings Co. Sec. 5, T. 22 S., R. 18 E., MDBM. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 12365.— Pliocene, San Joaquin Formation. La Lomica, south end of North Dome, Kettleman Hills, Kings Co. Center of southern boundary line of sec. 6, T. 23 S., R. 19 E., MDBM. Collected by Ralph Stewart. *Pholadopsis pectinata.*

USGS loc. 12370a.— Pliocene, San Joaquin Formation. Arroyo del Camino, west flank of Nortn Dome, Kettleman Hills, Kings Co. Sec. 10, T. 22 S., R. 17 E., MDBM. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 12372.— Pliocene, San Joaquin Formation. Arroyo del Camino, west flank of North Dome, Kettleman Hills, Kings Co. Sec. 15, T. 22 S., R. 17 E., MDBM. *Acila* zone. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 12373.— Pliocene, San Joaquin Formation. Arroyo Somero, North Dome, Kettleman Hills, Kings Co. Sec. 14, T. 22 S., R. 17 E., MDBM. *Pecten* zone. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 12374.— Pliocene, San Joaquin Formation. Arroyo Conchoso, North Dome, Kettleman Hills, Kings Co. Sec. 19, T. 22 S., R. 18 E., MDBM. *Pecten* zone? Collected by Ralph Stewart. *Pholadopsis pectinata.*

USGS loc. 12421.— Pliocene, Etchegoin Formation. West side of ridge extending north from El Chichon, North Dome, Kettleman Hills, Kings Co. Sec. 12, T. 22 S., R. 17 E., MDBM. *Macoma* zone. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 12424.— Pliocene, Etchegoin Formation. South slope of east end of El Serrijon, North Dome of Kettleman Hills, Kings Co. *Macoma* zone. Collected by Ralph Stewart [loc. 280S]. *Zirfaea pilsbryi.*

USGS loc. 12426.— Pliocene, Etchegoin Formation. Fork of Arroyo Doblegado, southeast of Las Paredes, North Dome, Kettleman Hills, Kings Co. Sec. 17, T. 22 S., R. 18 E., MDBM. Twenty feet below barnacle layer. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 12511.— Pliocene, San Joaquin Formation. Arroyo Torcido, North Dome, Kettleman Hills, Kings Co. NE 1/4 sec. 1, T. 22 S., R 17 E., MDBM. Top of greenish-gray mud below *Neverita* sandstone. Collected by W.P. Woodring. *Penitella* sp. indet.

USGS loc. 12628.— Pleistocene, San Pedro Sand. Gaffey anticline on [old] Harbor Boulevard [now Wilmington and San Pedro Road], opposite the San Pedro Lumber Co., San Pedro, Los Angeles Co. Collected by W.P. Woodring, September 11, 1931. *Barnea subtruncata.*

USGS loc. 12630.— Pleistocene. Crest of hill on east side of Cherry Avenue, city of Signal Hill, Los Angeles Co. Collected by W.P. Woodring, September 13, 1931. *Barnea subtruncata, Zirfaea pilsbryi.*

USGS loc. 12645.— Pliocene, San Joaquin Formation. Cascajo Hill, west flank of South Dome, Kettleman Hills, Kern Co. NW 1/4 sec. 3, T. 25 S., R. 19 E., MDBM. Collected by W.P. Woodring, October 17, 1931. *Zirfaea pilsbryi.*

USGS loc. 12653.— Pliocene, San Joaquin Formation. Near El Arco, on west flank of South Dome, Kettleman Hills, Kings Co. SE 1/4 sec. 33, T. 24 S., R. 19 E., MDBM. Collected by W.P. Woodring, October 31, 1931. *Zirfaea pilsbryi.*

USGS loc. 12656.— Pliocene, San Joaquin Formation. West of Oyster Hill, South Dome of Kettleman Hills, Kings Co. Sec. 21, T. 24 S., R. 19 E., MDBM. Collected by W.P. Woodring [loc. 111W]. *Zirfaea pilsbryi.*

USGS loc. 12657.— Pliocene, San Joaquin Formation. North of Oyster Hill, South Dome of Kettleman Hills, Kings Co. Sec. 21, T. 24 S., R. 19 E., MDBM. Collected by W.P. Woodring [loc. 112W]. *Zirfaea pilsbryi.*

USGS loc. 12660.— Pliocene, San Joaquin Formation. West of 25th Avenue, and ESE of Oyster Hill, east flank of South Dome, Kettleman Hills, Kings Co. NE 1/4 sec. 27, T. 24 S., R. 19 E., MDBM. Collected by W.P. Woodring, November 3, 1931. *Zirfaea pilsbryi.*

USGS loc. 12793.— Pliocene, San Joaquin Formation. North of Oyster Hill, South Dome, Kettleman Hills, Kings Co. NW 1/4 NW 1/4 sec. 27, T. 24 S., R. 19 E., MDBM. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 12794.— Pliocene, San Joaquin Formation. North of Oyster Hill, South Dome, Kettleman Hills, Kings Co. NW 1/4 NW 1/4 sec. 27, T. 24 S., R. 19 E., MDBM. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 12818.— Pliocene, Etchegoin Formation. Southwest of Discovery Ridge, North Dome, Kettleman Hills, Kings Co. NE 1/4 sec. 11, T. 22 S., R. 17 E., MDBM. *Siphonalia* zone. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 12956.— Pliocene. "On 3000 foot point of ridge in southeast corner of sec. of 2610 foot hill," northeast flank of Caliente Mountains, San Luis Obispo Co. Collected by Robert Anderson, July 20, 1909. *Zirfaea pilsbryi.*

USGS loc. 13125.— Pleistocence, Second terrace. Along path in Peck Park, 650 feet SSE of 252 foot hill, San

Pedro, Los Angeles Co. Collected by W.P. Woodring, June 24, 1933. *Zirfaea pilsbryi, Penitella penita.*

USGS loc. 13130.— Pleistocene, Second terrace. Top of sea cliff near east end of Warmouth Street, ½ mile northwest of Whites Point, San Pedro, Los Angeles Co. Collected by W.P. Woodring, July 22, 1933. *Penitella penita.*

USGS loc. 13775.— Pleistocence, Palos Verdes Sand. East face of Graham Bros. [in 1935] sand pit, ca. 1400 feet southeast of south end of Madison St., community of Walteria, city of Torrance, Los Angeles Co. Collected by W.P. Woodring, July 15, 1935. *Penitella* sp. indet.

USGS loc. 13779.— Pleistocene, Palos Verdes Sand. West side of Mesa Street, 100 feet south of 3rd Street, San Pedro, Los Angeles Co. Collected by W.P. Woodring, July 23, 1935. *Zirfaea pilsbryi.*

USGS loc. 14087.— Pliocene, San Joaquin Formation, Cascajo Conglomerate. South slope of Cerro Ultimo, North Dome, Kettleman Hills, Kings Co. NW 1/4 NW 1/4 sec. 34, T. 22 S., R. 18 E., MDBM. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 14113.— Pliocene, Etchegoin Formation. Just above road on west side of Las Paredes, North Dome, Kettleman Hills, Kings Co. NW 1/4 NW 1/4 sec. 17, T. 22 S., R. 18 E., MDBM. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 14118.— Pliocene, Etchegoin Formation. Upper part of Arroyo Murado, northwest of El Pulgar, North Dome, Kettleman Hills, Kings Co. NW 1/4 NW 1/4 sec. 18, T. 22 S., R. 18 E., MDBM. Collected by Ralph Stewart. *Penitella turnerae.*

USGS loc. 14119.— Pliocene, Etchegoin Formation. East slope of La Tusa, North Dome, Kettleman Hills, Kings Co. SE 1/4 SE 1/4 sec. 12, T. 22 S., R. 17 E., MDBM. Base of *Patinopecten* zone. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 14122.— Pliocene, Etchegoin Formation. Arroyo Murado, southeast of La Clavija, North Dome, Kettleman Hills, Kings Co. SW 1/4 NW 1/4 sec. 7, T. 22 S., R. 18 E., MDBM. Barnacle layer. Collected by Ralph Stewart. *Zirfaea pilsbryi.*

USGS loc. 14397.— Miocene, Temblor Formation, upper member. Reef Ridge northwest of Garza Peak, Kings Co. Center of sec. 12, T. 23 S., R. 16 E., MDBM. *Zirfaea dentata.*

USGS loc. 14408.— Miocene, Temblor Formation, upper member. Near Beltram Creek on Reef Ridge, Fresno Co. SW 1/4 sec. 30, T. 22 S., R. 16 E., MDBM. *Zirfaea dentata.*

USGS loc. 14409.— Miocene, Temblor Formation, upper member. Arroyo Pinoso on Reef Ridge, Fresno Co. SE 1/4 sec. 23, T. 22 S., R. 15 E., MDBM. *Zirfaea dentata.*

USGS loc. 14410.— Miocene, Temblor Formation, upper member. West side of Zapato Creek, Fresno Co. NW 1/4 NE 1/4 sec. 21, T. 22 S., R. 16 E., MDBM. *Zirfaea dentata.*

USGS loc. 14609.— Pliocene, Careaga Sandstone, Graciosa Member. West side of cut on Southern Pacific Railroad, 0.8 miles northeast of Schuman's siding, north slope of the Casmalia Hills, Santa Barbara Co. Collected by W.P. Woodring, August 24, 1938. *Zirfaea pilsbryi.*

USGS loc. 14622.— Pliocene, Careaga Sandstone, Graciosa Member. Graciosa Ridge, on edge of slump on west side of canyon, 200 feet WSW of Union Oil Co. Newlove No. 30 well, 3.4 miles southeast of Orcutt, Santa Barbara Co. Collected by W.P. Woodring [loc. W611]. *"Pholadidea penita"* [not seen].

USGS loc. 14648.— Pliocene, Careaga Sandstone, Cebada Member. 1000 feet northwest of Union Oil well Newlove No. 42, south slope of Orcutt Hill, 3.7 miles southeast of Orcutt, Santa Barbara Co. Collected by W.P. Woodring, August 24, 1939. *Penitella gabbii, P. turnerae.*

USGS loc. 14722.— Pliocene, Careaga Sandstone, Graciosa Member. Loose blocks on west side of Howard Canyon, Solomon Hills, 2.6 miles NNE of Los Alamos, Santa Barbara Co. Collected by R.P. Bryson, July 25, 1939. *Penitella gabbii, P.* sp. indet.

USGS loc. 14768.— Pliocene, Careaga Sandstone, Cebada Member. Fugler Point, 1.1 miles north of Garey, Santa Barbara Co. Four foot fossil bed at southeast end of bluff. Collected by W.P. Woodring and R.P. Bryson, August 16, 1939. *"Pholadidea* cf. *P. penita"* [not seen; probably *Penitella gabbii* and/or *P. turnerae*].

USGS loc. 14769.— Pliocene, Careaga Sandstone, Cebada Member. Fugler Point, 1.1 miles north of Garey, Santa Barbara Co. From below 4 foot fossil bed [see USGS loc. 14768] and southeast of brachiopod bed. Collected by W.P. Woodring and R.P. Bryson, August 16, 1939. *Penitella* sp. indet.

USGS loc. 14867.— Pliocene, Sisquoc Formation. Crest of Purisima Hills, one mile southeast of Redrock Mountain, Santa Barbara Co. Center of sec. 16, T. 7 N., R. 32 W., SBBM. *Penitella* sp. indet.

USGS loc. 14879.— Pliocene, Foxen Mudstone. Dump at Waldorf asphalt mine, 3 miles SSE of Guadalupe, Santa Barbara Co. Collected by W.P. Woodring and M.N. Bramlette, August 17, 1938. *"Pholadidea penita"* [not seen; probably *Penitella gabbii* and/or *P. turnerae*].

USGS loc. 14966.— Pleistocene [?]. Canyon in marine terrace 1/2 mile southeast of Point Sal Landing and 100 feet inland, Santa Barbara Co. Elevation 40 feet. [This station number represents both a Pleistocene terrace deposit and the Pliocene Foxen Mudstone, neither of which is listed on the label with the specimen.] Collected by W.P. Woodring, October 19, 1940. *Penitella* sp. cf. *P. penita.*

USGS loc. 15052.— Pleistocene. Rear of lowest terrace (900 feet inland) on east side of first canyon southeast of Lions Head, Santa Barbara Co. Elevation 115 feet. Collected by W.P. Woodring, October 9, 1940. *Zirfaea pilsbryi.*

USGS loc. 15864.— Pleistocene. Yakatat Bay region, Gulf of Alaska, Alaska. *Penitella kamakurensis.*

USGS loc. 18284.— Pliocene, Empire Formation. Dredged from the channel adjacent to North Spit, Coos Bay, Coos Co., Oregon. Collected from spoil bank by Ellen James [Moore], 1949-1950. *Penitella turnerae.*

USGS loc. 18459.— Miocene. North of Santiago Canyon Road and ca. 0.7 miles southwest of the spillway of Irvine Lake, Orange Co. Elevation 1,150 feet. Collected by J.G. Vedder. *Zirfaea dentata.*

USGS loc. 18558.— Pliocene, ? Etchegoin Formation. Low hills on east side of San Benito River, southeast of San Benito, San Benito Co. Collected by C.J. Bleifus, 1936. *Zirfaea* sp. cf. *Z. pilsbryi.*

USGS loc. 18732.— Miocene. West side of road south of the divide, Old Topanga Canyon, Los Angeles Co. N. 55° E. from Calabasas Peak. Collected by W. A. English and W.S.W. Kew, October 25, 1918. *Zirfaea dentata.*

USGS loc. 18740.— Miocene. In largest NE-SW canyon in the Bacon Hills, western Kern Co. *Mulinia* (?) bed about 100 feet below conglomerate. Center of N 1/2 sec. 27, T. 28 S., R. 20 E., MDBM. Collected by Mr. Lohman, August 6, 1934. *Zirfaea dentata.*

USGS loc. 18743.— Pliocene. Mount Pinos quadrangle, California. *Penitella conradi.*

USGS loc. 21653.— Pleistocene. Near Army Camp Beach, San Nicolas Island. 8400 feet north and 3650 feet east of lat. 33° 14' 30" N., long. 119° 30' 30" E. Altitude 45-60 feet. Collected by J.G. Vedder, S.R. Dabney, and D.J. Milton, 1955 [loc. SN-1]. *Penitella conradi.*

USGS loc. 21654.— Pleistocene. On main ridge east of hill 818, San Nicolas Island, 4575 feet south and 600 feet west of lat. 33° 14' 30" N., 119° 28' 00" E. Altitude 730± feet. Collected by J.G. Vedder, 1955 [loc. SN-2]. "*?Penitella* sp." [not seen].

USGS loc. 21655.— Pleistocene. On main ridge west of hill 818, San Nicolas Island. 3300 feet south and 1875 feet west of lat. 33° 14' 30" N., 119° 28' 00" E. Altitude 735± feet. Collected by J.G. Vedder, 1955 and 1956 [loc. SN-3]. *Penitella penita, P. conradi, P. gabbii, Parapholas californica.*

USGS loc. 21664.— Pleistocene. At east end of San Nicolas Island, 5000 feet south and 9375 feet east of lat. 33° 14' 30" N., 119° 28' 00" E. Altitude 65-70 feet. Collected by J.G. Vedder and N.C. Privrasky, 1956 [loc. SN-12]. *Zirfaea pilsbryi, Chaceia ovoidea, Parapholas californica.*

USGS loc. 23621.— Pliocene, Foxen Mudstone. Waldorf asphalt mine, 3 miles SSE of Guadalupe, Santa Barbara Co. Collected September 23, 1931. *Penitella gabbii.*

UNITED STATES GEOLOGICAL SURVEY (DENVER)

[Collection now housed at Menlo Park Branch.]

USGS-D loc. 49.— Pliocene, Nuwok Formation. At a sharp bend in Carter Creek, flowing into Camden Bay, Arctic coast, Alaska. *Arctica carteriana* zone, from 110 to 210 feet below top of measured section. 69° 57' 45" N. lat., 144° 46' W. long. Collected by R.H. Morris. "*?Martesia* sp." [=teredinid burrows].

UNITED STATES GEOLOGICAL SURVEY (MENLO PARK)

USGS-M loc. 979.— Pliocene, Pancho Rico Formation. South side of Pancho Rico Creek, Salinas Valley, Monterey Co. 700 feet S., 1200 feet W. of NE corner sec. 15, T. 22 S., R. 10 E., MDBM. Collected by D.L. Durham, 1960. "*Zirfaea* sp." [not seen].

USGS-M loc. 980.— Pliocene, Pancho Rico Formation. Base of bluff on south side of Pancho Rico Creek, Salinas Valley, Monterey Co. 1600 feet north and 1400 feet west of SE cor. sec. 11, T. 22 S., R. 10 E., MDBM. Collected by D.L. Durham, 1960. *Zirfaea dentata.*

USGS-M loc. 1071.— Miocene, ? Topanga Formation. Hill 2049, on ridge north of Mesa Peak, Santa Monica Mountains, northwest of community of Malibu Beach, Los Angeles Co. Collected by J.G. Vedder, R.F. Yerkes, and J.E. Schoellhamer. *Zirfaea dentata.*

USGS-M loc. 1449.— Pleistocene, Battery Formation. Exposure in sea cliff 600 feet west of intersection of Modoc Street and Pebble Beach Drive, Crescent City, Del Norte Co. Lens of fossiliferous sand overlying truncated surface of hard Mesozoic sandstone. Elevation 22 feet. NW 1/4 NW 1/4 sec. 30, T. 16 N., R. 1 W., HBM. Collected by W.O. Addicott, November, 1958. *Penitella turnerae.*

USGS-M loc. 1542.— Miocene, Montesano Formation. In bed of Canyon River, 700 feet west of SE cor. sec. 35, T. 21 N., R. 7 W., WBM, Grisdale quadrangle, Grays Harbor Co., Washington. Boring into underlying Astoria Formation with *Platyodon colobus fowleri.* "*Zirfaea* sp." [not seen], *Penitella lorenzana.*

USGS-M loc. 1676.— Upper Miocene or lower Pliocene, Pancho Rico Formation. On first ridge west of Salinas River, 1050 feet north and 2500 feet west of SE cor. sec. 29, T. 22 S., R. 10 E., MDBM, Monterey Co. Collected by D.L. Durham and D.C. Wiese, 1962. Filled pholadid burrow.

USGS-M loc. 1690.— Pleistocene. Terrace cut into Miocene Monterey Formation on the south side of Point Año Nuevo, about 1 mile ENE of Año Nuevo Island, San Mateo Co. Collected from 200-300 foot exposure along beach, by W.O. Addicott, 1962. *Zirfaea* sp. aff. *Z. pilsbryi, Penitella turnerae; in situ.*

USGS-M loc. 1691.— Pleistocene. Terrace cut into Pliocene Purisima Formation, near top of sea cliff at the outer edge of an incipient sea stack west of Point Santa Cruz, Santa Cruz, Santa Cruz Co. Collected by W.O. Addicott, July, 1962. *Penitella turnerae.*

USGS-M loc. 1710.— Pleistocene. Terrace deposits exposed in cuts along California Highway 1 near the eastern end of Escondido Beach, 2-1/2 miles northeast of Point Dume, Los Angeles Co. Collected by W.O. Addicott and R.F. Yerkes, April, 1963. *Penitella* sp. cf. *P. conradi.*

USGS-M loc. 1715.— Pliocene, Merced (?) Formation. Road cut and pipeline trench on north side of Arastradero Road, 1200 feet west of intersection with Page Mill Road, city of Los Altos Hills, Santa Clara Co. Collected by E.H. Pampeyan, J.G. Vedder, and W.O. Addicott, 1962-1963. *Zirfaea pilsbryi.*

USGS-M loc. 1722.— Pleistocene, Palos Verdes Sand. Basal marine terrace deposit in major gully draining NNE into salt pond area of Upper Newport Bay, northeast of old landing strip, city of Newport Beach, Orange Co. (=LACMNH loc. 66-2). Collected by M.E. Rogers. *Zirfaea pilsbryi.*

USGS-M loc. 1728.— Pleistocene, Palos Verdes Sand. Harbor Boulevard, San Pedro, Los Angeles Co. ("same

as Arnold's (1903) lumber yard locality"). Collected by M.E. Rogers. *Penitella penita.*

USGS-M loc. 1966.— Pliocene, Pancho Rico Formation. North side of Powell Canyon, Salinas Valley, Monterey Co. 50 feet N. 1,550 feet E of SW corner sec. 36, T. 22 S., R. 11 E., MDBM. Collected by W.O. Addicott and D.L. Durham, 1964. *"Zirfaea pilsbryi"* [*?=Z. dentata,* not seen].

USGS-M loc. 2011.— Pleistocene, Palos Verdes Sand. Cherry Avenue, top of Signal Hill, city of Signal Hill, Los Angeles Co. Collected by M.E. Rogers. *Penitella penita.*

USGS-M loc. 2017.— Pleistocene, Palos Verdes Sand. Southeast corner of Oliver and Pacific Streets, San Pedro, Los Angeles Co. Collected by M.E. Rogers. *Zirfaea pilsbryi, Penitella penita.*

USGS-M loc. 2147.— Pleistocene. Terrace deposit in sea cliffs on north side of Point Año Nuevo, 900 feet north of Green Oaks Creek, San Mateo Co. Elevation 10-15 feet. Collected by W.O. Addicott, W.C. Bradley, and R. Curry, September, 1964. *Zirfaea pilsbryi, Penitella turnerae; in situ.*

USGS-M loc. 2798.— Pleistocene. Terrace deposit on south side of Coquille Point, west of Bandon, Coos Co., Oregon. SE 1/4 sec. 26, T. 28 S., R. 15 W., WBM. Collected by R. Janda, W.O. Addicott, and Mr. Hunter, 1966-1967. *Penitella penita.*

USGS-M loc. 3026.— Pleistocene? In very small cove beneath circle drive in Yaquina Bay State Park, north of north Yaquina Bay jetty, Lincoln Co., Oregon. 400 feet west and 100 feet north of SE cor. sec. 7, T. 11 S., R. 11 W., WBM. Collected by E.W. Baldwin. *Zirfaea pilsbryi.*

USGS-M loc. 3073.— Miocene, Montesano Formation. Basal formational contact in road cut just south of bridge over Satsop River, Mason Co., Washington. 200 feet west and 900 feet north of SE cor. sec. 36, T. 19 N., R. 7 W., WBM. Collected by G.A. Fowler. *?Zirfaea* sp. (?ancestoral to *Chaceia*).

USGS-M loc. 3117.— Miocene, Montesano Formation. Basal formational contact, in stream bank on east side of Canyon River, Grays Harbor Co., Washington. On section line 450 feet west of SE cor. sec. 35, T. 21 N., R 7 W., WBM. Collected by G.A. Fowler. *Penitella lorenzana.*

USGS-M loc. 3779.— Miocene, Escudo Formation. "Buttonbed," on south side of Escudo Mountain, Kern Co., in coarse to very coarse grained sandstone. 1575 feet north and 2450 feet west of SE cor. sec. 36, T. 25 S., R. 18 E., MDBM. Collected by W.O. Addicott, April, 1968. *Zirfaea* sp. cf. *Z. dentata.*

USGS-M loc. 4621.— Pliocene, Paso Robles Formation. In quarry on south side of Atascadero-Creston road about two miles east of Atascadero, San Luis Obispo Co. Collected by W.O. Addicott, J.S. Galehouse, and D.L. Durham. *Nettastomella rostrata.*

USGS-M loc. 4622.— Pleistocene? Near base of channel cut into Nye Formation and lying unconformably beneath late Pleistocene marine terrace at Hinton Point, Yaquina Bay, Lincoln Co., Oregon. Near SE 1/4 sec. 16, T. 11 S., R. 11 W., WBM. Collected by R. Janda, 1970. *Zirfaea pilsbryi.*

USGS-M loc. 4623.— Pleistocene. Bluffs on north side of Fivemile Point, Coos Co., Oregon. 1,100 feet S and 600 feet W of NE cor. sec. 19, T. 27 S., R. 14 W., WBM. Collected by R. Janda. 1970. *Penitella penita.*

UNIVERSITY OF WASHINGTON (SEATTLE)

[Probably all collected by C.E. Weaver. Most of the specimens below are no longer in the University's collections.]

UW loc. 719.— Pliocene, Empire Formation. In the sea cliffs on the east side of South Slough in Coos Bay, Coos Co., Oregon. Fossils from the base of a massive, medium-grained, brown sandstone. Fossils well preserved *"?Pholadidea californica"* [not seen; probably *Penitella turnerae*].

UW loc. 725.— Pliocene, Empire Formation (Coos Conglomerate). Fossil Point on the east side of South Slough in Coos Bay, Coos Co., Oregon. Very firmly cemented conglomerate containing thin lenses of sandstone. Fossils are abundant. *"Pholadidae penita"* [not seen; probably *Penitella turnerae*].

UW loc. 752.— Pliocene, Empire Formation. From a sandstone layer in the sea cliffs 630 feet east of Tunnel Point, Coos Bay, Coos Co., Oregon. 660 feet above the base of the Tunnel Point Formation. *Penitella turnerae.*

UW loc. 1238.— Oligocene, San Ramon Formation. Pholadid borings at base of the San Ramon in the east limb of the Pacheco syncline; in a cut along Industrial Highway, Contra Costa Co. *"Pholadidea (Penitella) lorenzana"* [not seen; *=Penitella durhami*].

UW loc. 3374.— Miocene, Sobrante Sandstone. Exposure of sandstone in pasture-land in the east limb of Pacheco syncline (south of Vine Hill Fault), Contra Costa Co. 5,200 feet S. 50° W. from overpass at intersection of Pacheco Road and Santa Fe Railway. *"Pholadidea* cf. *penita"* [not seen].

UW loc. 3378.— Miocene, Briones Sandstone. West limb of Pacheco syncline 6,700 feet S. 40° W. from the overpass at intersection of Pacheco Road and Santa Fe Railway, Contra Costa Co. From lower part of the formation. *"Pholadidea* cf. *penita"* [not seen].

UW loc. 3379.— Oligocene, San Ramon Formation. Exposure in cut along Santa Fe Railway in east limb of Pacheco Syncline, 6,100 feet due west of overpass at intersection of Pacheco Road and Santa Fe Railway, Contra Costa Co. *"Pholadidea* cf. *penita"* [not seen].

UW loc. 3414.— Miocene, Briones Sandstone. Exposure in west limb of Pacheco Syncline, 3,200 feet S. 41° W. from intersection of Morello Road and Santa Fe Railway, Contra Costa Co. *Zirfaea dentata* [not seen].

UW loc. 3415.— Miocene, Briones Sandstone. Exposure in east limb of Pacheco Syncline, 3,500 feet S. 8° W. from intersection of Morello Road and Santa Fe Railway, Contra Costa Co. *Zirfaea dentata* [not seen].

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FIGURES 3—12

Barnea (*Anchomasa*) *subtruncata* (Sowerby)

Fig. 3-4. SDSNH 04276. Pleistocene, Palos Verdes Sand, Upper Newport Bay, Orange Co., California (SDSC loc. 533). Exterior and interior of right valve. Apophysis broken. X 3.

Fig. 5 LACMNH 2450. Pleistocene, Palos Verdes Sand, San Pedro, Los Angeles Co. (LACMNH loc. 300). Muscle scar pad is abnormally produced. X 1-1/2.

Fig. 6. SDSNH 62941. Recent, Alamitos Bay, Los Angeles Co. (?). Protoplax, posterior is up. X 1-1/2.

Fig. 7 SDSNH 53165. Same. Interior of left valve. X 1.

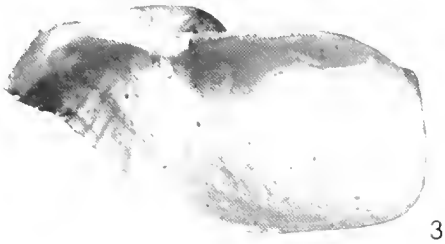
Cyrtopleura (*Scobinopholas*) *costata* (Linné)

Fig. 8. SDSNH 04277. Pliocene, Imperial Formation, Carrizo Creek, Imperial Co. (SDSNH loc. 51). Internal mold of right valve with some shell remaining. X 1-1/4.

Fig. 9-10. LACMNH 2451. Pleistocene, Norfolk Formation, Virginia Beach, Princess Anne Co., Virginia (LACMNH loc. 482). Exterior and interior of right valve. X 1.

Cyrtopleura (*Scobinopholas*) sp.

Fig. 11-12. USNM 5913. "Miocene? Neeah Bay, Pugets Sound, Oregon" [Washington]. Left valve, and dorsal view of same specimen. Complicated "hinge" structure is characteristic of *Cyrtopleura s.l.* X 1-1/2.



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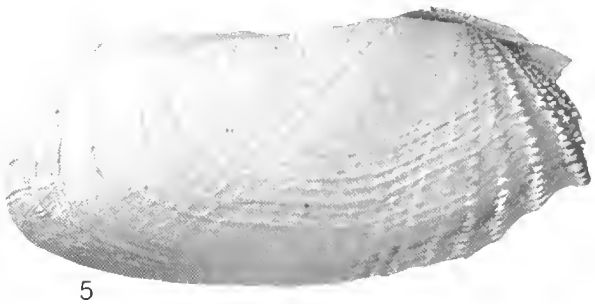

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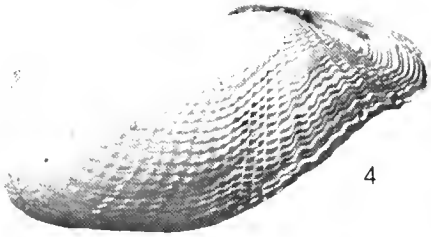

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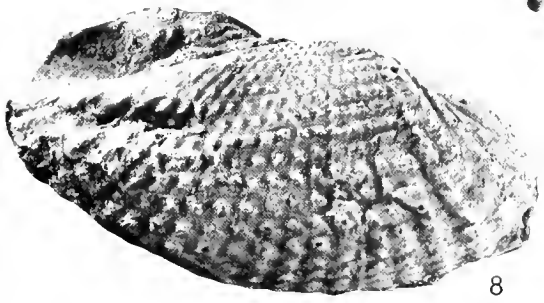

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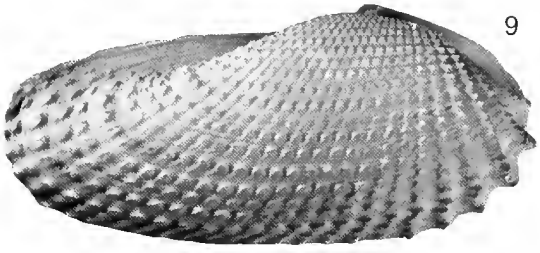

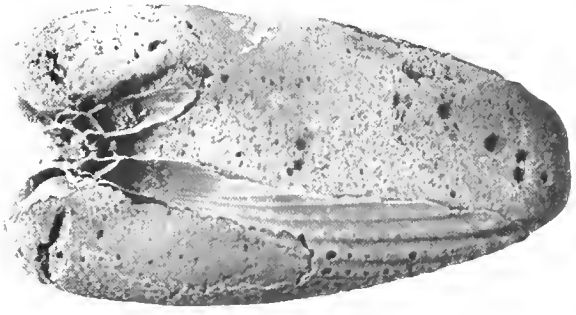

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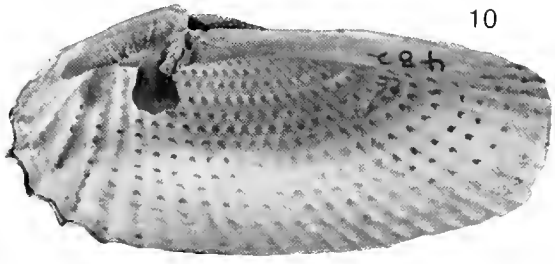

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FIGURES 13—19

Zirfaea dentata Gabb

Fig. 13 USNM 165573. Miocene, Vaqueros Formation, north of Coalinga, Fresno Co. (USGS loc. 4803). Exterior of left valve. X 1.

Fig. 14-15. UCMP 31180. Miocene, San Pablo group, no locality data. Left valve, and dorsal view of same specimen. X 1.

Zirfaea pilsbryi Lowe

Fig. 16-17. SDSNH 53166 [*ex* 7041]. Recent, Bolinas Bay, Marin Co. Interior and exterior of left valve. X 1.

Fig. 18. LACMNH 2452. Pleistocene, San Pedro Sand, San Pedro, Los Angeles Co. (LACMNH loc. 300). Exterior of left valve. X 1.

Zirfaea sp. aff. ~~att~~. *Z. pilsbryi* Lowe

Fig. 19. CAS 54822. Pleistocene, Cape Blanco, Coos Co., Oregon (CAS loc. 20). Exterior of right valve. This variety is close to *Chaceia ovoidea* and to *Zirfaea pilsbryi*. X 1.

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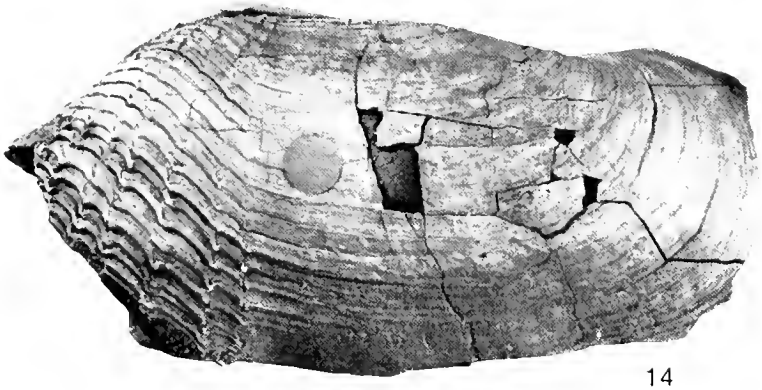

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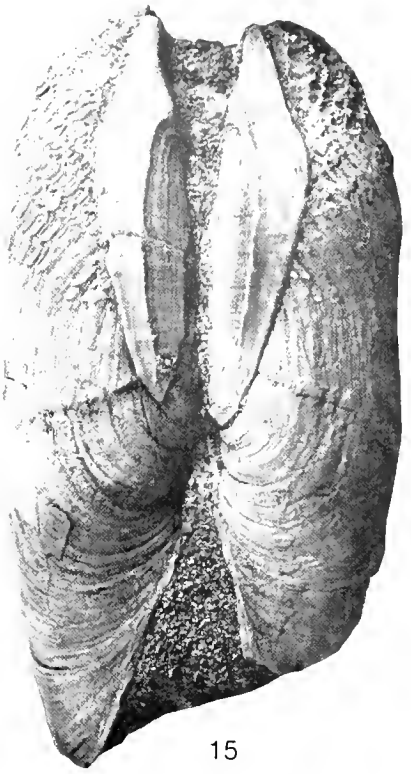

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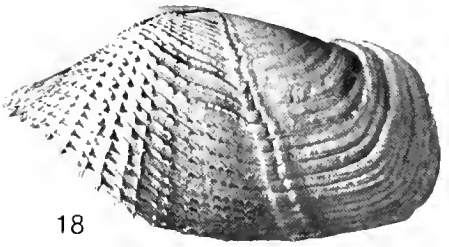

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FIGURES 20—27

Chaceia ovoidea (Gould)

Fig. 20. SDSNH 04278. Pleistocene, Palos Verdes Sand, Upper Newport Bay, Orange Co. (SDSNH loc. 0330). Interior of right valve. X 2.

Fig. 21. SDSNH 04279. Same (SDSC loc. 537). Right valve of stunted and deformed specimen. Dorsal extension of callum is partially broken. ca. X 1-1/3.

Fig. 22. SDSNH 04280. Same (SDSC loc. 537). Exterior of left valve. X 1-1/4.

Fig. 23. SDSNH 04281. Same (SDSC loc. 537). Interior of broken right valve. Struts inside of callum are unusual. Shape of ventral muscle scar is characteristic. X 1.

Fig. 24. SDSNH 53167 [*ex* 22685]. Recent, no data. Exterior of left valve of typical specimen. X 1.

Fig. 25-26. SDSNH 53168. Recent, Carpenteria, Santa Barbara Co. Dorsal, and ventral views of unusually complete adult mesoplax; from specimen ca. 84 mm in length. X 2.

Fig. 27. SDSNH 40221. Recent, Seal Beach, Orange Co. Interior of right valve. Beak protrudes past callum. X 1.


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FIGURES 28—40

Penitella lorenzana (Clark)

Fig. 28-30. UCMP 33491. Oligocene, San Ramon Formation, Walnut Creek, Contra Costa Co. (UCMP loc. 1131). Left valve, mesoplax, and dorsal view of paratype. X 1-1/2.

Fig. 31. UCMP 30323. Same (UCMP loc. 1131). Left valve of holotype. X 1-1/2.

Fig. 32. CAS 54823. Oligocene, San Ramon Formation, Carquinez, Contra Costa Co. (CAS loc. 36499). Right valve. Callum extends beyond beak. X 1-1/4.

Penitella durhami Adegoke

Fig. 33-34. UCMP 30108. Oligocene, San Ramon Formation, Contra Costa Co. (UCMP loc. A-4296, *not* A-7762). Right valve, and dorsal view of holotype. X 1.

Fig. 35. UCMP 30102. Same (UCMP loc. A-7762). Left valve of a paratype. Beak does not imbed in callum. Umbonal reflection appears loosely appressed. X 1-1/2.

Penitella gabbii (Tryon)

Fig. 36-38. SDSNH 53169 (*ex* 50958). Recent, Bolinas, Marin Co. Right valve, and dorsal and ventral views of mesoplax of same specimen. Apophysis flattened. ca. X 1-3/4.

Fig. 39-40. SDSNH 53170 (*ex* 17908). Recent, Monterey Bay, Monterey Co. Right valve, and dorsal view of same specimen. Folded periostracum between valves is common. Loosely appressed umbonal reflection is diagnostic. X 1-1/2.

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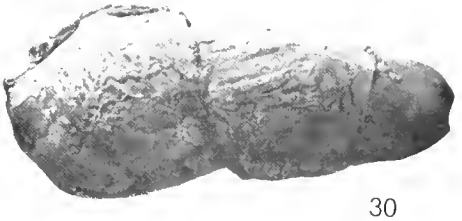

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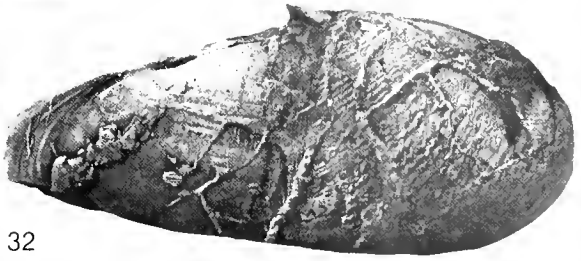

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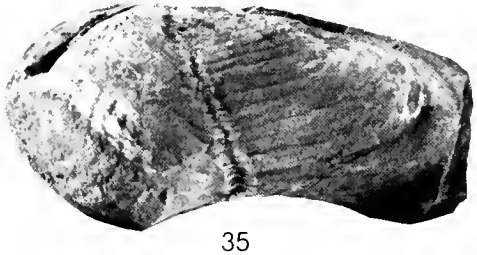

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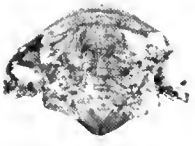

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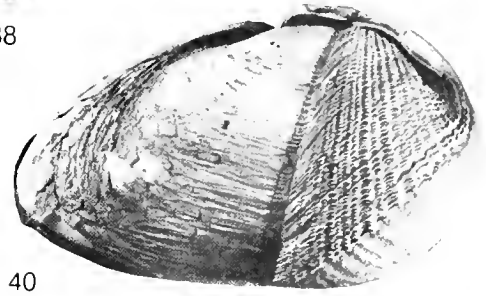

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FIGURES 41—54

Penitella conradi Valenciennes

Fig. 41-43. LACMNH 2453. Pleistocene, Lomita Marl, San Pedro, Los Angeles Co. (LACMNH loc. 435). Fig. 41-42, LACMNH 2453b: Dorsal and ventral views of adult mesoplax. Fig. 43, LACMNH 2453a: Interior of right valve. All X 2.

Fig. 44-45. LACMNH 2454. Same (LACMNH loc. 435). Dorsal view, and exterior of left valve of same specimen. Apophysis broken. X 2.

Penitella penita (Conrad)

Fig. 46. SDSNH 53171 (*ex* 22695). Recent, Anaheim Bay, Orange Co. Exterior of left valve. Excessive callum is due to individual boring into soft substrate. X 1-1/2.

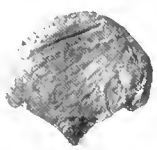
Fig. 47-48. SDSNH 04283. Pleistocene, Palos Verdes Sand, Upper Newport Bay, Orange Co. (SDSC loc. 533). Exterior and interior of left valve of typical specimen. X 2.

Fig. 49. CAS 54824. Pleistocene, Palos Verdes Sand, Deadman Island, Los Angeles Co. (CAS loc. 92). Exterior of right valve showing extreme crowding of concentric ridges. X 1-1/2.

Fig. 50-51. USNM 1868. Pleistocene, Palos Verdes Sand, San Pedro, Los Angeles Co. Interior of right valve (apophysis broken), and exterior of left valve. Lectotype of *Penitella speloeum* Conrad. X 1-1/2.

Fig. 52. CAS 54831. Same as Fig. 49 (CAS loc. 92). Right valve showing repaired injury caused by boring of neighboring pholadid. X 1-1/2.

Fig. 53-54. SDSNH 04284. Pleistocene, Rosarito Beach, Baja California, Mexico (SDSNH loc. 2531). Dorsal view showing mesoplax, and exterior of right valve. X 1.



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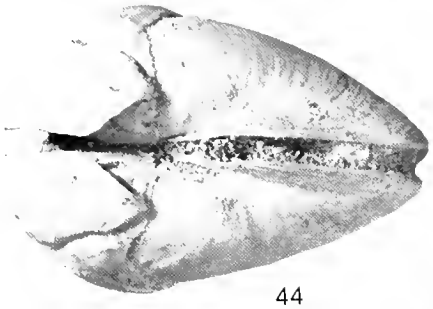

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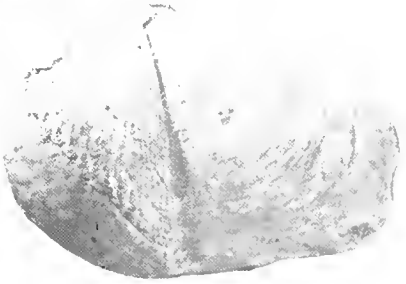

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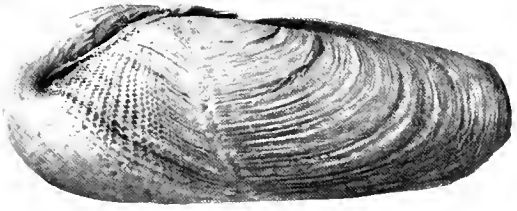

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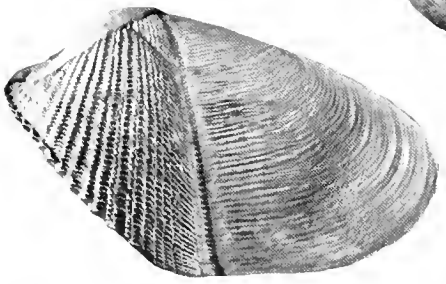

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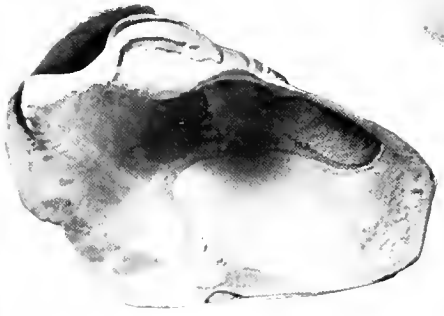

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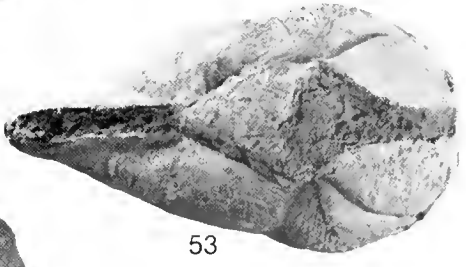

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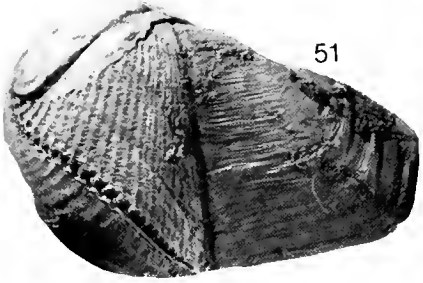

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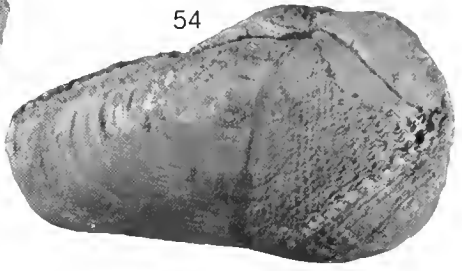

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FIGURES 55—64

Penitella fitchi Turner

Fig. 55-56. SDSNH 04186. Pleistocene, Palos Verdes Sand, Upper Newport Bay, Orange Co. (SDSNH loc. 2561). Exterior of left valve and interior of right valve of juvenile specimen. Bladed apophysis and rounded beak are characteristic. X 2.

Fig. 57. USNM 111401. Recent, San Diego, San Diego Co. Exterior of right valve. Periostracal leaves missing. X 1-1/2.

Fig. 58. LACMNH A.2777. Recent, Redondo Beach, Los Angeles Co. Exterior of right valve. Periostracal leaves are diagnostic. X 1-1/2.

Fig. 59. SDSNH 04282. Same as Fig. 55-56 (SDSC loc. 537). Exterior of broken right valve. Dorsal "bump" is distinctive. Ca. X 1+.

Penitella kamakurensis (Yokoyama)

Fig. 60. USNM 189802. Pleistocene, near Yakatat Bay, Alaska (USGS loc. 15864). Left valve of paired specimen. X 1.

Penitella turnerae Evans and Fisher

Fig. 61-62. SDSNH 00200. Pleistocene, near Goleta, Santa Barbara Co. Interior, and exterior of left valve. Apophysis, and umbonal reflection are characteristic. X 1.

Fig. 63. LACMNH 2455. Same (LACMNH loc. 416). Exterior of juvenile specimen left valve. Note angled anterior margin. X 1-1/2.

Fig. 64. USNM 189803. Pliocene, Foxen Mudstone, near Guadalupe, Santa Barbara Co. (USGS loc. 4473). Dorsal view of adult specimen. Mesoplax and dorsal extension of callum are characteristic. X 1.

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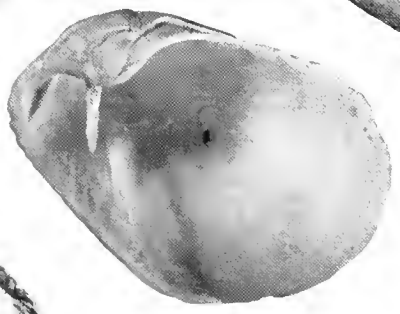

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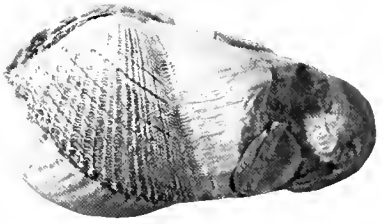

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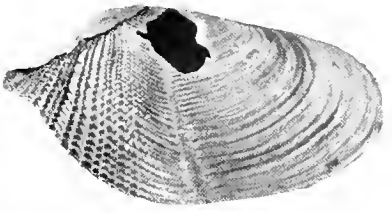

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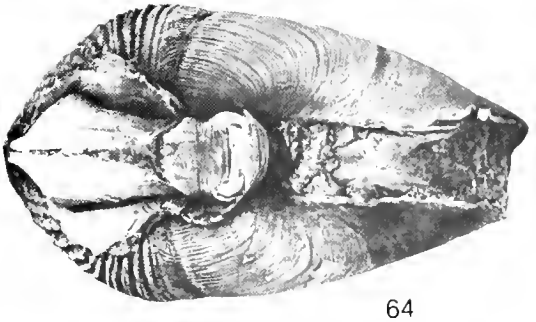

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FIGURES 65—75

Martesia meganosensis Clark and Woodford

Fig. 65. UCMP 31297. Eocene, Meganos Formation, northeast of Mt. Diablo, Contra Costa Co. (UCMP loc. 3577). Right valve of juvenile holotype. X 8.

Fig. 66. UCMP 31298. Same (UCMP loc. 3159). Right valve of adult paratype. X 3.

Martesia (*Paramartesia*) *tolkieni* Kennedy, sp. nov.

Fig. 67. USNM 163804a. Eocene, Lodo Formation, west side of San Joaquin Valley, Merced Co. (USGS loc. 5712). Internal mold of right valve of adult paratype. X 2-1/2.

Fig. 68. SDSNH 04292 [latex mold of USNM 163804b]. Same (USGS loc. 5712). Oblique dorsal view showing mesoplax, metaplax, and dorsal reflection of valve, of a paratype. X 3.

Fig. 69. USNM 163804c. Same (USGS loc. 5712). Specimen showing several paratypes. X 2.

Fig. 70. USNM 163804d. Same (USGS loc. 5712). Ventral view of paratype showing hypoplax (posterior is up). X 2.

Opertochasma turnerae (Hickman)

Fig. 71. UO 27314. Oligocene, Eugene Formation, Eugene, Land Co., Oregon (UO loc. 2553). Dorsal view of holotype. X 5.

Fig. 72. UO 27733. Same (UO loc. 2553). Exterior of left valve of a paratype. X 5-6.

Parapholas californica (Conrad)

Fig. 73. SDSNH 04285. Pleistocene, Point Loma, San Diego Co. (SDSNH loc. 2419). Exterior of right valve. Disc-posterior slope ridge and attachment lines of periostracal plates have have eroded away. Fne anterior slope sculpture is typical. X 1-1/2.

Fig. 74. UCMP 10608. Pleistocene, Palos Verdes Sand, Newport Beach, Orange Co. (UCMP loc. A-3132). Dorsal view of paired specimen. Divided mesoplax is complete. X 1.

Fig. 75. SDSNH 04291. Pleistocene, Cedros Island, Baja California, Mexico (SDSNH loc. 2630). Interior of left valve. Buildup of calcium carbonate on apophysis is not uncommon. X 1.

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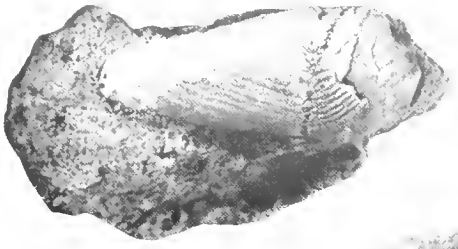

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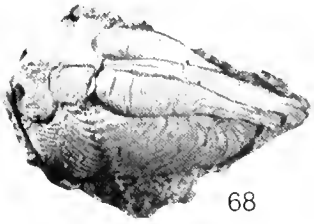

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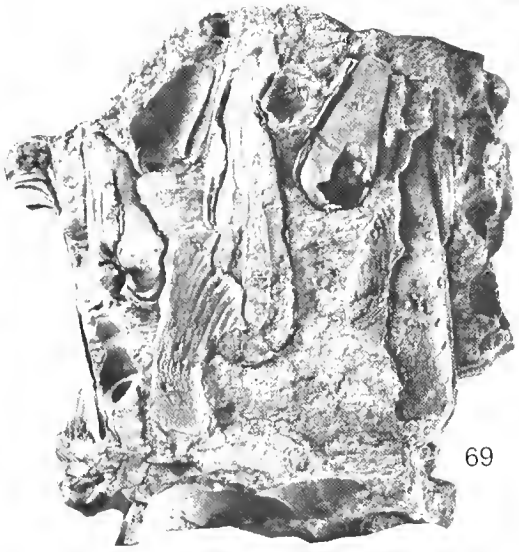

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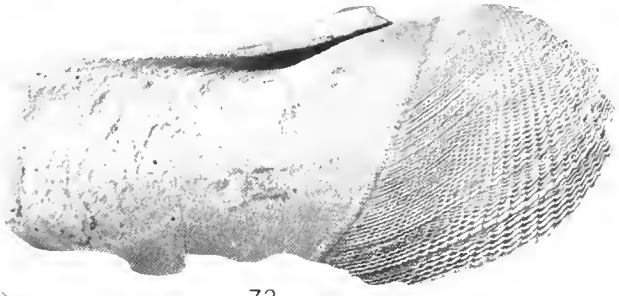

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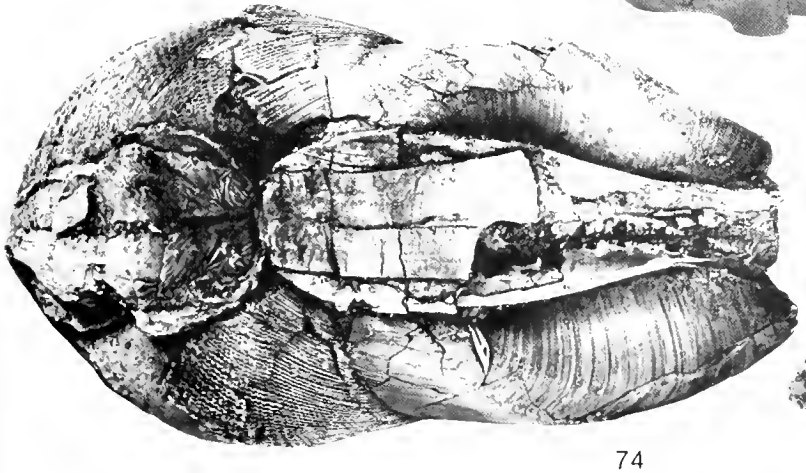

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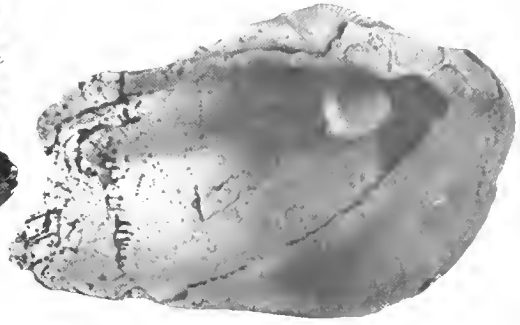

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FIGURES 76—90

Nettastomella rostrata (Valenciennes)

Fig. 76. SDSNH 04286. Pleistocene, Palos Verdes Sand, Upper Newport Bay, Orange Co. (SDSC loc. 533). Exterior of juvenile left valve. X 4.

Fig. 77-78. SDSNH 04287. Same (SDSC loc. 533). Exterior, and interior of right valve of adult. X 3.

Nettastomella japonica (Yokoyama)

Fig. 79-81, 85. MCZ 229137. Recent, Masset Island, Queen Charlotte Islands, British Columbia, Canada. Exterior of adult left valve; exterior and interior of adult left valve; dorsal view of adult specimen. Callum is larger on left valve. ca. X 2-3.

Pholadopsis pectinata Conrad

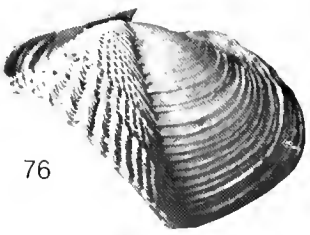
Fig. 82. USNM 495749. Pliocene, San Joaquin Formation, Kettleman Hills, Kings Co. (USGS loc. 12374). Exterior of adult left valve. X 1-1/2.

Fig. 83-84. USNM 189804. Same (USGS loc. 12374). Interior and exterior of juvenile right valve. X 1-1/2.

Fig. 86-87. MCZ 228109. Recent?, San Carlos Bay, near Guaymas, Sonora, Mexico. Exterior and interior of adult left valve. X 1-1/2.

Fig. 88. USNM 189805. Same as Fig. 83-84 (USGS loc. 12374). Internal mold of adult left valve. X 1-1/2.

Fig. 89-90. MCZ 228109. Same as Fig. 86-87. Interior and exterior of adult right valve. X 1-1/2.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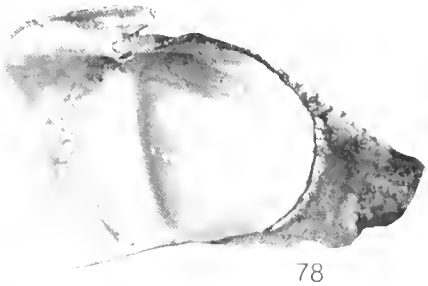
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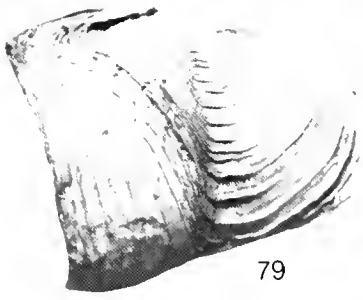
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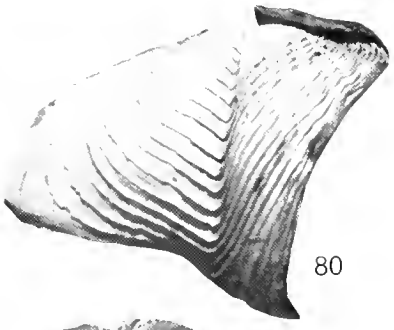
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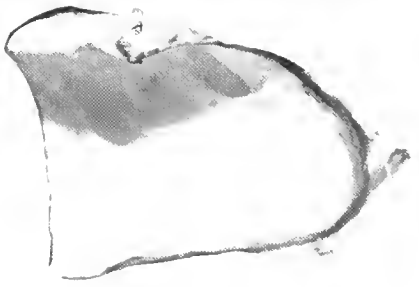
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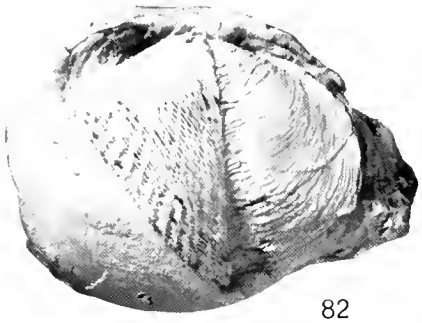
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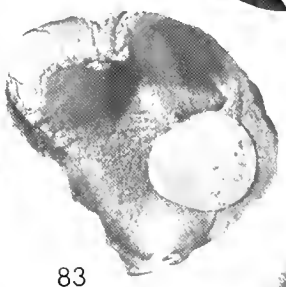
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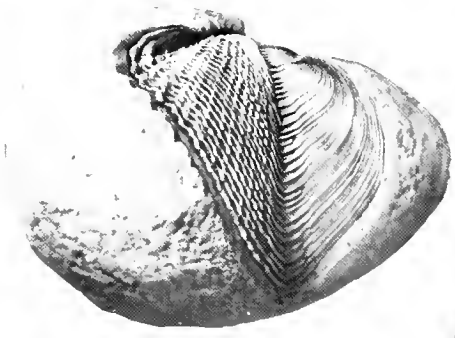
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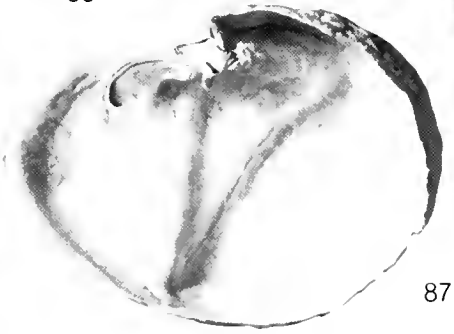
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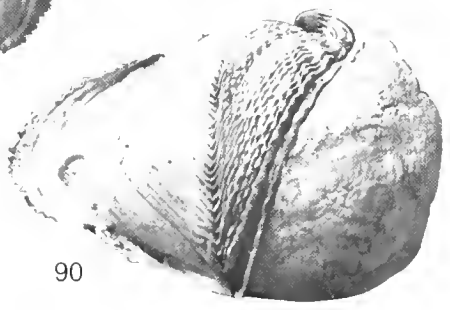
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FIGURES 91—103

"Jouannetia" sp. Clark and Woodford

Fig. 91-92. UCMP 31340. Eocene, Meganos Formation, Contra Costa Co. (UCMP loc. 3158). Dorsal view, and right valve of unique specimen. X 2.

Parapholas sp. indet.

Fig. 93. USNM 189806. Pliocene?, near La Purisima, Baja California, Mexico (USGS loc. 9330). Posterior half of left valve, showing preserved periostracal plates. X 1-1/2.

Opertochasma clausa (Gabb)

Fig. 94. UCMP 11947. Cretaceous, Chico group, Pentz's Ranch, Butte Co. Left valve of holotype of *Martesia clausa* Gabb. X 2.

Anomia peruviana d'Orbigny

Fig. 95. SDSNH 04288. Pleistocene, Palos Verdes Sand, Upper Newport Bay, Orange Co. (SDSC loc. 533). Specimen began growth in truncated pholad burrow and spread out on the surface. X 1.

Chama pellucida Broderip

Fig. 96. SDSNH 04289. Same (SDSC loc. 533). Growth began at right, moved down, around, and straight up. X 1-1/4.

Ostrea lurida Carpenter

Fig. 97. SDSNH 04290. Same (SDSC loc. 533). Deformed oyster has taken shape of pholadid burrow it inhabited. X 1-1/4.

Turnus plenus Gabb

Fig. 98. UCMP 31459. Cretaceous, "Division A" (probably Horsetown Formation), Cottonwood Creek, Shasta Co. Left valve of lectotype. X 2.

"Martesia(?)*"* sp. Dickerson

Fig. 99. UCMP 10607. Paleocene, Martinez Formation, Lower Lake, Lake Co. (UCMP loc. 784). Note similarity to *Turnus* [Fig. 98]. X 1-3/4.

Cast of pholadid burrow

Fig. 100. CAS 54827. Pliocene, Merced Formation, Moss Beach, San Mateo Co. (CAS loc. 34437). Probably formed by *Penitella penita*, which was associated with this specimen. X 1.

"Zirphaea" plana White

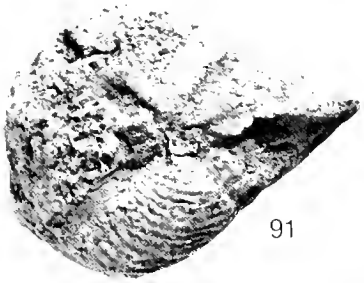
Fig. 101. USNM 20129. Cretaceous or Eocene, "Chico-Tejon series," Martinez, Contra Costa Co. Right valve of holotype. X 4.

Unidentified pholadid

Fig. 102. CAS 54826. Miocene, Temblor Formation, Jasper Canyon, Fresno Co. (CAS loc. 1841). Right valve of poorly preserved paired specimen. X 1.

Burrow of *Chaceia ovoidea* (Gould)

Fig. 103. CAS 54825. Pliocene?, near Oil City, Fresno Co. (CAS loc. 28485). Scratch marks on bottom were caused by rasping action of shell. X 1.



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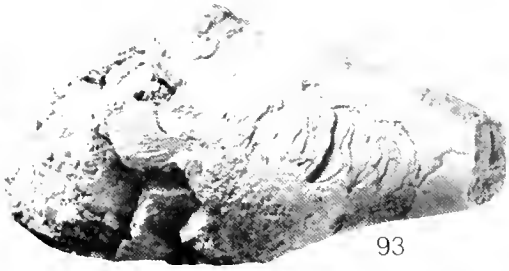

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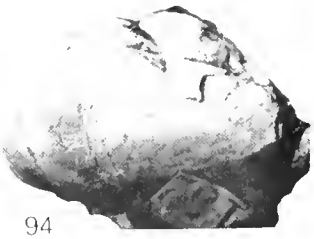

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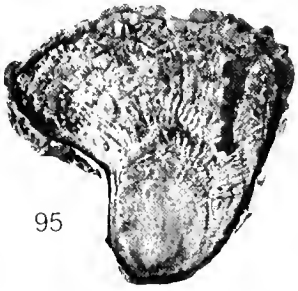

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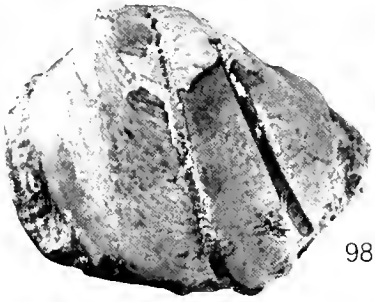

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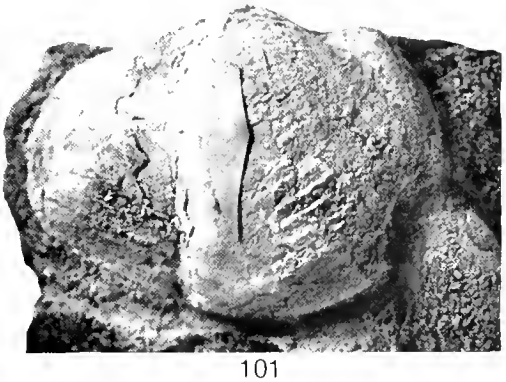

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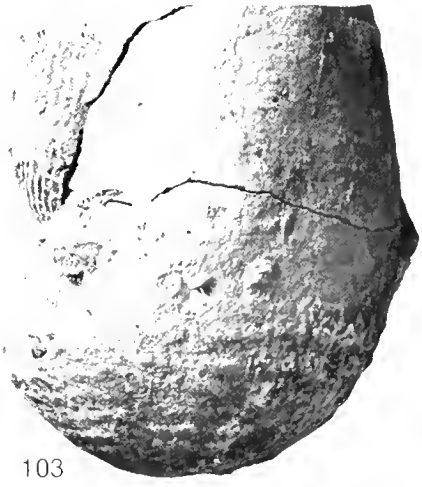

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