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NEW CRETACEOUS AND TERTIARY PHOLADIDAE (MOLLUSCA: BIVALVIA) FROM CALIFORNIA

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ABSTRACT—Cretaceous and early Tertiary Pholadidae (Mollusca: Bivalvia) from the Pacific Slope of North America are rare and only poorly known. Three new species, each the earliest known Pacific Slope representative of its respective genus, are described: *Barnea* (*Anchomasa*) *saulae* n. sp. (Pholadinae) from the Upper Cretaceous (Coniacian and Santonian) Redding Formation near Redding, uppermost Sacramento Valley, Shasta County, northern California; *Chaceia fulcherae* n. sp. (Martesiinae) from three widely separated areas of outcrop represented by 1) the middle Miocene ("Temblor") Temblor Formation near Oil City and in Jasper Canyon, western Fresno County, central California, 2) the middle Miocene ("Temblor") Topanga(?) Group in the northern Santa Ana Mountains, Orange County, southern California, and 3) the upper Miocene (Wishkahan) Montesano Formation on the Middle Fork of the Satsop River, Mason County, western Washington; and *Netastoma squiresi* n. sp. (Jouannetiinae) from the lowest Eocene (uppermost "Meganos") part of the Santa Susana Formation north of Simi Valley in the Santa Susana Mountains, Ventura County, southern California.

INTRODUCTION

FOSSIL REPRESENTATIVES of the molluscan bivalve family Pholadidae are rare in Cretaceous and lower Tertiary formations along the Pacific Slope of North America. Although some wood-boring species, such as *Opertochasma clausa* (Gabb, 1864) (subfamily Martesiinae) and *Turnus plenus* Gabb, 1864 (subfamily uncertain), have at least a meager fossil record in some Upper Cretaceous formations in California, soft-sediment or rock borers were previously unknown. The few specimens known from Paleocene and Eocene rocks are generally poorly preserved, and some cannot be unequivocally assigned to existing genera (Kennedy, 1974). *Zirfaea dentata* Gabb, 1866, is relatively common in some shallow marine Miocene formations in California, but most of the extant eastern Pacific genera and species do not have a fossil record older than Pliocene or Pleistocene (Kennedy, 1974).

Described herein are three new species: *Barnea* (*Anchomasa*) *saulae* n. sp. (subfamily Pholadinae) from the Upper Cretaceous of northern California; *Chaceia fulcherae* n. sp. (subfamily Martesiinae) from the middle Miocene of central and southern California, the upper Miocene of western Washington, and, provisionally, the upper Oligocene of southwestern British Columbia; and *Netastoma squiresi* n. sp. (subfamily Jouannetiinae) from the lower Eocene of southern California (Figure 1). Extant West American species of *Barnea* (*Anchomasa*) and *Netastoma* previously had been known as fossils only from the Pliocene and Pleistocene (Kennedy, 1974). The holotype of *Chaceia fulcherae* n. sp. previously had been regarded as Pliocene in age, but otherwise the genus was not known from rocks older than Pleistocene (Kennedy, 1974). The sediment-filled borings from the upper Miocene of the central California coast attributed to "*Chaceia*(?)" by Adegoke (1966) and to "*Nettastomella rostrata*" by Evans (1967) both represent misidentifications (Kennedy, 1974, p. 37). The generic assignments of the new species of *Chaceia* and *Netastoma* are not unequivocal, and arguments could be made for placing them in *Zirfaea* Gray, 1842, and *Pholadopsis* Conrad, 1849, respectively.

Morphological terminology follows that of Kennedy (1974, p. 11–13, fig. 2 [note, however, in the center illustration, "PC" should read "PL" and above left of the pallial sinus, "AMS" should read "PMS"]).

The following institutional acronyms are used: CAS, California Academy of Sciences; CIT, California Institute of Technology (collections at LACMIP); CSUN, California State University, Northridge; LACMIP, Natural History Museum of Los Angeles County; PRI, Paleontological Research Institution, Ithaca, New York; SU, Stanford University (collections at CAS); UCLA, University of California, Los Angeles; UCMP, University of California Museum of Paleontology; UCR, University of California, Riverside; USGS, U.S. Geological Survey; and USNM, U.S. National Museum of Natural History (Smithsonian Institution).

SYSTEMATIC PALEONTOLOGY

Phylum MOLLUSCA Linnaeus, 1758
Class BIVALVIA Linnaeus, 1758
Order MYOIDA Stoliczka, 1870
Superfamily PHOLADACEA Lamarck, 1809
Family PHOLADIDAE Lamarck, 1809
Subfamily PHOLADINAE Lamarck, 1809
Genus BARNEA Risso, 1826

Type species.—*Barnea spinosa* Risso, 1826 (=*Pholas candidus* Linnaeus, 1758), by monotypy (Turner, 1954, p. 19).

Comparison.—Species of *Barnea* differ from those in other genera of the Pholadinae by having only a single lanceolate protoplax (anterior-dorsal accessory plate). The umbonal reflection is not septate, as in *Pholas* Linnaeus, 1758, nor are the valves divided by an umbonal-ventral sulcus, as in *Zirfaea* Gray, 1842. *Cyrtopleura* Tryon, 1862, has a complicated socket arrangement in the umbonal region that is absent in *Barnea*.

Subgenus ANCHOMASA Leach, 1852

Type species.—*Anchomasa pennantiana* Leach, 1852 (=*Pholas parvus* Pennant, 1776), by monotypy (Turner, 1954, p. 23).

Comparison.—*Anchomasa* differs from *Barnea* s.s. in gaping widely anteriorly, and in some cases posteriorly, and by the constriction of its anterior extremity (beak). The shell of *Barnea* s.s. is rounded anteriorly and has slit-like anterior pedal and posterior siphonal gapes.

BARNEA (ANCHOMASA) SAULAE n. sp.
Figure 2.1, 2.2

Diagnosis.—Shells thin, fragile, moderately small for subgenus, reaching 5 cm in length and 2 cm in height, elongate, not truncate; anterior pedal gape approximately one-third of overall

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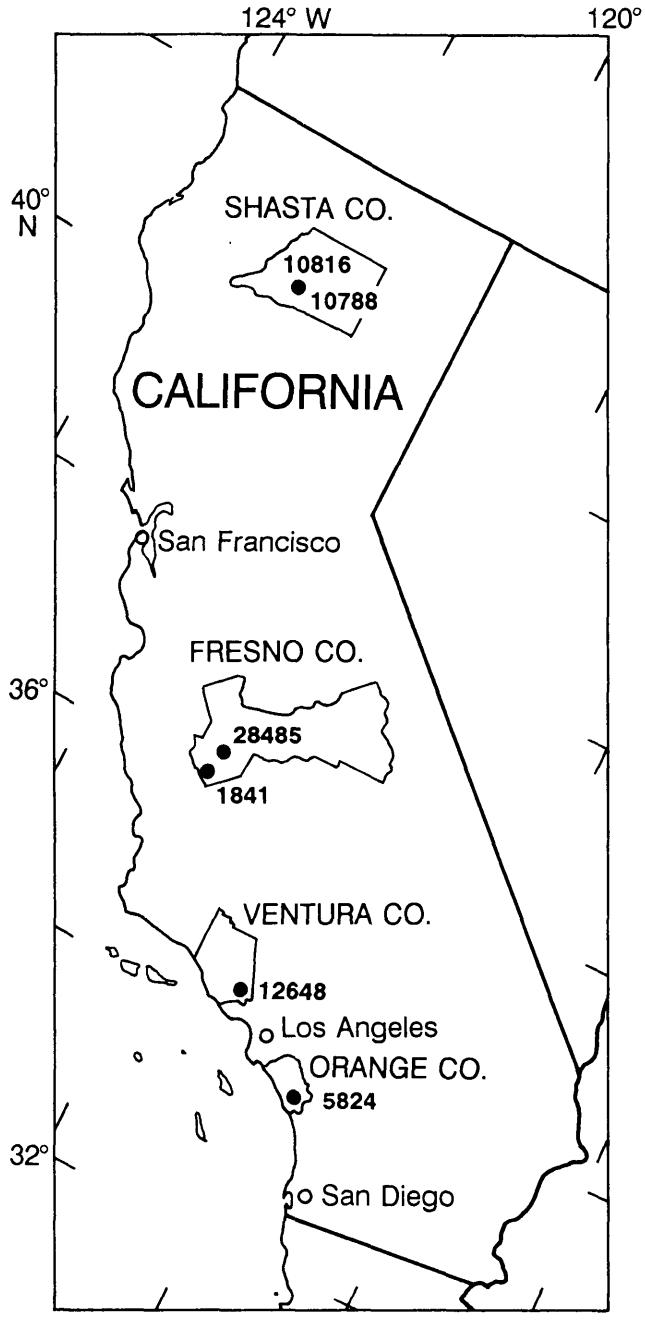

FIGURE 1—Index map of California showing approximate locations of fossil localities mentioned in text. Occurrences are: *Barnea* (*Anchomasa*) *saulae* n. sp., Shasta County, LACMIP locs. 10788 and 10816 (type locality); *Chaceia fulcherae* n. sp., Fresno County, CAS locs. 1841 and 28485 (type locality), and Orange County, LACMIP loc. 5824; and *Netastoma squiresi* n. sp., Ventura County, LACMIP loc. 12648 (type locality).

length; external sculpture formed by intersecting concentric ridges and radial ribs, slightly clathrate; radial ribs most prominent on central part of disc, present posteriorly as far as break between disc and posterior slope; sculpture evident on interior of shell due to its thinness.

Description.—Shells thin, fragile, moderately small for subgenus, probably reaching 5 cm in length and 2 cm in height, beaked and widely gaping anteriorly, elongate, rounded posteriorly, not truncate. Valves not divided by umbonal-ventral sulcus. Anterior slope and disc regions sculptured with intersecting radial ribs and concentric ridges that form a clathrate pattern over part of the shell, evident internally as grooves and pits due to thinness of valves. Radial sculpture more prominent than concentric ridges on disc, extending posteriorly to approximate demarcation of disc and posterior slope; apparent on anterior slope only as aligned spinose imbrications. Umbonal reflection flared for most of length, narrowing abruptly, and appressed to inner side of umbo, separated from anterior slope by narrow V-shaped furrow or crease, expressed internally as narrow ridge extending anteriorly to beaks.

Protoplax missing on both the holotype and paratype. Details of the interior aspect of the shell, including the muscle insertion scars, pallial line and sinus, chondrophore, and apophysis, unknown due to the preservation in indurated matrix.

Comparison.—The differences between *Barnea* (*Anchomasa*) *saulae* n. sp. and *B.* (*A.*) *scaphoidea* (Stephenson, 1953) (Figure 2.3), the only other described Cretaceous species of *Barnea,* are subtle ones. *Barnea saulae* n. sp. is larger, has a slightly less prominent sigmoidal curvature of the anterior margin around the pedal gape, and possesses radial sculpture that extends farther posteriorly than in *B. scaphoidea. Barnea scaphoidea* is more elongate, and its radial ridges only extend across the anterior two-thirds of the length of the shell. The protoplax is not known for either species.

Holotype.—LACMIP 8403, the greater part of an isolated right valve in matrix, from LACMIP loc. 10816. Length, 42 mm (incomplete); height, 20 mm.

Paratype.—LACMIP 8404, nearly complete internal mold with some remaining shell of isolated right valve in matrix, from LACMIP loc. 10788. Length, 31 mm (nearly complete); height, 18 mm.

Type locality.—LACMIP loc. 10816 (CIT loc. 1007), Upper Cretaceous, lower Coniacian, Redding Formation, member IV of Popenoe (1943). Hills north of Oak Run, approximately 11 km northeast of Millville, east of Redding, Shasta County, California.

Distribution.—The species is known only from two localities in the Redding Formation east of Redding, Shasta County, California. The type locality above Oak Run (LACMIP loc. 10816) and the paratype locality between Basin Hollow and Clover Creeks (LACMIP loc. 10788) span a stratigraphic interval from lower Coniacian, in member IV of Popenoe (1943), to Santonian, in the lower part of member V (L. R. Saul, personal commun.).

Discussion.—*Barnea* (*Anchomasa*) *saulae* n. sp. is one of the oldest species in the genus. Turner (1954, p. 16) cited a stratigraphic range for *Barnea* from Lower Cretaceous to Holocene, but subsequently (Turner, 1969, p. N708) recorded it only from the Miocene onward. The oldest species appears to be *Pholas*? *scaphoides* Stephenson, 1953, described from the Cenomanian (Upper Cretaceous) Woodbine Formation of Texas. The species (Figure 2.3) lacks any evidence of the septate umbonal reflection that is so diagnostic of *Pholas* and its subgenera, and is placed herein into *Barnea* (*Anchomasa*). Kelly (1988), in his review of Mesozoic pholadids, based his early record of *Pholas,* subgenus *Monothyra* Tryon, 1862, on *P.? scaphoides.*

Etymology.—The species name honors LouElla R. Saul, in recognition of her contributions to our understanding of the Cretaceous molluscan faunas of the Pacific Slope of North America.

Subfamily MARTESIINAE Grant and Gale, 1931
Genus CHACEIA Turner, 1955

Type species.—*Pholas ovoidea* Gould, 1851, by original designation (Turner, 1955, p. 66).

Comparison.—*Chaceia* was proposed as a monotypic genus for the large and distinct *C. ovoidea,* which differs from species in other genera of the Martesiinae, particularly *Penitella* Valenciennes, 1846, by its large size, wide anterior and posterior gapes, large "warty" siphon, broadly U-shaped mesoplax, only partial callum, and lack of a siphonoplax. If *Chaceia fulcherae* n. sp. is to be included in *Chaceia,* and not *Zirfaea,* then the definition of the genus will have to be amended to account for the apparent lack of even a partial callum in ancestral species (Kennedy, 1985). Species of *Zirfaea* have a small V-shaped mesoplax, weakly to moderately developed umbonal-ventral sulcus, and, like all members of the Pholadinae, lack a callum and siphonoplax.

CHACEIA FULCHERAE n. sp.
Figure 2.4–2.8

? *Zirfaea* sp. CLARK AND ARNOLD, 1923, p. 156, Pl. 16, fig. 2.
? *Zirfaea* sp. ADDICOTT, 1966, p. 646 (USGS loc. M1542; specimen(s) not seen, not found by Kennedy, 1974, p. 92).
Chaceia ovoidea (Gould, 1851). KENNEDY, 1974, p. 38, 39, both in part (CAS loc. 28485 only, as "aff." [on errata sheet]); not p. 37–39, figs. 20–27 (=*C. ovoidea* (Gould, 1851)). Not *Pholas ovoidea* Gould, 1851.
Unidentified pholadid. KENNEDY, 1974, p. 126, fig. 102.
Burrow of *Chaceia* sp. aff. *C. ovoidea* (Gould). KENNEDY, 1974, p. 126 (aff. on errata sheet), fig. 103.

Diagnosis.—Relatively large pholadid, reaching 10 cm in length, elongate and subcylindrical, anterior margin with prominent sigmoidal curvature, anterior slope short in relation to combined length of disc and posterior slope, umbonal-ventral sulcus moderately well defined, disc and posterior slope with well-defined low rounded concentric ridges, callum and dorsal extension of callum absent.

Description.—Shell large, reaching 10 cm in length and 5 cm in height, elongate and subcylindrical, anterior slope relatively short, approximately one-third of overall length, widely gaping anteriorly, anterior margin with prominent sigmoidal curvature from beak to ventral margin, posterior margin rounded, posterior-dorsal margin flaring somewhat. Anterior slope sculptured by upright concentric ridges with radially aligned flutes or ruffles that can be knobby appearing rather than sharp or spinose; concentric ridges pass through umbonal-ventral sulcus and continue onto disc and posterior slope as low, rounded concentric ridges. Umbonal-ventral sulcus relatively well defined, impinges upon ventral margin near its juncture with the pedal opening. Umbonal reflection free anteriorly, appressed over umbo, with well-defined muscle scar pad. Mesoplax unknown, perhaps broadly rounded posteriorly (see Discussion). Callum and dorsal extension of callum absent in all known specimens.

Details of interior aspect of shell, including muscle insertion scars, pallial line and sinus, and apophysis, unknown due to mode of preservation of existing specimens.

Comparison.—From *Chaceia ovoidea, C. fulcherae* n. sp. differs in its greater length to height ratio, proportionately smaller anterior slope in relation to disc and posterior slope lengths, less distinct umbonal-ventral sulcus, and apparent lack of even a partial callum or dorsal extension thereof. *Zirfaea dentata* from the Miocene of California is also elongate and subcylindrical, but its umbonal-ventral sulcus is only weakly defined and passes across the shell far posterior of the highly sculptured anterior slope that is comarginal with the pedal gape (see Kennedy, 1974, figs. 13–15). From *Zirfaea pilsbryi* Lowe, 1931, a Pliocene to Recent species, *C. fulcherae* n. sp. differs by its elongate subcylindrical shape, more prominent umbonal-ventral sulcus, more prominent sigmoidal curvature of the anterior margin, and lack of spinose projections on the concentric ridges.

Holotype.—CAS 54825.01, paired valves in posteriorly truncated sediment-filled boring, from CAS loc. 28485. Length, 80 mm (incomplete, projected length about 10 cm); height, 50 mm.

Paratypes.—CAS 54826.01, from CAS loc. 1841; LACMIP 11444 (juvenile pair), and 11445 (adult pair in sediment-filled boring), from LACMIP loc. 5824. All other specimens are excluded from consideration as type material.

Type locality.—CAS loc. 28485, Miocene, "Temblor"(?) Stage, Temblor(?) Formation, "one mile" (1–2 km) south of Oil City, north of Coalinga, Fresno County, California (see locality descriptions).

Distribution.—Despite possible questions about the exact locality and stratigraphic position for the holotype (see below), the species is widely distributed in the middle Miocene ("Temblor" Stage) of California, including the Temblor Formation near Oil City (the type locality) and in Jasper Canyon (CAS loc. 1841), both Fresno County, to Orange County, in the Topanga(?) Group at Upper Oso Reservoir (LACMIP loc. 5824) in the northern Santa Ana Mountains. In the upper Miocene (Wishkahan Stage) of western Washington, a pholadid boring from the basal Montesano Formation at USGS loc. M3073 yielded an external mold of a partial specimen that is probably *C. fulcherae* n. sp. (Figure 2.7, 2.8). The record of *Zirfaea* sp. by Addicott (1966, p. 646) from the Montesano Formation at USGS loc. M1542 may also represent *C. fulcherae* n. sp., but the specimens could not be located for comparison (Kennedy, 1974, p. 92). *Zirfaea* sp. of Clark and Arnold (1923, p. 156, Pl. 16, fig. 2; CAS 66602.01, ex SU 295, not UCMP 30065 as cited) from the upper Oligocene (Juanian Stage) Sooke Formation west of Sooke (CAS loc. 66602) on the southern end of Vancouver Island, British Columbia, is represented by a single partial specimen and is only provisionally assigned to *C. fulcherae* n. sp.

Discussion.—The description of *Chaceia fulcherae* n. sp. now allows for the identification of a number of previously enigmatic *Zirfaea*- and *Chaceia*-like pholadid specimens that did not compare favorably with any previously described species. These specimens were too derived, particularly in the development and placement of the umbonal-ventral sulcus, to be assigned to the only Miocene *Zirfaea, Z. dentata* Gabb, or to its Pliocene and younger descendant, *Z. pilsbryi* Lowe. The oldest of these specimens may be the small, partial specimen of "*Zirfaea* sp." of Clark and Arnold (1923) from the upper Oligocene (Juanian Stage) Sooke Formation on Vancouver Island, British Columbia. Unequivocal identification as *C. fulcherae* n. sp., however, should await additional, better preserved material. The apparent similarity to juvenile *Z. pilsbryi* noted by Kennedy (1974, p. 74, 81) was based on the strength and position of its umbonal-ventral sulcus, which is commonly better defined in juvenile specimens of *Z. pilsbryi* than in adults.

The holotype of *Chaceia fulcherae* n. sp. (Figure 2.6) was originally associated in the CAS collection with several specimens of *Zirfaea dentata,* although the lithologies and styles of preservation differed enough to question a single provenance. On that basis, I considered the present holotype specimen to be geologically younger (Pliocene?) and identified it as *Chaceia* sp. aff. *C. ovoidea,* believing it to be ancestral to *C. ovoidea* (Kennedy, 1974, p. 38, 39 [errata sheet]). It would seem now that the original Miocene age was probably correct, although the collection from CAS loc. 28485 may be a mixture of specimens from the Temblor Formation and the upper Miocene ("Margaritan") Santa Margarita Formation as suggested by the CAS locality records. The oldest examples of representative *C. ovoidea* are from the lower Pliocene ("Etchegoin" Stage) Etchegoin Formation, San Emigdio Mountain, Kern County, southern California (UCR loc. 1446).

The specimen of *Chaceia fulcherae* n. sp. from the Montesano Formation of western Washington (USGS loc. M3073) illus-

trated in Figure 2.7 and 2.8 was also questionably identified as a *Zirfaea* and thought to represent a form ancestral to *C. ovoidea* (Kennedy, 1974, p. 36, 93).

The greatest documented abundance of *Chaceia fulcherae* n. sp. is in the middle Miocene ("Temblor" Stage) Topanga(?) Group in the northern Santa Ana Mountains, where over 300 sediment-filled borings were collected from an area being prepared for the Upper Oso Reservoir (LACMIP loc. 5824; Figure 1). Most are 10–12 cm in length and comparable in size to the holotype boring (CAS 54825.01), although only a few have revealed impressions of the original pholadid shells, which have been leached away. Many of the filled borings preserve an ornate pattern of "chatter marks" on their basal end as a result of the rasping action of the beak and anterior margin during the boring process. Similar ornamented borings have been given the ichnofossil name *Gastrochaenolites ornatus* Kelly and Bromley (1984, p. 801, fig. 7A–D). The holotype of *G. ornatus* was created by a specimen of *Zirfaea crispata* (Linnaeus, 1758).

Although the mesoplax of *Chaceia fulcherae* n. sp. is unknown, one sediment-filled borehole from the Upper Oso Reservoir locality (LACMIP loc. 5824) still preserves an impression near the umbonal region that suggests *C. fulcherae* n. sp. may have had a mesoplax that was broadly rounded posteriorly, possibly similar to the adult mesoplax of *C. ovoidea,* which is also broadly rounded posteriorly (cf. Kennedy, 1974, figs. 25, 26). The mesoplax of *Zirfaea dentata* is unknown. The mesoplax of *Z. pilsbryi* is V-shaped and similar in aspect to the juvenile mesoplax of *C. ovoidea.*

Although description of *Chaceia fulcherae* n. sp. resolves identification of various Miocene and Oligocene(?) specimens at the species level, determination of the "correct" generic and subfamilial assignment is not as straightforward. The Pholadinae are borers of firm to indurated sediments, and may possess shells that are either closed anteriorly or have a pedal gape that remains open throughout life. Of the Pholadinae, only *Zirfaea* has a weakly to moderately developed umbonal-ventral sulcus, and all genera lack a callum and siphonoplax. Members of the Martesiinae, which are predominantly rock and wood borers, have a prominent, well-defined umbonal-ventral sulcus that separates the highly ornamented anterior slope from the relatively smooth disc and posterior slope, a wide open pedal gape that is closed by a callum in the adult stage, and various accessory plates around the margins of the shell. *Chaceia ovoidea* has the well-developed sulcus and sculpturally differentiated anterior and posterior regions, but has only a partial (incomplete) callum. The apparent lack of a callum in *C. fulcherae* n. sp. suggests that it should be placed in *Zirfaea* in the Pholadinae, but the moderately well developed umbonal-ventral sulcus, sculpturally differentiated anterior and posterior regions, and a mesoplax possibly similar to that of *C. ovoidea* indicate placement with *Chaceia* in the Martesiinae. Placement in *Chaceia* and the Martesiinae is warranted on the grounds that it best elucidates the ancestral (evolutionary) relationship of *C. fulcherae* n. sp. to *C. ovoidea,* and the definition of *Chaceia* is thus amended to account for the apparent lack of even a partial callum in the ancestral condition.

Etymology.—The species name honors the memory of my sister-in-law, Janet Krantz Fulcher (1930–1984).

Subfamily JOUANNETIINAE Tryon, 1862
Genus NETASTOMA Carpenter, 1864
[Conserved, ICZN Opinion 1296, 1985]

Type species.—*Netastoma Darwinii* Sby [*Pholas darwinii* G. B. Sowerby II, 1849], by monotypy (see comments in Turner, 1955, p. 141, and Coan and Kennedy, 1980, p. 114).

Comparison.—*Netastoma* differs from the larger and more bulbous *Pholadopsis* Conrad, 1849, to which it is most closely related, by the absence of a mesoplax, the very large, unequal callum, and the pectinate siphonoplax of the right valve. Juvenile shells are not easily distinguishable, but the umbonal reflection of *Netastoma* has a straighter dorsal margin and extends posteriorly over the umbo, whereas in *Pholadopsis* it is shorter, dorsally convex, and usually terminates on the anterior side of the umbo. In addition, the angle at which the anterior concentric ridges impinge on the umbonal-ventral sulcus is similar to the angle of departure in *Pholadopsis,* whereas in *Netastoma* the angle of departure is approximately 90° to the sulcus. In *Netastoma* the callum is a peripheral band of calcareous material that borders a large central periostracal region, and the siphonoplax is developed on both valves, usually equally. *Jouannetia* DesMoulins, 1828, is a distinct genus that is not closely related to either *Netastoma* or *Pholadopsis,* although the latter has been treated as a subgenus of *Jouannetia* by earlier workers, mainly because of the apparent similarity of their globose forms in the adult stage.

NETASTOMA SQUIRESI n. sp.
Figure 2.9, 2.10

Diagnosis.—Shell average-sized for genus, reaching 12 mm in length and 8 mm in height in juvenile stage, anterior and disc-posterior slopes about equally developed. Anterior slope sculptured by sharp, well-defined concentric ridges and prominently intersecting radial ribs forming pointed projections; radial ribs absent close to umbonal-ventral sulcus; concentric ridges pass through umbonal-ventral sulcus as sharp, well-defined ridges and continue posteriorly onto the disc at about a 90° angle with sulcus. Umbonal reflection flaring, not overturned (but missing over umbo on holotype), smooth, lacking continuation of concentric sculpture of anterior slope.

Description.—Shell reaching about 12 mm in length and 8 mm in height in juvenile stage, beaked, widely gaping anteriorly, rounded posteriorly. Anterior slope sculptured with moderately spaced, thin, sharply defined concentric ridges and intersecting radial ribs, intersections forming pointed (spinose?) projections; radial ribs weakening posteriorly, absent close to umbonal-ventral sulcus. Concentric ridges impinge on umbonal-ventral sul-

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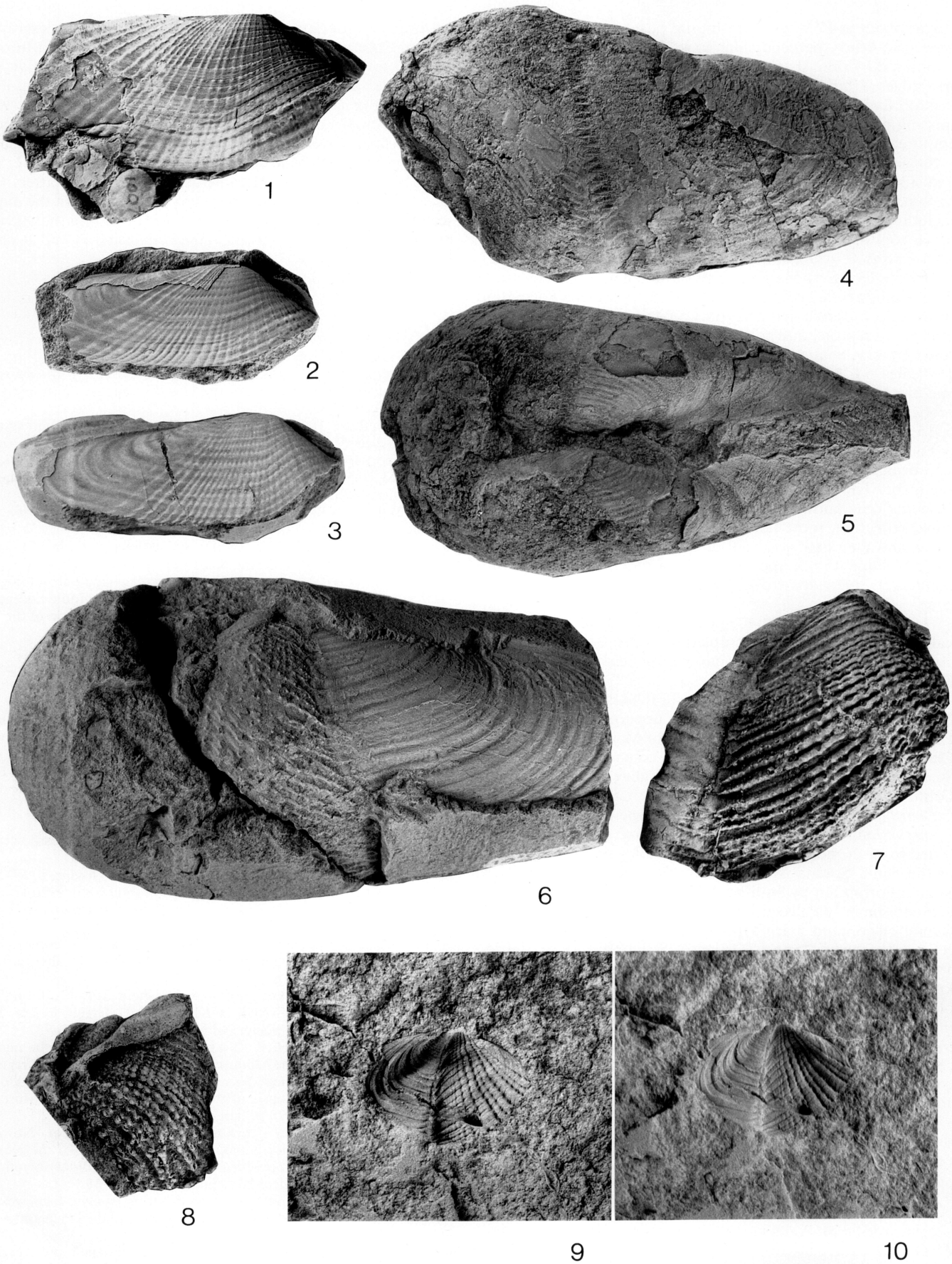
FIGURE 2—*1, 2, Barnea (Anchomasa) saulae* n. sp., ×1.5. *1,* holotype, LACMIP 8403 from LACMIP loc. 10816, incomplete right valve, length 42 mm; *2,* paratype, LACMIP 8404 from LACMIP loc. 10788, nearly complete internal mold of right valve with some remaining shell, length 31 mm. *3, Barnea (Anchomasa) scaphoidea* Stephenson, 1953, ×1.5; holotype, USNM 105591 from USGS Mesozoic loc. 19105 (Woodbine Formation, near Denison, Grayson County, Texas), internal mold with little remaining shell of isolated right valve, length 41 mm. *4–8, Chaceia fulcherae* n. sp., ×1.0. *4, 5,* paratype, CAS 54826.01 from CAS loc. 1841, left valve (*4*), and dorsal view of paired valves (*5*), length 98 mm; *6,* holotype, CAS 54825.01 from CAS loc. 28485, left valve of pair in sediment-filled borehole, length of boring 112 mm; *7, 8,* hypotype, LACMIP 11490, latex casts taken from external mold in sediment-filled borehole from USGS Cenozoic loc. M3073, anterior part of right valve (*7*), and anterior slope and umbonal reflection of left valve (*8*). *9, 10, Netastoma squiresi* n. sp., ×3.0. *9,* holotype, LACMIP 8405 from LACMIP loc. 12648, external (concave) mold of left valve, length 10 mm (incomplete); *10,* same specimen lighted to give the effect of being a convex right valve.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cus at about a 45° angle, continuing posteriorly across sulcus onto disc nearly perpendicular to it. Posterior slope and disc sculptured by thin, sharply defined, moderately spaced concentric ridges. Umbo located near midline of shell. Umbonal reflection flaring, but narrow and elongate, not overturned (but missing over the umbo on the holotype), not sculptured with continuations of concentric ridges of the anterior slope.

Single specimen available is a juvenile valve that lacks callum and siphonoplax, both useful adult characters in species of *Netastoma* and *Pholadopsis*. Details of interior aspect of shell, including muscle insertion scars, pallial line and sinus, and umbonal region, are not discernible on external mold of holotype.

Comparison.—"*Jouannetia* sp." of Clark and Woodford (1927, p. 102, Pl. 18, fig. 6), the generic allocation of which is uncertain, from the upper Paleocene or lower Eocene Meganos Formation in central California, has a proportionately larger anterior slope than combined disc and posterior slope, and appears to be sculptured by low, rounded concentric ridges anteriorly (Kennedy, 1974, figs. 91, 92) rather than with the sharp concentric ridges and pointed(?) projections of *Netastoma squiresi* n. sp. Another probable jouannetiinine species, *"Zirphaea" plana* White (1889, p. 15, Pl. 4, fig. 22) from indeterminate Cretaceous, Paleocene, or Eocene strata of the "Chico–Tejon series" at Martinez, central California, is too poorly preserved for unequivocal generic assignment. The holotype (USNM 20129; Kennedy, 1974, fig. 101) and only known specimen appears to have a shorter umbonal reflection, more like species of *Pholadopsis* than *Netastoma*, and the raised and well-defined concentric ridges on the anterior slope do not appear to have a radial component with pointed(?) projections as does the holotype of *Netastoma squiresi* n. sp.

Holotype.—LACMIP 8405, external mold of juvenile left valve. Length, 10 mm (incomplete); height, 7 mm; projected dimensions without callum or siphonoplax, length 12 mm, height 8 mm.

Type locality.—LACMIP loc. 12648 (CSUN loc. 967), lower Eocene, uppermost "Meganos" Stage, uppermost Santa Susana Formation, approximately 1 km ENE of Marr Ranch, between Chivo Canyon and Las Llajas Canyon on south slope of Santa Susana Mountains, north side of Simi Valley, Ventura County, California.

Distribution.—Known only from the type locality.

Discussion.—The holotype of *Netastoma squiresi* was collected from the north side of the Simi Valley on the south slope of the Santa Susana Mountains in an area mapped as Santa Susana Formation by Squires (1983). Although that formation is predominantly Paleocene in age, the uppermost 100 m of the formation contains marine mollusks indicative of the lower Eocene part of the uppermost "Meganos" Stage (Saul, 1983; Squires, 1988). If correctly assigned to *Netastoma, N. squiresi* is the oldest known representative of the genus, which is unknown in rocks older than Pliocene (Kennedy, 1974). The sediment-filled borings erroneously attributed to *Nettastomella* (=*Netastoma*) *rostrata* (Valenciennes, 1846) by Evans (1967) from the upper Miocene ("Margaritan") Pismo Formation on the central California coast belong to an unidentified species of *Penitella* (Kennedy, 1974, p. 37, 67).

Etymology.—The species name honors Richard L. Squires, in recognition of his contributions to our understanding of Eocene invertebrate faunas of western North America.

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REFERENCES

ADDICOTT, W. O. 1966. New Tertiary marine mollusks from Oregon and Washington. Journal of Paleontology, 40:635–646.

ADEGOKE, O. S. 1966. Silicified sand-pipes belonging to *Chaceia*(?) (Pholadidae:Martesiinae) from the late Miocene of California. The Veliger, 9:233–235.

CARPENTER, P. P. 1864. Supplementary report on the present state of our knowledge with regard to the Mollusca of the west coast of America. Report of the British Association for the Advancement of Science for 1863, p. 517–686. [Reprinted, 1872, Smithsonian Miscellaneous Collections, 10(252):1–172.]

CLARK, B. L., AND R. ARNOLD. 1923. Fauna of the Sooke Formation, Vancouver Island, with description of a new coral by T. Wayland Vaughan. University of California Publications, Bulletin of the Department of Geological Sciences, 14:123–234.

——, AND A. O. WOODFORD. 1927. The geology and paleontology of the type section of the Meganos Formation (lower middle Eocene) of California. University of California Publications, Bulletin of the Department of Geological Sciences, 17:62–142.

COAN, E. V., AND G. L. KENNEDY. 1980. *Nettastomella* Carpenter, 1865 (Mollusca: Bivalvia: Pholadidae): proposed conservation under the plenary powers. Z.N. (S.) 1054. Bulletin of Zoological Nomenclature, 37:114–116.

CONRAD, T. A. 1849. Descriptions of new fresh water and marine shells. Proceedings of the Academy of Natural Sciences of Philadelphia, 4:152–156.

DESMOULINS, C. 1827 [1828]. Description de trois genres nouveaux de coquilles fossiles du terrain tertiaire de Bordeaux. Société Linnéenne de Bordeaux, Bulletin d' Histoire Naturelle, 2:226–255 [not seen].

EVANS, J. W. 1967. A re-interpretation of the sand-pipes described by Adegoke. The Veliger, 10:174–175.

GABB, W. M. 1864. Description of the Cretaceous fossils, p. 57–217. *In* F. B. Meek and W. M. Gabb, Palaeontology of California. Volume I. Geological Survey of California, Sherman and Company, Philadelphia.

——. 1866–1869. Cretaceous and Tertiary fossils. Palaeontology of California. Volume II. Geological Survey of California, Sherman and Co., Philadelphia, 299 p.

GOULD, A. A. 1851. Descriptions of new shells from California collected by Maj. William Rich and Lieut. T. P. Green, U.S.N. Proceedings of the Boston Society of Natural History, 4:87–93.

GRANT, U. S., IV, AND H. R. GALE. 1931. Catalogue of the marine Pliocene and Pleistocene Mollusca of California and adjacent regions. Memoirs of the San Diego Society of Natural History, 1:1–1036.

GRAY, J. E. 1842. Synopsis of the contents of the British Museum. Edition 44. London, 308 p. [not seen].

I.C.Z.N. (International Commission on Zoological Nomenclature). 1985. Opinion 1296. Request for the use of the plenary powers to conserve *Nettastomella* Carpenter, 1865 (Bivalvia) refused. The Bulletin of Zoological Nomenclature, 42:37–38.

KELLY, S. R. A. 1988. Cretaceous wood-boring bivalves from western Antarctica with a review of the Mesozoic Pholadidae. Palaeontology, 31:341–372.

——, AND R. G. BROMLEY. 1984. Ichnological nomenclature of clavate borings. Palaeontology, 27:793–807.

KENNEDY, G. L. 1974. West American Cenozoic Pholadidae (Mollusca: Bivalvia). San Diego Society of Natural History Memoirs, 8:2–127 + errata sheet.

——. 1985. The bivalve family Pholadidae in the northeastern and northwestern Pacific: review of nomenclatural problems. Western Society of Malacologists, Annual Report, 17:12–13.

LAMARCK, J. B. P. A. DE M. DE. 1809. Philosophie zoologique, ou exposition des considérations relatives à l'histoire naturelle des animaux, la diversité de leur organisation et des facultés qu'ils en obtiennent, aux causes physiques qui maintiennent en eux la vie, et donnent lieu aux mouvements qu'ils exécutent; enfin à celles qui produisent les unes les sentiments, et les autres l'intelligence de ceux qui en sont doués, 2 volumes. Paris, 885 p. [not seen].

LEACH, W. E. 1852. Molluscorum Britanniae Synopsis: a synopsis of the Mollusca of Great Britain, arranged according to their natural affinities and anatomical structures, edited by J. E. Gray. John van Voorst, London, 376 p. [not seen].

LINNAEUS, C. 1758. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonyms, locis. Tomus I. Editio decima, reformata: Holmiae [Stockholm], 824 p. [Facsimile reprinted 1956, British Museum (Natural History), London.]

LOWE, H. N. 1931. Note on the west coast *Zirfaea*. The Nautilus, 45: 52–53.

PENNANT, T. 1776. British Zoology. Volume 4. Cymmorodorion Society, London [not seen].

POPENOE, W. P. 1943. Cretaceous: east side Sacramento Valley, Shasta and Butte Counties, California. Bulletin of the American Association of Petroleum Geologists, 27:306–312.

RISSO, A. 1826. Aperçu sur l'histoire des mollusques qui vivent sur les bords de la Mediterranée boréale et des coquilles, terrestres fluviatiles, et marines, subfossiles, fossiles et petrifiées, qui gisent dans les diverses formations de Alpes Maritimes. Histoire naturelle des principales productions de l'Europe meridionale, 4, 439 p.

SAUL, L. R. 1983. Notes on Paleogene turritellas, venericardias, and molluscan stages of the Simi Valley area, California, p. 71–80. *In* R. L. Squires and M. V. Filewicz (eds.), Cenozoic Geology of the Simi Valley Area, Southern California. Society of Economic Paleontologists and Mineralogists, Pacific Section, Volume and Guide Book.

SOWERBY, G. B., II. 1849. Monograph of the genus *Pholas*. Monograph of the genus *Triomphalia*. Monograph of the genus *Xylophaga*. Thesaurus Conchyliorum, or figures and descriptions of Recent shells, 2:485–505.

SQUIRES, R. L. 1983. Geologic map of the Simi Valley area, southern California, 1 sheet (scale 1:24,000). *In* R. L. Squires and M. V. Filewicz (eds.), Cenozoic Geology of the Simi Valley Area, Southern California. Society of Economic Paleontologists and Mineralogists, Pacific Section, Volume and Guide Book.

——. 1988. Geologic age assignments of west coast Eocene marine mollusks, p. 107–112. *In* M. V. Filewicz and R. L. Squires (eds.), Paleogene Stratigraphy, West Coast of North America. Society of Economic Paleontologists and Mineralogists, Pacific Section, Volume 58.

STEPHENSON, L. W. 1952 [1953]. Larger invertebrate fossils of the Woodbine Formation (Cenomanian) of Texas. U.S. Geological Survey Professional Paper, 242:1–226.

STOLICZKA, F. 1870–1871. Cretaceous fauna of southern India. Volume III. The Pelecypoda, with a review of all known genera of this class, fossil and Recent. Memoirs of the Geological Survey of India, Palaeontologica Indica, series 6, 3:1–222 [1870], i–xxii + 223–538 [1871].

TRYON, G. W., JR. 1862. On the classification and synonymy of the Recent species of Pholadidae. Proceedings of the Academy of Natural Sciences of Philadelphia, 14:191–221.

TURNER, R. D. 1954. The family Pholadidae in the western Atlantic and the eastern Pacific. Part I—Pholadinae. Johnsonia, 3:1–63.

——. 1955. The family Pholadidae in the western Atlantic and eastern Pacific. Part II—Martesiinae, Jouannetiinae and Xylophaginae. Johnsonia, 3:65–160.

——. 1969. Superfamily Pholadacea Lamarck, 1809, p. 702–741. *In* R. C. Moore (ed.), Treatise on Invertebrate Paleontology, Mollusca 6, Part N, Bivalvia, Volume 2. Geological Society of America and University of Kansas Press, Lawrence.

VALENCIENNES, A. 1846. Mollusques, 27 pls. [no text]. *In* Abel DuPetit-Thouars, Voyage autour de monde sur la Frégate La Venus, pendant les années 1836–1839, Atlas de Zoologie. Gide et Cie, Paris.

WHITE, C. A. 1889. Invertebrate fossils from California, Oregon, Washington, and Alaska. U.S. Geological Survey Bulletin, 51:1–102.

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APPENDIX

LOCALITY DESCRIPTIONS

CAS loc. 1841. Middle Miocene, "Temblor" Stage, Temblor Formation. [Pholadid] boring into Cretaceous shales, base of Temblor Reef, Jasper Canyon, western Fresno County, California. Collected by G. D. Hanna, September 1929.

CAS loc. 28485. Miocene, Temblor(?) Formation. "One mile" (1–2 km) southeast of Oil City, north of Coalinga, Fresno County, California. Collected by Joe Knowles, 1915–1935. "(Possibly the Temblor and Santa Margarita fossils were slightly mixed in locs. 28485 . . .)" (V. A. Zullo, personal commun.).

CAS loc. 66602 (SU loc. N. P. 129). Upper Oligocene, Juanian Stage, Sooke Formation. Sandstone and conglomerate in sea cliffs between the mouths of Kirby (formerly Coal) and Muir Creeks, Orveas Bay between Otter Point and Sheringham Point, west of Sooke, Renfrew District, southern end of Vancouver Island, British Columbia, Canada. Probably collected by Ralph Arnold or Harold Hannibal, early 1900s.

LACMIP loc. 5824. Middle Miocene, "Temblor" Stage, Topanga(?) Group. Pholads and other burrowing clams in top 0.3 m of dark-gray shale and overlying buff shaley sandstone below conglomerate unit, in freshly excavated areas for Upper Oso Reservoir on east side of Oso Creek valley, northeast of El Toro, northern Santa Ana Mountains, Orange County, California. NE¼, SW¼, SW¼, sec. 9, T6S, R7W, SBBM (USGS 7.5 min Santiago Peak, California quadrangle, 1954, scale 1:24,000). 33°39′37.3″N, 117°37′16.5″W. Collected by L. G. Barnes (LGB–1900), 12 April 1979; E. C. Wilson (OD–2), P. G. Owen, and B. J. Welton, 29 May and 19 June 1979.

LACMIP loc. 10788 (CIT loc. 1008). Upper Cretaceous, Santonian Stage, Redding Formation, lower part of member V of Popenoe (1943). Southwest end of ridge forming divide between Basin Hollow Creek and Clover Creek, approximately 8 km ENE of Millville, east of Redding, Shasta County, California. SE¼, NW¼, sec. 33, T32N, R2W, MDBM (USGS 15 min Millville, California quadrangle, 1953, scale 1:62,500). 40°35′25.3″N, 122°05′57.3″W. Sandstone slabs cropping out at head of small southwest-trending ravine, and overlying massive cliff-forming conglomerate cropping out on north face of ridge. Collected by W. P. Popenoe (P30–31) and D. W. Scharf, 11 April 1931.

LACMIP loc. 10816 (CIT loc. 1007). Upper Cretaceous, lower Coniacian Stage, Redding Formation, member IV of Popenoe (1943). Hard limey sandstones cropping out on lower slope of hills north of Oak Run and about 0.6 km (0.4 mi) due north of Hathaway Brothers ranch house, approximately 11 km northeast of Millville, east of Redding, Shasta County, California. Approximately 0.55 km southeast of NW cor. sec. 16, T32N, R2W, MDBM (USGS 15 min Millville, California quadrangle, 1953, scale 1:62,500). 40°38′01.3″N, 122°06′04.5″W. Collected by W. P. Popenoe (P29–31) and D. W. Scharf, 9 August 1931.

LACMIP loc. 12648 (CSUN loc. 967). Lower Eocene, uppermost "Meganos" Stage, uppermost Santa Susana Formation. Limey concretionary lense (20 m long, 30–40 cm thick) exposed 47–61 m below top of formation on south side of unmaintained dirt road on eastern spur of ridge crest between Chivo Canyon and Las Llajas Canyon approximately 1 km ENE of Marr Ranch, south slope of Santa Susana Mountains on north side of Simi Valley, Ventura County, California. SE¼, SE¼, SW¼, sec. 29, T3N, R17W, SBBM (USGS 7.5 min Santa Susana, California quadrangle, 1951 (PR 1969), scale 1:24,000). 34°18′34.4″N, 118°40′56.1″W. Elevation 1,725 ft. Collected by R. L. Squires, 28 February 1986.

UCR loc. 1446. Lower Pliocene, "Etchegoin" Stage, Etchegoin Formation. [? Shell Oil Company oil well] E. C. 31, San Emigdio Mountain, Kern County, California. Collection of Shell Oil Company of California.

USGS loc. M1542. Upper Miocene, Wishkahan Stage, Montesano For-

mation, basal contact. In bed of Canyon River, Grays Harbor County, Washington. 214 m (700 ft) west of SE cor. sec. 35, T21N, R7W, WBM (USGS 15 min Grisdale, Washington quadrangle, 1955, scale 1:62,500). Large bivalves boring into underlying Astoria Formation. Collected by W. O. Addicott.

USGS loc. M3073. Upper Miocene, Wishkahan Stage, Montesano Formation, basal formational contact. Road cut just south of bridge over the Middle Fork of the Satsop River, southwest corner of Mason County, Washington. 61 m (200 ft) west and 275 m (900 ft) north of SE cor. sec. 36, T19N, R7W, WBM (USGS 15 min Wynoochee Valley, Washington quadrangle, 1955, scale 1:62,500). Collected by G. A. Fowler, early 1960's.