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STONE CITY AND COOK MOUNTAIN (MIDDLE EOCENE) SCAPHOPODS FROM SOUTHWEST TEXAS

KENNETH A. HODGKINSON

Exxon Company, U.S.A., Houston, Texas

ABSTRACT

At least 18 species of scaphopods are recognized in samples from the Stone City and Cook Mountain Formations (Claibornian Stage) of the Brazos River Valley in southeastern Texas. These include 11 species of *Cadulus,* 4 of *Dentalium,* and 3 of *Fustiaria;* 10 of the species are described and named for the first time.

Apical fragments of scaphopods from these formations show that some scaphopods truncate their apexes by periodically discarding a significant portion of the test. This is especially evident in species of *Dentalium.*

INTRODUCTION

Middle Eocene exposures along the Brazos and Little Brazos Rivers in southeastern Texas yield numerous specimens of a wide variety of macrofossils, especially mollusks. Although this fauna has long been known to paleontologists, only a relatively few forms have received detailed analysis. Experience in the age and environmental interpretation of well samples from Eocene subsurface sections in generally adjacent parts of the Gulf Coast, however, demonstrates that some forms (particularly small types) occur in the subsurface rather commonly and generally are not associated with diagnostic microfossils. Accordingly, increased understanding of such types and the precise definition of short-ranging taxa are needed to facilitate subsurface interpretations over a wide area.

LOCAL STRATIGRAPHY AND ENVIRONMENTAL RELATIONSHIPS

This and planned subsequent studies of selected elements in the middle Eocene fauna of southeastern Texas are based on detailed collecting at a few localities. Information on the nature of sections exposed at these localities and on their depositional environment, therefore, are recorded rather fully using personal observations and many previously published discussions.

Middle Eocene outcrops in the Brazos River valley are located in the Gulf Coastal Plain of southeastern Texas (Fig. 1) where good exposures are rare because the nonresistant strata are easily weathered and eroded. Seldom is more than several feet of section available. Thus, Stone City bluff and nearby exposures on Little Brazos River, where exposures are nearly vertical and include richly fossiliferous beds, contribute importantly to understanding of Tertiary stratigraphy.

Stone City bluff, the first-recorded Tertiary fossil locality in Texas and the type locality of the Stone City Formation, extends some 1,500 feet along the south or right bank of the Brazos River (Fig. 2). This bluff (Texas Bureau of Economic Geology locality 26-T-1) is near the bridges of Texas 21 and the Southern Pacific Railroad, 11.4 miles west of the courthouse in

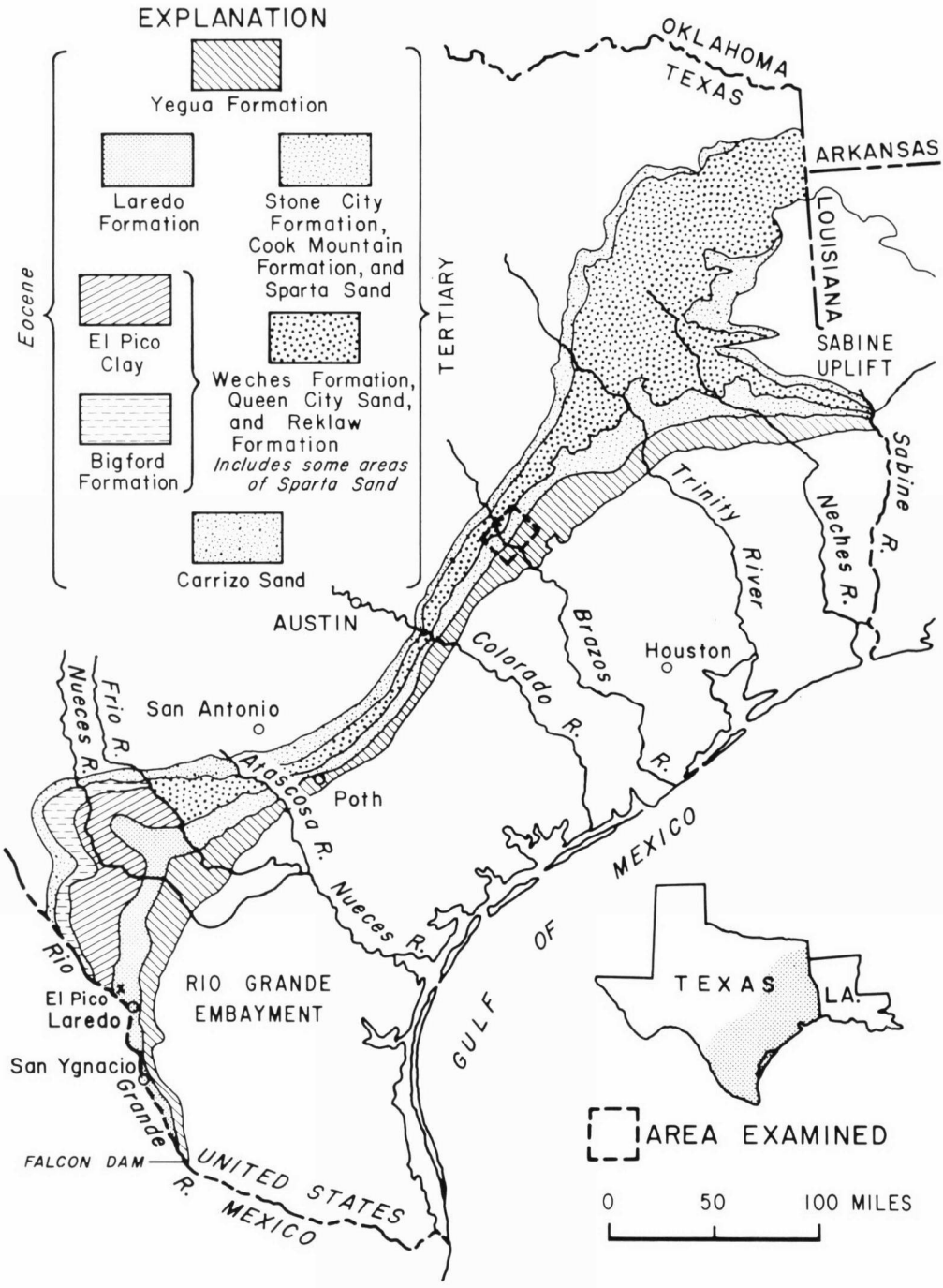


FIG. 1. Outcrop area of the Claiborne Group in Texas (after Eargle, 1968).

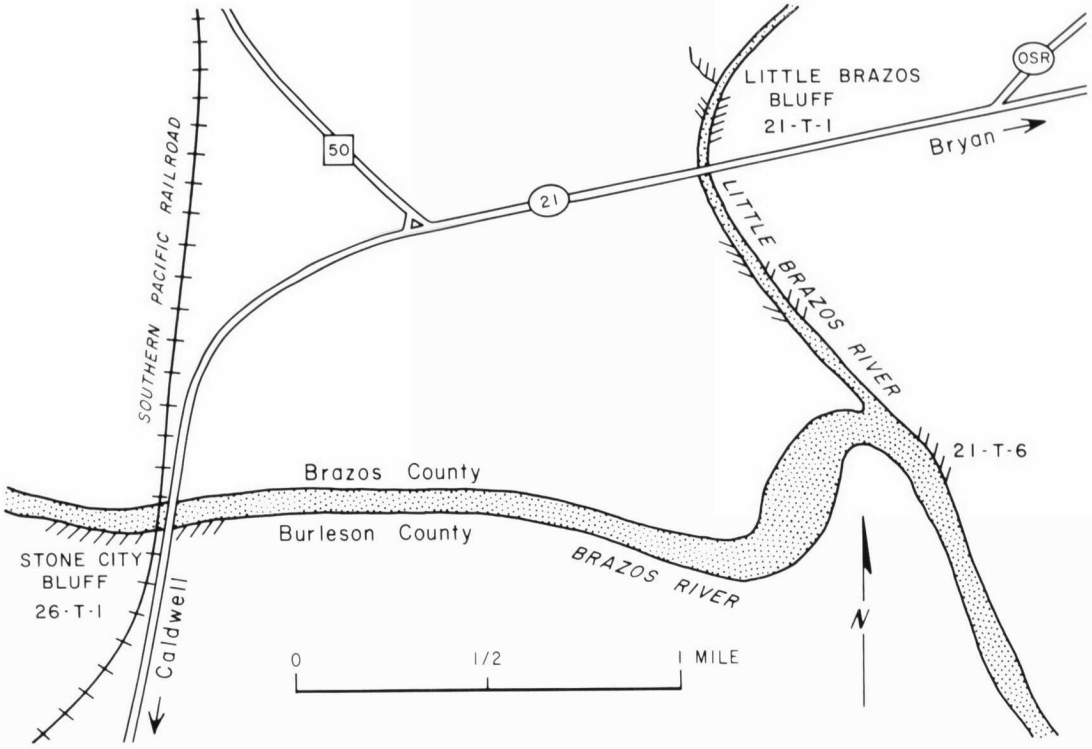


FIG. 2. Stone City bluff (Texas Bur. Econ. Geology loc. 26-T-1), Little Brazos bluff (loc. 21-T-1), and other Claiborne exposures in the Brazos River valley.

Bryan, Brazos County and 11.5 miles northeast of the intersection of Texas 21 and 36 at Caldwell, Burleson County. It has become so important that the beds and fauna at this locality are discussed in most general descriptions of Coastal Plain Tertiary.

At low-river stage several feet of the Sparta Sandstone (Fig. 3), a nonmarine fluviatile or deltaic sand devoid of fossil mollusks, are exposed at the base of Stone City bluff. Disconformably overlying the Sparta Sandstone is the type Stone City Formation (61.1 feet).

The Stone City Formation is well exposed in Rocky Creek (also called Rock Branch) which enters the south side of Brazos River approximately one-half mile upstream from the Texas 21 bridge. The section here consists of alternating dark carbonaceous clays containing discontinuous silt and sand lenses and beds of fossiliferous calcareous glauconitic sands. Concretions are abundant at several levels.

A hard layer, named the Moseley Limestone by Renick & Stenzel (1936), forms the most prominent bench at Stone City bluff. This layer is neither a true limestone nor a laterally continuous unit, but results rather from the weathering and local cementation at the surface of a fossiliferous glauconitic bed. A conglomerate (possibly basal conglomerate) composed of glauconitic calcareous claystone occurs locally just above the "Moseley Limestone." According to Stenzel, this conglomerate marks a disconformity between the Stone City and overlying Cook Mountain Formations.

Stenzel, Krause, & Twining (1957) suggested that the Stone City beds at this locality were deposited in a lagoon or estuary where salinity was almost normal. Glauconitic beds were deposited in areas subject to waves or tidal currents and, therefore, were well aerated. Intervening clays, on the other hand, are more representative of a mud-flat environment.

SERIES	EUROPEAN STAGES	GROUP	FORMATIONS	MEMBERS
MIDDLE EOCENE	AUVERSIAN	CLAIBORNE	YEGUA	
			COOK MOUNTAIN (CROCKETT)	Mount Tabor
				Spiller
				Landrum
				Hurricane
				Wheelock
	LUTETIAN		STONE CITY	
			SPARTA	
			THERRILL	
			WECHES	Viesca
				Tyus
			QUEEN CITY	
			REKLAW	Marquez
				Newby
			CARRIZO	

FIG. 3. Middle Eocene stratigraphic units of southeast Texas. Gaps produced by regional disconformities are indicated by slanted lining. (After Stenzel, Krause, & Twining, 1957, p. 37.)

Scaphopods, gastropods, pelecypods, serpulid worm tubes, ostracodes, foraminifers, bryozoans, hexacorals, spores, and pollen are common in the glauconitic fossil zones. Also generally present are teeth, bones, scales, otoliths, and dermal plates of several kinds of fish and teeth and stinging barbs of rays. Remains of decapods, cephalopods, echinoids, ophiuroids, insects, chitons, barnacles, charophytes, sponges, brachiopods, and plants are found more rarely. Trace fossils, such as corkscrew-shaped burrows, are preserved commonly in the sediment.

Approximately 24 feet of the Wheelock Member of the Cook Mountain Formation (Crockett) disconformably overlies the Stone City Formation. Most of the Wheelock Member is covered by alluvium at this locality but it is exposed in several small ravines. One of the largest exposures is in a small ravine near the southeastern corner of the highway bridge.

Little Brazos bluff (Texas Bureau of Economic Geology locality 21-T-1) is on the east side of the Little Brazos River just upstream from the bridge of Texas 21 (Fig. 4). This is 1.8 miles east of Stone City bluff, 13.3 miles northeast of the highway intersection at Caldwell, and 9.6 miles west of Bryan. Stenzel (1936) and Scott

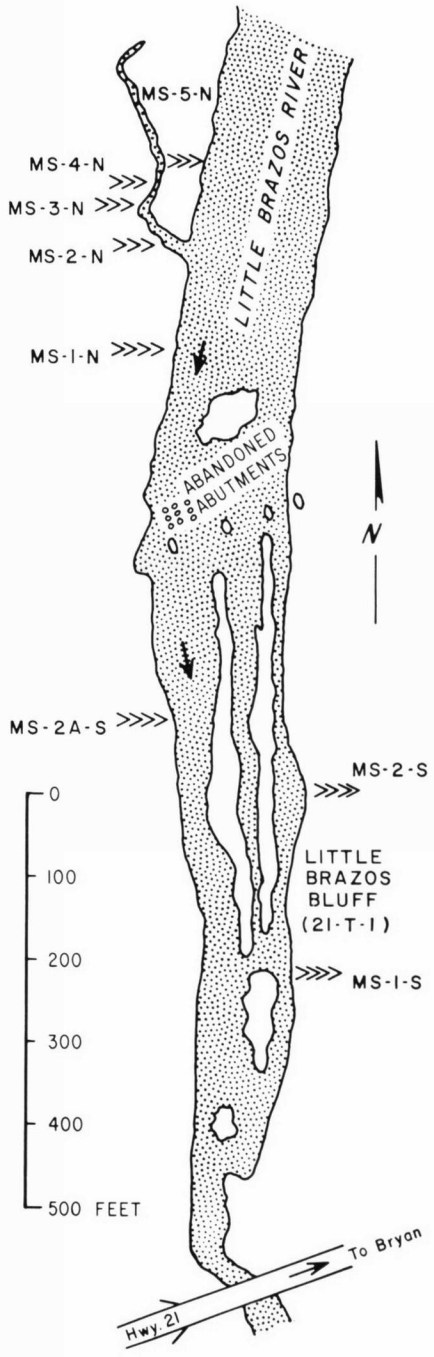


FIG. 4. Location of sections on the Little Brazos River measured and described by Scott (1963, fig. 4).

(1963) described and illustrated the stratigraphy of this bluff and that of older beds exposed on the opposite side of the Little Brazos River. This 30-foot composite section includes the best local exposures of the Cook Mountain Formation.

At the base of this section is a one-foot ironstone bed which contains concretions and crab burrows. This is the "Little Brazos Limestone" of Stenzel (1936) and is about 30 feet stratigraphically above the top of the Stone City Formation (Berg, 1970, p. 50). Downstream from Little Brazos bluff are several exposures of glauconitic clay and ironstone units containing large concretions.

Most Cook Mountain exposures on the Little Brazos River consist of medium gray fossiliferous shale and glauconitic marl with thin sand, bentonite, and concretionary ironstone layers. On the basis of a foraminiferal study, Greenfield (1957), suggested that the area was covered by brackish marsh to inner- and middle-neritic environments. Scott (1963), from sedimentary structures and megafossils, interpreted this section as consisting of tidal mud-flat deposits grading upward into a marsh environment.

Near the junction of the Little Brazos and Brazos Rivers is a fine-grained sandstone containing poorly preserved fossil mollusks. This youngest Cook Mountain exposure in the vicinity mostly is covered by waters of the Brazos River but can be observed at low-water stage. The beds here are fine-grained, cross-bedded to well-laminated with scattered shell placers and silty clay with grass fragments. Scott (1963) reported, "The relatively high angle cross-beds have a prominent bimodal distribution of the dip directions. This type of cross-bed is common in tidal channels. The well-laminated sand with abundant *Xenohelix* and *Ophimorpha* burrows is interpreted as a sand-flat emergent during low tide. The silty clay beds are rich in plant material and are interpreted as a mud flat trapped by the baffle effect of marine 'grasses' on a 'grass' flat."

PREVIOUS WORK

The road crossing the Brazos River at Stone City bluff (Moseley's Ferry) and over the Little Brazos River near Little Brazos bluff is old and well traveled. It originated as an Indian trail and later became variously known as the Camino Real, the San Antonio Road, or Old Nacogdoches Road. It is now called Old Spanish Road by the Texas Highway Department.

One of the early travelers on this road was the 28-year-old Dr. Ferdinand Roemer who, on July 29, 1846, "discovered" the fossiliferous beds exposed at Stone City bluff. Several years later (1848) he wrote, "While on a tour to the upper Brazos I discovered, in the neighborhood of the town of Caldwell, strata of a ferruginous sandstone with numerous well preserved Tertiary shells. Crossing afterwards the Brazos, not far from this town, I had a still better opportunity to see this formation along the steep bank of this river. It consists of alternating strata of brown, ferruginous sandstone and of dark-colored plastic clays, both teeming with fossils."

Since Roemer's time many geologists and paleontologists have visited the exposures on the Brazos and Little Brazos Rivers and have reported on the fauna and stratigraphy. In 1889, R. A. F. Penrose, Jr. (1890) made a boat trip down the Brazos River examining and describing various Tertiary bluff sections. His report contains the first systematic description of the section exposed at Stone City bluff. Heilprin (1891) identified and published on the fossils collected by Penrose. Kennedy, Harris, and Penrose visited the locality together in 1891 or 1892 and in 1893. Kennedy examined the rocks and made extensive fossil collections which he sent to G. D. Harris for identification. Alexander Deussen (1914) visited all of the known Claiborne exposures on the Brazos River, prepared a columnar section, and collected fossils which were sent to T. W. Vaughn. The director of the Geological Survey of Texas, E. T. Dumble (1920), also reported on Stone City bluff.

In a generalized stratigraphic study of the Brazos River, Renick & Stenzel (1931) recognized that strata exposed at Stone City bluff formed the basal part of the Crockett Formation (Claiborne Group) and were, in part, laterally equivalent with the Sparta Sandstone. In 1936 Stenzel recognized two lithologically and faunally unlike units in the bluff. He excluded the lower unit from the Crockett Formation and proposed the name Stone City beds. In 1940 Stenzel proposed reinstatement of the name Cook Mountain Formation for the upper unit.

The most complete description of the Stone City Formation is by Stenzel, Krause, & Twining

(1957). They described in detail the history, lithology, environments of deposition, and pelecypod fauna of the type section. A number of guidebooks include descriptions of this locality (Matthews, 1950; Smith, 1956, 1958, 1962a, 1962b; Zingula, 1961; Atlee *et al.,* 1967; Ethridge *et al.,* 1968; and Berg *et al.,* 1970). Exposures of the Cook Mountain Formation (Wheelock Member) on the Little Brazos River are best described in a guidebook by Scott (1963).

Francis Moore (1859) first identified Stone City fossils, assigning them to forms already known from other Eocene exposures. Gabb (1860a, 1860b) and Conrad (1865a, 1865b, 1867) first recognized new species. Later authors who contributed to a better understanding of this remarkable fauna are Heilprin (1891), Harris (1893, 1895), Aldrich (1895), Kennedy (1896), Johnson (1899), Deussen (1914), Renick & Stenzel (1931), Stenzel (1934, 1936, 1940), Palmer (1937), Stenzel & Turner (1940), Greenfield (1957), Stenzel, Krause, & Twining (1957), and Berggren (1957).

Although Stone City bluff and outcrops on Little Brazos River have been famous collecting localities for more than a century, many species of the different faunal elements remain undescribed. Renick & Stenzel (1931) listed the fauna of several areas in the Brazos River valley and included the following scaphopods.

Scaphopods from Brazos Valley Outcrops

	PRESENT AT STONE CITY BLUFF	PRESENT IN LITTLE BRAZOS RIVER EXPOSURES
Dentalium minutistriatum Gabb	X	X
Cadulus juvenis Meyer	X	X
Cadulus subcoarcuatus (Gabb)	X	—
Cadulus sp. indet.	—	X

No additional species of scaphopods have been listed from these two localities since that time.

Ten scaphopod species are described for the first time in this paper even though Claibornian mollusks of the Brazos River valley have been studied seriously for over 80 years. Although a very local area and a short geological interval have been covered, the differentiation and naming of new species seem well justified because 1) the beds have been collected extensively and several sampled intervals probably were not collected previously; 2) bulk samples were processed, most of the disaggregated sediment was washed through a 50-mesh screen (size of openings = .0117 inch, 0.297 mm) and discarded, and the remaining residue had a high concentration of fossil mollusks; 3) large volumes of washed residues were examined microscopically so that many small specimens were found which otherwise would have been missed; 4) attention was directed specifically toward picking and examining scaphopods so that many specimens were found which are missed in general examinations of the molluscan fauna; 5) because scaphopods have fewer diagnostic characteristics than other classes of mollusks, differentiation of these forms commonly is difficult but abundant collected material permitted a statistical approach that led to improved understanding of these forms; 6) preliminary and cursory examination of samples from a few other Texas localities shows that some species here described occur widely (summary of these occurrences given on p. 7). Additional work on scaphopods of these areas is anticipated.

COLLECTING TECHNIQUES

A few of the scaphopods described in this report (mainly large specimens of *Dentalium*) were visible in surface exposures and collected individually in the field; most, however, were collected during microscopic examination of large volumes of washed residues. These residues were obtained by heating and drying bulk samples, treating heated samples with Varsol, soaking the treated material in hot water, and then washing fines from disaggregated material through a 50-mesh screen. Bulk samples (each 2 to 3 pounds) were collected at two-foot intervals throughout each exposure. Larger, and more closely spaced samples, were taken where beds were obviously rich in fossils.

ACKNOWLEDGMENTS

Appreciation is expressed to Dr. Katherine Van Winkle Palmer for examination of specimens, valuable comments on identification and taxonomy, and loan of type specimens from the Paleontological Research Institution. Drs. Richard S. Boardman and Porter M. Kier loaned types from the U.S. National Museum as did Dr. Horace G. Richards from the Academy of Nat-

Distribution of Southeastern Texas Middle Eocene Scaphopods

LOCALITY	*Cadulus brazosensis* Hodgkinson, n. sp.	*Cadulus curtus* Hodgkinson, n. sp.	*Cadulus juvenis* Meyer	*Cadulus stonecityensis* Hodgkinson, n. sp.	*Cadulus subcoarctatus* (Gabb)	*Dentalium minutiannulatum* Hodgkinson, n. sp.	*Dentalium minutistriatum* Gabb	*Dentalium* sp. A	*Dentalium* sp. B	*Fustiaria acicula* Hodgkinson, n. sp.	*Fustiaria* leroyi Hodgkinson, n. sp.
On dirt road 2.15 mi S. of Augusta, Houston Co. (Weches Fm.)	—	—	—	—	X	—	—	—	—	—	—
Burleson bluff, right bank of Brazos R. 13.6 mi NE Caldwell, Burleson Co. (Weches Fm.)	—	—	—	—	—	—	—	—	—	X	—
Bluff on right bank of Colorado R., Smithville, Bastrop Co. (Weches Fm.)	—	—	—	—	X	—	X	—	—	X	—
Hurricane Bayou, 3.5 mi NE Crockett, Houston Co. (Cook Mtn. Fm.)	X	X	X	X	X	—	X	—	X	X	X
(Alabama Ferry, left bank Trinity R., 7.5 mi W-SW Porter Springs, Houston Co. (Cook Mtn. Fm.)	X	X	X	X	X	—	X	X	X	X	X
Two Mile Creek, 5.3 mi SW of Leona, Leon Co. (Cook Mtn. Fm.)	X	—	X	—	X	—	X	—	—	X	—
Flat Branch, 0.4 mi from entrance gate on Middleton-Guys Store County Road, Leon Co. (Cook Mtn. Fm.)	—	—	—	X	—	—	X	—	—	X	—
Right side of Colorado R., 0.8 mi downstream from County line, 1.6 mi. NE of Kirtley, Fayette Co. (Cook Mtn. Fm.)	—	X	—	—	—	X	—	—	—	X	—
Pin Oak Creek, at crossing of old Smithville-Winchester Road, Bastrop Co. (Cook Mtn. Fm.)	—	X	—	—	—	X	—	—	—	X	X

ural Sciences of Philadelphia. Grateful acknowledgment is made also to those who assisted in the preparation of the present report. Dr. Richard P. Zingula, Imperial Oil Limited, acquainted me with the Brazos River valley area, read the manuscript, and made many helpful comments. Mr. Duane O. LeRoy, Exxon Company. U.S.A., assisted in preparation of illustrations and manuscript and actively supported the effort. Miss Mary K. Myers, Exxon Company, U.S.A., drafted the figures. Mr. T. H. Miller, Esso Production Research Co., did most of the photography. He also was instrumental in obtaining the scanning-electron microscope photographs. My wife, Erlene, was a valued field colleague and typed preliminary copies of the manuscript. The final draft was typed by Mrs. Betty Ludwick. Acknowledgment is made to Dr. Russell M. Jeffords, Esso Production Research Co., who critically reviewed and edited preliminary and final manuscripts. Thanks are due also to Exxon Company, U.S.A., for making facilities available to carry on the research and for permission to publish these findings.

MORPHOLOGICAL FEATURES OF SCAPHOPODS

Ludbrook (1960, p. 137) and Emerson (1962, p. 462) have discussed and illustrated many of the morphological features of scaphopods. These features are included in the scaphopod descriptions of this paper, but the present study shows a critical need for additional details that facilitate a more thorough analysis. Thus morphological features and measurements shown in Figure 5 have been used.

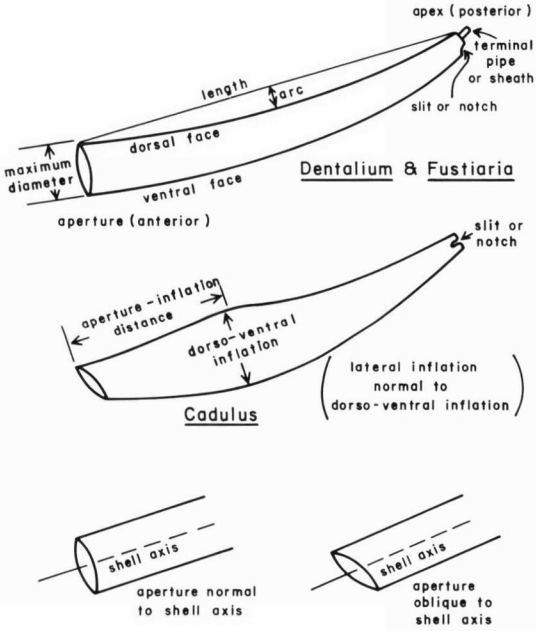


FIG. 5. Morphological features of scaphopods.

Measurements used to describe species in the genera *Fustiaria* and *Dentalium* include length, maximum diameter, number of ribs at a given diameter, and number of annulations per unit length (1 mm). Because tests of the genus *Cadulus* have a more complex shape, additional or different measurements are used. The maximum diameter (inflation) does not occur at the anterior end but is formed somewhere between the aperture and midlength of the test. Although the tests of most species are circular in cross section, some are oval. In the latter case both dorsoventral and lateral inflations are measured. Other measurements include the distance from the anterior end to the inflation. This is the distance from the dorsal margin of the anterior end to the dorsal position of greatest inflation (Fig. 5).

Ratios calculated include: 1) Maximum diameter/length *(Dentalium* and *Fustiaria);* 2) Dorsoventral inflation/length *(Cadulus);* 3) Lateral inflation/length *(Cadulus);* 4) Inflation/length (*Cadulus* with oval cross section); 5) Anterior to inflation distance/length *(Cadulus).*

Growing scaphopods truncate their posterior end. Abbott (1954, p. 54) wrote, "The adult shell is open at both ends. It is added to at the larger, anterior end by the mantle edge, while at the posterior end there may be a gradual loss of shell through wear and absorption." Keen (1971, p. 883) stated, "The scaphopod shell increases in size by growth at the anterior end, and as it does so, a part of the smaller or posterior end is dissolved away," and Emerson (1962, p. 462) noted, "The original apex, as in some gastropods, is only retained in extremely young individuals. As the animal increases in size, enlargement of the anal orifice is accomplished by constant truncation of the posterior tip of the tube. The loss of the apical part of the shell appears to be occasionionally caused by accidental breakage, less commonly by chemical erosion, but most frequently by readsorption or solution by the mantle, such as occurs in several groups of the gastropods."

The types of truncation described by Abbott, Keen, and Emerson probably are valid, but some scaphopods truncate their apexes by periodically discarding a significant length of the posterior portion of the test. Numerous apical fragments of *Dentalium (Antalis) minutistriatum* Gabb and *D. (A.) minutiannulatum* Hodgkinson, n. sp., have been found. These discarded apical portions (Fig. 6; see Pl. 4, fig. 1, 2, 4, 6, 7, 9, 10; Pl. 5, fig. 2, 3; Pl. 6, fig. 1-3) have ventral and dorsal notches on the posterior end and points on the anterior end which reflect notches at the apex. Similar apical fragments occur in recent sediments from the Atlantic Ocean. By some mechanism or process, probably absorption, shell material is removed at some distance from the apex and in such a configuration so that slits are already formed when truncation occurs. Apical fragments of *Cadulus* indicate that individuals of this genus also truncate periodically.

After truncation, a pipe or sheath may form

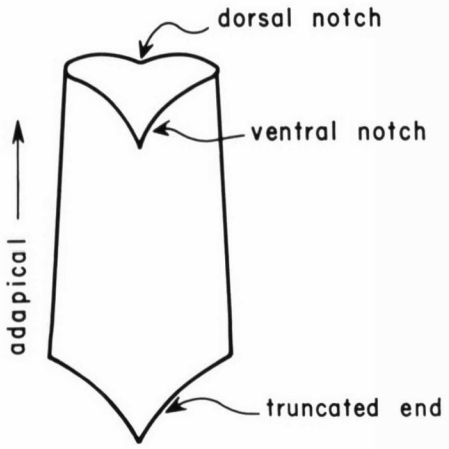


FIG. 6. Truncated posterior end of *Dentalium*.

at the apex of the living shell (Fig. 7). In *Dentalium (Antalis) minutiannulatum* Hodgkinson, n. sp., this sheath may be short with well-defined ventral and dorsal notches, long without notches or with less distinct notches, or long with well-defined notches. In the latter case resorption probably occurred because growth lines of the sheath terminate sharply at the notches. The terminal pipe of *Fustiaria (Episiphon) acicula* Hodgkinson, n. sp., is produced after truncation. This is indicated by the smooth, worn surface of the apex and ventral notch which suggests that the mantle of the scaphopod was in contact with this surface before the pipe was formed.

The purpose of these pipes and sheaths is not known, but they form in response to some outside influence. These extensions are not constant in length and, indeed, may be lacking.

The classification given by Emerson (1962) of generic and subgeneric groups is used here. The detailed descriptions of these taxa are readily available and thus are not reproduced.

Type specimens have been deposited with the U.S. National Museum (USNM, Catalog no. 36), the Paleontological Research Institution (PRI), and the Academy of Natural Sciences of Philadelphia (ANSP).

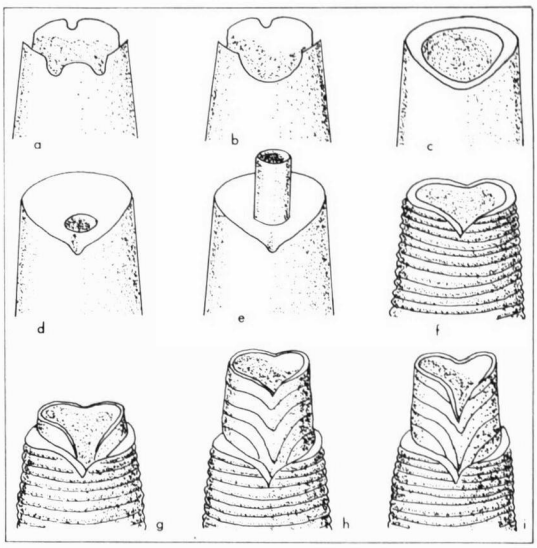


FIG. 7. Apical features of several scaphopods.
a,b. Dorsal views of *Cadulus (Polyschides) subcoarcuatus* (Gabb).——*a.* Typical form showing nature and position of the five apical slits.——*b.* Wide and deep dorsal slit.
c-e. Ventral views of *Fustiaria (Episiphon) acicula* Hodgkinson, n. sp.——*c.* Simple aperture.——*d.* Constriction of apical orifice (dorsal plug) and shallow ventral notch. *e.* Terminal pipe.
f-i. Ventral views of *Dentalium (Antalis) minutiannulatum* Hodgkinson, n. sp.——*f.* Simple aperture with shallow dorsal and deep ventral notches.——*g.* Short sheath showing dorsal and ventral notches corresponding to those of the shell.——*h.* Longer sheath, notches of sheath become shallower.——*i.* Long sheath showing secondary deepening of notches. Resorption of shell material is indicated by sharp truncation of growth lines at notches.

SYSTEMATIC DESCRIPTIONS

CADULUS (CADULUS) OUACHITENSIS Palmer

Figure 8,e-f; Plate 1, figure 6; Plate 2, figure 1

Cadulus (Cadulus) ouachitensis Palmer, 1937, p. 21, pl. 3, fig. 18,19.——Palmer & Brann, 1965, p. 362.

"Shell small; obese; typical *Cadulus s. s.;* greatest inflation about medium in length; apical end constricted more than the posterior and flattened dorsally and ventrally while the anterior aperture is rounded; ventral line is nearly straight . . . . Length 2 mm. (chord subtending arc of the shell); greatest diameter, 0.7 mm." (Palmer, 1937).

Discussion.—This short, strongly inflated form is presently the only species of the subgenus *Cadulus* found in the Claiborne Eocene of the Brazos River valley. Specimens from the Stone City Formation at Stone City bluff and from the Wheelock Member, Cook Mountain Formation, on the Little Brazos River are essentially identical with type specimens from Louisiana.

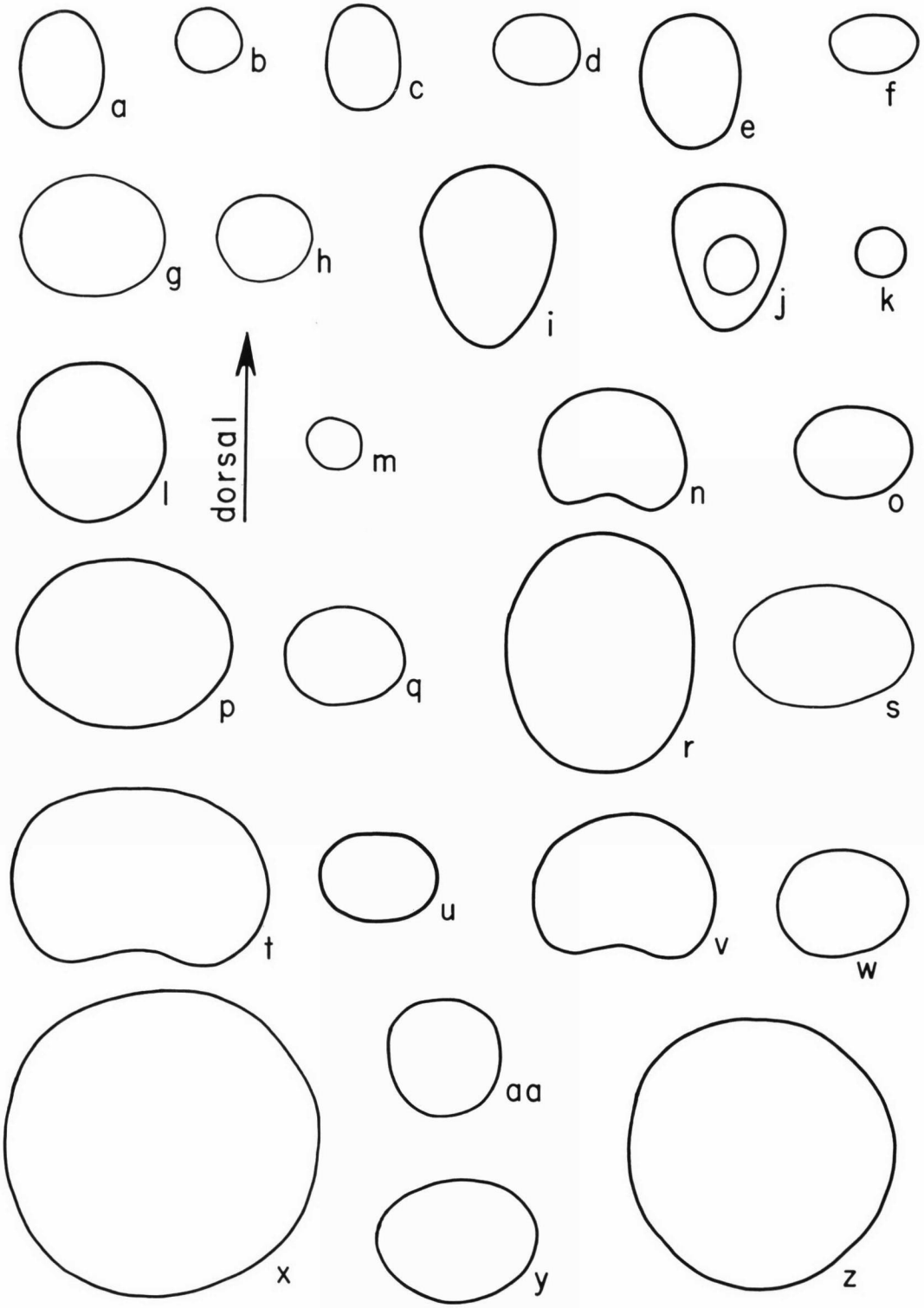


FIG 8. *(For explanation see facing page.)*

Measurements (mm) and Ratios for Six Specimens of Cadulus (Cadulus) ouachitensis Palmer

	LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	1.91	0.67	0.82	0.35	0.43
MAXIMUM	2.09	0.76	0.95	0.36	0.45
MINIMUM	1.82	0.61	0.76	0.33	0.42

Occurrence.—Cadulus (Cadulus) ouachitensis Palmer was described from the Cook Mountain Formation at Lapiniere Landing on the east bank of the Ouachita River, Ouachita Parish, and at Columbus, Sabine Parish, Louisiana. It is very rare in the Stone City Formation at Stone City bluff and in the Wheelock Member on the Little Brazos River. Six complete and 12 broken specimens were collected.

Types.—Syntypes PRI 2644 and PRI 2645.

CADULUS (GADILA) BRAZOSENSIS Hodgkinson, n. sp.

Figure 8,p-q; Plate 1, figures 7-10; Plate 2, figure 7

Small to medium arcuate shell with smooth and polished surface. Inflation normally near anterior end, diameter of shell decreases rapidly from inflation to margin of anterior orifice. Circular aperture oblique to axis. Posterior orifice round, simple. Slight constriction near the apex noted in some specimens.

Discussion.—This form resembles *Cadulus (Gadila) moseleyensis* Hodgkinson, n. sp., but is larger and the inflation is more prominent and farther from the aperture. It also resembles *Cadulus ("Dischides") abruptus* Meyer & Aldrich (1886) in having the inflation near the aperture. The new species, however, lacks apical slits, is much smaller, and differs in shape. The shape of *Cadulus (Gadila) brazosensis* Hodgkinson, n. sp., varies somewhat within the Cook Mountain Formation so that specimens from Scott's locality MS-5-N on the Little Brazos River are inflated near the aperture and weakly constricted at the apex. Specimens from Scott's locality MS-2A-S, 200 yards farther downstream and younger stratigraphically, on the other hand, have the inflation farther from the aperture. Color banding is well preserved on some specimens. The species is named for its occurrence in the Brazos River valley.

Measurements (mm) and Ratios for 29 Specimens of Cadulus (Gadila) brazosensis Hodgkinson, n. sp. from Scott's Locality MS-2-N, Little Brazos River

	LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	4.23	0.86	0.59	0.20	0.14
HOLOTYPE	4.17	0.92	0.59	0.20	0.13
MAXIMUM	5.02	0.99	0.84	0.26	0.18
MINIMUM	3.35	0.76	0.45	0.18	0.11
STANDARD DEVIATION	0.40	0.06	0.11	0.02	0.02
STANDARD ERROR OF MEAN	0.07	0.01	0.02	0.00	0.00

FIG. 8. Shapes and relative size of orifices in species of *Cadulus* and *Fustiaria* herein described (dorsal position toward page top). Larger orifice is aperture, smaller is apical opening.——*a,b. Cadulus (Gadila) erleneae* Hodgkinson, n. sp.——*c,d. Cadulus (Gadila) juvenis* Meyer.——*e,f. Cadulus (Cadulus) ouachitensis* Palmer.——*g,h. Cadulus (Gadila) moseleyensis* Hodgkinson, n. sp.——*i.* Aperture of *Fustiaria (Episiphon) acicula* Hodgkinson, n. sp.——*j.* Adult posterior orifice of *Fustiaria (Episiphon) acicula* Hodgkinson, n. sp., showing location of inner tube or pipe.——*k.* Juvenile posterior orifice of *Fustiaria (Episiphon) acicula* Hodgkinson, n. sp.,——*l,m. Fustiaria (Fustiaria) leroyi* Hodgkinson, n. sp.——*n,o. Cadulus* sp. A.——*p,q. Cadulus (Gadila) brazoensis* Hodgkinson, n. sp.——*r,s. Cadulus (Gadila) stonecityensis* Hodgkinson, n. sp.——*t,u. Cadulus (Gadila) palmerae* Hodgkinson, n. sp.——*v,w. Cadulus (Gadila) zingulai* Hodgkinson, n. sp.——*x,y. Cadulus (Polyschides) subcoarcuatus* (Gabb).——*z,aa. Cadulus (Gadila) curvus* Hodgkinson, n. sp.

Measurements (mm) and Ratios for 38 Specimens of Cadulus (Gadila) brazosensis Hodgkinson, n. sp. from Scott's Locality MS-2A-S, Little Brazos River

	LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	4.11	0.90	1.01	0.22	0.25
MAXIMUM	4.56	1.14	1.44	0.25	0.31
MINIMUM	3.57	0.76	0.68	0.19	0.18
STANDARD DEVIATION	0.28	0.06	0.16	0.02	0.03
STANDARD ERROR OF MEAN	0.05	0.01	0.03	0.00	0.01

Occurrence.—Abundant in lower part of Little Brazos River section. Restricted to strata below the bentonite bed in the Wheelock Member, Cook Mountain Formation.

Types.—Holotype USNM 180431 and paratypes 180448, PRI 29222, ANSP 31500 from Scott's locality MS-2-N on the Little Brazos River. Paratypes USNM 180432-180434 from MS-2A-S. All in Wheelock Member below the bentonite bed (Fig. 9).

CADULUS (GADILA) CURVUS Hodgkinson, n. sp.

Figure 8,z-aa; Plate 1, figures 12-14

Arcuate, slender shell medium in size, gently curved, surface smooth and polished. Inflation very near the anterior end, decreasing slightly to the apertural margin. Aperture round and normal or oblique to the shell axis. Posterior orifice round, simple.

Discussion.—This shell resembles *Cadulus (Gadila) brazosensis* Hodgkinson, n. sp., and *C. (G.) moseleyensis* Hodgkinson, n. sp., but is larger, the anterior slope is much less prominent, and the point of inflation is relatively closer to the aperture. This form also is similar in size and shape to *Cadulus bloutense* Mansfield (1935) from the upper middle Miocene but that species has a broader test (greater diameter in relation to length) and a more constricted aperture.

Like *Dentalium (Episiphon) aciculum* Hodgkinson, n. sp., many specimens (31 of 73 collected tests; i.e., 43%) have been broken and repaired by subsequent growth. Specimens from the lower part of the Wheelock Member exposed at Stone City bluff are much smaller than those in overlying strata and may constitute a distinct species.

Measurements (mm) and Ratios for Five Specimens of Cadulus (Gadila) curvus Hodgkinson, n. sp. from Stone City Bluff, Lowermost Wheelock Member, Cook Mountain Formation

	LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	4.11	0.73	0.34	0.18	0.08
MAXIMUM	4.33	0.81	0.35	0.19	0.09
MINIMUM	3.80	0.69	0.33	0.17	0.08

Measurements (mm) and Ratios for 29 Specimens of Cadulus (Gadila) curvus Hodgkinson, n. sp. from Little Brazos River, Wheelock Member, Cook Mountain Formation

	LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	5.42	0.95	0.61	0.18	0.11
HOLOTYPE	6.08	1.07	0.86	0.18	0.14
MAXIMUM	7.00	1.10	1.14	0.20	0.19
MINIMUM	4.56	0.81	0.38	0.15	0.06
STANDARD DEVIATION	0.63	0.08	0.17	0.01	0.03
STANDARD ERROR OF MEAN	0.12	0.01	0.03	0.00	0.01

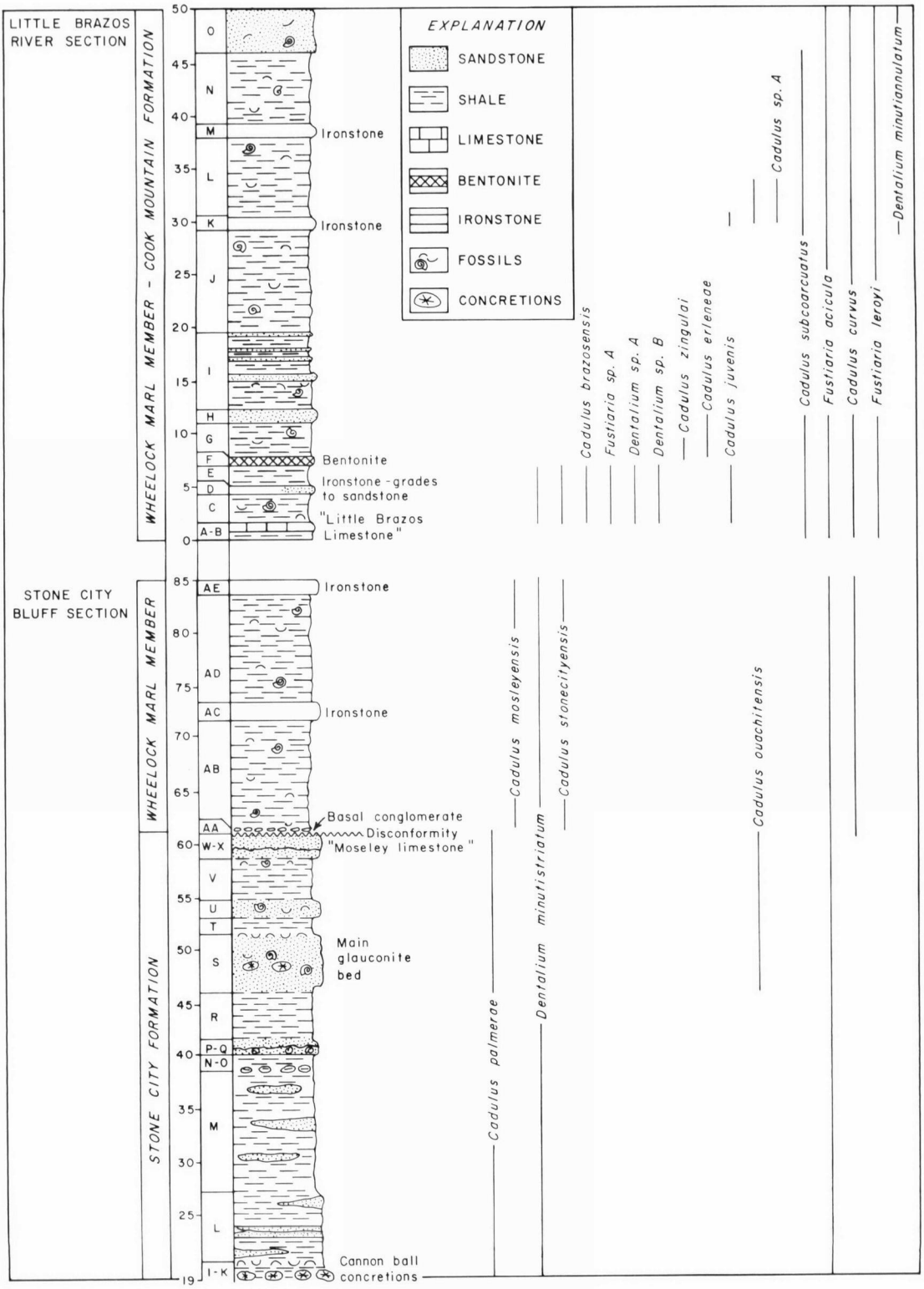


FIG. 9. Ranges for species from the Little Brazos River section, Brazos County, and Stone City bluff section, Burleson County, Texas.

EXPLANATION OF PLATES

PLATE 1

(All lateral views and all, except as noted, ×11)

FIGURE

1-2. Cadulus (Gadila) erleneae Hodgkinson, n. sp., from Wheelock Member, Little Brazos bluff, bed G.——*1.* Holotype, USNM 180425.—2. Paratype, USNM 180426.

3,4. Cadulus (Gadila) moseleyensis Hodgkinson, n. sp., from Wheelock Member, Stone City bluff, bed AD. ——*3.* Paratype, USNM 180427.——4. Holotype, USNM 180428.

5. Cadulus (Gadila) juvenis Meyer, from Wheelock Member, Little Brazos River (Scott's loc. MS-2-N), bed C, USNM 180429.

6. Cadulus (Cadulus) ouachitensis Palmer, from Stone City Formation, Stone City bluff, bed S. USNM 180430, ×12.

7-10. Cadulus (Gadila) brazosensis Hodgkinson, n. sp., from Wheelock Member, Little Brazos River.——*7.* Holotype, USNM 180431 (Scott's loc. MS-2-N), bed C.——*8.* Paratype, USNM 180432 (Scott's loc. MS-2A-S), bed E.——*9.* Paratype, USNM 180433 (Scott's loc. MS-2A-S), bed E.——*10.* Paratype, USNM 180434 (Scott's loc. MS-2A-S), bed E.

11. Cadulus (Gadila) zingulai Hodgkinson, n. sp., from Wheelock Member, Little Brazos bluff, bed G. Holotype, USNM 180435.

12-14. Cadulus (Gadila) curvus Hodgkinson, n. sp., from Wheelock Member.——*12.* Paratype, USNM 180436, Little Brazos bluff, bed I.——*13.* Holotype, USNM 180437, Little Brazos bluff, bed I. ——*14.* Paratype, USNM 180438, Stone City bluff, upper foot of bed AD.

15,16. Cadulus (Gadila) palmerae Hodgkinson, n. sp., from Stone City Formation, Stone City bluff, bed S.——*15.* Holotype, USNM 180439.——*16.* Paratype, USNM 180440.

17. Cadulus (Gadila) stonecityensis Hodgkinson, n. sp., from the Wheelock Member, Stone City bluff, upper foot of bed AD. Holotype, USNM 180441.

PLATE 2

(Scanning electron microscope photographs; all lateral views except as noted)

FIGURE

1. Cadulus (Gadila) ouachitensis Palmer, from Wheelock Member, in first exposure downstream from Texas Highway 21 bridge over Little Brazos River bed J, USNM 180442, ×21.

2. Cadulus (Gadila) juvenis Meyer, from Wheelock Member, Little Brazos River (Scott's loc. MS-2-N), bed E. USNM 180443, ×27.

3. Cadulus (Gadila) moseleyensis Hodgkinson, n. sp., from Wheelock Member, Stone City bluff, upper foot of bed AD. Paratype, USNM 180444, ×27.

4. Cadulus (Gadila) sp. A from Wheelock Member, first exposure downstream from Texas Highway 21 bridge over Little Brazos River, bed J. USNM 180445, ×21.

5. Cadulus (Gadila) erleneae Hodgkinson, n. sp., from Wheelock Member, Little Brazos bluff, bed G. Paratype, USNM 180446, ×21.

6a,b. Cadulus (Gadila) zingulai Hodgkinson, n. sp., from Wheelock Member, Little Brazos bluff, bed G, ×22.——*6a.* Dorsal view of paratype USNM 180447.——*6b.* Lateral view.

7. Cadulus (Gadila) brazosensis Hodgkinson, n. sp., from Wheelock Member, Little Brazos River (Scott's loc. MS-2-N), bed C. Paratype, USNM 180448, ×22.

8. Cadulus (Gadila) palmerae Hodgkinson, n. sp., from Stone City Formation, Stone City bluff, bed S. Paratype, USNM 180449, ×22.

PLATE 3

(All lateral views except as noted)

FIGURE

1. Dentalium sp. A from Wheelock Member, Little Brazos River (Scott's loc. MS-2A-S), bed E. USNM 180450, ×10 (orientation not known).

2-6, 8. Fustiaria (Episiphon) acicula Hodgkinson, n. sp., from Wheelock Member, Little Brazos River (Scott's loc. MS-2-N), bed C.——*2.* Paratype, USNM 180451, ×11.——*3.* Paratype, USNM 180452, ×11.——*4.* Paratype, USNM 180453, ×18.——*5.* Paratype, USNM 180454, ×18.——*6.* Paratype, USNM 180455, ×17.——*8.* Holotype, USNM 180456, ×17.

7. Dentalium sp. B, from Wheelock Member, Little Brazos River (Scott's loc. MS-2A-S), bed E. USNM 180481, × 10.

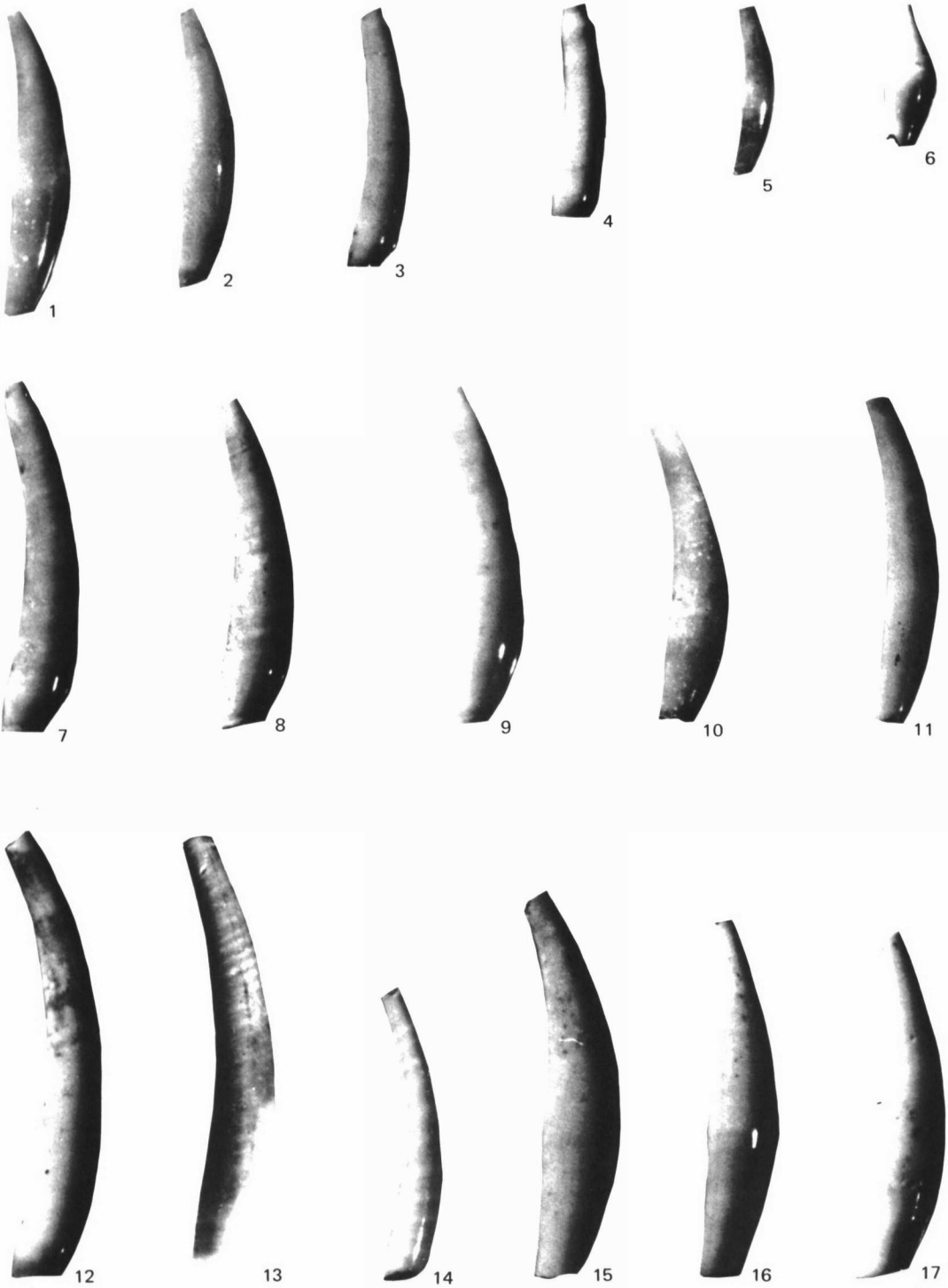
9-11. Cadulus (Polyschides) subcoarcuatus Gabb, from Wheelock Member, Little Brazos bluff, bed G.——*9.* USNM 180457, ×10.——*10.* USNM 180458, ×10.——*11.* USNM 180459, ×13.

12. Fustiaria (Fustiaria) leroyi Hodgkinson, n. sp., from Wheelock Member, Little Brazos River (Scott's loc. MS-2-N), bed C. Holotype USNM 180460, ×11. (Illustrated orientation of this straight or slightly curved species not known.)

PLATE 4

FIGURE

1, 8-12. Dentalium (Antalis) minutistriatum Gabb from Stone City Formation, Stone City bluff, bed S (except fig. 12).——*1.* Ventral view of USNM 180461 showing apical sheath, ×22.——*8.* Lateral view of USNM 180462, ×15.——*9.* Ventral view of USNM 180463 showing growth rings (and lack of longitudinal ribs) of juvenile test, ×22.——*10.* Ventral view of USNM 180464, ×22.——*11.* Lat-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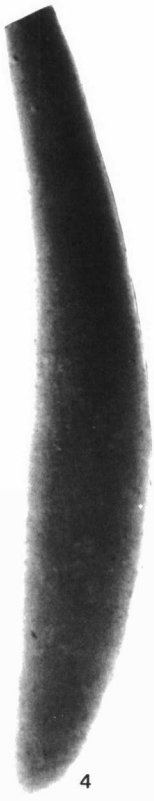
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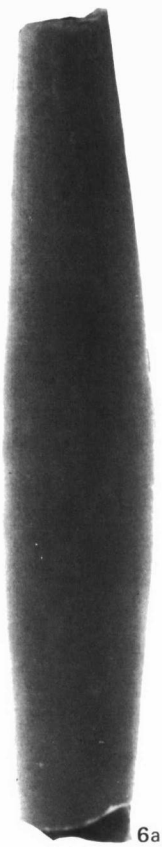
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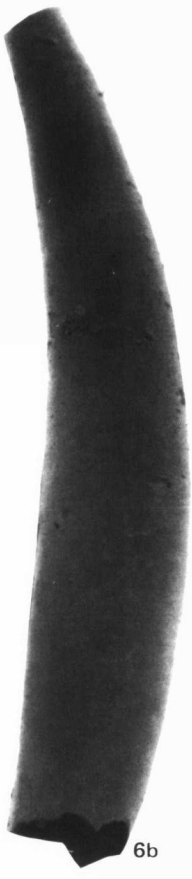
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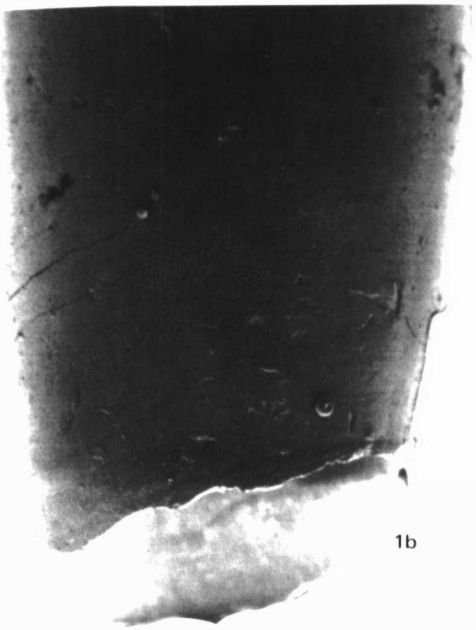

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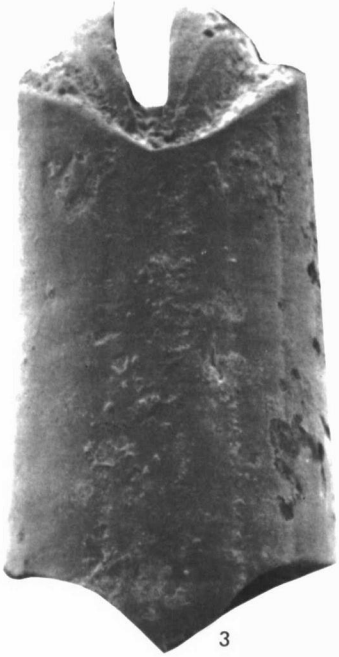

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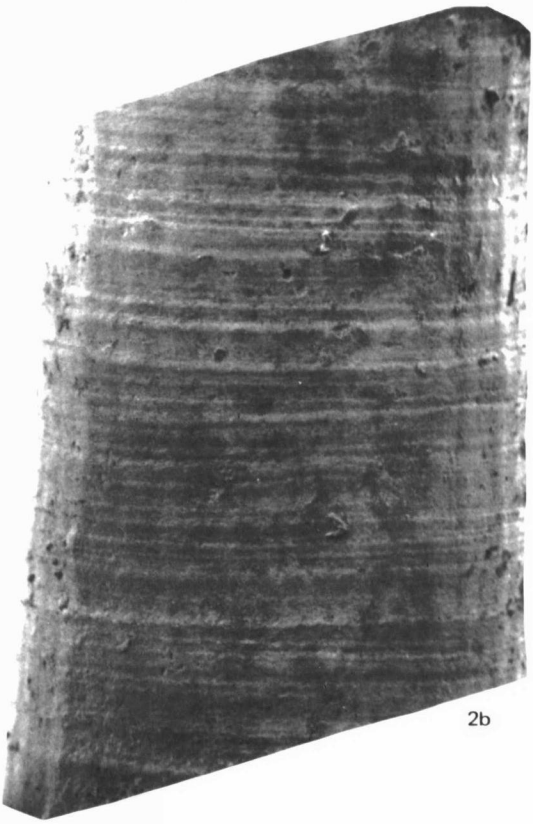

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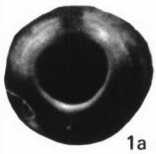

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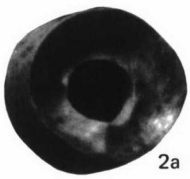

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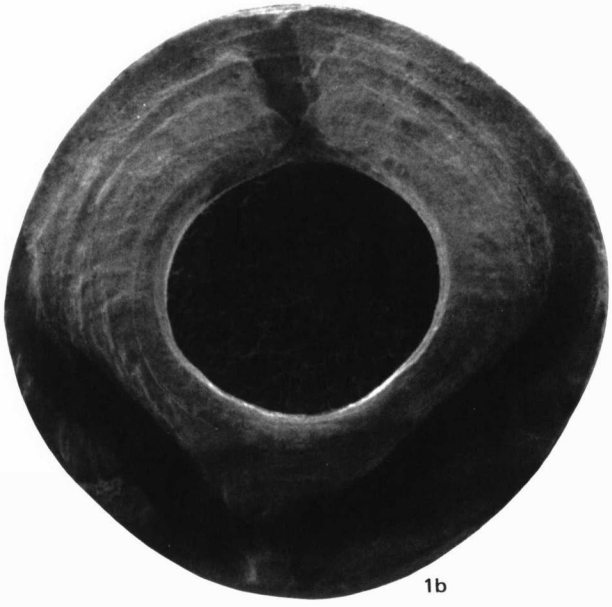

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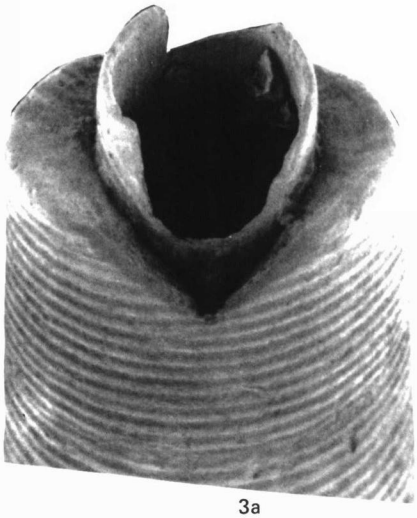

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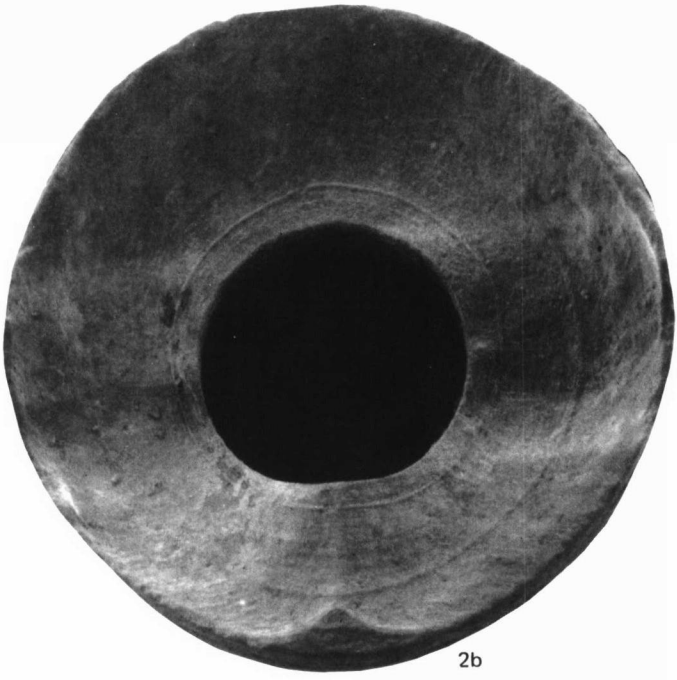

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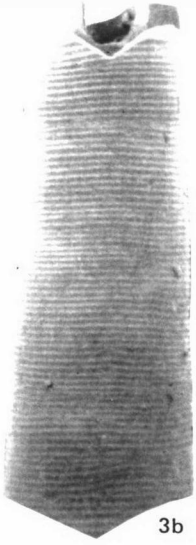

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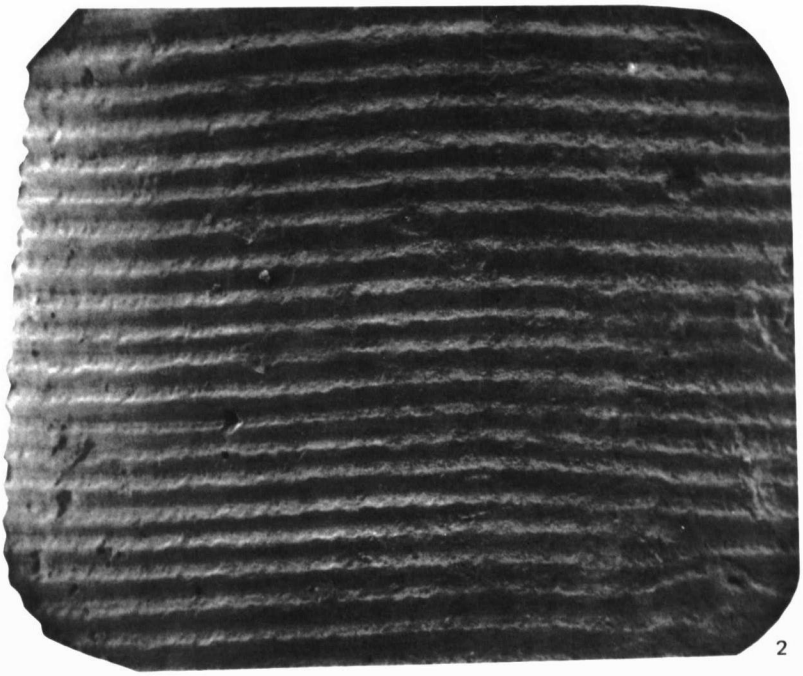

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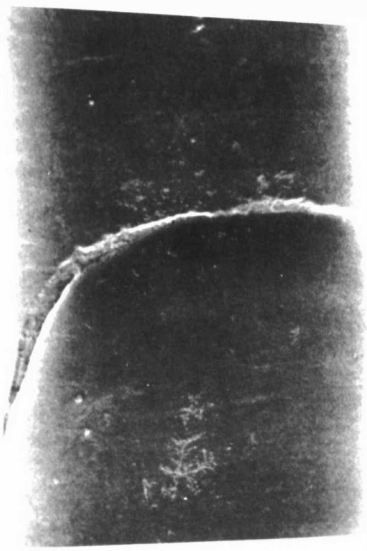

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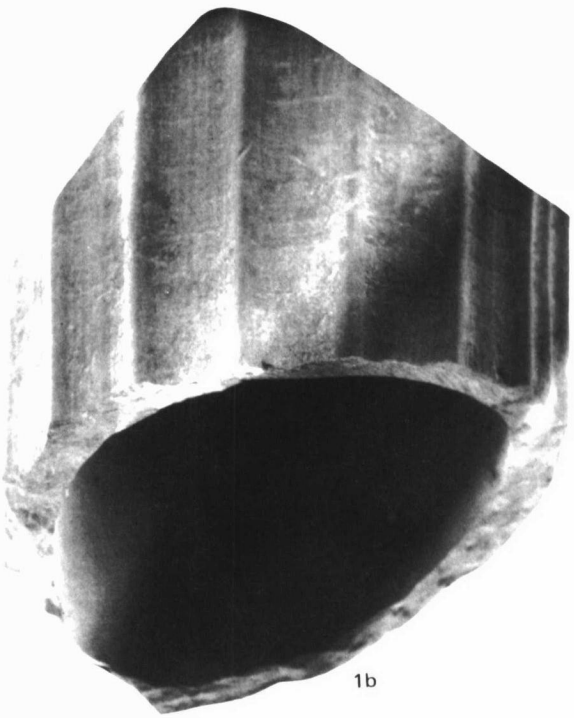

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eral view of USNM 180465, ×3.——*12*. Lateral view of smooth form from Wheelock Marl, Little Brazos River (Scott's loc. MS-2A-S), bed E. USNM 180472, ×5.

2-7. *Dentalium (Antalis) multiannulatum* Hodgkinson, n. sp., from Wheelock Member in first exposure downstream from Texas Highway 21 bridge over the Little Brazos River, bed J.——*2*. Ventral view of papatype, USNM 180466, ×11.——*3*. Lateral view of holotype, USNM 180467, ×2.5. ——*4*. Ventral view of paratype, USNM 180468, ×11.——*5*. Lateral view of paratype, USNM 180469, ×11.——*6*. Ventral view of paratype, USNM 180470, ×11.——*7*. Ventral view of paratype, USNM 180471, ×18.

PLATE 5

(Scanning electron microscope photographs)

FIGURE

1a,b. *Cadulus (Polyschides) subcoarcuatus* Gabb from Wheelock Member, Little Brazos bluff, bed G.——*1a*. Lateral view of apical fragment showing one dorsolateral slit (left slit on photograph) and one ventral-lateral slit (right), USNM 180473, ×105. ——*1b*. Lateral view of anterior end, ×60.

2a,b, 3. *Dentalium (Antalis) minutistriatum* Gabb from Stone City Formation, Stone City bluff, bed S.——*2a*. Ventral-lateral view (same specimen as Pl. 4, fig. 9), ×17.——*2b*. Lateral view, ×90.——*3*. Ventral view showing development of sheath, ×60. Specimen lost after photographing.

PLATE 6

(*1b, 2b, 3a,b,* scanning electron microscope photographs)

FIGURE

1a,b, 2a,b, 3a,b. *Dentalium (Antalis) minutiannulatum* Hodgkinson, n. sp., from Wheelock Member in first exposure downstream from Texas Highway 21 bridge over the Little Brazos River, bed J.——*1a*. Posterior end of a truncated segment. Paratype, USNM 180474, ×14.——*1b*. ×55.——*2a*. Anterior end of a truncated segment. Paratype USNM 180475, ×14.——*2b*. ×55.——*3a*. Ventral view, posterior end of a truncated segment showing development of dorsal notch and sheath. Paratype USNM 180476, ×60.——*3b*. Ventral view, ×22.

PLATE 7

(Scanning electron microscope photographs)

FIGURE

1a,b. *Dentalium* sp. B from Wheelock Member, Little Brazos River (Scott's loc. MS-2A-S), bed E.——*1a*. Lateral view of USNM 180477, ×22.——*1b*. Anterior end, ×108.

2. *Dentalium (Antalis) minutiannulatum* Hodgkinson, n. sp. (same specimen as Pl. 6, fig. *3a,b*), ×95.

3. *Fustiaria (Episiphon) acicula* Hodgkinson, n. sp. (same specimen as Pl. 3, fig. *8*), ×130.

PLATE 8

(Scanning electron microscope photographs)

FIGURE

1a,b, 2. *Fustiaria (Fustiaria) leroyi* Hodgkinson, n. sp., from Wheelock Member, Little Brazos River (Scott's loc. MS-2-N), bed C.——*1a*. Paratype, USNM 180478, ×17.——*1b*. ×110.——*2*. Dorsal view, specimen lost after photographing, ×65.

3, 5a,b. *Fustiaria (Episiphon) acicula* Hodgkinson, n. sp., from Wheelock Member, Little Brazos River (Scott's loc. MS-2-N), bed C.——*3*. Specimen lost after photographing, ×60.——*5a*. Ventral view showing pipe and shallow dorsal groove. Paratype, USNM 180479, ×17.——*5b*. Anterior end, ×95.

4. *Fustiaria* sp. A, from Wheelock Member, Little Brazos River (Scott's loc. MS-2-N), bed C. Specimen lost after photographing, ×95.

Occurrence.—Found in the Wheelock Member, Cook Mountain Formation, in exposures on the Brazos River and throughout exposures on the Little Brazos River.

Types.—Holotype USNM 180437 and paratypes USNM 180436, PRI 29223, and ANSP 31501 from Little Brazos bluff just under second sandstone unit above bentonite. Paratype USNM 180438 from beds just under highest ironstone ledge at Stone City bluff (these beds exposed in ravine at southeast corner of highway bridge).

CADULUS (GADILA) ERLENEAE Hodgkinson, n. sp.

Figure 8,a,b; Plate 1, figures 1,2; Plate 2, figure 5

Shell arcuate, small and slender, smooth, polished. Inflation near middle. Decreases rapidly from inflation to small anterior and posterior openings. Aperture strongly oblique to shell axis, dorsoventrally elongated. Posterior orifice round, simple.

Discussion.—This form is smoother and glassier than specimens of other species collected from the Brazos River valley. It also is unusual

in that the apertures are very small in comparison to the inflation. None of 110 available specimens shows breakage and subsequent rehealing of the test. Some specimens of all others described in this paper show repair of damaged tests. The species is named for my wife Erlene.

Measurements (mm) and Ratios for 33 Specimens of Cadulus (Gadila) erleneae Hodgkinson, n. sp. from Little Brazos River

	LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	3.80	0.78	1.64	0.21	0.43
HOLOTYPE	4.26	0.88	1.77	0.21	0.42
MAXIMUM	4.33	0.88	1.90	0.24	0.46
MINIMUM	3.12	0.76	1.44	0.18	0.39
STANDARD DEVIATION	0.28	0.03	0.11	0.01	0.03
STANDARD ERROR OF MEAN	0.05	0.01	0.02	0.00	0.01

Occurrence.—Common in Little Brazos River exposures between the bentonite and first overlying sandstone layer (Wheelock Member, Cook Mountain Formation).

Types.—Holotype USNM 180425 and paratypes USNM 180426, 180446, PRI 29224, ANSP 31502.

CADULUS (GADILA) JUVENIS Meyer

Figure 8,c,d; Plate 1, figure 5; Plate 2, figure 2

Cadulus juvenis Meyer, 1886, p. 66, pl. 3, fig. 4.——Dall, 1892, p. 444.——Aldrich, 1895, p. 4.——Pilsbry & Sharp, 1898, p. 237.——Renick & Stenzel, 1931, p. 103.——Palmer & Brann, 1965, p. 362.

Gadus juvenis (Meyer), Cossman, 1893, p. 20.

Cf. *Cadulus juvenis* Meyer, Harris, 1894, p. 157.

Cadulus (Cadulus) juvenis Meyer, Harris & Palmer, 1947, p. 216, pl. 26, fig. 14.

"Small, inflation near the middle; slender, not compressed; smaller aperture forming an ellipse, one side of which is flattened. Locality.—Jackson, Miss.: not rare." (Meyer, 1886).

Discussion.—In 1895 Aldrich wrote, "*Cadulus juvenis* Meyer is common in Texas from Moseley's Ferry, Burleson Co., and in Lee County. It is tumid, with posterior end nearly circular; anterior strongly oval, and flattened on one side; the cingulum is over one-third from the anterior." *Cadulus juvenis* Meyer was also listed by Renick & Stenzel (1931) as occurring at both Stone City bluff and Little Brazos River exposures.

The holotype was examined and found to compare favorably with specimens from the Brazos River valley. Meyer described the posterior orifice as forming an ellipse with a flattened side, and Aldrich described the posterior orifice as nearly circular with the aperture strongly oval and flattened on one side. Neither the holotype nor specimens described in this paper, however, have a prominent flattened side. The shape of the orifices of specimens from the Brazos River valley does not support the statements of Meyer and Aldrich.

The species is assigned herein to the subgenus

Measurements (mm) and Ratios for Nine Specimens of Cadulus (Gadila) juvenis Meyer

	LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	2.57	0.58	1.15	0.23	0.45
MAXIMUM	2.62	0.61	1.29	0.24	0.50
MINIMUM	2.47	0.53	1.03	0.21	0.42
STANDARD DEVIATION	0.05	0.02	0.08	0.01	0.03
STANDARD ERROR OF MEAN	0.02	0.01	0.03	0.00	0.01

Gadila because of its slender form and lack of apical slits.

Occurrence.—Cadulus (Gadila) juvenis Meyer was first described from the Jackson Eocene (Moody's Branch Marl at Jackson, Mississippi). Only one specimen was found in sediments from Stone City bluff even though Aldrich described them as common. Possibly the topographic expression of the bluff has changed considerably since 1895 so that specimens now are much less common. Nine complete and 18 broken specimens were collected from low outcrops on the west side of the Little Brazos River just upstream from Texas 21 bridge. None were found in the more extensive and younger exposures on the opposite bank. One specimen was found in strata downstream from the bridge. All specimens found to date in the Brazos River valley are from the Wheelock Member, Cook Mountain Formation.

Types.—Holotype USNM 638814.

CADULUS (GADILA) MOSELEYENSIS Hodgkinson, n. sp.

Figure 8,g,h; Plate 1, figures 3,4; Plate 2, figure 3

Small arcuate shell having smooth and polished surface. Inflation very near anterior end. Both openings circular to slightly oval. Aperture normal to shell axis and flattened on ventral side in some individuals.

Discussion.—This form closely resembles *Cadulus (Gadila) brazosensis* Hodgkinson, n. sp., but is smaller and has nearly parallel sides, a more prominent constriction near the apex, and inflation closer to the aperture. Probably this form evolved into *C. (G.) brazosensis.* The species is named for its occurrence at Moseley's Ferry (Stone City Bluff).

Occurrence. — Throughout the Wheelock Member, Cook Mountain Formation, at Stone City bluff.

Types.—Holotype USNM 180428, paratypes USNM 180427, 180444, PRI 29221, ANSP 31499.

CADULUS (GADILA) PALMERAE Hodgkinson, n. sp.

Figures 8,t,u; Plate 1, figures 15,16; Plate 2, figure 8

Arcuate, inflation in advance of middle. Surface smooth, polished. Posterior orifice round, simple. Aperture dorsoventrally flattened and normal to shell axis. Some specimens have a small lip on ventral edge of aperture.

Discussion.—Probably this form has been referred previously to *Cadulus (Polyschides) subcoarcuatus* (Gabb) but it is quite distinct. The inflation of *C. (G.) palmerae* is nearer the center, the aperture is dorsoventrally flattened, and apical slits are lacking. This species named for Dr. Katherine Van Winkle Palmer.

Occurrence.—This species is abundant in the Stone City Formation. It has not been found in the Wheelock Member at Stone City bluff nor in outcrops on the Little Brazos River.

Types.—Holotype USNM 180439 and paratypes USNM 180440, 180449, PRI 29225, ANSP 31503 from the main glauconite ledge, Stone City bluff.

Measurements (mm) and Ratios for 51 Specimens of Cadulus (Gadila) moseleyensis Hodgkinson, n. sp.

	LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	3.01	0.68	0.35	0.23	0.12
HOLOTYPE	2.93	0.70	0.46	0.24	0.16
MAXIMUM	3.80	0.78	0.54	0.29	0.17
MINIMUM	2.24	0.59	0.18	0.18	0.06
STANDARD DEVIATION	0.33	0.05	0.08	0.02	0.03
STANDARD ERROR OF MEAN	0.05	0.01	0.01	0.00	0.00

Measurements (mm) and Ratios for 33 Specimens of Cadulus (Gadila) palmerae Hodgkinson, n. sp.

	LENGTH	LATERAL INFLATION	DORSO-VENTRAL INFLATION	APERTURE TO INFLATION	LATERAL INFLATION/ LENGTH	DORSO-VENTRAL INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	4.09	1.06	0.97	1.39	0.26	0.24	0.34
HOLOTYPE	4.71	1.06	0.98	1.75	0.23	0.21	0.37
MAXIMUM	4.94	1.30	1.13	2.01	0.31	0.27	0.41
MINIMUM	3.43	0.81	0.75	1.06	0.23	0.20	0.26
STANDARD DEVIATION	0.27	0.10	0.08	0.16	0.02	0.02	0.03
STANDARD ERROR OF MEAN	0.05	0.02	0.01	0.03	0.00	0.00	0.01

CADULUS (GADILA) STONECITYENSIS Hodgkinson, n. sp.

Figure 8,r,s; Plate 1, figure 17

Shell smooth and slender, inflation near the middle. Posterior orifice round and simple, aperture slightly elongated dorsoventrally and oblique to shell axis.

Discussion.—This shell is similar to *Cadulus (Polyschides) subcoarcuatus* (Gabb) but the aperture is dorsoventrally elongated, and apical slits are lacking. It is named for its occurrence at Stone City bluff.

Occurrence.—Common in the Wheelock Member at Stone City bluff and rare in outcrops on the Little Brazos River where it is restricted to strata below the bentonite bed.

CADULUS (GADILA) ZINGULAI Hodgkinson, n. sp.

Figure 8,v,w; Plate 1, figure 11; Plate 2, figures 6a,b

Shell small, tapers gradually from inflation to both orifices. Maximum inflation about two-fifths length of shell from aperture. Dorsoventrally flattened aperture (normal to shell axis) has prominent lip on ventral side. Posterior orifice circular, no apical slits.

Discussion.—This is the only collected species having a distinct lip. A few specimens of *Cadulus (Gadila) palmerae* Hodgkinson, n. sp., and *Cadulus* sp. A have a faint lip, but in other respects all are quite dissimilar. Species named for Dr. Richard P. Zingula.

Occurrence.—Seven complete and two broken specimens were found in exposures on the Little Brazos River in claystone immediately above (within a one-foot interval) the bentonite bed (Wheelock Member, Cook Mountain Formation).

Types.—Holotype USNM 180435, paratypes USNM 180447, PRI 29227, ANSP 31505 from just above bentonite layer, Little Brazos bluff.

Measurements (mm) and Ratios for Five Specimens of Cadulus (Gadila) stonecityensis Hodgkinson, n. sp.

	LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	5.15	1.11	1.97	0.22	0.38
HOLOTYPE	4.64	1.10	1.75	0.24	0.38
MAXIMUM	5.70	1.19	2.36	0.24	0.41
MINIMUM	4.26	1.01	1.67	0.20	0.34

Types.—Holotype USNM 180441 and paratypes PRI 29226, ANSP 31504 from beds just under highest ironstone ledge at Stone City bluff (beds exposed in ravine at southeast corner of Highway 21 bridge).

Measurements (mm) and Ratios for Seven Specimens of Cadulus (Gadila) zingulai Hodgkinson, n. sp.

	LENGTH	LATERAL INFLATION	DORSO-VENTRAL INFLATION	APERTURE TO INFLATION	LATERAL INFLATION/ LENGTH	DORSO-VENTRAL INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	4.69	0.94	0.85	1.82	0.20	0.18	0.39
HOLOTYPE	4.64	0.90	0.81	1.76	0.19	0.17	0.38
MAXIMUM	4.94	1.03	0.91	1.95	0.22	0.19	0.40
MINIMUM	4.40	0.91	0.76	1.67	0.19	0.17	0.37

CADULUS (GADILA) sp. A

Figure 8,n,o; Plate 2, figure 4

Shell smooth, polished. Posterior orifice rounded. Aperture dorsoventrally flattened, oblique to shell axis, and inverted ventrally with small lip. Inflation near middle.

Discussion.—This species of *Cadulus* is similar in shape to *Cadulus (Gadila) erleneae* Hodgkinson, n. sp., but is somewhat larger and has a differently shaped aperture with a faint lip. The aperture resembles those of *C. (G.) zingulai* Hodgkinson, n. sp., and *C. (G.) palmerae* Hodgkinson, n. sp., but is somewhat smaller. Only two specimens of this form were found.

Measurements (mm) and Ratios for Figured Specimen USNM 180445, Cadulus (Gadila) sp. A

LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/LENGTH
4.71	0.83	1.90	0.18	0.40

Occurrence.—Found in the first outcrop downstream from Texas Highway 21 bridge over Little Brazos River. These beds lie below a prominent ironstone layer (Wheelock Member, Cook Mountain Formation).

CADULUS (POLYSCHIDES) SUBCOARCUATUS (Gabb)

Figures 7,a,b; 8,x,y; Plate 3, figures 9-11; Plate 5, figures 1,a,b

Ditrupa subcoarcuata Gabb, 1860b, p. 386, pl. 67, fig. 47.
Gadus subcoarctatus sic (Gabb), Conrad, 1866, p. 10.
Cadulus subcoarctatus sic (Gabb), Dall, 1892, p. 444.——Aldrich, 1895, p. 4.
Cadulus (Dischides) subcoarcuatus (Gabb), Palmer, 1937, p. 24, pl. 2, fig. 26; pl. 78, fig. 1, holotype.——Brann & Kent, 1960, p. 148.——Palmer & Brann, 1965, p. 363.

"Arcuate, widened in advance of the middle; aperture contracted, circular; surface polished. Dimensions.—Length .33 in., greatest diameter .07 in., diameter .135 in. Locality.—Common at Wheelock." (Gabb, 1860b).

Discussion.—Palmer (1937, p. 24) stated, "Gabb's figure of the holotype is poor. The Meyer drawing of the holotype has been compared with the specimen. The drawing is good . . . Meyer shows the small slits at the apical end. Several specimens have been found which reveal similarly placed slits. The margin of the shell away from the slits in all cases is broken so that the true nature may not yet be determined . . . . Most of the specimens have the apical end broken sharply and regularly, leaving an even margin, hence the species would appear to lack the apical slits. From the character of the most perfect of the slits preserved, one assumes the anal opening to be bilabiate and the species to belong to the subgenus *Dischides*."

Most complete specimens have five, rather than two, slits on the apical end. The slit on the ventral side generally is shallow; the two lateral slits adjacent to the ventral side are deepest; and the slits adjacent to the dorsal surface are prominent but not as deep as the other pair. Occasionally, possibly through breakage, a broad, deep dorsal slit (Fig. 7) develops. This probably is an abnormal condition and may not have been common in the living scaphopod. Seemingly only the two deeper slits are preserved on the holotype. The Academy of Natural Sciences of Philadelphia was unable to locate the type specimens so that no direct comparison could be made. Because this

form has five slits, it belongs to the subgenus *Polyschides.*

Occurrence.—Holotype from Town Branch of Cedar Creek near Wheelock, Robertson County, Texas. Also found in Bastrop, Houston, Leon, and Sabine Counties, Texas and in Sabine Parish, Louisiana. Common in outcrops on the Little Brazos River, rare in the Wheelock Member, Stone City bluff. Specimens (with five apical slits and similar in shape and size to specimens found in the Brazos River valley) have been found in the Weches Formation exposed on the south bank of the Colorado River at Smithville, Bastrop County and in a roadcut along a dirt road 2.15 mi south of Augusta, Houston County, Texas.

Types.—Holotype, ANSP 13263 (not located for present study, possibly lost).

Measurements (mm) and Ratios for 23 Specimens of Cadulus (Polyschides) subcoarcuatus (Gabb)

	LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/ LENGTH
MEAN	7.25	1.38	1.85	0.19	0.26
HOLOTYPE	8.38	1.78	—	0.21	—
MAXIMUM	9.58	1.78	2.66	0.21	0.33
MINIMUM	6.39	1.28	1.53	0.17	0.19
STANDARD DEVIATION	0.56	0.06	0.23	0.01	0.04
STANDARD ERROR OF MEAN	0.12	0.01	0.05	0.00	0.01

Measurements (mm) of a Single Specimen (USNM 180480) of Cadulus (Polyschides) subcoarcuatus (Gabb)

[From Weches Formation 2.15 mi along dirt road south of Augusta, Houston County, Texas]

LENGTH	INFLATION	APERTURE TO INFLATION	INFLATION/ LENGTH	APERTURE TO INFLATION/LENGTH
7.41	1.41	1.82	0.19	0.25

DENTALIUM (ANTALIS) MINUTIANNULATUM
Hodgkinson, n. sp.

Figure 7,f-i; Plate 4, figures 2-7; Plate 6, figures 1-3; Plate 7, figure 2

Shell slightly curved, marked with numerous fine annulations (20-40 per mm) which are spaced closer in youth, wider at maturity, and closer again in later maturity and old age. These annulations are normal or only slightly oblique to the shell axis. A small percentage of mature and gerontic tests have very faint longitudinal ornamentation superimposed on the stronger annulations. Mature specimens may show slight lateral compression. The posterior orifice has V-shaped notch on ventral side and shallower notch on dorsal side. A thin tube or sheath, which is often notched like the shell, may extend from apex.

Discussion.—Annulations may be lacking on the anterior portion of test because of injury or old age. The sheath extending from the apex varies considerably in size and shape. It may be absent, short (with ventral and dorsal notches reaching shell margin), or long (with notches of sheath perched above those of shell).

The holotype of *Dentalium "annulatum"* Meyer, a juvenile fragment from the Gosport Sand at Claiborne bluff, Monroe County, Alabama, was examined and found to differ from *Dentalium (Antalis) minutiannulatum.* That juvenile specimen has fewer annulations per mm, the annulations are less distinct, and they are not as rounded as in this new species. Palmer (1937, p. 19) suggested that *Dentalium "annulatum"* might be the annulated juvenile stage of *Dentalium (Antalis) minutistriatum* Gabb. I have found mature fragments from the Gosport Sand of Little Stave Creek, Clarke County, Alabama which seem to be the same species as *Dentalium "annulatum."* Therefore, Meyer's species probably is valid. Palmer also has pointed out that

the name is preoccupied and a new name should be chosen.

Specimens found at Shipp's Ford on the Colorado River and in outcrops on Pin Oak Creek, Bastrop County, Texas (Cook Mountain Formation) resemble *Dentalium (Antalis) minutiannulatum*. Additional work must be done before it can be ascertained whether or not these forms are conspecific. A lower Eocene species, *Dentalium multannulatum* Aldrich (from the Tuscahoma Formation at Greggs Landing on the Alabama River, Monroe County, Alabama) has fine annulations but they are oblique to the shell axis.

Measurements (mm) of holotype: Length, 28.50; maximum diameter, 2.85. No complete specimens were found. Hence, no measurement of length gives the length of the living organism.

Occurrence.—Found in all exposures on the Little Brazos River downstream from Texas Highway 21 bridge.

Types.—Holotype USNM 180467, paratypes USNM 180466, 180468-180471, 180474-180476, PRI 29228, ANSP 31506, all from beds just under first ironstone layer downstream from Texas Highway 21 bridge which crosses over the Little Brazos River. Wheelock Member, Cook Mountain Formation.

DENTALIUM (ANTALIS) MINUTISTRIATUM Gabb

Plate 4, figures 1, 8-12; Plate 5, figures 2,3

Dentalium minutistriatum Gabb, 1860b, p. 386, pl. 67, fig. 46.——Conrad, 1865b, p. 34.——Conrad, 1866, p. 10.——Heilprin, 1891, p. 40.——Dall, 1892, p. 438, in part.——Pilsbry & Sharp, 1898, p. 209.——Clark & Martin, 1901, p. 158, in part, not pl. 29, fig. 7 (= *Dentalium* sp.).——Deussen, 1924, p. 67, pl. 22, fig. 5.——Renick & Stenzel, 1931, p. 103.——Trowbridge, 1932, pl. 42, fig. 10.

Cf. *Dentalium minustistriatum sic* Gabb, Cossman, 1893, p. 19, pl. 1, fig. 22.

Dentalium (Antalis) minutistriatum Gabb, Palmer, 1937, p. 17, pl. 2, fig. 33-36, 38, 41.——Harris & Palmer, 1947, p. 210, pl. 26, fig. 28.——Brann & Kent, 1960, p. 319-320.——Palmer & Brann, 1965, p. 368.

Dentalium (Graptacme) minutistriatum Gabb, Shimer & Shrock, 1944, p. 523, in part, pl. 214, fig. 13 (copy of Deussen) not fig. 12 (=*Dentalium* sp.).

"Very slightly curved, marked by numerous small longitudinal ribs, all of the same size, no trace of alternation; aperture round. *Dimensions*—Length 1 in., width of aperture .08 in. Locality.—Common at Wheelock." (Gabb, 1860b).

Discussion.—Mature specimens of *Dentalium minutistriatum* normally have numerous, regular, longitudinal, microscopic ribs. These ribs are absent on immature portion of test, often become weak or dissappear because of injury or old age, and may be eroded easily from a specimen. In some instances well-preserved, uninjured specimens have a highly polished surface with no visible ribs. Numerous such specimens have been found at Alabama Ferry on the Trinity River, Houston County, Texas (Hurricane Lentil). Here most specimens have well-defined ribs, some tests have ribs which are barely discernable under microscopic examination, and some are smooth. That is, there is a complete graduation from shells with well-defined ribs to specimens with a smooth test. One highly polished, smooth shell (Pl. 4, fig. 12) was found in sediments between Little Brazos Limestone and the bentonite layer (Wheelock Member) on the west side of the Little Brazos River just upstream from Texas Highway 21 bridge.

Annular rings are prominent on the juvenile portion of specimens and can be seen also less prominently on the mature portion. A dorsal notch and a deeper ventral notch occur on the apical end of the test as well as on the thin sheath that projects from the posterior orifice. This sheath (Pl. 5, fig. 3) tends to constrict the area of the opening much more than that of *D. minutiannulatum*.

A single nepionic tip was found which shows the initial bulbous tip with the apical orifice well developed including a well-defined V-shaped notch on the ventral side. This bulbous portion

Measurements (mm) and Ratios for Three Specimens of Dentalium (Antalis) minutistriatum Gabb

	LENGTH	MAXIMUM DIAMETER	NUMBER OF RIBS AT MAXIMUM DIAMETER	MAXIMUM DIAMETER/ LENGTH
Entire specimen from Stone City Bluff	41.00	3.42	70	0.80
Specimen from Little Brazos River	22.04	1.76	Smooth	0.08
Holotype	25.40	2.03	—	0.08

is about one mm in length and is followed by a constricted neck one mm long. Several prominent bands or folds occur on this neck. A second, very short, constriction then precedes the normal growth of the juvenile test. A similar nepionic tip (of *Dentalium laqueatum* Verrill) has been described by Henderson (1920, p. 24).

Because most specimens are broken, significant measurements are difficult to obtain. The first ribs appear on the tests at a diameter of 0.75 to 1.0 mm. The number of ribs were counted on 100 specimens at measured diameters ranging from 0.79 mm to 3.43 mm. The average number of ribs per mm of diameter is shown below.

Diameter (mm)	Average no. of ribs per mm of diameter
.79-0.99	43
1.00-1.49	34
1.50-1.99	27
2.00-2.49	24
2.50-2.99	22
3.00-3.43	20

Occurrence.—This species is abundant at most fossiliferous horizons at Stone City bluff and on the west side of the Little Brazos River in outcrops upstream from Texas 21 bridge where it is restricted to the strata below the bentonite bed. *Dentalium minutistriatum* previously has been reported from Texas, Louisiana, Mississippi, Alabama, South Carolina, Virginia, and Maryland.

Type.—Holotype, ANSP 13264 (broken). Cook Mountain Formation, Wheelock, Robertson County, Texas.

DENTALIUM sp. A

Plate 3, figure 1

Several small fragments of a juvenile *Dentalium* with nine ribs have been found that resemble the juvenile portions of Palmer's (1937) *Dentalium* sp. and the Jacksonian *Dentalium (Antalis) danvillensis*. Because of the small size of these apical fragments, they presently cannot be identified at the species level.

Occurrence.—West side of Little Brazos River upstream from Texas 21 Highway bridge. Stratigraphically above the Little Brazos Limestone and below the bentonite bed.

DENTALIUM sp. B

Plate 3, figure 7; Plate 7, figures 1 a,b

Several small specimens of an 18-20 ribbed *Dentalium,* which is distinctly different from *D. minutistriatum* have been found in the Wheelock Member on the Little Brazos River. Stenzel (1939, p. 157) noted the occurrence of *Dentalium* sp. cf. *D. blandum* de Gregorio approximately at the boundary between the Wheelock and Landrum Members of the Cook Mountain Formation in Leon County, Texas. The apical ribs on *D. blandum* number at least 16, hence the juvenile fragments found in the Brazos River valley may belong to this or a closely related species. These specimens, however, presently cannot be identified because of their small size.

Occurrence.—In Wheelock Member of the Cook Mountain Formation. West side of Little Brazos River upstream from Texas 21 bridge. Found between Little Brazos Limestone and bentonite bed.

FUSTIARIA (EPISIPHON) ACICULA Hodgkinson, n. sp.

Figures 7,c-e; 8,i-k; Plate 3, figures 2-6, 8; Plate 7, figure 3; Plate 8, figures 3, 5a,b

Test small, very slender, curved, and laterally compressed. Surface glassy, smooth, and lacking sculpture. Shell wall thickened at truncated apex. More shell material is deposited on dorsal than on ventral interior of test so that posterior opening is nearer ventral edge of shell. Apex either simple, notched on ventral side, or with thin tube projecting from orifice.

Discussion.—A few specimens, both juvenile and mature, have both a ventrally notched apex and a thin tube projecting from the truncated end. The notched apex suggests that the mantle of the organism was in contact with the apex before the thin tube was secreted. This combination of apical features also indicates that the tube is not an inner lining of the test that remained intact when the shell was broken or truncated. Even those specimens having a tube projecting from a simple orifice support this contention as the truncated ends are smooth, slightly rounded, and obviously worn and polished.

All collected specimens are broken at the anterior end so that presently the nature of the aperture cannot be determined confidently. Several specimens have a fine line encircling the test near the midpoint(s) of one or more slight constrictions. This line may indicate the position and shape of a former aperture. If such is the case, then the aperture is simple and has the same shape as the cross-sectional form of the test.

Of 254 collected specimens 68 (24%) show repair and continued growth after severe damage to the test (Pl. 3, fig. 4-6, 8; Pl. 7, fig. 3). Because all available fossil specimens are broken and many comprise only a small part of a complete test, certainly the percentage of shells of living organisms injured and then repaired is much higher than the figure given above. Specimens repaired after severe damage show that the living organism normally broke at an angle oblique to the axis of the test. Specimens broken experimentally or during recovery and preparation broke at right angles to the shell axis.

Because all specimens are broken, standard deviation has not been computed. Greater ratio values above are insignificant and only lower values are meaningful. These show that the length of this species is at least 15 times as great as the maximum diameter.

Occurrence.—Several specimens have been found in the Stone City Formation at Stone City bluff. The species is abundant in the Wheelock Member in outcrops on the Little Brazos River and is also found in the Weches Formation (Claiborne) at Burleson bluff on the Brazos River, Burleson County, Texas.

Types.—Holotype USNM 180456, paratypes USNM 180451-180455, 180479, PRI 29230, ANSP 31508 from Scott's locality MS-2-N on the Little Brazos River. Collected from beds just under the bentonite layer.

Measurements (mm) and Ratios for 35 Specimens of Fustiaria (Episiphon) acicula Hodgkinson, n. sp.

	LENGTH	MAXIMUM DORSO-VENTRAL DIAMETER	MAXIMUM LATERAL DIAMETER	MAXIMUM DORSO-VENTRAL DIAMETER/ LENGTH	MAXIMUM LATERAL DIAMETER/ LENGTH
MEAN	5.32	0.51	0.43	0.10	0.09
HOLOTYPE	8.82	0.55	0.48	0.06	0.05
MAXIMUM	9.06	0.65	0.55	0.19	0.14
MINIMUM	1.75	0.22	0.18	0.06	0.05

FUSTIARIA (FUSTIARIA) LEROYI Hodgkinson, n. sp.

Figures 8,l,m; Plate 3, figure 12; Plate 8, figures 1a,b, 2

Shell smooth, long and slender, straight or slightly curved with low, rounded, irregularly spaced, annular wrinkles. Aperture and posterior orifice circular. Apex slightly notched in some specimens. Juvenile portions of tests smooth, have closely spaced encircling grooves or possibly are weakly annulated.

Discussion.—Pilsbry & Sharp (1898, p. 115, pl. 20, fig. 33-45) noted that the Recent form *Dentalium eburneum* Linné "has a small rounded-oval orifice with a slight notch on the convex side or none," and that the species "is remarkable for its irregularly placed, low, swollen rings." They placed *D. eburneum* in the subgenus *Rhabdus* (type species, *D. rectius* Carpenter).

Emerson (1962) noted marked differences in shell character and distribution between *Dentalium rectius* Carpenter, *D. perceptum* Mabille & Rochebrune, and *D. eburneum* Linné (all of

Measurements (mm) and Ratios for 131 Specimens of Fustiaria (Fustiaria) leroyi Hodgkinson, n. sp.

	LENGTH	MAXIMUM DIAMETER	MAXIMUM DIAMETER/ LENGTH
MEAN	3.26	0.38	0.13
HOLOTYPE	6.54	0.55	0.08
MAXIMUM	7.75	0.60	0.28
MINIMUM	1.06	0.13	0.06

which had been included in the subgenus *Rhabdus* by Pilsbry & Sharp). Emerson restricted this subgenus to include only very thin, slightly curved species which, typically, entirely lack sculpture or have microscopic concentric striae. He referred *D. eburneum,* with its annular swellings, to the subgenus *Fustiaria.* Because the species here described has essentially the same features as *D. eburneum,* it is assigned similarly.

The species is named for Mr. Duane O. LeRoy.

Standard deviation not indicated because most specimens are broken. Length of longest specimen is 18 times maximum diameter.

Occurrence.—Common in outcrops of the Wheelock Member on the Little Brazos River.

Types.—Holotype USNM 180460, paratypes USNM 180478, PRI 29229, ANSP 31507 from Scott's locality MS-2-N on the Little Brazos River. Collected from beds just under bentonite layer.

FUSTIARIA sp. A

Plate 8, figures 4a,b

Small, juvenile fragments of a weakly to strongly segmented *Fustiaria* have been found in exposures of the Wheelock Member on the Little Brazos River. The strongly segmented tests resemble the apical end of *Dentalium circinatum* Sowerby (from the Eocene of the Paris Basin) except that they have a slight notch rather than a long apical slit. There is a slight resemblance to the encircling grooves on the juvenile portion of *Fustiaria (Fustiaria) leroyi* Hodgkinson, n. sp., but the scanning electron microscope shows them to be quite dissimilar. Only small fragments (1.0-1.5 mm in length, 0.22-0.26 mm maximum diameter) have been found.

Occurrence.—Between Little Brazos Limestone and bentonite bed. West side of Little Brazos River (Scott's locality MS-2-N) and upstream from Texas Highway 21 bridge.

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