COSTELLACESTA, A NEW SUBGENUS OF *LIMA* FROM THE CRETACEOUS OF THE GULF AND ATLANTIC COAST PROVINCE

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ABSTRACT

The new subgenus *Costellacesta* is proposed for large Maestrichtian species of *Lima* with an opisthocline shell, large lunule and byssal gape, single (posterior) auricle, a resilifer situated posterior to the beak, and ornamentation consisting of fine costellae intercalated between prominent, equally developed costae. Three species of *Costellacesta* are known and described: *L. (C.) riddlei,* n. sp., the type species (oldest; Chiwapa Sandstone Member, Mississippi), *L. (C.) sayrei* Stephenson (Corsicana Marl, Texas), and *L. (C.) insolita* Stephenson (youngest: upper Peedee Formation, North Carolina). These represent a single line of descent without significant break. Successively younger species demonstrate the following evolutionary trends: change in marginal outline, particularly an increase in concavity of the dorsoanterior margin; increase in the relative size of the lunule and byssal gape; re-

duction in the strength of the costae and costellae; increase in number of costellae, and decrease in number of costae per unit length; possible decrease in maximum adult size.

Costellacesta is possibly ancestral to plicate Cenozoic *Limas* of the subgenus *Plicacesta* Vokes. The habitat of *Costellacesta* was probably analogous to that of living giant *Limas (Acesta, Plicacesta)*—cold, deep waters of the continental slope and abyss, rarely ranging into warm, shallow shelf environments. This might explain the uncommon occurrence of *Costellacesta* in shallow water Cretaceous deposits of the Atlantic and Gulf Coastal Plain Province. The subgenus is known only from this area, and probably represents an endemic group.

I. Introduction

Lima is a common element of Gulf and Atlantic Coast Cretaceous pelecypod assemblages. Individual species are widely distributed and are represented in a variety of lithologies, rendering them potentially important in biostratigraphic zonation and correlation. The American species of *Lima* are divisible into several distinct lineages, some of which are treated as sections or subgenera by many workers. One of the most unusual Cretaceous lineages, and one which appears to be endemic to the Gulf and Atlantic Coast Province, is the group of giant *Lima* comprising a new subgenus, *Costellacesta* Kauffman. This lineage is possibly ancestral to the Cenozoic and Recent subgenus *Plicacesta* Vokes (1963).

Costellacesta is characterized by its large size, inequilateral (opisthocline) shell, single (posterior) auricle, large lunule and byssal gape, slightly oblique resilifer situated posterior to the beaks, and by the surface ornamentation, which consists of narrow, sparsely fluted costae and numerous, delicate, intercalated costellae. Unlike many other Cretaceous *Lima,* species of *L. (Costellacesta)* are rare and geographically restricted; few complete specimens are known. Cenozoic and Recent giant *Lima* of the subgenera *Plicacesta* and *Acesta* are similarly restricted.

Three species of *Costellacesta* are known from Upper Cretaceous sediments of the Atlantic and Gulf Coast Province. These are, from oldest to youngest: *Lima (Costellacesta) riddlei* Kauffman, n. sp. (Chiwapa Member, Ripley Formation, Mississippi), *L. (C.) sayrei* Stephenson (Corsicana Marl, Navarro Group, Texas), and *L. (C.) insolita* Stephenson (Upper Peedee Formation, Owl Creek - Providence - Prairie Bluff equivalent, North Carolina). These species occur in successive stratigraphic units, without overlapping ranges, and probably represent a continuous evolutionary sequence. Known species of *Lima (Costellacesta)* are exclusively Maestrichtian in age, and occur only in the upper half of the *Exogyra costata* zone (see Sohl, 1960, fig. 3).

II. Acknowledgments

Specimens of *Lima (Costellacesta) riddlei,* n. sp., the type species, were collected and donated to the Smithsonian Institution by Mr. W. C. Riddle of Memphis, Tennessee, as part of a program undertaken by the Mid-South Earth Science Club to provide the Institution with research material. To Mr. Riddle and his associates I offer my sincere thanks. Drs. Harold E. Vokes of Tulane University, A. Lee McAlester of Yale University, John Pojeta, Jr., and Norman F. Sohl of the U. S. Geological Survey reviewed the manuscript and offered valuable criticism. Dr. Sohl was also instrumental in locating specimens and provided valuable assistance in stratigraphic interpretation. Drawings are by Mr. L. B. Isham and Mr. L. R. Purnell, and photography by Mr. Jack Scott, all of the U. S. National Museum.

III. Biostratigraphy

The three known species of *Lima (Costellacesta)* occur at widely scattered localities; no two species have been found in the same area. Nevertheless, the stratigraphic relationships between the species are well established (fig. 1). The oldest form, *L. (C.) riddlei,* n. sp., occurs exclusively in the Chiwapa Sandstone Member of the Ripley Formation (Mellen, 1958; equivalent to the Keownville Limestone Member of Sohl, 1960, p. 18, fig. 3) near Ingomar and Pontotoc, Mississippi. The youngest member of the lineage, *L. (C.) insolita* Stephenson occurs only in the upper part of the Peedee Formation at the New Rocky Point quarries, Pender County, North Carolina (upper part of the *Exogyra costata* zone, Late Maestrichtian: Stephenson, 1927, p. 13). Here it is associated with a fauna of Owl Creek - Prairie Bluff - Providence age (Stephenson, 1927, Sohl, oral communica-

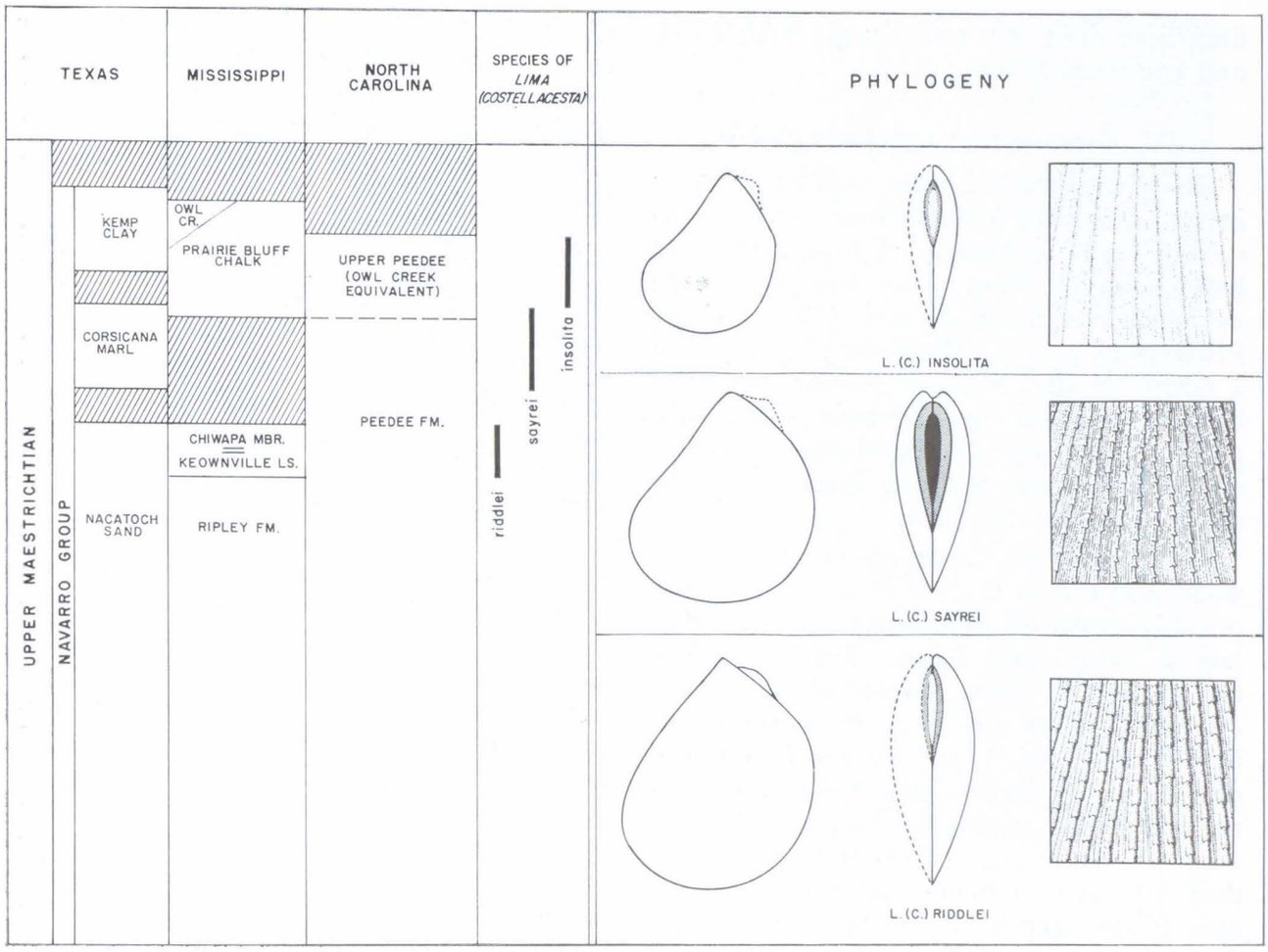

Figure 1—Stratigraphic occurrence, and phylogeny of *Costellacesta,* showing change in shape, decrease in overall size, variation in size of the lunule and byssal gape, and change in ornamentation on progressively younger species of the subgenus. Byssal gape black where definitely known, otherwise approximated by blank area in lunule. Drawings for *L. (C.) riddlei* based on holotype (USNM 132632), for *L. (C.) sayrei* on paratype (USNM 132636), and for *L. (C.) insolita* on holotype (USNM 73431). Outlines reduced ¼; ornamentation approximately X ½.

tion, 1964). Near Ingomar and Pontotoc the Prairie Bluff Chalk disconformably overlies the Chiwapa Sandstone Member of the Ripley, and although *L. (C.) insolita* does not occur here, its age relationship to *L. (C.) riddlei,* n. sp., is clearly established.

The relative stratigraphic position of *L. (C.) sayrei* from the Corsicana Marl of Texas is not as clearly defined. The Corsicana contains a fauna considered to be transitional between those of the Chiwapa Member and Prairie Bluff Chalk. In addition, there is a certain amount of faunal overlap between the Corsicana and each of these units. As a whole, the Corsicana fauna is not duplicated on the eastern Gulf Coast, however, suggesting that no lithologic equivalent occurs in this area. The Corsicana probably occupies a time span represented on the eastern Gulf Coast by a widespread disconformity between Owl Creek - Prairie Bluff strata and those of the Chiwapa Sandstone Member of the Ripley (Sohl, 1960, fig. 3). This disconformity was recognized and widely traced by Stephenson and Munroe (1937), p. 806), and is present at Ingomar and Pontotoc (Sohl, oral communication, 1964). *Lima (Costellacesta) sayrei* Stephenson therefore appears to lie stratigraphically between *L. (C.) riddlei,* n. sp., and *L. (C.) insolita* Stephenson. No species of *Costellacesta* are known to have overlapping ranges, but they are too rare to be considered important stratigraphic indices.

The subgenus *Costellacesta* is known only from Maestrichtian deposits of the Gulf and Atlantic Coast Province (fig. 1). Its range lies in the upper part of the *Exogyra costata* zone, and is approximately equivalent to the range zone of *Turritella bilira* Stephenson (Chiwapa through Owl Creek: Sohl, 1960, fig. 3. Range defined by solid and dashed

lines now definitely established; Sohl, 1964, oral communication).

IV. Phylogeny and Evolution

The *Costellacesta* lineage appears abruptly in the American Maestrichtian, and no ancestral stock is known. *Costellacesta* may have stemmed from some foreign lineage introduced in the Gulf and Atlantic Coast Province as a fully differentiated group, but a search of the principal foreign literature has not revealed any members of the subgenus, or an obvious ancestral group. Present evidence indicates that the lineage is probably endemic to this area.

The rarity of *Costellacesta* in shallow water Cretaceous Coastal Plain sediments is possibly explained by analogy with the habitats of living giant *Lima*s. Vokes (1963a) has shown that living species of *Acesta* and *Plicacesta,* which are structurally similar to *Costellacesta* (pl. 1, fig. 2) are found predominantly in deep waters of the outer continental shelf, continental slope, and abyss (fig. 2). Only one species is found in less than 300 feet of water and this species is rare at this depth. It is reasonable to assume that species of *Costellacesta* were similarly distributed. If so, the ancestors and early representatives of the subgenus, and perhaps most species of the group, would thus be preserved in deep water Cretaceous sediments not presently exposed on the emergent portion of the continent. The few Cretaceous species that ranged into shallow sublittoral waters are the only ones found today in the inner shelf deposits of the Atlantic and Gulf Coastal Plain.

Although the number of specimens available for study is limited, the three known species of *Costellacesta* seem to form an evolving lineage in which some general evolutionary trends can be noted (fig. 1). Notably among these is the increase in number, but decrease in relative size and strength of the costellae in progressively younger species. The oldest known species, *L. (C.) riddlei,* n. sp., has 1 to 3 prominent fluted costellae in interspaces between adjacent costae; the middle member of the lineage, *L. (C.) sayrei* has 3 to 6 smaller, smooth costellae per interspace. On *L. (C.) insolita* the costellae are even narrower and fainter, and are visible only on parts of the shell where the ornament is coarsest. Possibly, this reflects a trend toward elimination of the costellae in the lineage. Unfortunately, the only known specimen of *L. (C.) insolita* is worn and does not permit accurate determination of the number and total extent of its costellae.

The costae exhibit additional changes through time, becoming narrower, less prominent, less numerous, and more widely spaced in progressively younger species (fig. 1). The apparent decrease in size of the adult shell, and variation in size of the lunule through time may be additional evolutionary trends, but this cannot be substantiated without more material.

The reduction in size and partial loss of costellae in the youngest member of the group, coupled with the retention of the primary radiating elements of the ornamentation (costae), gives rise to a form closely resembling species of the subgenus *Plicacesta,* known only from the Cenozoic and Recent (Vokes, 1963a). Species of *Plicacesta* lack costellae and have plicae rather than costae. This suggests close relationship or possible ancestry of *Costellacesta* to *Plicacesta.* Additional evidence for the ancestry of *Plicacesta* may be provided by future studies of certain large, coarsely plicate, Indian and European Cretaceous limids, such as *Lima ("Acesta") obliquistriata* (Forbes) (India), and *L. dujardini* Deshayes or *L. marrotiana* d'Orbigny (France). These species resemble *Plicacesta* in gross shell morphology, and are contemporary with and older than *Costellacesta.* They may represent an extension of *Plicacesta* into the Cretaceous, or may simply be coarsely ribbed *Plagiostoma.* Unfortunately, certain critical characters of these plicate Cretaceous species, such as the position and nature of the resilifer, and presence or absence of an anterior auricle, are not yet known. Subgeneric relationships cannot be determined without this knowledge.

V. The Ecology of Giant Limas

Ecologic data for living species of giant *Lima* (subgenera *Acesta, Plicacesta*) have recently been assembled by H. E. Vokes (1963a, b). The following comments are drawn from these and other works on Recent pelecypods.

The giant *Lima*s have wide geographic distribution, occurring from the latitudes of

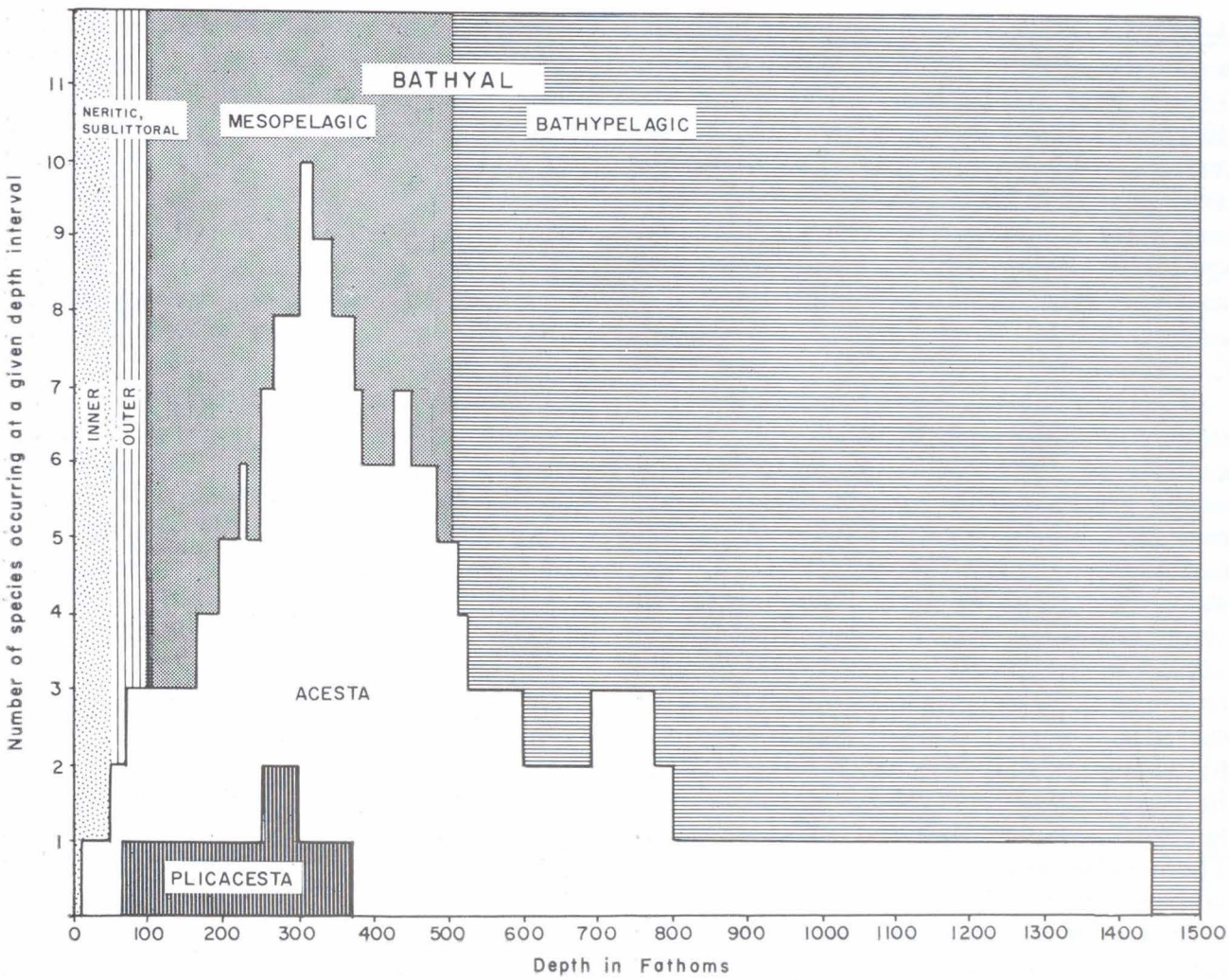

Figure 2—Depth distribution of living giant *Limas* (subgenera *Acesta, Plicacesta*). Data from Vokes (1963a, b).

Norway, Iceland, and Greenland [*L. (Acesta) excavata* (Fabricius)] south of *Patagonia* [*L. (A.) patagonica* Dall]. They are most common in the tropical and warm temperate regions of the Indo-Pacific, especially in the Philippines, East Indies (Sumatra and Borneo), and Japanese Islands. *Plicacesta* is unknown outside the Indo-Pacific, while *Acesta* has two Atlantic representatives. The Cretaceous subgenus *Costellacesta,* however, occurs exclusively in the Atlantic Province, and is the only large coarsely ribbed group of *Limas* with a posterior resilifer known from this area. It may have occupied an ecologic niche in the Atlantic during the Cretaceous similar to that presently occupied by *Plicacesta* in the Pacific.

Most species of *Acesta* and *Plicacesta* inhabit deep water of the outer continental shelf and continental slope (fig. 2). Vokes cited a bathymetric range of 16 to 1450 fathoms (96 to 8700 feet) and an average depth occurrence of 336.4 fathoms (2018.4 feet) for all living species of *Acesta* except *L. (A.)* angolensis Adam and Knudson, which occurs from 400 to 500 meters depth off Angola. Only one species, *L. (A.) goliath* Sowerby occurs uncommonly in water shallower than 300 feet. The two living species of *Plicacesta* have a combined bathymetric range of 337 to 2194 feet; the average depth for *L. (P.) smithi* Sowerby is 1265 feet, and for *L. (P.) sphoni* Hertlein 1650 feet. Since dead shells were most commonly dredged in all samples analyzed, and living specimens are not usually differentiated in dredge records, these depths are at best an approximation of the living range of the various species. However, they conclusively show a deep water habitat preference in the giant *Limas* (fig. 2).

Available temperature records for stations from which *Acesta* was taken show an average water temperature of 48.4° F. (Range 35-59.2° F.). Eliminating the warm water form, *L. (A.) rathbuni,* the average habitat temperature for all other species is 45.7° F. (Vokes, 1963a, p. 85). In some species,

depth distribution is controlled rigidly by water temperature (Vokes, 1963a, p. 80). Temperature may be the primary control on distribution in most species, though this remains to be tested. *Costellacesta* occurs with what have been considered warm, shallow water faunas but it is rare in these assemblages, as are modern giant *Limas*, and was probably more widely distributed in cooler, deeper waters during the Upper Cretaceous.

Bottom sediment was recorded from 33 stations yielding species of *Acesta.* Vokes' analysis of these data (p. 85) shows a strong preference for mud, or fine sand and mud bottoms (color predominantly green; rarely gray, blue) (24 localities). Species of *Acesta* are more rarely found associated with sand (4 occurrences), *Globigerina* ooze, ooze and sand, shell and coral bottom, rock and shell bottom, and on stones (1 occurrence each). Species of *Costellacesta* are found associated with chalky marl *(sayrei),* fine argillaceous sand *(insolita)* and chalky sandstone to arenaceous chalk *(riddlei).* These sediments are well within the range of those inhabited by *Acesta* at present.

Species of *Costellacesta* probably had habitat requirements similar to those of living giant *Limas.* This would account for the rarity in the shallow shelf sediments that characterize the Cretaceous of the Atlantic and Gulf Coastal Plain. As today, rare Cretaceous species lived on the shallow portion of the continental shelf in warmer waters; *L. (C.) riddlei, L. (C.) sayrei,* and *L. (C.) insolita* represent this shallow water element of *Costellacesta.* The preservation of complete fragile shells belonging to the known Cretaceous species probably indicates they lived near their burial site, and were not transported far after death.

Most species of *Lima* are sessile forms, attaching by byssal threads to rocks and other hard objects. Some build elaborate nests of byssal threads in order to protect their nonretractile mantle tentacles from predators. Vokes (1963a) records *L. (A.) excavata* as having been found attached by a byssus; the attachment habits of other living giant *Limas* are unknown. Many species of *Lima,* including a number of those which normally attach, possess the added ability to swim, and lie free on the bottom when not swimming. Yonge (1958, p. 171) has described the swimming:

"A swimming *Lima* is a most charming sight. Progress is made with a series of rather languid movements with each of which the long fringe of tentacles slowly rises and then gently descends around the white shell."

Although any individual swimming incident in *Lima* is short, the animal is capable of moving a considerable distance during its lifetime as long as it remains unattached. Further, it has the ability, as an adult, to be environment selective, a distinct asset to the survival potential of its offspring. Thus the individual, and its larvae, are commonly more rapidly and widely distributed than in wholly sessile pelecypods or vagrant benthonic forms, an important consideration for the paleontologist employing *Lima* in correlation.

VI. Systematic Descriptions

Family Limidae

Genus Lima Bruguiere, 1797

Lima Bruguiere, 1797, Tabl. Encycl. Meth., Vers Coq., 2, p. 206. (Valid according to International Code of Zoological Nomenclature 1961, Art. 16, a, vii; see discussion of Vokes, 1963a, p. 75, 76).
Lima Bruguiere. Cuvier, 1798, Tabl. Elem., p. 421.
Lima Bruguiere. Lamarck, 1799, Mem. Soc. d'Hist. Nat. de Paris, 1, p. 88.
Mantellum Roeding, 1798, Mus. Bolt., p. 160.
Radula Klein. Mörch, 1853, Cat. Conch. Yoldi, 2, p. 57.
Radula Klein. Adams and Adams, 1858, Genera of Recent Mollusca, 2, p. 556, 557.
Lima Bruguiere. H. E. Vokes, 1963, Tulane Stud. Geol., 1, No. 2, p. 75, 76.

Type species: *Ostrea lima* Linnaeus=*Lima squamosa* Lamarck; by subsequent tautonomy (Lamarck, 1801).

Diagnosis: Shell thin, small to moderately large; outline ovate, obliquely subovate, or subquadrate; predominantly equivalve, slightly to greatly inequilateral, with one (posterior) or two small, unequally developed auricles. Anterior byssal gape small to large; posterior gape uncommonly developed. Lunule commonly present. Valves nearly smooth, with incised radiating lines, costellate, costate, or finely plicate. Commissure smooth to crenulate. Hinge line short; cardinal area consisting of central triangular resilifer, erect to oblique, beneath or posterior to beak, bounded laterally by flat cardinal plates for ligament attachment. Pallial line entire, faint. Monomyarian, posterior adductor muscle scar large, in some cases complex, irregular, commonly situated posterocentrally.

Subgenus COSTELLACESTA Kauffman, n. subgen.

Type species: *Lima (Costellacesta) riddlei* Kauffman, n. sp.

Diagnosis: Large, equivalve, moderately inequilateral opisthocline, slightly prosogyre to pisthogyre. Outline obliquely subovate, with long straight dorsoanterior edge. Lunule large, well defined. Byssal gape lanceolate, large, dorsoanterior to mid-anterior. Posterior auricle small, dorsoposteriorly situated, separated from main body of shell by well defined auricular sulcus. No anterior auricle. Surface covered by prominent, evenly developed, widely and subequally spaced costae, smooth to finely fluted or spinose at intersection with major growth lines. Adult costae narrower than interspaces between them, 1-6 fine, evenly spaced, subequally developed costellae commonly intercalated between adjacent costae. Commissure flat to very faintly undulating. Hinge line short, straight, situated mainly below and posterior to beaks. Resilifer slightly oblique to hinge line, triangular, moderately large, situated just posterior to beak. Lateral cardinal plates flat, triangular, unequal. Pallial line and musculature unknown. Shell thin.

Remarks: Costellacesta is distinct from the subgenus *Acesta* Adams and Adams in lacking an anterior auricle, having a more projecting, beak and narrower umbone, in its larger lunule and byssal gape, more prominent auricular sulcus, and in having prominent radial sculpture, consisting of narrow costae and intercalated costellae, covering the entire valve. *Plicacesta* is even more similar to *Costellacesta,* but can be distinguished by its radial plicae of only one size which involve the entire thickness of the shell and are reflected internally. In addition, the plicae are broader than the interspaces between them, and are coarser, broader, and more crowded than those on species of *Costellacesta.* Finally, *Plicacesta* appears to have at least a remnant anterior auricle, a more oblique resilifer, and commonly a smaller lunule and byssal gape than found on *Costellacesta.* The subgenus *Costellacesta* is uncommon, and is known only from the Maestrichtian deposits of the Gulf and Atlantic Coast Province, from Texas to North Carolina.

Many Jurassic species of *Lima* attain a size equivalent to that of *Costellacesta, Acesta,* and *Plicacesta.* Most of these belong to the subgenus *Plagiostoma* and are not closely comparable. One group, however, the subgenus *Regalilima* Cox, has many morphologic features suggestive of the giant Cretaceous, Cenozoic, and Recent *Limas*, in particular the valve outline, single (posterior) auricle, large lunule and byssal gape. *Regalilima* is distinct in having radial sculpture consisting of incised lines, and a resilifer which appears to lie directly beneath the beak. Nevertheless the similarities are so striking that it is not difficult to envision the *Acesta - Costellacesta - Plicacesta* complex as having arisen from such a group.

The morphologic criteria and the magnitude of structural differences which distinguish *Costellacesta* from other subgenera of *Lima* are equivalent to those which separate far better known limid subgenera such as *Acesta* and *Plicacesta.* These well studied subgenera probably arose from a common Mesozoic stock, and are known to have evolved as distinct lineages through the Cenozoic. *Costellacesta* appears to have had a similar history. The restricted number of specimens available for study, and lack of knowledge concerning its ancestors and descendants should not detract from the recognition of *Costellacesta* as a distinct subgenus.

LIMA (COSTELLACESTA) RIDDLEI, n. sp.

Pl. I, figs. 3, 4, 6

Material: A single, nearly complete, large right valve showing the hinge characters; two moderately well preserved, medium size valves (right and left); a large shell fragment.

Description: Summary of measurements presented in Table 1. Shell attaining large size, equivalve, height greater than length; moderately inequilateral, opisthocline, opisthogyre. Outline subtriangular to trigonal-subovate; valves oblique (pl. 1, fig. 4). Posterior and ventral margins moderately and subevenly rounded; anteroventral margin more narrowly rounded; anterior margin straight to very slightly curved (convex outward), steeply inclined to hinge axis. Valves moderately convex dorsocentrally, on umbone; ventral, ventrolateral, posterior flanks slightly convex, gradually flattening toward margin. Anterior slope, especially dorsal half, gently convex centrally, abruptly truncated and sharply incurved at edge of lunule. Lunule poorly known, apparently long, moderately broad, excavated, and largely filled with a lanceolate byssal gape equal to one-third or one-half of the anterior margin. Rim of lunule at perimeter of gape apparently narrow.

Beak pointed, somewhat projecting, apical angle slightly greater than 90° (pl. 1, fig. 4); umbone poorly defined, moderately convex, costate. Umbonal midline straight, slightly opisthogyre. Beak situated about

five-eights the length from the anterior margin. Anterior auricle not developed. Posterior auricle small (pl. 1, fig. 4), outline subcrescentic, with straight dorsal margin, gently rounded posterior margin. Auricle flat to slightly convex, separated from main body of valve by narrow, moderately deep, well defined auricular sulcus.

Entire surface of valve covered with evenly spaced, moderate size, subequally developed, straight, primary costae (pl. 1, fig. 3, 4) with steep flanks and flat to gently rounded crests over early part of valve, becoming fluted and more narrowly rounded ventrally and laterally near valve margins. Fluting produced at intersections with coarsest growth lines. Costae slightly more crowded posteriorly and centrally than anteriorly. Costal interspaces shallow, flat-based, slightly to moderately broader than costae on ventral two-thirds of valve, narrow dorsally. 1 to 3 costellae intercalcated in interspaces between adjacent costae on ventral one-half to two-thirds of valve (pl. 1, fig. 3); 2 or 3 costellae per interspace most common near margin. First formed costellae appear about one-third the height below the dorsal margin; second and third costellae for each interspace appear at or ventral to midvalve, expanding slightly toward margins. Ornament of auricle similar, but with more crowded costae and fewer costellae. Commissure flat to gently undulating at points where costae intersect margin of valve.

Concentric ornamentation on dorsal three-quarters of valve consisting of very faint, fine, crowded growth lines. Growth lines coarser on ventral one-quarter of valve, at widely spaced intervals crowded and prominent, associated with small concentric constrictions, particularly prominent near anterior and posterior margins.

Hinge line short, straight to slightly curved. Cardinal area broad, short, thick, situated below and posterior to beaks, consisting of a central triangular resilifer, posterior to beak and somewhat oblique to hinge axis, bounded by flat, subtriangular, lateral cardinal plates (fig. 3). Muscle scar, pallial line unknown. Shell thin, smooth internally.

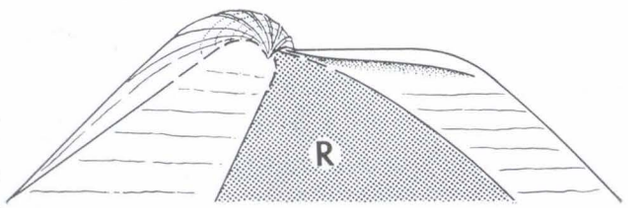

Figure 3—Cardinal area of *Lima (Costellacesta) riddlei* Kauffman, n. sp. showing position of resilifer (R) posterior to beak. Beak and apex of resilifer reconstructed (dashed lines). Ventral margin of cardinal area buried in matrix. Holotype, USNM 132632; enlarged X 2½.

Remarks: Lima (Costellacesta) riddlei, n. sp., is distinct from *L. (C.) sayrei* Stephenson, the most closely comparable Cretaceous species, in having a subtriangular outline, a straight to slightly curved (convex outward)

TABLE 1

MEASUREMENTS OF *LIMA (COSTELLACESTA) RIDDLEI,* N. SP.
(E = ESTIMATED ON BASIS OF RECONSTRUCTION OF VALVE)

	Holotype USNM 132632	Paratype USNM 132633	Paratype USNM 132634
Height (mm)	91.5	75 E	59 E
Length (mm)	75.5	62.3	
Width (mm)	17.4	11.2	11
Distance, anterior margin to beak, along line parallel to hinge axis (mm)	41.4	38.4	
Length of posterior auricle (mm)	18		
Height of posterior auricle (mm)	11		
Angle of inclination: entire valve	95°	105° E	
Angle of inclination: beak, umbo	94°	98° E	
Angle between hinge axis and dorso anterior margin	48°	55° E	
Angle between hinge axis and auricular sulcus	37°		
Auricular angle (between posterior, dorsal margins)	36°		
Number of costae 10 mm below beak	41	36	38
Number of costae in 20 mm length, 20 mm below beak	21	19	21
Terminal number of costae	45	41	
Number of costellae in 20 mm length, 20 mm below beak	5	23	25
Terminal number of costellae	78	54 E	
Length of hinge line (mm)	22.9		
Angle of inclination of resilifer to hinge axis	81°		

dorsoanterior margin, a straighter midline, slightly more convex valves, a smaller, narrower lunule and byssal gape, fewer but coarser costellae per interspace, arising at a later developmental stage, and straighter more numerous, more crowded, and more prominent costae (compare pl. I, figs. 3, 4 with figs. 7, 9). *Lima (Costellacesta) insolita* Stephenson is smaller, having faint, greatly reduced costellae, and smooth, low, rounded, more widely spaced costae.

Lima (Costellacesta) riddlei is chosen as the type species of *Costellacesta* because it is the best known of the three species placed in this group; the holotype exhibits most of the essential characters of the subgenus, including the cardinal area. The species is named in honor of Mr. William C. Riddle of Memphis, Tennessee, who collected and contributed the types, and many other specimens of Cretaceous mollusks, to the study collections of the Smithsonian Institution.

Stratigraphic and geographic position: The holotype and two paratypes were collected from the Chiwapa Sandstone Member (= Keownville Limestone Member) of the Ripley Formation near Ingomar, Union County, Mississippi. The third paratype (USNM 132634) comes from USGS locality 25418 (locality 38 of Sohl, 1960, p. 36, 37), from roadcuts on new Mississippi State Route 6, 3.5 miles east of Pontotoc, NE1/4 SW1/4 sec. 35, T. 9 S., R. 3 E., Pontotoc County, Mississippi, in the Chiwapa Limestone Member.

Types: Holotype, a nearly complete right valve, USNM 132632. Largest paratype, a medium size right valve, USNM 132633; a smaller paratype, about two-thirds of a crushed left valve, USNM 132634; a paratype, a shell fragment sectioned to observe thickness and inner valve surface, USNM 132635.

LIMA (COSTELLACESTA) SAYREI Stephenson

(Pl. I, figs. 5, 7, 9)

Lima ? sayrei STEPHENSON, 1941, The larger invertebrate fossils of the Navarro Group of Texas: Univ. Texas Publ. no. 4101, p. 146, 147, pl. 23, figs. 12, 13.

Material: The primary types of the species: 2 nearly complete, articulated pairs of adult valves (USNM 76476, 132636); 1 fragment of a large valve (USNM 76477).

Description: Summary of measurements presented in Table 2. Shell large, thin, equivalve, moderately inequilateral, opisthocline. Outline subovate; dorsal margin apparently short, straight over posterior auricle; dorsoanterior margin long, straight to slightly concave, moderately inclined to hinge axis; ventroanterior, ventral, posterior margins moderately and unevenly rounded greatest curvature ventroanteriorly, decreasing pos-

TABLE 2

MEASUREMENTS OF *LIMA (COSTELLACESTA) SAYREI* STEPHENSON
(L = MEASURED ON LEFT VALVE; R = MEASURED ON RIGHT VALVE; C = MEASURED ON BOTH ARTICULATED VALVES AND VALVES SAME; E = ESTIMATED)

	Holotype USNM 76476	Paratype USNM 76477
Height (mm)	95 C	84 C E
Length (mm)	84 C	79.2 C
Width (mm)	16.6 R	14.9 R
	32.6 C	30 L
Distance, beak to anterior margin, along line parallel to hinge axis (mm)	32.5 C	49.2 L E
Length of lunule, along margin (mm)	55.5 C	54.6 C
Width of lunule; maximum (mm)	14.4 C	15.7 C
Length of byssal gape, along margin (mm)		40.3 C E
Width of Byssal gape; maximum (mm)		6.1 C
Angle of inclination, entire valve	110 C	108 C
Angle of inclination, beak and umbone	88 C E	86 C E
Angle between hinge axis and dorsoanterior margin	40 C	42 L
Angle between hinge axis and dorsoposterior margin	57 C	52 L
Number of costae 10 mm below beak	29 L	
Number of costae in 20 mm length, 20 mm below beak	14 L	19 L
Total number of costae at margin	35 L	39 L
Number of costellae in 20 mm length, 20 mm below beak	30 L	44 L
Total number of costellae at margin	130 L	165 L

teriorly; margin concave and notched dorsoposteriorly beneath auricle. Central dorsal parts of valve slightly to moderately convex, ventral, ventrolateral, posterior flanks slightly flattened, dorsoanterior flanks steeply inclined into lunule. Lunule poorly preserved on all specimens (pl. 1, fig. 5); lanceolate, long, occupying dorsal one-half of anterior margin, excavated, moderately deep, apparently sharply defined and partially over hung by abruptly truncated dorsoanterior margin. Anterior byssal gape long, moderately narrow, lanceolate (pl. 1, fig. 5); commissure slightly upturned around gape, flat to very faintly undulating over remainder of valve.

Beaks not known. Umbone slightly to moderately convex, apparently erect to slightly prosogyre. Anterior auricle absent; anterior edge of cardinal area rounded, slightly projecting and incurved at dorsal extremity of byssal gape, similar to illustrated specimen of *L. (Plicacesta) smithi* (pl. 1, fig. 1). Posterior auricle small, flat, incompletely known on both specimens (see Stephenson, 1941, pl. 23, fig. 12) apparently straight dorsally, rounded posteriorly, with distinct ornamentation. Posterior auricular sulcus narrow, moderately deep, well defined, an enlarged and much deepened interspace between costae. Hinge line not preserved, assumed similar to *L. (C.) riddlei,* n. sp. Pallial line, musculature, unknown.

Ornamentation consisting of 34 to 38 simple primary costae separated by 3 to 6 fine intercalated costellae per interspace (pl. 1, fig. 7). Costae prominent, subevenly spaced, equally developed, narrow, steep-sided, with rounded crests, originating on early part of umbone, their trace straight to slightly curved over most of shell, gently sinuous ventrally and ventrolaterally at intersections with major concentric elements. Costae slightly more crowded posteriorly than anteriorly; 2 to 3 costae closely crowded on inturned edges of lunule and on steep part of dorsoposterior flank descending into auricular sulcus. Costae fluted to subspinose at somewhat regular intervals where intersected by major growth lines (pl. 1, fig. 7); 4-10 flutes per centimeter, best developed ventrally. Costellae fine, thread-like, evenly spaced and equally developed in broad flat interspaces between costae; straight to slightly sinuous, beaded due to irregularities produced at intersections with majority of growth lines (pl. 1, fig. 7). 1 to 2 costellae present between each pair of costae on earliest part of umbone preserved; number increasing by intercalation throughout growth of shell, with 5 to 6 commonly found in interspaces near margin of adult shell (pl. 1, fig. 7, 9). Concentric ornament consisting of faint to well defined but small, crowded growth lines over entire shell, and 2 to 3 scattered, narrow zones of moderate to coarse growth lines, and more rarely lamellae, near margin (outer 1 inch or less).

Ornamentation of posterior auricle distinct, consisting of crowded, coarsely fluted costae like those on main body of shell, separated by equally wide or narrower, rounded interspaces rarely bearing a single, intercalated, fluted costella.

Remarks: Lima (Costellacesta) sayrei Stephenson is the largest and most ornate species of the lineage. It is known only from Stephenson's 3 type specimens. Although he partially excavated them, Stephenson did not note the lunule with its large byssal gape. Consequently, he reversed anterior and posterior throughout his description, considering the left valve the right, and the auricle as being anterior. Comparison of the species of *Costellacesta* with the similar, living, *Lima (Plicacesta) smithi* (pl. I, figs. 1, 2) clearly shows that the major byssal gape is dorsoanterior and situated in a prominent lunule, the anterior auricle is absent, and the valves are opisthocline. Anterior and posterior are determined on *L. (P.) smithi* by the resilifer (oblique and posterior to the beak) and the well developed posterior adductor muscle scar. A parallel orientation in *Costellacesta* is determined by the position of the lunule and byssal gape on all species, and by the position of the resilifer in *L. (C.) riddlei,* n. sp.

The distinction between *L. (C.) sayrei* and *L. (C.) riddlei* have been discussed under the "Remarks" section for the latter species. *L. (C.) sayrei* is distinguished from *L. (C.) insolita* Stephenson by its larger size, more rounded outline, more prominent and slightly more numerous fluted costae, and especially by its more numerous, more extensive beaded costellae. *L. (C.) sayrei* also appears to have a larger byssal gape, and better defined lunule. Stephenson illustrated the holotype (1941, pl. 23, fig. 12).

Stratigraphic and geographic distribution: Lima (Costellacesta) sayrei is known only from the Corsicana Marl, Navarro Group, at U.S.G.S. locality 15621, in a ravine east of Medio Creek, 0.8 mile south of Castroville road, near Castroville, Texas; at U.S.G.S. locality 15622, from a bluff on Medio Creek about 0.8 mile "below" (south of) Castroville road; and from 6 miles east of Castroville, Texas (Texas Bureau 53; locality of holotype).

Types: Holotype, the largest set of relatively complete articulated valves USNM 76476. Paratypes, a well preserved set of articulated valves (U.S.G.S. loc. 15621), USNM 132636 (pl. I, figs. 5,9) (formerly

a part of USNM 76477, unfigured paratype lot); a shell fragment showing the ornament (USGS loc. 15621, USNM 76477).

LIMA (COSTELLACESTA) INSOLITA Stephenson

Pl. I, figs, 8, 10

Lima insolita STEPHENSON, 1927, Additions to the Upper Cretaceous Invertebrate faunas of the Carolinas: Proc. U. S. Natl. Mus., v. 72, art. 10, p. 13, pl. 5, fig. 10.

Material: A single, nearly complete, worn adult left valve, the holotype (USNM 73431).

Description: Summary of measurements presented in Table 3. Shell moderately large, thin, presumably equivalve; inequilateral, moderately opisthocline; height greater than length. Outline subovate, with long, slightly concave, dorsoanterior margin. Ventroanterior margin strongly curved; ventral, posterior margins moderately, and subevenly rounded (pl. 1, fig. 10). Dorsal margin not preserved. Umbone slightly to moderately convex; ventral, ventrolateral, posterior flanks slightly convex medially, becoming flatter toward margin. Dorsoanterior flank abruptly truncated, moderately to narrowly rounded at edge of lunule. Lunule poorly defined, depressed, occupying two-thirds of dorsoanterior margin. Byssal gape unknown, probably long and narrow.

Beaks unknown. Umbo suberect, broad, not well defined. No anterior auricle developed. Posterior auricle, if present, not preserved. Hinge line, internal structures unknown.

Radial ornamentation consisting of 28 to 30 straight simple primary costae extending from early part of umbone to margin. Costae narrow, low, rounded, smooth equally developed, subevenly spaced (more crowded anteriorly), separated by much larger, flat interspaces, a few of which bear very faint, fine, scattered, discontinuous costellae (pl. 1, fig. 8), 1 to 2 per interspace preserved, but probably much more extensive on unworn shells of species. Costellae smooth, straight, very low, rounded. Concentric ornamentation consisting of numerous, crowded, very faint growth lines over entire valve, and a few, scattered, moderately prominent growth lines near margin. Commissure smooth to very broadly undulating.

Remarks: As in *L. (C.) sayrei,* Stephenson did not note the position of the lunule and main byssal gape in this specimen, and considered it a right valve; anterior and posterior are reversed throughout his description.

The holotype is worn, and thus the precise nature of the delicate surface ornamentation cannot be determined. In spite of this, the wide spacing of the costae, lower number of costae, fainter discontinuous costellae, and the smaller, less rounded valve are sufficient to distinguish the species from *L. (C.) sayrei* and *L. (C.) riddlei,* n. sp. The species appears to be most closely related to, and derived from *L. (C.) sayrei.* It is the youngest known member of the lineage. Apparent reduction of the costellae, and retention of well defined costae, may reflect ancestry to the Cenozoic-Recent subgenus *Plicacesta* Vokes.

TABLE 3
MEASUREMENTS: HOLOTYPE OF *LIMA (COSTELLACESTA) INSOLITA* STEPHENSON

Height, including reconstruction of beak (mm)	63
Length (mm)	53.3
Width (mm)	9.8
Distance, anterior margin to beak, along line parallel to hinge axis (mm)	26.4
Angle of inclination, entire valve	105°
Angle of inclination; beak, umbo	85°
Angle between hinge axis and dorsoposterior slope	42°
Angle between hinge axis and dorsoanterior slope	46°
Number of costae 10 mm below beak	28-30
Number of costae in 20 mm length, 20 mm below beak	17
Total terminal number of costae	28-30

Stratigraphic and geographic position: The only known specimen is from the upper part of the Peedee Formation, in sediments bearing an Owl Creek-Prairie Bluff fauna (upper part of the zone of *Exogyra costata* Say: Late Maestrichtian). It was found at U. S. Geological Survey locality 13585, in the New Rocky Point quarries, one mile northeast of Rocky Point Station, Pender County, North Carolina.

Type: Holotype, USNM 73431; a nearly complete left valve.

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EXPLANATION OF PLATE I

Figures — Page

1, 2, — *Lima (Plicacesta) smithi* Sowerby 98

1, Interior and 2, exterior views (X1) of a left valve from Echigo, Japan; USNM 344887; Hirasé Collection, Division of Mollusks, USNM. Illustrated for comparison with members of *L. (Costellacesta).*

3, 4, 6 — *Lima (Costellacesta) riddlei* Kauffman, n. sp. 95

3, Portion of right valve (fig. 4) showing adult ornamentation (X2).

4, Lateral view (X1), holotype (USNM 132632), a right valve.

6, Anterior view (X1) of holotype showing margin of lunule.

5, 7, 9 — *Lima (Costellacesta) sayrei* Stephenson 97

5, Anterior view (X1) of Stephenson's unfigured paratype (USNM 132636) showing limits of lunule, position of byssal gape (space inside byssal gape retouched to improve contrast), infolded anterior margin of cardinal area.

7, Portion of the same adult shell near margin (X2) showing details of ornamentation; left valve.

9, Lateral view of left valve (paratype, USNM 132636, of figs. 5, 7) with auricle broken off.

8, 10 — *Lima (Costellacesta) insolita* Stephenson 99

8, Portion of left valve shown in fig. 10 (X2), showing costae and faint, discontinuous, intercalated costellae.

10, Lateral view (X1) of left valve, the holotype (USNM 73431) and only known specimen.

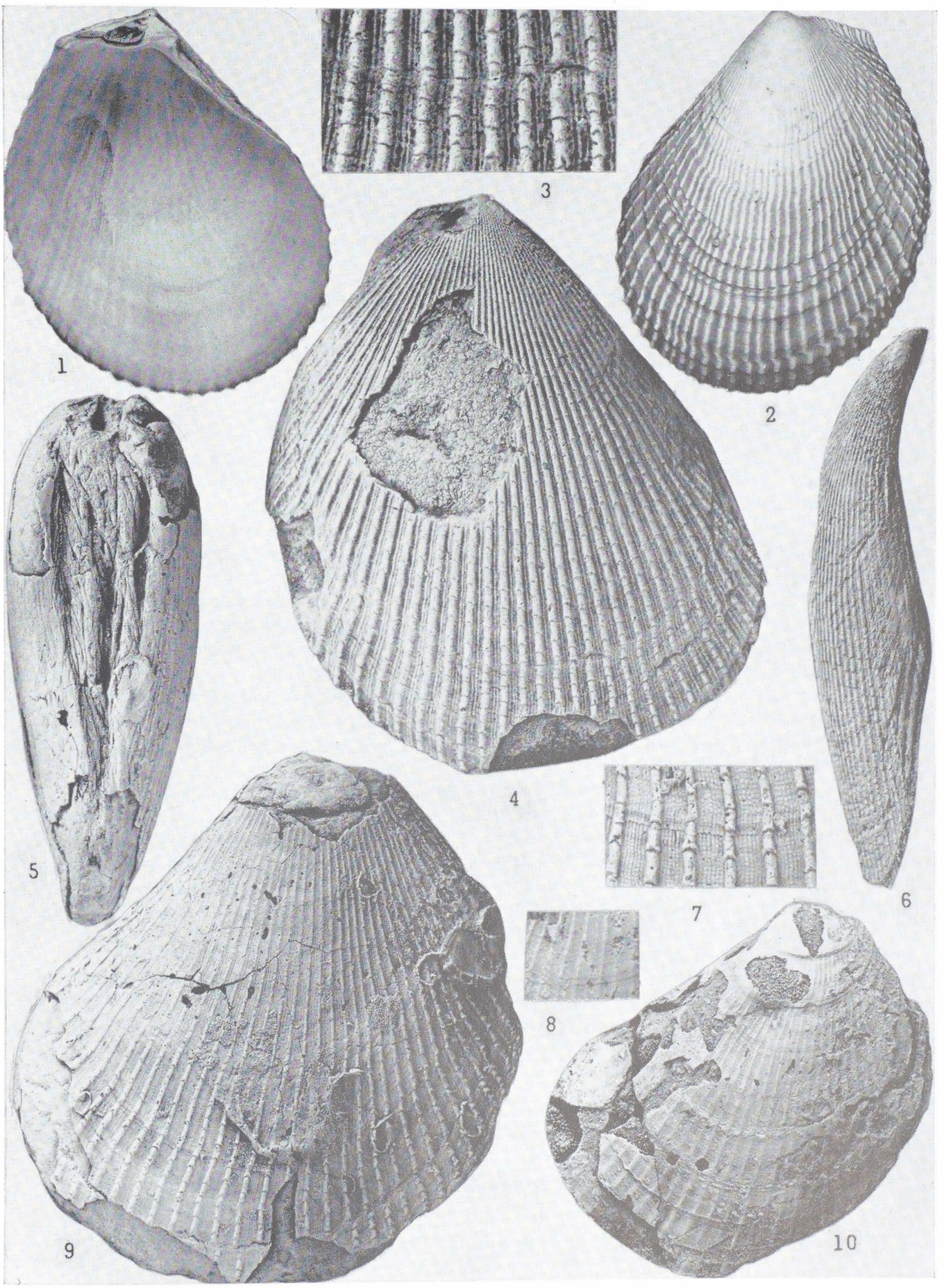

PLATE I