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UPPER CRETACEOUS MOLLUSCA FROM SOUTHERN CALIFORNIA

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ABSTRACT

One new genus and thirteen new species of Mollusca are described from the Upper Cretaceous fauna of the Santa Ana Mountains, southern California. New generic assignments based upon discovery and study of previously unobserved structural features are offered for a number of common and well-known Cretaceous molluscan species. Some genera hitherto unknown in the Upper Cretaceous of the Pacific Coast are recognized, and their affinities are discussed.

In this paper are described and figured thirteen new species and one new genus of Upper Cretaceous Mollusca from the Santa Ana Mountains, southern California. In addition there are presented notes on the dentition and systematic relationships of a number of Upper Cretaceous Mollusca that were described many years ago but that until now have been imperfectly known. For each form discussed is given the stratigraphic range in the Upper Cretaceous beds of the Santa Ana Mountains. Such observations upon the relationships of these forms and of the occurrence of allied species as have seemed pertinent are included in the discussions. The synonymies of previously described species list only those references in which the species has been described, figured, or discussed, omitting citations in fossil lists. Genotypes are cited for genera not previously recognized in the Upper Cretaceous of the Pacific Coast.

In the course of the study of which a part of the results has been included in this paper, I have benefited from the helpful advice of Dr. J. P. Buwalda and Dr. Chester Stock, of the Division of Geological Sciences, California Institute of Technology. Dr. L. W. Stephenson, Dr. J. B. Reeside, Jr., and Dr. Ralph Stewart, of the United States Geological Survey, have given me much assistance in the determination of the systematic positions and relationships of a number of the fossil species herein discussed and have made helpful suggestions many times in the course of the work.

Dr. B. N. Moore, of the United States Geological Survey, has given me free use of the collections of Cretaceous fossils he made some years ago in the Santa Ana Mountains. Dr. A. Myra Keen, of Stanford University, has studied the specimens of *Pachycardium coronaense* discussed in this report and has given me valuable advice as to their relationships and systematic position. The authorities in charge of the paleontological museums of the United States National Museum, the California Academy of Sciences, the

Leland Stanford Junior University, and the University of California have been most courteous and helpful in making the facilities and collections in their charge available to me. I am glad to acknowledge the aid I have had from each of these sources.

The generalized section is given below of the stratigraphic subdivisions of the Upper Cretaceous sedimentary rocks of the Santa Ana Mountains as recognized in this paper.

Numbers in parentheses following citations in the discussions of species refer to the numbered references at the end of this paper. Where more than one citation has been made from any one reference the page number is included in the parentheses, following the reference number.

Generalized section of formations in the Santa Ana Mountains, California

Eocene.

Martinez? formation: Prevailingly light-colored coarse sandstone, conglomerates, and shale, with some coal seams. In part marine.

Unconformity.

Upper Cretaceous.

Williams formation:

Pleasants member: Light-colored shaly sandstones with many beds of limy fossiliferous sandstone intercalated. Approximate thickness, 320 feet.

Schulz member: Light-colored, coarse, arkosic sandstones with numerous beds of well-rounded boulders. Unfossiliferous. Average thickness, 200 feet.

Unconformity.

Ladd formation:

Holz member: Dark bluish- to brownish-gray micaceous sandy shale or siltstone, with interbedded arkosic sandstones and nonpersistent coarse conglomerate lenses. Fossiliferous in the upper half. Thickness, 1,500 feet ±.

Baker member: Gray to brownish, massive to thick-bedded boulder conglomerate below, grading up into thick-bedded to shaly arkosic soft brown sandstone above. Sandstones at top highly fossiliferous. Thickness, 200 feet ±.

Cretaceous?

Trabuco formation: Soft red friable deeply weathered massive boulder conglomerate. Un fossiliferous. Thickness, 300–400 feet.

Unconformity.

Pre-Cretaceous.

Basement complex: Metamorphosed sediments intruded by andesitic dikes and stocks.

SYSTEMATIC DESCRIPTIONS

Class PELECYPODA
Order PRIONODESMACEA
Family LIMOPSIDAE

Genus TRINACRIA Mayer

Genotype: *Trigonocoelia crassa* Deshayes.

TRINACRIA COR Popenoe, n. sp.
Plate 45, figures 1–3

Description: Shell large and massive for the genus, high, short, angular; beaks small, sharply incurved, opisthogyrous; dorsal anterior margin concave directly in front of the beaks, merging thence into the tumid anterior margin; ventral margin nearly straight; posterior margin abruptly truncate immediately back of the beaks, separated from the lateral portions of the shell by an abrupt umbonal angulation; lateral and ventral surfaces of the shell meeting at nearly a right angle; posterior shell surface back of the angulation nearly flat; sculpture of fine

growth lines with occasional deeper incised concentric grooves marking resting stages of growth; very fine rather widely spaced radial lines appear on well-preserved specimens; area short, amphidetic, shallow, directly beneath the beaks; dentition of about five minute chevron-shaped teeth on each side of the beak; muscle scars and pallial line unknown.

Holotype: California Inst. Technology, Invertebrate Paleo. Cat. no. 3418.

Dimensions of holotype: Length, 16.0 mm., height, 14.0 mm., thickness of one valve, 6.4 mm.

Distribution: Holz shale member, *common;* Williams formation, *common.*

Discussion: This species is also found in the Upper Cretaceous of the Simi Hills and of the Santa Monica Mountains, southern California, and also in the "type Chico" beds of Chico Creek, Butte County, California.

One other species of *Trinacria* (*T. galeata*) has been described from Cretaceous beds by Holzapfel (11, p. 213), but the genus is most numerous in the Eocene beds of the Paris Basin and of Alabama. *Trinacria* has been reported from the Oligocene of Washington by Clark (5, p. 81), and from the Miocene Alum Bluff group of Florida by Dall (7), and Gardner (10), but Stewart (18, p. 82) has questioned the reference of these species to *Trinacria.* If these references be incorrect, the known range of the genus is Upper Cretaceous and Eocene.

Trinacria cor is larger and more massive than any other member of the genus known to me, and it is also distinguished by its abruptly truncated posterior border and by its high beaks.

Family LIMIDAE

Genus LIMA Bruguiere
Subgenus LIMATULA Wood

LIMA (LIMATULA) sp. cf. L. SUCIENSIS Whiteaves

Plate 45, figure 4

Description: Shell small, thin, slightly inequilateral, rather more high than broad, outline gibbous; anterior dorsal slope shallowly concave from the umbo to about one-half the distance from the umbo to the ventral border; ears approximately equal, small; beaks low and pointed; sculpture on the posterior half of the shell consisting of very fine radiating ribs crossed by fine growth lines, producing a minute cancellation; sculpture of the anterior portion of the shell of low smooth sharp-crested ridges separated by interspaces several times wider than the ridges; anterior dorsal slope unornamented except for growth lines.

Dimensions of figured specimen: Height, 18.0 mm., length, 17.2 mm., thickness of one valve, approximately 4.0 mm.

Distribution: Ladd formation, Baker member, *rare.*

Discussion: The subgenus *Limatula* to which this species is referred includes straight or slightly oblique forms with pronounced sculpture on the middle part of the valve, but with the posterior and anterior slopes of the valves only slightly sculptured, or smooth.

This *Lima* agrees fairly well in outline and in size with Whiteaves' figure of *L. suciensis* (20, p. 399, pl. 51, fig. 2) and may be conspecific with it. Whiteaves' description includes these remarks:

> Surface markings consist of small narrow radiating ribs that are everywhere crossed by concentric striae or lines of growth. From eleven to fourteen of these ribs are a little larger than the rest, and in testiferous specimens, the spaces between them when examined with a lens are seen to be occupied by from four to six close-set minute radiating ridges.

These features suggest the subgeneric characters of *Limatula*, but unfortunately Whiteaves' figure of the species is not sufficiently good to determine the characters of the shell accurately.

Apparently no other described species of *Lima* from the Pacific Coast Cretaceous is likely to be confused with that from the Santa Ana Mountains.

Subgenus ACESTA H. and A. Adams

LIMA (ACESTA) BETA Popenoe, n. sp.
Plate 45, figure 5

Description: Shell moderately large, thin, fragile, pyriform, slightly convex; beaks low; anterior margin nearly straight, excavated dorsally; anterior ear very slightly developed; posterior and ventral margins forming a sweeping regular curve; posterior ear small, obliquely truncate; sculpture consisting of narrow radiating ribs toothed on the crests and separated from one another by concave interspaces three to four times wider than the ribs; interrib areas ornamented only by fine growth lines; resilium pit oblique, directed toward the posterior side.

Holotype: California Inst. Technology Invert. Paleo. Cat. no. 3424.

Dimensions of holotype: Height, 35.3 mm., length, 27.3 mm., thickness of one valve, approximately 5.0 mm.

Distribution: Ladd formation, Baker member, *abundant* and *characteristic*.

Discussion: The subgenus *Acesta* to which this species is referred includes Limas with straight anterior margins, small to obsolete anterior ears, and with oblique ligament pits extending under the posterior ear.

Among other West Coast Cretaceous Limas, only *L. microtis* Gabb appears to resemble *L. beta*. In his diagnosis of *L. microtis*, Gabb (9, p. 202) remarks:

> Ornamented by numerous flat radiating ribs, not dichotomous, the interspaces forming shallow grooves serrated on the sides and marked in the middle by a series of small pits or punctations.

In contrast to this description, the ribs of *L. beta* are sharp-crested and denticulate on top. No sign of punctations or serrations appears on the interspaces.

Family MYTILIDAE Fleming

Genus INOPERNA Conrad

Genotype: *Inoperna carolinensis* Conrad.

INOPERNA BELLARUGOSA Popenoe, n. sp.
Plate 45, figures 6, 7

Description: Shell of moderate size, elongate, compressed, gently concave on the ventral and convex on the dorsal margins, margins diverging slightly posteriorly; beaks low and small, markedly anterior but not terminal; anterior end smoothly rounded into the ventral margin; posterior end also smoothly rounded, with no marked posterior truncation; posterior umbonal angulation low and broad, extending from the umbo to the ventral posterior margin; sculpture consisting of narrow concentric lamellae paralleling the border of the shell, and of strong undulations developed upon the dorsal posterior border, paralleling the growth lines dorsally but dying out along the posterior umbonal angulation; undulations variable in their development on different individuals; internal characters of the shell unknown.

EXPLANATION OF PLATE 45

All figures are natural size except as otherwise stated. The letters CIT are an abbreviation of California Institute of Technology.

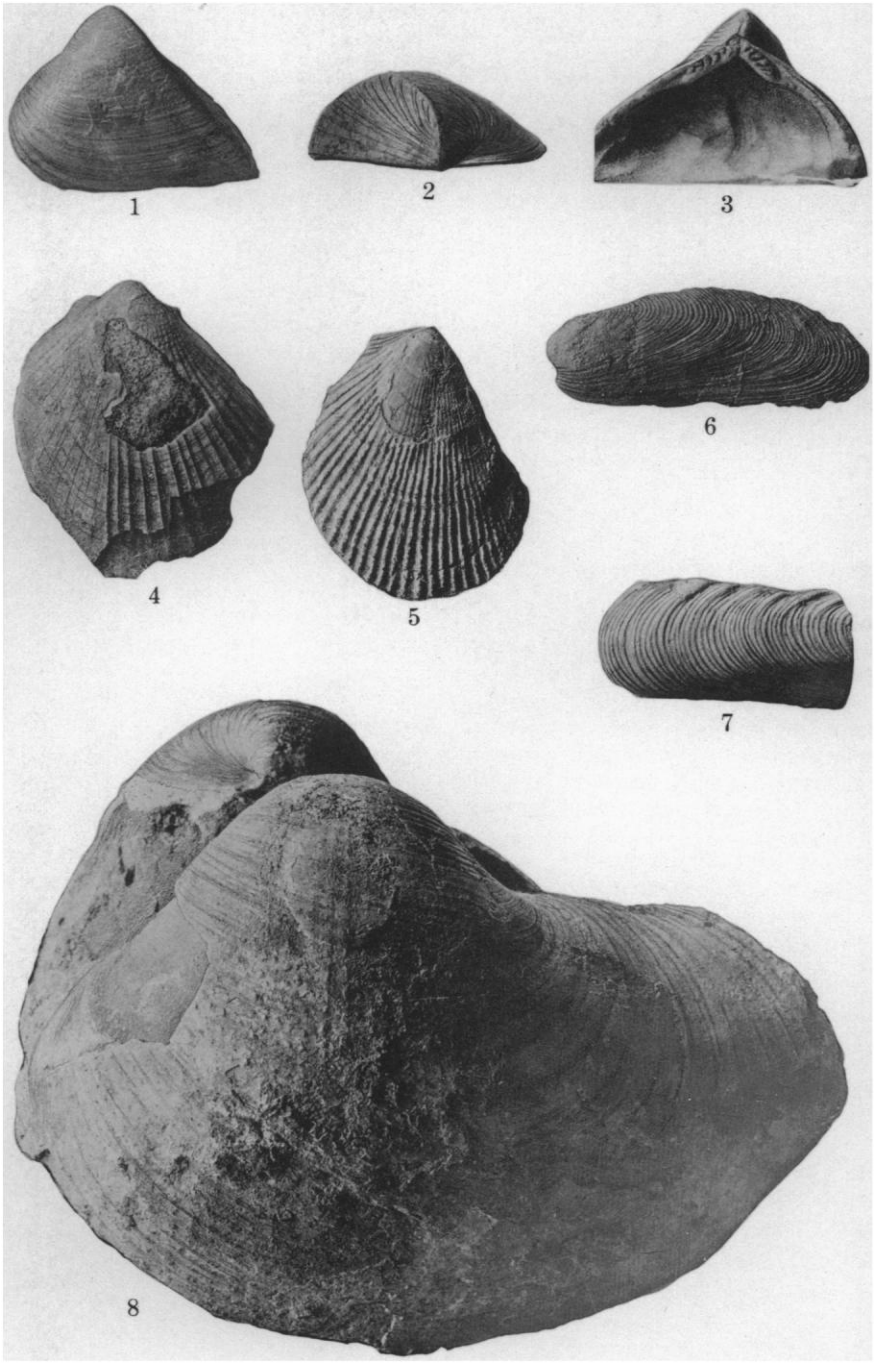
FIGS. *1–3*—*Trinacria cor* Popenoe, n. sp. Holotype, CIT Cat. no. 3418. ×2. *1*, Exterior of left valve; *2*, umbonal view of left valve; *3*, hinge of left valve. (p. 380)

4—*Lima* (*Limatula*) sp. cf. *L. suciensis* Whiteaves. Figured example, CIT Cat. no. 3422. ×2. Exterior of right valve. (p. 381)

5—*Lima* (*Acesta*) *beta* Popenoe, n. sp. Holotype, CIT Cat. no. 3424. Exterior of right valve. (p. 382)

6, 7—*Inoperna bellarugosa* Popenoe, n. sp. *6*, Holotype, CIT Cat. no. 3420. Exterior of left valve; *7*, Paratype, CIT Cat. no. 3421. Fragment of right valve showing characteristic coarse undulations on dorsal posterior border. (p. 382)

8—*Liopistha* (*Psilomya*) *hardingensis* (Packard). Figured specimen. CIT Cat. no. 3426. View of complete individual from left side. (p. 383)



Popenoe, Upper Cretaceous Mollusca

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3420; paratype, no. 3421.

Dimensions of holotype: Length, 42.3 mm., height, 18.7 mm., thickness of both valves, 13.9 mm.

Distribution: Ladd formation, Baker member, *common*.

Discussion: *Inoperna bellarugosa* resembles *Volsella siskiyouensis* (Gabb) somewhat in the character of the sculpture, but differs from the latter species by the characteristic dorsal posterior undulatory sculpture of *Inoperna*, by its more smoothly rounded posterior margins, and by the more gently tapering outline of the shell. *Inoperna bellarugosa* probably represents those forms from the Santa Ana Mountains that have been identified as *V. siskiyouensis*.

Inoperna flagellifera (Forbes) from the Valudayur group of India (Stoliczka, 19, p. 379) and the upper Greensand of England (Woods, 21, vol. 1, p. 99) is longer and more slender than *I. bellarugosa*. *I. carolinensis* Conrad, the genotype, from the Upper Cretaceous of the Atlantic and Gulf Coast of the United States, apparently has the dorsal undulations somewhat more numerous and less pronounced. Woods (21, p. 99) states that "*Modiola*" *flagellifera* belongs to a molluscan group characteristically developed in the Jurassic rocks.

Genus BRACHIDONTES Swainson

Genotype: *Brachidontes sulcata* Swainson.

BRACHIDONTES BIFURCATUS Popenoe, n. sp.

Plate 46, figure 2

Description: Shell small, thin, inflated; beaks low, incurved, markedly anterior; anterior end narrow, inflated, rounded; dorsal margin straight, two-thirds the length of the entire shell; posterior margin gently convex, obliquely truncate; ventral margin slightly emarginate; posterior umbonal ridge sharply angular near the beaks, becoming progressively lower and more broadly rounded toward the posteroventral border; sculpture consisting of numerous close-set radiating flat-topped ribs, separated by interspaces as wide as the ribs, strongly developed on the posterodorsal slope of the shell and on the umbonal ridge, where they bifurcate in some individuals; radial sculpture abruptly disappears slightly in advance of the umbonal angulation; sculpture on the anterior portion of the shell usually of growth lines only, or with very minute radial striae in addition; internal shell border crenate; dentition unknown.

Holotype: California Inst. Technology Invert. Paleo. Cat. no. 3425.

Dimensions of holotype: Length, 8.0 mm., height, 5.0 mm., thickness of one valve, 2.0 mm.

Distribution: Williams formation, *very rare*.

Discussion: This species is placed in the genus *Brachidontes* on the basis of the shape and sculpture of the shell, and of the crenate inner margin, which is visible in broken specimens. This appears to be the first record of *Brachidontes* in the Cretaceous of the Pacific Coast. The genus has been recognized in the Upper Cretaceous beds of the Western Interior region of the United States and Canada by Meek, White, Stanton, and others, and by Woods (21, vol. 1, p. 101 et seq.) in the Greensand of England.

Family POROMYACIDAE

Genus LIOPISTHA Meek

Section PSILOMYA Meek

LIOPISTHA (PSILOMYA) HARDINGENSIS (Packard)

Plate 45, figure 8; plate 46, figure 16

Homomya hardingensis PACKARD, *1922*, Uni. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 423, pl. 32, figs. 1a, 1b.

Description: These notes supplement the original description of the species. Sculpture consists of rather coarse concentric growth lines, of undulatory concentric ridges strongly developed in the region of the beaks but becoming progressively fainter ventrally and vanishing

at a distance of three or four centimeters ventral to the beaks, and of radial lines strongly developed at the beaks but appearing on the ventral flanks of the shell as rows of rather widely spaced raised granules. Where these granules have been broken off, their bases appear as shallow pits. Dentition not well shown but consists apparently of two lamellar teeth in the right valve, the anterior tooth being smaller and oblique; one rather small tooth in the left valve separates the sockets that receive the right cardinals; ligament external and rather short; a pronounced ridge extends from the beak to the anterior extremity delimiting a concave anterior dorsal area devoid of sculpture except for growth lines; anterior end apparently close; posterior end narrowly gaping.

Distribution: Ladd formation, Baker member, *rare*.

Discussion: This large shell is a *Liopistha* of the group of *L. superba* (Stoliczka) from the Trichinopoly group of India, and of *L. gigantea* (Sowerby) from the Upper Cretaceous beds of Blackdown, England. *L. hardingensis* differs from both of these other species in having a narrower and more pointed posterior end. I have found no reference to the presence of members of the section *Psilomya* elsewhere in the Cretaceous of North America.

Section LIOPISTHA s.s.

LIOPISTHA ANAANA (Anderson)

Plate 46, figures, 1, 3

Pholadomya anaana ANDERSON, *1902*, Calif. Acad. Sci., Proc., (3), vol. 2, no. 1, p. 73, pl. 7, fig. 151.

Liopistha anaana PACKARD, *1916*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 9, no. 12, p. 146.

Description: These notes may be added to the original description: Hinge of the left valve with two cardinal teeth, posterior tooth rather oblique and strong; anterior left cardinal parallel to the hinge margin, smaller than the posterior cardinal; hinge of the right valve also with two cardinal teeth; posterior cardinal blunt, oblique, situated close up under the anterior hinge margin, bounded above and below by sockets that receive the cardinal teeth of the left valve; right anterior cardinal very small, broken; ligament external, narrow, short; posterior dorsal slope unornamented except for growth lines; strong radial ribs are found immediately before the posterior dorsal slope, continuing to the anterior region of the shell where they become progressively finer and more close-set; valves apparently close in front, gaping behind.

Distribution: Ladd formation, Baker member, *abundant* and *characteristic*.

Discussion: *Liopistha anaana* is probably to be referred to *Liopistha* s.s. as

EXPLANATION OF PLATE 46

FIGS. *1, 3—Liopistha anaana* (Anderson). ×1½. Figured examples, CIT Cat. no. 3427. *1*, Hinge of right valve; *3*, Hinge of left valve. (p. 384)

2—Brachidontes bifurcatus Popenoe, n. sp. Holotype, CIT Cat. no. 3425. ×3. Exterior view of right valve. (p. 383)

4—Etea angulata (Packard). Figured example, CIT Cat. no. 3461. ×2. Hinge of right valve of immature specimen. (p. 385)

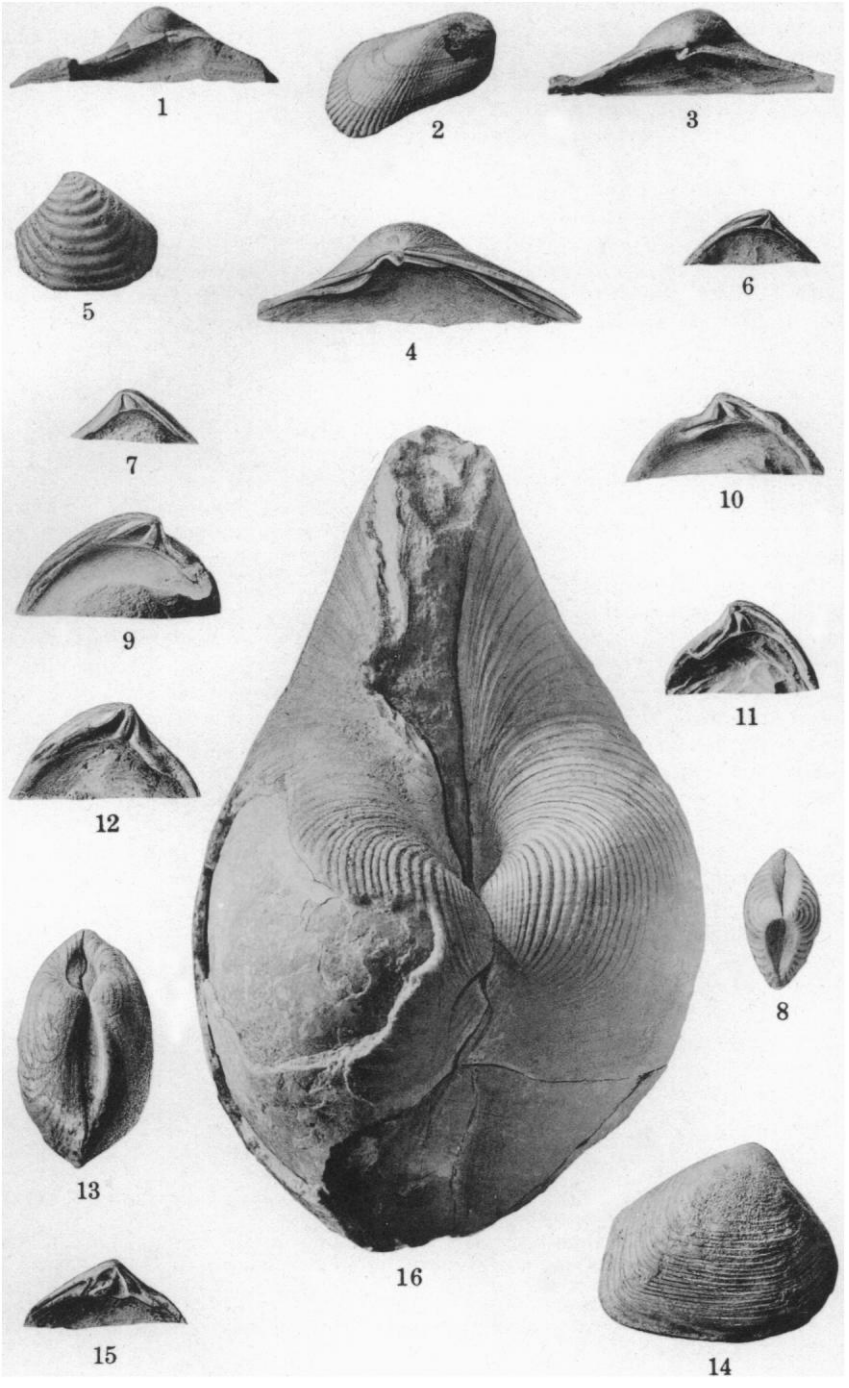
5–8—Astarte sulcata Packard. Figured examples, CIT Cat. no. 3428. ×2. *5*, Exterior of left valve; *6*, hinge of left valve; *7*, hinge of right valve; *8*, umbonal view of complete specimen. (p. 386)

9, 10—Eriphyla ovoides (Packard). Figured examples, CIT Cat. no. 3429. *9*, Hinge of left valve; *10*, hinge of right valve. (p. 386)

11, 12—Eriphyla lapidis (Packard). Figured examples, CIT. Cat. nos. 3430, 3431. *11*, Hinge of right valve; *12*, hinge of left valve. (p. 387)

13–15—Crassatella gamma Popenoe, n. sp. Holotype, CIT Cat. no. 3433. *13*, Umbonal view of complete specimen; *14*, exterior view of right valve. *15*, Paratype, CIT Cat. no. 3434. Hinge of left valve. (p. 388)

16—Liopistha (Psilomya) hardingensis (Packard). Figured example, CIT Cat. no. 3426. Umbonal view of complete specimen, showing concentric sculpture around the beaks. (p. 383)



Popenoe, Upper Cretaceous Mollusca

defined by Meek. Certainly the radial sculpture is the more prominent element in the ornamentation of the shell. There is a suggestion of concentric undulatory sculpture in the umbonal regions of well-preserved specimens, but this is seldom discernible far down on the sides of the valves. The radial sculpture is more prominent on the posterior part of the valves, but in some individuals as many as twelve to fifteen radial ribs growing weaker anteriorly are visible.

Dr. L. W. Stephenson, of the United States Geological Survey, informs me (oral communication) that the specimens of *Liopistha* s.s. that he has studied from the Atlantic Coast and Western Interior Cretaceous localities all show fine denticulations on the radial ribs. I have not seen any such ornamentation on any of the specimens from the Santa Ana Mountains. Its absence may be due to preservation, but I am inclined to believe these denticulations were never present on the California specimens. On the other hand, a few well-preserved individuals from the Santa Ana Mountains show what appear to be radial rows of broken-off tubercles suggestive of the sculpture of the section *Psilomya* as mentioned in the discussion of *L. hardingensis* above.

Pholadomya lucerna (Forbes) of the Trichinopoly and lower Valudayur beds of southern India strongly resembles *Liopistha anaana* in external aspect and if Meek (13, p. 235) is correct in assuming the Indian species to be a *Liopistha* the two forms are undoubtedly very closely allied. The chief external difference appears to be that the radial sculpture of *Pholadomya lucerna* is more strongly developed on the anterior areas of the shell.

Order TELEODESMACEA
Family PLEUROPHORIDAE
Genus ETEA Conrad

Genotype: *Etea carolinensis* Conrad.

ETEA ANGULATA (Packard)

Plate 46, figure 4

Meretrix angulata PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 425, pl. 33, fig. 5.

Description: The following notes supplement the original description of this species: Dentition of the right valve consists of two cardinal teeth and two lateral sockets; right anterior cardinal thin, laminar, oblique, lying close up under the lunular border; right posterior cardinal longer, more robust, weakly bifid, the anterior element of the bifid tooth being short and splintlike; tooth obliquely ventrally directed; anterior socket deep, short, close to the anterior cardinal; posterior socket deep, narrow, long, situated midway between the umbo and the posterior end of the shell; dentition of the left valve consists of two cardinal teeth and two lateral teeth; anterior cardinal stout, triangular, weakly bifid, situated directly beneath the beak; posterior cardinal long, thin, laminar, close up under the nymph; anterior lateral close to the beaks, short, stout, prominent; posterior lateral long, thin, distant from the beaks; ligament rather short, narrow, external; pallial line simple.

Distribution: Ladd formation, Holz shale member, *abundant* and *characteristic*.

Discussion: *Etea angulata* is characteristic of a zone in the Holz shale comprising several hundred feet of beds near the middle of the section. At this horizon the species is abundant and widespread. It has also appeared rarely in beds both near the top and near the bottom of the shale member.

Etea was erected by Conrad as a subgenus of *Veniella*. It has usually been so considered, but Stephenson (16, p. 392), in a recent publication has accorded *Etea* generic rank. This procedure is followed here. In comparison with *Veniella*, as typified by *V. mortoni* Conrad, *Etea* has a much thinner shell and more delicate hinge, is generally smooth instead of having a sculpture of coarse concentric corrugations and costae, has the posterior lateral teeth farther removed from the beaks, and apparently lacks the trans-

verse striations of the posterior laterals.

Etea has not been reported elsewhere on the Pacific Coast and I have found no reference to it elsewhere in the literature on the Upper Cretaceous of the Indo-Pacific region. The genus is represented in a number of localities in the Upper Cretaceous of the Atlantic and Gulf Coastal Plain of the United States. None of the specimens I have seen from these regions are so robust as *E. angulata*.

Family ASTARTIDAE

Genus ASTARTE Sowerby

ASTARTE SULCATA Packard

Plate 46, figures 5–8

Astarte? sulcata PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 424, pl. 33, fig. 6.

Description: The following notes are added to the original description of this species: Lunule and escutcheon both well-marked, rather broad, long, unsculptured; ligament short, small, inserted in a narrow trough; dentition of the right valve, one strong trigonal posterior tooth immediately beneath the beaks, and one very small laminar anterior tooth directed obliquely toward the ventral anterior border and situated close up under the lunule; dentition of the left value, one strong central trigonal cardinal; dorsal anterior margin of right valve and dorsal posterior margin of left valve fit into long, narrow and shallow grooves on the corresponding margins of the opposite valves; pallial line simple; internal margins of the valves smooth.

Distribution: Ladd formation, Baker member, *abundant* and *characteristic*.

Discussion: The genus *Astarte* s. l., has been divided into many sections and subgenera of which the distinctions are both confused and confusing. The subdivision of the genus to which *A. sulcata* is to be referred is yet uncertain. The species agrees fairly well with a species figured and discussed by Meek (13, p. 124) as *Eriphyla gregaria* M. and H. Meek, however, questions the reference of this latter species to *Eriphyla*, and it seems impossible that it should belong to this genus. *A. sulcata* appears to agree well with the *Astarte subcostata* group as figured and discussed by Woods (21, vol. II, p. 109 et seq.). Small astartes of this general type appear to be rather common in the Upper Cretaceous of Europe. With the possible exception of "*Eriphyla*" *gregaria* mentioned above, I know of no very closely related species in the American Interior or East Coast Cretaceous beds.

Genus ERIPHYLA Gabb

ERIPHYLA OVOIDES (Packard)

Plate 46, figures 9, 10

Astarte ovoides PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 424, pl. 30, fig. 1.

Description: The following notes may be added to the original description: Dentition consists of two cardinal teeth in each valve, and of a posterior lateral tooth in the right valve and a corresponding posterior lateral socket in the left valve; right posterior cardinal heavy,

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EXPLANATION OF PLATE 47

FIGS. *1*—*Crassatella gamma* Popenoe, n. sp. Paratype, CIT Invert. Paleo. Cat. no. 3434. Hinge of right valve. (p. 388)

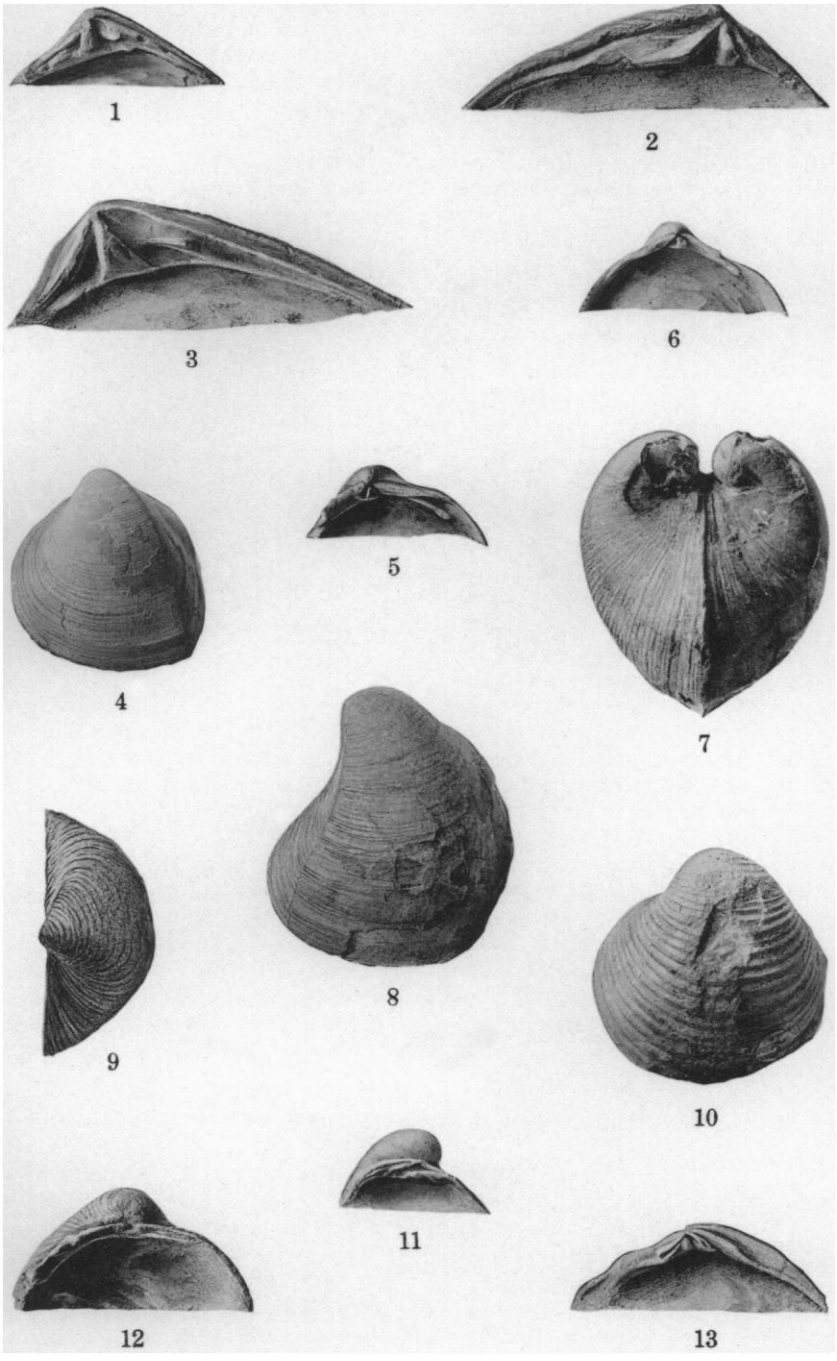
2, 3—*Crassatella lomana* Cooper. Figured examples, CIT Cat. no. 3432. *2*, Hinge of left valve; *3*, hinge of right valve. (p. 387)

4–6—*Pachycardium coronaense* (Packard). Figured examples, CIT Cat. no. 3435. *4*, Exterior of left valve; *5*, hinge of right valve; *6*, hinge of left valve. (p. 388)

7, 8, 11—*Isocardia delta* Popenoe, n. sp. Holotype, CIT Cat. no. 3436. *7*, Anterior view; *8*, exterior of left valve. *11*, Paratype, CIT Cat. no. 3438. Hinge of left valve. (p. 389)

9, 10, 12—*Clisocolus corrugatus* Popenoe, n. sp. Holotype, CIT Cat. no. 3439. *9*, Umbonal view of left valve; *10*, exterior view of valve; *12*, hinge of left valve. (p. 390)

13—*Cyprimeria moorei* Popenoe, n. sp. Syntype, CIT Cat. no. 3440. ×2. Hinge of right valve. (p. 391)



Popenoe, Upper Cretaceous Mollusca

oblique, trigonal; right anterior cardinal narrow, thin, situated vertically beneath the beak; right posterior lateral long, straight, rather heavy; left anterior cardinal rather heavy, situated nearly vertically beneath the beak; left posterior cardinal long, thin, curved, set close up under the nymph; posterior lateral socket long, narrow, shallow; ligament external, rather long; lunule short, deeply impressed; edge of left lunular margin projecting, and fitting into a narrow elongate socket just below the lunule of the right valve.

Distribution: Ladd formation, Baker member, *rare;* ?Holz shale member, *rare.*

Discussion: *Eriphyla* has been regarded as a subgenus of *Astarte* by many writers and as a genus of the Astartidae by as many others. Dall (8) considered *Eriphyla* more nearly related to the Crassatellidae. Stoliczka (19, p. 156) referred the genus to the Veneridae, near *Dosinia*. Meek (13, p. 122) questioned the generic position of the forms referred to *Eriphyla* by Stoliczka largely on account of the presence in Stoliczka's species of a slightly sinuous pallial line. Meek admitted that he had not seen the pallial line of the type of *Eriphyla* and admitted also that Stoliczka's species otherwise agreed well with Gabb's definition of the genus. Since that time, Woods (21, vol. 2, pls. 16, 17) has figured specimens of *Eriphyla* showing a sinuous pallial line, as has also Holzapfel (11, pl. 14). Specimens of *Eriphyla*, probably representing *E. umbonata* Gabb, now in the California Institute of Technology collections from the Upper Cretaceous beds at Clover Creek, Shasta County, California, also show this gently sinuous pallial line plainly. This feature alone is probably sufficient to separate *Eriphyla* generically from *Astarte*. *Eriphyla* is here regarded as a separate genus, tentatively placed in the Astartidae.

ERIPHYLA LAPIDIS (Packard)
Plate 46, figures 11, 12

Astarte lapidis PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 423, pl. 30, figs. 4a, 4b.

Distribution: Ladd formation, Holz shale member, *common.*

Discussion: Hinges of both valves of this species have been revealed and agree fully with Gabb's diagnosis of *Eriphyla*. They also agree fully with the dentition of *Eriphyla ovoides* (supra) and with hinges of specimens from Clover Creek, Shasta County, believed to represent *E. umbonata* Gabb.

Eriphyla lapidis bears considerable resemblance to *E. umbonata* in its general form and sculpture. Better material than that now available may show the two to be conspecific. *E. lapidis* seems to average larger than does *E. umbonata*, and seems likewise to be somewhat more ovoid in outline, however.

Family CRASSATELLIDAE

Genus CRASSATELLA Lamarck
Subgenus PACHYTHAERUS Conrad

CRASSATELLA LOMANA Cooper
Plate 47, figures 2, 3

Crassatella lomana COOPER, *1894*, Calif. State Min. Bur., Bull. 4, p. 48, pl. 3, fig. 47.—PACKARD, *1916*, Univ. Calif., Dept. Geol. Sci., Bull., vol. 9, no. 12, p. 146.

Distribution: Ladd formation, Holz shale member, *very abundant* and *characteristic;* ?Williams formation, *very rare.*

Discussion: This massive *Crassatella* is at once one of the most abundant, most characteristic, and most widely distributed fossils from the upper part of the Holz shale. It is present in great numbers in nearly every fossil collection from this part of the section, and occurs at but few other horizons.

Crassatella lomana was originally described from the Cretaceous shales at Point Loma Peninsula, San Diego. Cooper, in his original description, stated that the fossil lacked the concentric ridges of *C. tuscana*, being sculptured only by coarse lines of growth. In well-preserved specimens these growth-lines show considerable regularity and differ from the more finely chiseled ornamentation of *C. tuscana* more in degree than in kind. The only specimens of *C. tuscana*

now available to me are from Sucia Island, in the Gulf of Georgia. These specimens are somewhat smaller than *C. lomana*, have finer sculpture, rather more inflated shape, shorter posterior end, and a broader dorsal slope. The two species are probably closely related, but are undoubtedly distinct.

CRASSATELLA GAMMA Popenoe, n. sp.

Plate 46, figures 13–15; plate 47, figure 1

Description: Shell of moderate size, rather high, short, compressed, angular in outline; beaks not very prominent, slightly anterior to the middle of the shell, prosogyrate; lunule depressed, long, narrow, about two-thirds the length of the anterior dorsal border; anterior dorsal border nearly straight; anterior portion of ventral border rounded; posterior half of ventral border nearly straight; posterior end abruptly truncate nearly at right angles to the ventral posterior border; posterior dorsal slope comparatively broad, plane, bounded below by an abrupt umbonal angulation; escutcheon long, narrow; sculpture of fine concentric close-set rather irregular ridges.

Dentition of right valve: one strong trigonal posterior cardinal tooth directly beneath the beak bounded anteriorly by a narrow oblique socket and posteriorly by a rather deep triangular socket; anterior cardinal tooth nearly obsolete; ligament pit a triangular depression in the dorsal half of the hinge plate immediately behind the posterior cardinal tooth; anterior dorsal border bears a shallow lateral socket situated below the forward part of the lunule; posterior lateral tooth long, narrow, straight. Dentition of the left valve: anterior cardinal tooth narrow and oblique; posterior cardinal tooth rather short and thick, bounded above by the chondrophore; anterior lateral tooth short and narrow, situated below the anterior end of the lunule; posterior lateral socket long, narrow, extending nearly the full length of the escutcheon.

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3433.

Paratypes: California Inst. Technology, Invert. Paleo. Cat. no. 3434.

Dimensions of the holotype: Height, 26.0 mm., length, 30.5 mm., thickness of both valves, 17.1 mm.

Distribution: Ladd formation, Baker member, *abundant;* Holz shale member, *rare.*

Discussion: This *Crassatella* is common in and characteristic of the basal part of the Holz shale and of the uppermost part of the Baker member. It appears to have a limited stratigraphic range. It is somewhat similar to *Crassatella tuscana* in appearance, but differs from that form in being relatively higher, more compressed laterally, more sharply truncate posteriorly, with straighter ventral and dorsal margins, a longer and narrower lunule, and in general, greater angularity of form. I do not know of the appearance of this species outside of the Santa Ana Mountains region.

Superfamily CARDIACEA
Family CARDIIDAE

Genus PACHYCARDIUM Conrad

Genotype: *Cardium spillmani* Conrad.

PACHYCARDIUM CORONAENSE (Packard)

Plate 47, figures 4–6

Cardium coronaensis PACKARD, *1922*, Univ. Calif., Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 424, pl. 30, fig. 2.

Description: Shell small to medium in size, moderately inflated, shell substance rather thick; beaks high, narrow, prominent, prosogyrous, approximate; anterior dorsal margin broadly rounded, merging with a smooth curve into the arcuate ventral margin; posterior margin nearly vertically truncate, meeting the posterior ventral margin with an angle of slightly less than 90°; posterior dorsal border very short; ligament short and depressed; lunule restricted by a delicate incised line; hinge plate heavy; hinge angle approximately 55°.

Sculpture of the anterior and central slopes of the shell consists of delicate

incised evenly and closely spaced concentric lines that are most evident on the umbonal region and become progressively fainter ventrally; concentric sculpture usually nearly or quite invisible on the ventral regions of well preserved shells but generally well-shown on eroded specimens; sculpture of the posterior slope consists of about twenty very low delicate close-set rounded radial ribs that are most strongly developed next to the sharp humeral angle of the shell and become progressively fainter posteriorly; shell margin faintly denticulate where these ribs terminate.

Dentition consists of two cardinal teeth in each valve and strong anterior and posterior laterals; right anterior cardinal small, weak, anteriorly directed; right posterior cardinal strong, peglike, situated directly beneath the umbo; left anterior cardinal short, strong; left posterior cardinal thin and weak, directed obliquely backward; lateral teeth of both valves strong, distant from the beaks.

Distribution: Ladd formation, basal beds of Holz shale member, *rare*.

Dimensions of an example: Length, 31.8 mm., height, 32.8 mm., thickness of one valve, 9.5 mm. Dimensions of a second example: Height, 27.5 mm., length, 26.3 mm., thickness of one valve, approximately 8.6 mm.

Discussion: This species is believed to be identical with the one described by Packard from the Santa Ana Mountains as *Cardium coronaensis*. The sculpture of the type specimen of "*Cardium*" *coronaensis* has been destroyed by weathering, but in general shape, outline, and size, as well as in stratigraphic position the material used in my own study agrees well with Packard's type specimen.

Stewart (18, p. 277) has discussed the generic characters and distribution of *Pachycardium* and suggests that the genus is the Upper Cretaceous descendant of the Lower Cretaceous *Protocardia*. *Pachycardium* apparently is limited in its distribution to beds of Upper Cretaceous age. The genotype is from the Ripleyan of Owl Creek, Mississippi. Stewart mentions also the presence of *Pachycardium* in deposits at Coon Creek, Tennessee (*P. stantoni* (Wade)), and in the Ootatoor group of India (*P. bisectum* (Stoliczka)). Dr. A. Myra Keen, of Stanford University (personal communication), has noted the presence of the genus, in addition, in the Upper Cretaceous beds of New Jersey and Syria. She suggests that *P. coronaense* represents the first recorded appearance of the genus in the Upper Cretaceous of the Pacific Coast.

Superfamily ISOCARDIACEA
Family ISOCARDIIDAE

Genus ISOCARDIA Lamarck
Genotype: *Isocardia cor* Lamarck.

ISOCARDIA DELTA Popenoe, n. sp.
Plate 47, figures 7, 8, 11

Description: Shell of medium size, thin, fragile, greatly inflated; beaks very high, prominent, distant, spirally coiled, prosogyrous; anterior dorsal margin deeply concave below the beaks; anterior extremity obtuse and rounded; ventral margin broadly curved; posterior extremity meeting the ventral margin at an abrupt angle and merging with the dorsal posterior border in a sweeping curve; dorsal posterior slope and lateral face of the shell meeting along a rounded curving angulation extending from the beaks to the ventral posterior border; ligament narrow, rather short, external; lunule and escutcheon undefined; pallial line unknown.

Dentition of the right valve consists of two curved laminar teeth arranged parallel to the hinge-line, situated one above the other, separated by a groove that receives the ventral cardinal tooth of the left valve; left valve also with two laminar horizontal cardinal teeth, the posterior and dorsal tooth extending from the hinge-line posteroventrally; anterior and ventral cardinal parallel to the hinge border below the beaks, separated from the hinge border by a narrow groove, excavated on the ventral surface; lateral teeth apparently absent.

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3436.

Paratypes: California Inst. Technology Invert. Paleo. Cat. nos. 3437, 3438.

Dimensions of holotype: Height, 39.6 mm., length, 34.0 mm., thickness of both valves, 34.6 mm.

Distribution: Ladd formation, Baker member, *abundant* and *characteristic.*

Discussion: *Isocardia delta* is found in a narrow zone essentially including the uppermost beds of the Baker member. The shell of this species is very fragile, and few of the specimens collected have escaped crushing and distortion. *Isocardia delta* is probably at least subgenerically distinct from *I. cor*, the genotype, for the Cretaceous species lacks the characteristic posterior lateral teeth that are present in *I. cor* and in every other Tertiary or Recent *Isocardia* that I have seen. *Isocardia delta* was recognized in the Santa Ana Mountains Upper Cretaceous fauna by Packard but was not described.

A few other species of *Isocardia* have been described from Upper Cretaceous deposits both in the Atlantic Coastal Plain region and in Europe. The genus seems rare in the Cretaceous, however. *I. delta* seems to be the first definite record of the genus in the Pacific Coast Cretaceous deposits, for *Isocardia chicoensis* Waring appears to be a *Clisocolus*, probably *C. cordatus* Whiteaves.

Genus Clisocolus Gabb

Clisocolus corrugatus Popenoe, n. sp.
Plate 47, figures 9, 10, 12

Description: Shell of medium size, highly inflated, gibbous in outline; shell substance rather thick; beaks high, prominent, prosogyrous, sharply incurved; outline of shell margin below the beaks nearly circular to slightly oval; lunule and escutcheon undefined; ligament external, lodged in a deep narrow furrow; hinge edentulous but with a slight thickening of the hinge-line below the beaks and with a shallow pit centrally placed, dorsal to the thickened part; lateral teeth absent; sculpture consisting of rather coarse raised concentric corrugations, spaced at approximately 2 mm. intervals on the median flanks of the mature shell; character of muscle scars and pallial line unknown.

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3439.

Dimensions of holotype: Height, 31.5 mm., length, 31.5 mm., thickness of one valve, 14.4 mm.

Distribution: Ladd formation, Baker member, *rare.*

Discussion: *Clisocolus corrugatus* is readily distinguished from *C. cordatus* Whiteaves by the character of its coarse widely spaced concentric sculpture. Usually the latter species is larger, higher, and more gibbous in outline than *C.*

Explanation of Plate 48

Figs. *1*, *2*—*Cyprimeria moorei* Popenoe, n. sp. Syntypes, CIT Cat. no. 3440. ×2. *1*, Exterior of right valve; *2*, hinge of left valve. (p. 391)

3, *5*—*Tenea inflata* (Gabb). Figured examples, CIT Cat. nos. 3441, 3442. *3*, Hinge of right valve; *5*, hinge of left valve. (p. 391)

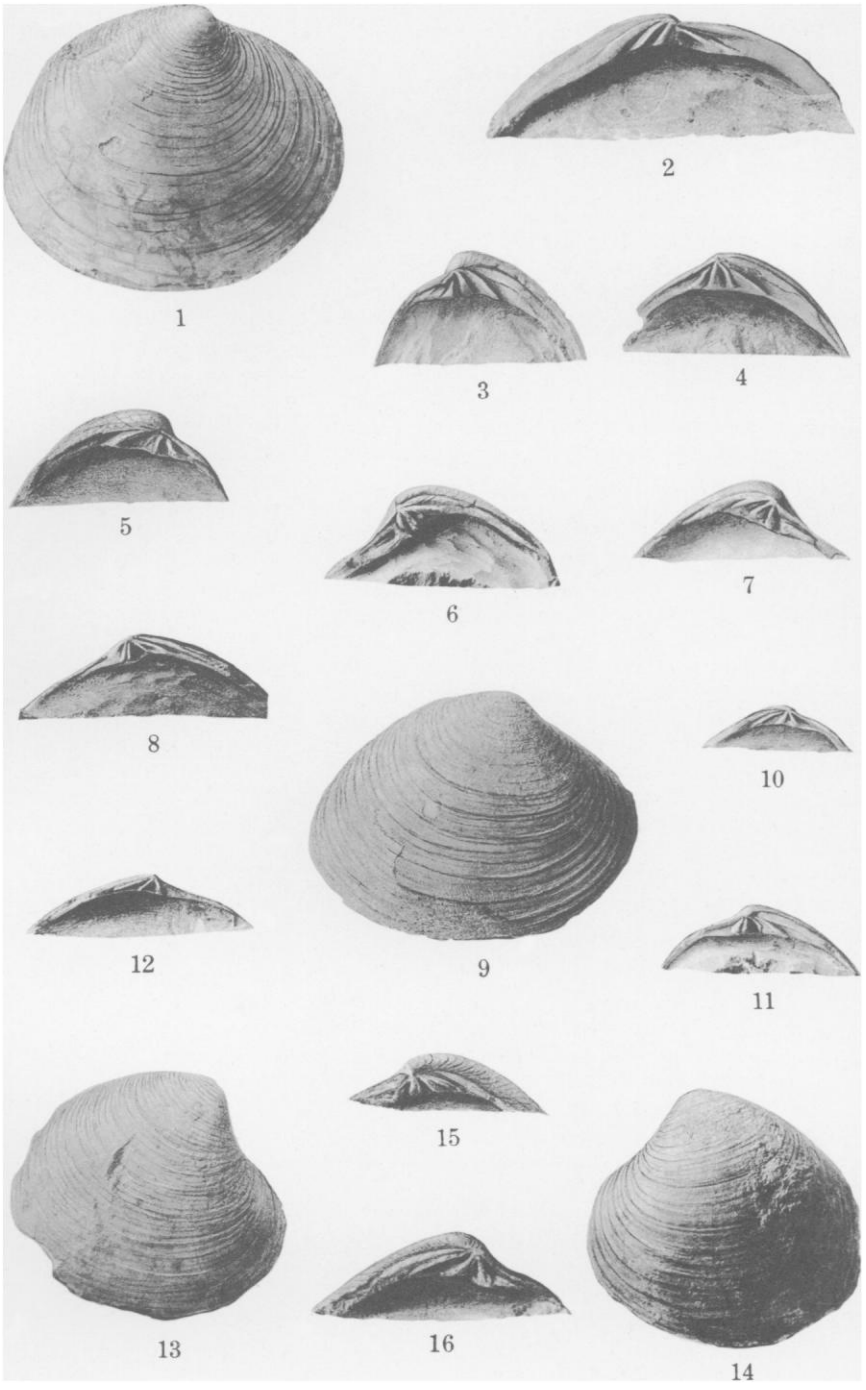
4—*Flaventia lens* (Gabb). Figured example, CIT Cat. no. 3443. Hinge of right valve of a specimen from Butte Creek, Butte County, California. (p. 392)

6, *7*, *13*, *14*—*Calva regina* Popenoe, n. sp. and gen. Syntypes, CIT Cat. no. 3447. *6*, Hinge of right valve; *7*, hinge of left valve; *13*, exterior of right valve; *14*, exterior of left valve. (p. 395)

8, *12*—*Legumen oöides* (Gabb). Figured examples, CIT Cat. no. 3446. *8*, Hinge of right valve; *12*, hinge of left valve. (p. 394)

9, *10*, *11*—*Flaventia zeta* Popenoe, n. sp. Holotype, CIT Cat. no. 3444. *9*, Exterior of right valve. Paratype, CIT Cat. no. 3445. *10*, Hinge of left valve; *11*, hinge of right valve. (p. 393)

15, *16*—*Aphrodina ? arata* (Gabb). Figured examples, CIT Cat. nos. 3448, 3449. ×2. *15*, Hinge of right valve, *16*, hinge of left valve. (p. 397)



Popenoe, Upper Cretaceous Mollusca

corrugatus. I do not know of the occurrence of this species outside of the Santa Ana Mountains.

Superfamily VENERACEA
Family VENERIDAE

Genus CYPRIMERIA Conrad

Genotype: *Cytherea excavata* Morton.

CYPRIMERIA MOOREI Popenoe, n. sp.
Plate 47, figure 13; plate 48, figures 1, 2

Description: Shell rather small, thin, fragile, compressed, oval in outline, slightly longer than high; beaks low, slightly anterior; margin very gently concave just in front of the beaks, elsewhere smoothly curved in a broad ellipse; ornamentation of fine regular growth-lines only; no lunule or escutcheon; ligament external, deep-seated, long, very narrow; pallial line with a shallow sinus.

Dentition of three cardinal teeth in each valve; anterior left cardinal long, very thin, thickening anteriorly, strongly oblique to the shell-margin above and the ventral hinge-plate margin below, bounded dorsally and ventrally by deep narrow sockets; median left cardinal short, broad, trigonal, situated directly below the beak; posterior left cardinal rather long, thin, slightly curved, diverging at an acute angle from the nymph which it underlies; anterior and median right cardinals thin and long, extending obliquely forward from the beaks, subparallel, but diverging somewhat anteriorly; posterior cardinal narrow, gently curved, extending obliquely posteroventrally from the beaks, thickening somewhat toward the posterior end, deeply cleft along the crest; lateral teeth absent.

Syntypes: California Inst. Technology, Invert. Paleo. Cat. no. 3440.

Dimensions of syntypes: Right valve, length, 27.3 mm., height, 21.6 mm., thickness of valve, approximately 4.2 mm.; left valve, length, 24.4 mm., height, 19.6 mm., thickness, approximately 2.3 mm.

Distribution: Ladd formation, Holz shale member, *rare*.

Discussion: This shell is named in honor of Dr. B. N. Moore, of the United States Geological Survey. Doctor Moore collected all of the material upon which this species is based, and generously made his collections available for this study.

Cyprimeria moorei is probably the first *Cyprimeria* to be reported from the Pacific Coast Upper Cretaceous. Whiteaves (20, p. 379) has referred to *Cyprimeria* several specimens from Sucia Island which he at first identified as *Meretrix lens* Gabb, a species since shown by Stewart to belong to the genus *Flaventia* Jukes-Brown (18, p. 247). It has been possible to expose the hinges of several specimens of *Flaventia lens* from the Santa Ana Mountains, from northern California, and from Sucia Island. The hinge characters of all of these agree almost exactly with those of *Flaventia ovalis* illustrated by Woods (21, vol. 2, p. 191, pl. 29, figs. 19–26), and with Whiteaves' illustration of the hinge of "*Cyprimeria*" *lens*. It is believed that Whiteaves' specimens are to be referred to *Flaventia* rather than to *Cyprimeria*. A second species cited by Whiteaves from the Upper Cretaceous of British Columbia, *Cyprimeria ? tenuis* Meek, is neither described nor figured, and its actual relationships are very dubious.

Genus TENEA Conrad

Genotype: *Tenea parilis* Conrad.

TENEA INFLATA (Gabb)
Plate 48, figures 3, 5

Dosinia inflata GABB, *1864*, Paleontology Calif., vol. 1, p. 168, pl. 23, fig. 149.—STEWART, *1930*, Acad. Nat. Sci. Philadelphia Spec. Pub. 3, p. 231.

Description: The following notes are given on the dentition of this species: Right anterior cardinal very small, slender, short, diverging at a small angle from the hinge-margin directly anterior to the beak, extending ventrally only halfway across the hinge-plate; median right cardinal rather heavy, low, trigonal; posterior right cardinal heavy, long, slightly curved, situated close up under the nymph, from which it is separated

by a narrow groove; a thin lamellar ridge rising from the floor of the socket between the anterior and median right cardinals extends about halfway from the ventral edge of the hinge plate toward the beak; left anterior and median cardinals short, slender, joined dorsally, diverging ventrally at a high angle; posterior left cardinal long, laminar, oblique, situated just below the nymph; lateral teeth apparently absent; pallial sinus long, narrow, pointed, ascending, directed toward the umbos.

Distribution: *Dwarf variety*—Ladd formation, Baker member, *common; Giant variety*—Ladd formation, Holz member, *abundant.*

Discussion: *Tenea* has not been reported hitherto from the Pacific Coast Cretaceous, but is known from a number of localities in the Upper Cretaceous of the Atlantic and Gulf Coastal Plain of the eastern United States. The genotype is from the Cretaceous of New Jersey (Conrad, 3). *Cyclina magna* Wade from the Ripley formation of Coon Creek, Tennessee, is probably to be referred to this genus (personal communication from L. W. Stephenson) as may also be *Cyclina parva* Gardner of the Monmouth formation of Maryland. Holzapfel (11, p. 168, pl. 12, figs. 9–12) figures a shell identified as *Cytherea tumida* Goldfuss that is almost surely a *Tenea*. It is probable that many other Cretaceous species that have been described as *Dosinia* will be found referable to this genus.

A number of paleontologists have discussed the systematic position of *Tenea* without reaching any general agreement. Conrad originally suggested the relationship of *Tenea* to *Taras* [*Diplodonta*]. Many other writers, including Dall, Fischer, and Weller, have doubtfully or confidently placed this genus in the Ungulinidae. Whitfield on the other hand referred *Tenea* to the Veneridae, comparing it to *Dosinia*. It is my own opinion that *Tenea* is a Venerid genus, closely allied to *Dosinia* and *Cyclina*, though quite distinct from either. The reasons for this conclusion lie in the characters of the hinge, which appears to be typically Venerid in structure, and in the character of the long slender pointed ascending pallial sinus so similar to the sinuses of *Cyclina* and *Dosinia*.

Tenea inflata is represented by many excellent specimens from the middle and upper horizons of the Holz shale and from the uppermost beds of the Baker member. The specimens found in the shale are usually rather robust, thick-shelled, and large. Some of these individuals attain a height of 35 mm. Conversely, the specimens from the Baker member are invariably small, thin-shelled, and fragile. Few individuals from this part of the section will reach an altitude of as much as 20 mm. These differences are so constant and so closely correlated with stratigraphic position that one is tempted to consider that two species are represented. This view is strengthened by the fact that very few species are common to both the Baker sandstones and the Holz shale. Nevertheless, I have been unable to find any basis for separation of these forms other than size and thickness of shell, and feel these to be scarcely sufficient in themselves for separating species.

Genus FLAVENTIA Jukes-Brown

FLAVENTIA LENS (Gabb)

Plate 48, figure 4

Meretrix lens GABB, *1864*, Paleontology Calif., vol. 1, p. 164, pl. 23, fig. 143. *Cyprimeria lens* WHITEAVES, *1879*, Canada Geol. Survey, Mesozoic Fossils, vol. 1, pt. 2, p. 152, pl. 17, figs. 15, 15a; *ibid.* p. 379.
Flaventia ? lens STEWART, *1930*, Acad. Nat. Sci. Philadelphia, Spec. Pub. 3, p. 247, pl. 4, fig. 6.

Description: The following notes are offered on the hinge-structure of this species: Right anterior and median cardinals set close together, diverging ventrally, directed obliquely anteriorly; right posterior cardinals long, heavy, deeply bifid, the anterior element being short; left anterior and median cardinals short and strong, close together, diverging ventrally at a large angle; posterior

cardinal long, thin, situated below the nymph; ligament external, moderately long, submerged; lunule and escutcheon undefined; pallial sinus triangular, ascending; lateral teeth absent.

Distribution: Ladd formation, Holz member, *abundant;* Williams formation, *common.*

Discussion: Whiteaves (supra) was apparently the first to call attention to the hinge-structure of *Flaventia lens*, or at least was the first to publish his observations. He referred the species to *Cyprimeria*, but comparison of his figure of the hinge of a left valve with the hinge of true *Cyprimeria* reveals an error. Stewart (supra) first called attention to the similarity of the hinge of *F. lens* with that of *F. ovalis* (the genotype) and suggested the relationship, although he was unsuccessful in uncovering enough of the hinge of *F. lens* to permit him to feel sure of the identity. The present study verifies Stewart's determination of the generic position of *F. lens.*

FLAVENTIA ZETA Popenoe, n. sp.
Plate 48, figures 9–11

Description: Shell of medium size, strong, moderately inflated, elongate-oval in outline; beaks not very prominent, situated slightly anterior to the mid-length of the shell; anterior dorsal slope nearly straight from the beaks to the anterior end; ventral border smoothly curved between the anterior and posterior ends of the shell, forming nearly the arc of a circle; posterior dorsal border slightly arched, meeting the ventral border in a blunt angulation; ligament external, about one-half the length of the posterior dorsal border; lunule undefined; escutcheon spindle-shaped, long, narrow; ornamentation of growth-lines only, fine on the dorsal part of the shell, becoming coarse toward the ventral borders; pallial sinus short, broadly triangular, wide open at the base, ascending.

Hinge of three cardinal teeth and no laterals in each valve; right anterior and median cardinals short, slender, subparallel, diverging slightly distal to the beaks, directed obliquely forward from the beaks; right posterior cardinal strong, rather long, trigonal, very oblique, diverging at a small angle from the nymph, bifid, the anterior element being short and slender; left anterior and median cardinals short and thin, approximately equal in size, diverging from one another at a moderate angle directly ventral to the beaks; posterior left cardinal long, narrow, slightly curved, underlying and slightly divergent from the nymph; hinge plate of both valves shallowly excavated in front of the anterior teeth.

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3444.

Paratypes: California Inst. Technology, Invert. Paleo. Cat. no. 3445.

Dimensions of holotype: Height, 33.2 mm., length, 44.7 mm., thickness of both valves, 18.0 mm.

Distribution: Ladd formation, Baker member, *abundant* and *characteristic;* Holz shale member, *rare.*

Discussion: *Flaventia zeta* is to be distinguished from *F. lens* principally by its more elongate outline and by its higher beaks. Most of the mature specimens of *F. lens* are nearly equidimensional in length and height, whereas *F. zeta* is longer than high in the ratio of four to three. Assemblages of individuals of both species show considerable variation in shape, and end members of the variable series approach one another in proportions. Stratigraphically, the two species are complementary, *F. zeta* being common in the Baker member and very rare in the lower part of the Holz shale, whereas *F. lens* is common in the upper part of the Holz shale and rather rare in the Williams formation. The two species have not been found together.

Flaventia zeta appears to be represented in collections now at the California Institute of Technology from the basal Upper Cretaceous beds at Henley, Siskiyou County, California, and the species may be expected in other collections from northern California and southern Oregon from beds low in the Upper Cretaceous section. It may be repre-

sented in the fossil lists by forms that have been identified as *Flaventia lens*.

Genus LEGUMEN Conrad
Genotype: *Legumen ellipticum* Conrad.

LEGUMEN OOIDES (Gabb)
Plate 48, figures 8, 12

Tellina ooides GABB, *1864*, Paleontology Calif., vol. 1, p. 157, pl. 22, figs. 135, 135a.—ARNOLD, *1909*, U. S. Geol. Survey Bull. 396, p. 11, pl. 1, fig. 3.—PACKARD, *1916*, Univ. Calif., Dept. Geol. Sci., Bull., vol. 9, no. 12, p. 147.—STEWART, *1930*, Acad. Nat. Sci. Philadelphia, Spec. Pub. 3, p. 202, pl. 3, fig. 3.

Description: These internal features of the shell have been determined for *Legumen ooides*—cardinal teeth, three in each valve; lateral teeth absent; right anterior and median cardinals short, slender, prominent, subparallel, situated almost directly beneath the beaks; right posterior cardinal long, moderately prominent, subparallel to the nymph, bifid, the anterior element of the tooth being short and splintlike; left anterior and median cardinals also short, slender, and prominent, diverging from one another ventrally at an angle of approximately sixty degrees; left posterior cardinal long and thin, joined to the ventral border of the nymph; hinge-plate shallowly excavated immediately in front of the anterior cardinal teeth; lunule undefined; ligament submarginal, about one-half the length of the posterior dorsal margin of the shell; pallial sinus rather short, broad, blunt, directed toward the anterior adductor scar.

Distribution: Williams formation, *rare*.

Discussion: The characters of the dentition, ligament, lunule, and pallial sinus of *Legumen* are very similar to those features in *Flaventia*. The principal differences separating these genera appear to be: (a) the species of *Flaventia* tend to have rather thick shells, either equal in length and height or not much longer than high; the species of *Legumen* are usually quite elongate and are thin-shelled. (b) The right posterior cardinal tooth of *Flaventia* is comparatively larger than the corresponding tooth in *Legumen*, is more deeply bifid, and the anterior element of the tooth is longer and thicker. These differences may prove to be of no more than subgeneric importance. *Flaventia* would then become a subgenus of *Legumen*.

Stephenson (15, p. 319) suggests that *Baroda* Stoliczka is probably generically identical with *Legumen*. If this be so, *Legumen* is represented by a number of species widely distributed in the Upper Cretaceous beds of the World. I have not seen the hinge of *Baroda*, and those illustrations of the hinge available do not show whether or not the right posterior cardinal tooth is bifid. Jukes-Brown (12, p. 171) describes this tooth in *Baroda* as "entire." Since the bifid right posterior cardinal appears to be a constant character in the American species of *Legumen*, *Baroda* is probably distinct.

Genus CALVA Popenoe, n. gen.
Genotype: *Calva regina* Popenoe, n. sp.

Generic diagnosis: Venerid pelecypods of medium to large size, with heavy shells characteristically ornamented by fine concentric growth-lines with occasional irregularly spaced deeper concentric grooves developed; shape usually moderately elongated, beaks prominent and high, lunule somewhat depressed, usually circumscribed by an incised line; hinge of each valve bearing three cardinal teeth; anterior and posterior lateral teeth present in the left valve; corresponding anterior and posterior lateral sockets developed in the right valve; left anterior lateral tooth parallel to the forward border of the nymph, smooth, rather long; left posterior lateral tooth formed by a slightly salient projection of the hinge border; right posterior lateral socket long, narrow, moderately deep, distant from the beaks; right posterior cardinal tooth weakly bifid.

Within this genus will fall all or nearly all of the forms formerly referred to "*Venus*" *varians* Gabb, "*Meretrix*" *nitida* Gabb, and the varieties listed in connection with these names; a number of Cretaceous species that have been de-

scribed under such generic names as *Callista, Cytherea, Meretrix, Venus;* and in addition, many, if not all, of the Cretaceous species hitherto referred to the genus *Dosiniopsis* Conrad.

Dosiniopsis was erected in 1864 by Conrad (2) with *Dosiniopsis meeki* from Eocene deposits near Washington, D.C., as the genotype. *D. meeki* was later declared to be simply a variant of *D. lenticularis* (Rogers) by Clark and Martin (6). Meek (13, p. 179) apparently was the first person to mention in print the presence of a posterior lateral tooth in this genus—a rare feature in a venerid shell. Cossman (4) recognized Conrad's genus and placed therein three species previously described by Deshayes from the Eocene of the Paris Basin—*D. fallax, D. bellovacensis,* and *D. orbicularis* (Edwards). Cossman does not mention the presence of a posterior lateral tooth in these forms, but in the illustrations of these species given in the "Iconographie Coquilles Fossiles de Paris" of Cossman and Pissarro, all views showing the interior of the right valve show the posterior lateral plainly. Of Cretaceous forms referred to *Dosiniopsis* may be mentioned *Cytherea caperata* Sowerby and *Cytherea subrotunda* Sowerby, placed in *Dosiniopsis* by Jukes-Brown (12, p. 151) and later figured and described by Woods (21, vol. 2, pp. 181, 182, pl. 28, figs. 1–10). Palmer (14) has referred *Meretrix unzambiensis* Woods of the Upper Cretaceous of Pondoland, South Africa, to *Dosiniopsis*, and Meek (13, p. 184) described *Dosiniopsis nebrascensis* from beds of the Fort Pierre and Fox Hills groups of the Dakota Upper Cretaceous.

A review of the descriptions and figures of the above species indicates that all of the Cretaceous species referred to *Dosiniopsis*, together with the Pacific Coast Cretaceous shells referred to *Venus varians, Meretrix nitida* and varieties, have posterior lateral teeth, anterior lateral teeth and sockets that are smooth and not striated, posterior cardinal teeth that are weakly bifid, and in general are elongate in form. All the Eocene shells placed in *Dosiniopsis*, including the genotype, have strong deeply bifid right posterior cardinal teeth, striated anterior lateral teeth and sockets, and in general, lenticular outline. These differences together with the age difference of the two groups appear to justify a new genus to accommodate the Cretaceous species.

To the genus *Calva* are tentatively assigned *Venus varians* Gabb, *Meretrix nitida* Gabb, *Meretrix nitida* var. *major* Packard, *Meretrix umzambiensis* Woods, *Cytherea subrotunda* Sowerby, *Cytherea caperata* Sowerby, *Dosiniopsis nebrascensis* Meek, *Callista pseudoplana* Yabe and Nagao, and *"Cucullaea" bowersiana* Cooper.

CALVA REGINA Popenoe, n. sp.
Plate 48, figures 6, 7, 13, 14

Description: Shell of moderate size, nearly as high as long, inflated, rather thick; beaks prominent, rather high, placed anterior to the mid-length of the shell, prosogyrous; anterior dorsal border strongly concave; anterior end rather sharply rounded; ventral border broadly arched; posterior end bluntly truncate vertically; posterior dorsal border rather short, slightly arched; posterior dorsal slope nearly flat, broad, marked off from the lateral portion of the shell by a low rounded ridge extending from the beak to the ventral posterior border; lunule heart-shaped, sunken, circumscribed by a fine line; escutcheon faintly marked off, extending the length of the posterior dorsal border; ornamentation of evenly spaced, moderately fine growth-lines only; ligament rather short, sunk below the shell margin; characters of the muscle scars and pallial line unknown.

Right anterior and median cardinal teeth short, narrow, prominent, close together, slightly divergent ventrally, situated directly beneath the beaks; right posterior cardinal long, straight, shallowly bifid, subparallel to the nymph; anterior lateral socket long, narrow, moderately deep, smooth, parallel to the lunular border of the shell; posterior right lateral socket deep, bounded below

by a rather large projecting tooth; left anterior cardinal prominent, very slender, aligned almost vertically beneath the beak; left median cardinal thicker than the anterior, trigonal, directed obliquely backward; left posterior cardinal continuous with the ventral side of the nymph, slightly longer than the anterior teeth, not very massive; anterior lateral teeth long, wedge-shaped, parallel to the hinge border below the lunule, smooth; posterior lateral tooth, a slightly salient portion of the shell-margin just posterior to the rear end of the nymph.

Syntypes: California Inst. Technology, Invert. Paleo. Cat. no. 3447.

Dimensions of syntypes: Right valve, height, 34.4 mm., length, 36.5 mm., thickness of one valve, approximately 8.5 mm.; left valve, height, 33.2 mm., length, 37.0 mm., thickness of valve, approximately 10.8 mm.

Distribution: Ladd formation, Baker member, *common* and *characteristic.*

Discussion: *Calva regina* is fairly widespread but not abundant in the Baker sandstones. It may be distinguished from *Calva bowersiana* (Cooper), found in the upper Holz shale member and the Williams formation, by its abruptly truncate posterior end and the rather high, short, posterior dorsal slope. *C. regina* averages considerably smaller than *C. bowersiana* also. *Calva nitida* of the northern California Upper Cretaceous appears to be more pointed posteriorly than *C. regina* and usually is sculptured with irregularly spaced rather deeply incised concentric grooves, marking resting stages of growth.

CALVA BOWERSIANA (Cooper)

Cucullaea bowersiana COOPER, *1894*, Calif. State Min. Bur., Bull. 4, pt. 5, p. 48, pl. 5, figs. 16, ?62.

Meretrix nitida GABB var. *major* PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 425, pl. 31, fig. 2.

Aphrodina major ANDERSON and HANNA, *1935*, Calif. Acad. Sci., Proc., (4) vol. 23, no. 1, p. 28.

Distribution: Holz shale member, Ladd formation *rare;* Pleasants member, Williams formation, *abundant* and *characteristic.*

Discussion: Dr. L. G. Hertlein, of the California Academy of Sciences, called my attention to the type specimen of "*Cucullaea*" *bowersiana* Cooper, which is in the type collections of the Academy. Apparently at the time Cooper described *C. bowersiana* the umbonal region of the type was concealed in the matrix. This has since been exposed by further preparation of the specimen, revealing the beaks, the ligament area, and the lunule. The type is a venerid shell specifically identical with the large form from the Santa Ana Mountains described by Packard as *Meretrix nitida* Gabb, var. *major.* Packard's variety is thus a syno-

EXPLANATION OF PLATE 49

FIGS. *1*—*Cymbophora ashburnerii* (Gabb). Figured example, CIT Cat. no. 3450. ×1½. Hinge of left valve. (p. 397)

2—*Cymbophora gabbiana* (Anderson). Figured example, CIT Cat. no. 3451. Hinge of right valve. (p. 398)

3—*Euspira shumardiana* (Gabb). Figured example, CIT Cat. no. 3452. Apertural view. (p. 398)

4, 5—*Ampullina packardi* Popenoe, n. sp. Holotype, CIT Cat. no. 3453. *4*, Apertural view; *5*, view of the body whorl. (p. 399)

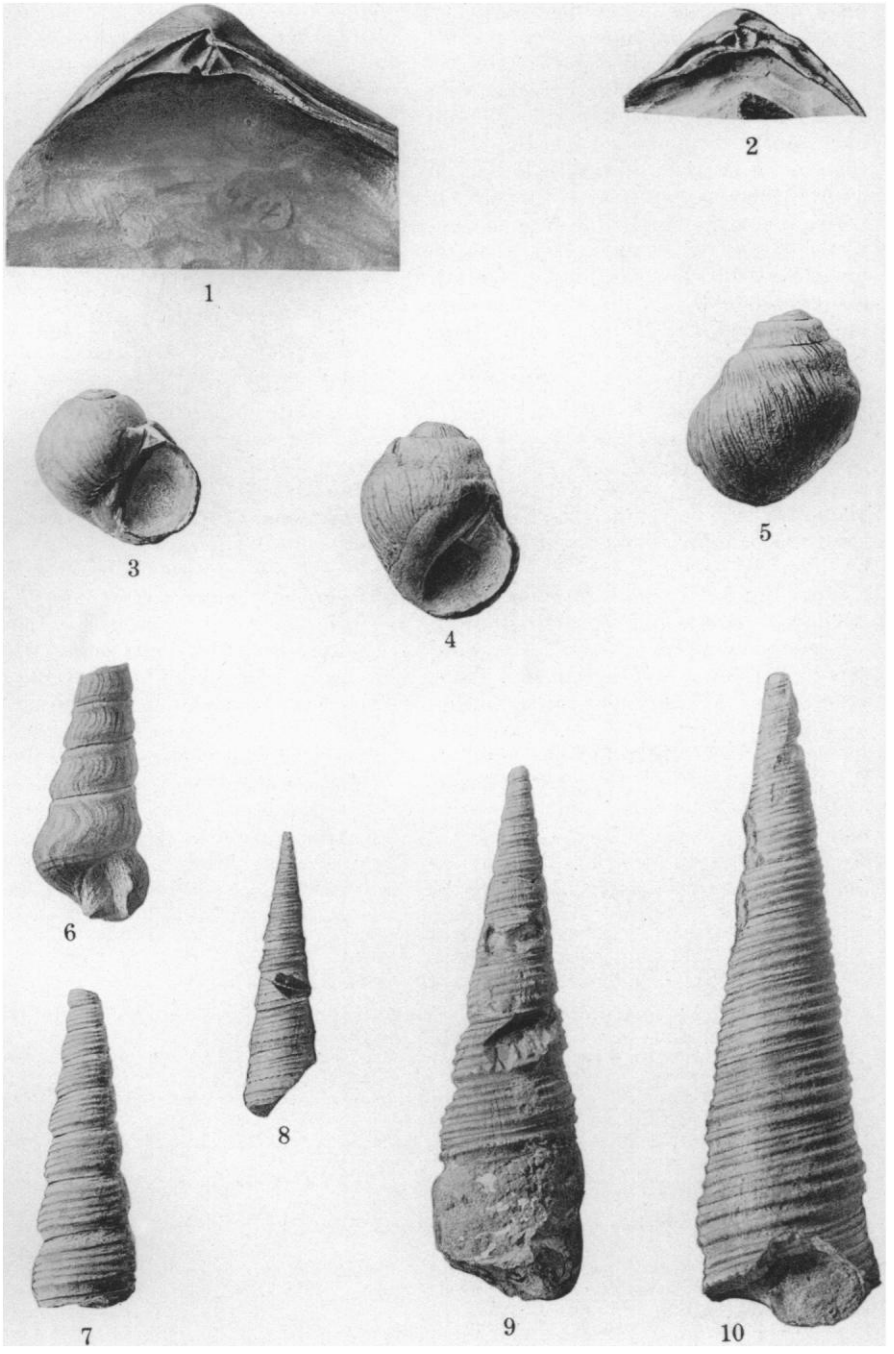
6—*Turritella ossa* Popenoe, n. sp. Holotype, CIT Cat. no. 3458. ×1¾. Apertural view. (p. 401)

7—*Turritella chicoensis* Gabb. Figured example, CIT Cat. no. 3454. Typical dwarf variety. (p. 400)

8—*Turritella iota* Popenoe, n. sp. Holotype, CIT Cat. no. 3457. (p. 401)

9—*Turritella chicoensis* Gabb. Figured example, CIT Cat. no. 3455. Giant round-whorled variety. (p. 400)

10—*Turritella chicoensis* Gabb. Figured example, CIT Cat. no. 3456. Giant flat-whorled variety. (p. 400)



Popenoe, Upper Cretaceous Mollusca

nym of "*C.*" *bowersiana* Cooper. Study of the hinge and other structural features of this large venerid shows it to accord well generically with the diagnosis of *Calva*, given above, and it is referred to that genus. *Calva bowersiana* is thought to be specifically distinct from *Calva nitida* (Gabb) and it is raised to the full rank of a species.

Identity of the specimen figured by Cooper with the specimen preserved in the California Academy of Sciences type collections is made certain by inspection of the cracks and fractures in the shell of the type specimen which have been perfectly reproduced in the figure (no. 61) given by Cooper to illustrate his new species *bowersiana*. As Cooper's specific name antedates Packard's by more than 30 years, it has unquestionable priority.

Calva bowersiana is found in the Upper Cretaceous beds of the Santa Monica Mountains and of the Simi Hills, southern California, and Anderson and Hanna (supra) have reported its presence in the Cretaceous of Santa Catarina Landing, Lower California.

Genus APHRODINA Conrad

APHRODINA? ARATA (Gabb)

Plate 48, figures 15, 16

Meretrix arata GABB, *1864*, Paleontology Calif., vol. 1, p. 166, pl. 30, fig. 250.—PACKARD, *1916*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 9, no. 12, p. 146.—STEWART, *1930*, Acad. Nat. Sci. Philadelphia, Spec. Pub. 3, p. 247, pl. 1, fig. 4.

Distribution: Ladd formation, Baker member, *very abundant* and *characteristic*.

Discussion: This species is referred to *Aphrodina* with some misgivings. The material available for study is poorly preserved, and it has so far proved impossible to expose the hinge without some breakage of the teeth. The hinges so far uncovered seem identical with the hinge of *Aphrodina tippana* Conrad (the genotype) except that the anterior lateral tooth and socket of *A. tippana* are rather long and are striated, whereas these structures are shorter and apparently smooth in *A. arata*. These differences may prove important enough to justify at least subgeneric separation of the two species.

Aphrodina arata is especially characteristic of the Baker member of the Ladd formation in the Santa Ana Mountains. This species has not been reported from higher horizons, but within this member it is found at nearly every fossiliferous locality. The species was originally described from "Cottonwood Creek, Shasta County," a locality from which Gabb described a number of other species that in the Santa Ana Mountains are confined to the Baker sandstone.

Callista (*Aphrodina?*) *tenuis* Meek and Hayden (13, p. 188) is very much like *A. arata*, as is *Cytherea minutula* Stoliczka from the Ariyalur group of south India.

Superfamily MACTRIDAE
Family MACTRACEA

Genus CYMBOPHORA Gabb

CYMBOPHORA ASHBURNERII (Gabb)

Plate 49, figure 1

Mactra ashburnerii GABB, *1864*, Paleontology Calif., vol. 1, p. 153, pl. 22, fig. 127.—ARNOLD, *1909*, U. S. Geol. Survey, Bull. 396, p. 11, pl. 1, fig. 4.

Cymbophora ashburnerii GABB, *1869*, Paleontology Calif., vol. 2, pp. 181, 236, pl. 29, fig. 69.—WHITEAVES, *1903*, Canada Geol. Sur., Mesozoic Fossils, p. 374.—STEWART, *1930*, Acad. Nat. Sci. Philadelphia, Spec. Pub. 3, p. 212, pl. 5, fig. 6a.

Spisula ashburnerii PACKARD, *1916*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 9, no. 16, p. 298, pl. 26, figs. 4, 5, pl. 27, fig. 1.

Description: The following is a description of the left valve of this species: Chondrophore narrow and shallow, its floor being almost flush with the inner face of the hinge-plate; on the anterior border of the chondrophore is a very thin laminar tooth (accessory lamella?) which is separated from the posterior limb of the bifid cardinal by a very narrow slit; bifid cardinal tooth stout, limbs short; lateral teeth strong and situated close to the beaks.

Distribution: Ladd formation, Holz shale member, *rare;* Williams formation, *abundant.*

Discussion: The hinge of *Cymbophora ashburnerii* was figured by Gabb (supra) and his figure was reproduced by Packard (supra). In neither figure, however, is the dentition well represented. Stephenson (15, pl. 85, figs. 5, 6) has figured both valves of *Cymbophora trigonalis.* The dentition of this latter species appears to agree in every particular with the dentition of *C. ashburnerii* (the genotype) as revealed in this study. Stephenson's illustrations may serve as convenient examples of the dentition of this genus. The hinge of the left valve of *C. ashburnerii* is figured also in the present article.

CYMBOPHORA GABBIANA (Anderson)
Plate 49, figure 2

Mactra ashburnerii GABB, *1864* (in part), Paleontology Calif., vol. 1, p. 153.
Cymbophora ashburnerii WHITEAVES, *1879,* Canada Geol. Sur., Mesozoic Fossils, p. 141, pl. 17, fig. 8, *1903,* p. 373, *not* p. 374.
Mactra gabbiana ANDERSON, *1902,* Calif. Acad. Sci. Proc. (3), vol. 2, no. 1, p. 74, pl. 7, fig. 156.—STEWART, *1930,* Acad. Nat. Sci. Philadelphia Spec. Pub. 3, p. 211.
Spisula gabbiana PACKARD, *1916,* Univ. Calif. Dept. Geol. Sci., Bull., vol. 9, no. 16, p. 299, pl. 27, fig. 2.

Description: These notes describe the dentition of this species. In the right valve are two cardinal teeth joined at their dorsal ends; anterior cardinal tooth short, thin, very oblique, nearly parallel to the dorsal shell-margin; posterior cardinal likewise narrow and rather short, aligned almost vertically beneath the beak; chondrophore shallow, rather narrow, bounded dorsally by a thin oblique posterior lamina which includes between it and the shell-margin, a deep narrow cavity; posterior and anterior lateral teeth stout and rather short, situated close to the umbonal region of the shell, separated from the dorsal border by a deep socket; lunule and escutcheon undefined; lateral teeth very lightly striated; in the left valve is a single strong bifid (inverted V-shaped) anterior cardinal tooth separated from a narrow prominent laminar posterior tooth (accessory lamella?) by a deep narrow slit; chondrophore and subumbonal cartilage groove as in the right valve; anterior and posterior lateral teeth single and strong.

Distribution: Ladd formation, Holz member, *rare;* Williams formation, *very abundant.*

Discussion: The hinge of this species accords in all ways with that of *Cymbophora ashburnerii.* The species is doubtless a true *Cymbophora,* for the difference in sculpture separating the two forms is probably of no more than specific importance. Whiteaves (supra, p. 142) and Stewart (supra, p. 211) have called attention to the similarity of *C. gabbiana* to *Mactra tripartita* G. B. Sowerby of the Trichinopoly group of India.

Cymbophora gabbiana is especially well represented in the Williams formation. Few large collections may be made from this formation without getting abundant specimens of this species. The localities in the Holz shale from which the species is obtained are high in the section near the Holz-Williams contact. The fossil thus appears to be a good marker for the higher beds of the Upper Cretaceous of this region. The abundance of the species in certain localities in the Upper Cretaceous beds of the Simi Hills and the Santa Monica Mountains of southern California is probably of considerable significance in the correlation of these sections with that of the Santa Ana Mountains.

Class GASTROPODA
Subclass STREPTONEURA
Order TAENIOGLOSSA
Family NATICIDAE

Genus EUSPIRA Agassiz

EUSPIRA SHUMARDIANA (Gabb)
Plate 49, figure 3

Lunatia shumardiana GABB, *1864,* Paleontology Calif., vol. 1, pp. 106, 224, pl. 19, fig. 61.
Gyrodes compressus WARING, *1917,* Calif. Acad. Sci., Proc. (4), vol. 7, no. 4, p. 67, pl. 9, fig. 6.

Gyrodes californica PACKARD, *1922*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 429, pl. 35, figs. 2, 2a.
Polinices shumardianus STEWART, *1927*, Acad. Nat. Sci. Philadelphia, Proc., vol. 78, p. 325, pl. 21, fig. 11.

Distribution: Ladd formation, Holz shale member, *common;* Williams formation, *?rare.*

Discussion: Packard (supra) in describing *Gyrodes californica* differentiated it from *G. compressus* Waring on the basis of the presence of a compressed subsutural zone in the latter species and its absence in the former. I have been able in this study to compare rather large collections of both species from the type localities of each. In any collection containing as many as half a dozen individuals, some specimens will show this depressed subsutural zone and some will not. In other respects no features upon which two separate species could be erected are discernible. The presence or absence of this depression is believed to be a feature of individual variation and of less than specific importance. Packard's species and Waring's species are therefore conspecific.

Gyrodes, to which this species has been referred, was established by Conrad in 1860 as a subgenus of *Natica*. Since that time, it has been treated as a distinct genus by nearly every worker who has had occasion to study the group. In reviewing *Gyrodes*, Meek remarked (13, p. 309):

> This genus is readily distinguished by its thin shell, wide open umbilicus, bounded by an angular more or less crenate margin and without a trace of callosity within, as well as by the truncated, slightly concave, and more or less wrinkled upper edge of its volutions—a combination of characters unknown in any other type of the Naticidae.

Every feature mentioned by Meek as characterizing *Gyrodes* is absent from the species here discussed, which can in no way be considered to be *Gyrodes*. The species accords well with *Polinices shumardianus* (Gabb) as figured by Stewart (supra). The species may be a *Polinices*, as Stewart suggests. Its narrow, almost closed umbilicus and the umbilical callosity that is truncate below the umbilicus and broad above are so similar to the characteristics of *Euspira* that I have tentatively referred the species to that genus.

Euspira shumardiana appears to be limited in the Santa Ana Mountains to the higher part of the Holz shale and to the Williams formation. The individuals from the latter horizon are much smaller than are those from the shale, but there seems no other basis for separating them.

Genus AMPULLINA Lamarck

AMPULLINA PACKARDI Popenoe, n. sp.

Plate 49, figures 4, 5

Amauropsis pseudoalveata PACKARD, *1922* (in part), Univ. Calif. Dept. Geol. Sci., Bull., vol. 13, no. 10, p. 429, *not* plate 35, figs. 1a, 1b, 3.

Description: Shell small to medium in size, robust; spire rather short; body whorl very large, about seven-eighths the height of the shell; suture linear, bordered by a narrow sloping shoulder; whorl just below the shoulder markedly impressed by a shallow encircling sulcus; remainder of body whorl globular; anterior apertural margin only slightly produced; columella excavated anteriorly and covered with a smooth heavy callus that entirely conceals the umbilicus; anterior apertural margin rather broadly rounded with a conspicuous fasciole; aperture narrow posteriorly; ornamentation of fine growth-lines with development occasionally of fine, narrow, regularly spaced axial lines.

Holotype: California Inst. Technology Invert. Paleo. Cat. no. 3453.

Dimensions of holotype: Length, 24.1 mm., diameter of last whorl, 20.8 mm.

Distribution: Ladd formation, Holz shale member, *common* and *characteristic.*

Discussion: Doctor Packard evidently included this species in his description of "*Amauropsis*" *pseudoalveata*, which represents a distinct species and is confined in its occurrence in the Santa Ana Moun-

tains to the horizon of the Baker member of the Ladd formation.

Ampullina packardi is distinguished from *A. pseudoalveata* by these features: *A. packardi* has a narrow, sloping shoulder to the whorl, a pronounced encircling sulcation below the shoulder, and a rather short and rounded anterior apertural margin. *A. pseudoalveata* has a rather broad, flat or channeled shoulder to the whorl, is nearly flat to slightly concave below the shoulder, has a produced and peaked anterior apertural margin, and averages at least one-half again larger than *A. packardi*. The difference in stratigraphic position of the two species has been outlined above.

A. packardi may be a descendant of *A. pseudoalveata*, for its immature members resemble the individuals of the larger and geologically older species considerably in general appearance. There is but little doubt that the two species are closely related.

Family TURRITELLIDAE

Genus TURRITELLA Lamarck

TURRITELLA CHICOENSIS Gabb

Plate 49, figures 7, 9, 10

Turritella chicoensis GABB, *1864*, Paleontology Calif., vol. 1, p. 133, pl. 21, fig. 91.—STEWART, *1927*, Acad. Nat. Sci. Philadelphia, Proc., vol. 78, p. 348, pl. 21, fig. 1.

Turritella pescaderoensis? ARNOLD, *1908*, U. S. Nat. Mus., Proc., vol. 34, p. 358, pl. 31, fig. 7.—PACKARD, *1916*, Univ. Calif. Dept. Geol. Sci., Bull., vol. 9, no. 12, pp. 142, 143, 145, 148.

Distribution: (a) Dwarf form, typical—middle and upper but not uppermost horizons of the Holz shale member, Ladd formation, *abundant* and *characteristic*.

(b) Giant form, round-whorled—uppermost horizon of the Holz shale member, Ladd formation, *very abundant* and *characteristic*.

(c) Giant form, flat-whorled—Williams formation, *occasional*.

Discussion: *Turritella chicoensis*, one of the most persistent and abundant fossils of the upper part of the Holz shale, was selected by Packard as the "zone fossil" of the shale portion of the Cretaceous section of the Santa Ana Mountains. This species appears in three well-characterized zones, each zone bearing a distinct mutation of the species. The lowermost zone is that of the more shaly beds in the upper half of the Holz shale, extending from about the middle part of the shale section, to within two hundred feet of the top of this member. The second zone includes a series of sandy beds with a probable maximum thickness of two hundred feet, at the very top of the Holz shale member. The third zone is that of the uppermost beds of the Williams formation.

The mutation of *Turritella chicoensis* characteristic of the lowermost zone outlined above is a medium-sized shell that is indistinguishable from typical *T. chicoensis* from the type locality in the canyon of Chico Creek, Butte County, California. This shell has rounded whorls, a depressed suture, four or five raised, rather widely spaced spirals on each whorl, and a narrow unornamented band on each side of the suture. This form is figured on plate 49, figure 7. The mutation of *T. chicoensis* found in the zone at the top of the Holz shale is a giant form, reaching in some individuals a length of 100 mm., or twice the length of the largest specimens of the species found in the zone below. Except for their robust size, these giants do not differ materially in either form or sculpture from the typical dwarf variety of the species. The third mutant of this species is found in the uppermost beds of the Williams formation. This mutant is a giant form that has developed a flat-sided whorl in many individuals due to the formation of strong spirals close to the suture line on both sides of the suture. This change in sculpture and whorl-shape would justify the description of this mutant as a distinct species were it not for the fact that fully one-half of the giant individuals appearing at this horizon are exactly like the round-whorled giants found in the highest beds of the Holz shale. Some of these flat-

sided mutants from the Williams formation are immense—perfect individuals in some instances equaling or exceeding a length of 100 mm. and being correspondingly robust.

TURRITELLA IOTA Popenoe, n. sp.
Plate 49, figure 8

Description: Shell of medium size, rather slender: whorls shallowly concave along the posterior four-fifths of the whorl, the sides of the whorl diverging to a definite keel or shoulder near the anterior suture, thence sloping abruptly from the keel inward to the suture; sculpture of three or four strong beaded spirals, separated by numerous fine spirals developed between the principal ones; aperture almost quadrate.

Holotype: California Inst. Technology Invert. Paleo. 3457.

Dimensions of holotype: Length (incomplete), 37.4 mm., diameter, 8.6 mm.

Distribution: Ladd formation, Holz member, *rare*.

Discussion: This *Turritella* is found rarely at a horizon very low in the Holz shale member, a short distance stratigraphically above the contact between the Holz and Baker members of the Ladd formation.

This species resembles somewhat *Turritella whiteavesi* Anderson and Hanna but differs from it in the pronounced keel on the anterior part of the whorls and on the slightly concave outline of the whorl posterior to this keel.

TURRITELLA OSSA Popenoe, n. sp.
Plate 49, figure 6

Description: Shell small, rather slender; apical angle about 18°; whorls gently convex anteriorly, concave posteriorly, slightly inflated just posterior to the suture, constricted at the suture; suture linear; side and base of whorl meeting in a smooth rounded curve; base oblique, gently convex, ornamented with a few very faint spiral lines most prominent at the juncture of the side and base of the whorl; aperture quadrate, slightly higher than wide; sculpture of growth-lines only, or of very faint spiral lines in addition to the growth lines; growth-lines inclined away from the aperture on the posterior part of the whorl, toward the aperture on the anterior part of the whorl, and crossing the base in almost a straight line.

Holotype: California Inst. Technology, Invert. Paleo. Cat. no. 3458.

Paratype: California Inst. Technology, Invert. Paleo. Cat. no. 3459, 3460.

Dimensions of holotype: Length (incomplete), 20.0 mm., diameter, 9.4 mm. Dimensions of a paratype: Length, 26.0 mm., diameter, 9.3 mm.

Distribution: Ladd formation, Holz shale member, *common*.

Discussion: *Turritella ossa* is confined in its distribution almost entirely to a number of scattered localities in the upper half of the Holz shale. It is quite abundant at these localities.

The species differs from any other California Cretaceous *Turritella* I have seen in the shape of its whorl, and in its very faint or obsolete sculpture. It is apparently represented in the Upper Cretaceous beds of the Simi Hills, Los Angeles County, California. I know of no other occurrence of the species.

REFERENCES

1. CONRAD, T. A., *Acad. Nat. Sci. Philadelphia, Jour.*, vol. 4, p. 289, 1860.
2. ——— *Acad. Nat. Sci. Philadelphia, Proc.*, vol. 16, p. 213, text fig., 1864.
3. ——— *Am. Jour. Conchology*, vol. 6, pp. 72, 73, 1870–1871.
4. COSSMAN, M., *Coquilles Fossiles de l'Eocène des Environs de Paris*, p. 113, 1886.
5. CLARK, B. L., Pelecypoda from the marine Oligocene of western North America: *Univ. Calif. Dept. Geol. Sci., Bull.*, vol. 15, no. 4, 1925.
6. CLARK, W. B., and MARTIN, G. C., Eocene deposits of Maryland: *Maryland Geol. Survey*, p. 171, 1901.
7. DALL, W. H., The Tertiary fauna of Florida: *Wagner Free Inst. Science, Trans.*, vol. 3, pt. 4, p. 604, 1898.
8. ——— *U. S. Nat. Mus., Proc.*, vol. 26, p. 933, 1903.
9. GABB, WILLIAM MORE, *California Geol. Survey, Paleontology*, vol. 1, 1864.
10. GARDNER, JULIA, The molluscan fauna of the Alum Bluff group of Florida:

U. S. Geol. Survey, Prof. Paper 142-A, p. 22, 1926.
11. HOLZAPFEL, E., Die Mollusken der Aachener Kreide: *Paleontographica*, Band 35, 1889.
12. JUKES-BROWN, A. J., On the genera of Veneridae represented in the Cretaceous and older Tertiary deposits: *Malac. Soc. London, Proc.*, vol. 8, 1908.
13. MEEK, F. B., A report on the invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: *U. S. Geol. Survey of the Territories*, vol. 9, 1876.
14. PALMER, K. W., The Veneridae of eastern America, Cenozoic and Recent: *Paleont. Americana*, vol. 1, pt. 5, p. 6, 1927.
15. STEPHENSON, L. W., The Cretaceous formations of North Carolina: *North Carolina Geol. and Econ. Survey*, vol. 5, 1923.
16. ——— Upper Cretaceous fossils from Georges Bank (including species from Banquereau, Nova Scotia): *Geol. Soc. America, Bull.*, vol. 47, no. 3, 1936.
17. STEWART, R. B., Gabb's California fossil type gastropods: *Acad. Nat. Sci. Philadelphia, Proc.*, vol. 78, 1927.
18. ——— Gabb's California Cretaceous and Tertiary type lamellibranchs: *Acad. Nat. Sci. Philadelphia, Spec. Pub.* 3, 1930.
19. STOLICZKA, FERDINAND, The Cretaceous fauna of southern India, the Pelecypoda: *Mem. Geol. Survey India, Paleontologia Indica*, ser. 6, no. 3, 1871.
20. WHITEAVES, J. F., *Canada Geol. Survey, Mesozoic Fossils*, vol. 1, 1876–1903.
21. WOODS, HENRY, A monograph of the Cretaceous Lamellibranchia of England: *Mon. Paleontographical Soc.*, vol. 1, 1899–1903, vol. 2, 1904–13.

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