1955

Morphology and systematic position of some Anomalinid foraminifera

Billy G. Deaver

MORPHOLOGY AND SYSTEMATIC POSITION OF SOME

ANOMALINID FORAMINIFERA

BY

BILLY G. DEAVER

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

Degree of

MASTER OF SCIENCE, GEOLOGY MAJOR

Rolla, Missouri

1955

Approved by- Don L. Frizzell
~~Professor~~ of Geology

MORPHOLOGIC AND TAXONOMIC STUDY OF SOME ANOMALID FORAMINIFERA

BY

BILLY G. DEAVER

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY

OF

THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

Degree of

MASTER OF SCIENCE, GEOLOGY MAJOR

Rolla, Missouri

1955

Approved by Don L. Frizzell

~~Associate~~ Professor ~~of~~ Geology

TABLE OF CONTENTS

ABSTRACT

Morphological studies of the following species are the basis for a partial revision of the Family Anomalinidae: *Anomalina acuta* Plummer, *A. midwayensis* (Plummer), *A. pseudopapillosa* Carsey, *A. vulgaris* (Plummer), *Anomalinoides pinguis* (Jennings), *Cibicides alleni* (Plummer), *C. beaumontianus* (d'Orbigny), *C. harperi* (Sandidge), *Cibicidina danvillensis* (Howe and Wallace), *Planulina correcta* (Carsey), and *P. dumblei* (Applin); a description of *Stensioina americana* Cushman and Dorsey, a discorbid foraminifer, is included for comparison. The classificatory position and incomplete content of the family are: Superfamily Discorbidea; Family Anomalinidae; Subfamily Anomalininae (*revised*) -- with ventral supplementary apertures: *Anomalina*, *Planulina*; Subfamily Cibicidinae -- with dorsal supplementary apertures: *Cibicides*, *Cibicidina*, *Anomalinoides*.

The anomalinid wall consists of radially crystalline calcium carbonate, deposited in successive enveloping lamellae, characteristic for the superfamily. In detail, the basic structure of the anomalinid and discorbid wall consists of (1) external and internal chitinoid films that also line the pores; (2) the lamellar calcareous

wall; and (3) a black line within the septum and varyingly within the outer wall, composed of organic and calcareous particles. Mural pores are large, but of variable size, in the Anomalinidae; in pores large enough for the details to be seen, each is covered by a finely perforate sieve plate, near its external opening.

Specific contributions of this report are: (1) emendation of the Anomalininae; (2) confirming presence of supplementary apertures in Anomalina and Planulina; (3) transfer of Anomalinoides to the Cibicidinae; (4) synonymizing Gavelinella with Anomalina; (5) transfer of "Cibicides" vulgaris to Anomalina; (6) discovery of the detailed wall structure in anomalinid and discorbid species; (7) recognition of sieve plates in the Anomalinidae; and (8) recognition that Hofker's "deuteropores" are simply large pores with contained sieve plates.

INTRODUCTION

Authorities have disagreed markedly on the classificatory position and content of the foraminiferal family Anomalinidae. In the past, genera of this group have been placed variously in the Rotaliidae (Galloway, 1933), Anomalinidae (Cushman, 1948), Discorbidae (Glaessner, 1945), and Cibicididae (Hofker, 1951, as Cibicidae), with varying subfamily arrangement. Emphasis sometimes has been placed on classificatory characters of minor importance, and different characters have been emphasized, with the result that quite diverse species often have been placed within the same genera.

At least part of the reason for disagreement in regard to family classification has been the dependence on external characters of the test. The aperture may be misinterpreted, and dorsal and ventral sides cannot always be correctly determined. Only Hofker (1951) has made detailed studies of the internal morphology of anomalinid foraminifera, and his taxonomic conclusions have not generally been accepted.

The present morphological and systematic study of species of relatively well known genera, was undertaken to establish their internal structure, to determine their mutual relationships, and to investigate their possible conformity with existing family and subfamily arrangements. Internal and external characters were considered, with special emphasis on details of the wall of the test, plan of growth, and characters of the apertures and foramina. This approach is essentially that initiated by Carpenter in 1862, carried on by Hofker since about 1925, and currently being applied by Arnold.

As a result of this study, Cushman's (1948) Family Anomalinidae is retained, with Subfamilies Anomalininae and Cibicidinae, but the family is accepted with provisional redefinition. The genus Anomalina is redefined, and Gavelinella is rejected (subjective synonym). Cibicides vulgaris (Plummer) is transferred to Anomalina. Anomalinoides, the type species of which was studied in detail, is transferred from the Anomalininae to the Cibicidinae.

An important discovery, made during the course of this study, is the multilayered structure of the anomalinid and discorbid wall. Chitinoid films cover the internal and external surfaces of the wall and line the pores. A black line, always present in the septum and occurring variably in the external wall, consists of irregularly disseminated chitinoid material. Sieve plates, apparently composed of both chitinoid and calcareous material, were recognized within the pores of species belonging to both anomalinid subfamilies. Hofker's (1951) "deuteropores" are recognized as large pores with sieve plates.

Acknowledgments: Dr. Don L. Frizzell suggested the problem, and has directed work on the project. Dr. J. L. Rosenfeld was consulted on petrographic aspects of the study, as were Messrs. B. R. Doe and G. B. French, and Mrs. D. L. Frizzell assembled the plates and aided in editing the manuscript. Unwashed samples from the micropaleontological collections of the Geology Department were the source of specimens studied. Successful investigation of foraminiferal wall structure was made possible by the recent acquisition, by the Geology Department, of a biological-type research microscope.

STATEMENT OF PROBLEM

The main objective of the project was to attempt clarification of the systematic relationships of species that have been referred variously to anomalinid genera. Toward that end, a number of operations were required.

The first problem was to secure an adequate supply of specimens of the Anomalinidae, and to prepare them for examination. Assemblages of different ages were desired, with sufficient anomalinids for quantitative and qualitative study.

The second phase of the project, as outlined, was to segregate well preserved specimens, to group them according to their specific relationships, and to identify the species represented. This required measurements, chamber counts, and tabulations of observable morphological features for large suites of specimens.

With species known, and their external morphology and variability established, the next objectives were the gross internal structures and the details of the wall. This approach included the study of thin sections in ordinary and polarized light, serial sectioning of specimens, decalcification of impregnated tests, and decalcification of thin sections and crushed fragments.

The final phase of the project consisted of an attempt to correlate the writer's results with those of previous workers, and to redefine where necessary some of the elements of existing classifications of the Family Anomalinidae.

REVIEW OF PREVIOUS WORK

Published results of two quite different kinds were used in approaching the problems relating to the Family Anomalinidae. Taxonomic interpretations, particularly as summarized in reference works on foraminifera, were the first to be considered. Second are the few papers on internal morphology and wall structure.

Classification

Cushman's modern taxonomic arrangements of foraminifera were published at intervals between 1925 and 1948. In his last version (Cushman, 1948, pp. 331-339) he recognized a Family Anomalinidae, subdivided into the Subfamilies Anomalininae and Cibicidinae. The basis for the subfamilies is primarily symmetry of the test (biconvex in the Anomalininae, planoconvex in the Cibicidinae) and, secondarily, the presence of a dorsal supplementary aperture in the Cibicidinae. Cushman regarded Anomalina as having a ventral aperture in the young, migrating to the periphery in the adult. Gavelinella, regarded in this report as a synonym of Anomalina, he placed in the Subfamily Discorbinae, Family Rotaliidae (1948, p. 289).

Galloway (1933, pp. 271-297) employed a somewhat more conservative system, with the Family

Rotaliidae subdivided into the Subfamilies Rotaliinae, Discorbinae, Cibicidinae, and Planorbulininae. Most of Cushman's Family Anomalinidae, as known then, was referred to the Subfamily Cibicidinae. Through a curious error, Galloway considered the supplementary aperture of Anomalina (overlooked by Cushman) to be dorsal, although his copy of the original figure of the type species clearly shows a ventral position. Nevertheless, he referred the genus to the Discorbinae (as Cushman did with the synonymous Gavelinella), which he defined as having a ventral aperture. Galloway's bases for classification were difference in size of pores of the wall, position of the aperture, and arrangement of later chambers.

Glaessner's (1945, pp. 145-148) arrangement of foraminifera is in some ways a synthesis of those of Cushman and Galloway. He reduced Cushman's Anomalinidae to a Subfamily Anomalininae, within a broadly defined family Discorbidae, rejecting the Subfamily Cibicidinae. His weighting of morphological characters was conservative and conventional, and he did not stress the size of pores.

Hofker (1951) raised the Order Foraminifera to subclass rank, proposing within it several new orders. His classification, in so far as it concerns the present study, is as follows:

Order Dentata

Suborder Protoforaminata -- Septum with a single foramen always connected with a toothplate, although in some forms the toothplate is obliterated.

Suborder Biforaminata -- Septum with two foramina: one is the protoforamen, with its toothplate; the second is a newly developed opening termed the deuteroforamen.

Suborder Deuteroforaminata -- Protoforamen more or less closed or totally reduced, the deuteroforamen remaining as the only foramen.

Hofker synonymized the genera *Anomalina*, *Anomalinoides*, and *Planulina* with *Cibicides*, referring *Cibicides* to the Family Cibicididae (as Cibicidae) within the Suborder Biforaminata. The family is characterized briefly as follows:

Aperture a protoforamen in which the toothplate is obliterated, with lip marginal to the aperture, never opening into the umbilical cavity; with deuteropores (groups of fine pores opening in-

to a larger cavity in the outer wall)
that are mainly restricted to the dorsal
side, ventral side often lacking pores;
walls usually opaque, yellowish or
brownish in thin section.

Internal morphology

Knowledge of the internal features and wall structure of foraminifera dates from Carpenter's (1862) classic treatise. This work, however, is largely devoted to the large and complex forms, and the smaller forms received a relatively minor treatment. Since Carpenter's work, very few studies of basic morphology of the smaller foraminifera have been made, most studies having been confined to external features.

A fundamental contribution to the knowledge of foraminifera recently was made by Wood (1948), who studied fossil and Recent tests with the petrographic microscope. Wood found four major types of wall, and a fifth aberrant type, as follows:

1. Agglutinating -- Test of cemented foreign particles; diverse material may be used, and cement differs in composition; calcareous cement may increase, with corresponding decrease of adventitious material;

some forms (as Textularia) are perforate.

2. Porcellanea -- Test of secreted crystals that are roughly equidimensional, subangular, and not elongated; crystals lack constant orientation, although a preferred orientation often is found in a given portion of the test.

3. Fusulinidae (including Endothyra) -- Test with uniform microstructure, similar to recrystallized tests of the Porcellanea; more advanced forms with minutely granular crystals, interspaces being filled with clear calcite matrix; (not a definitely established primary wall structure).

4. Hyalina -- Test composed of calcite crystals, with the C-axis normal to the spherical surface [radially crystalline]; with some granular forms, the granules equidimensional, sutured together, and somewhat diversely oriented.

5. Aberrant types -- Forms, such as Spirillina and Patellina, in which

the test is composed of a single crystal.

Wood found that most of the anomalinids that he studied belong within the Hyalina. He considered that pores, inasmuch as they occur in all major groups, are without classificatory importance. His approach ignored, or perhaps overlooked, the chitinoid layers of the foraminiferal test.

Smout (1954) described lamination of the wall in the Superfamily Rotaliidea, recognizing the same structure in the Superfamily Discorbidea, to which the Family Anomalinidae belongs. He postulated an enveloping series of lamellae, with exactly one lamella deposited during formation of each chamber.

Arnold (1954, 1954-A) recently has made important contributions to knowledge of the details of wall structure. Working with Recent specimens of the discorbid genus Discorinopsis, he extablished the presence of an internal chitinoid layer. This layer is transparent, very thin, and fragile, and extends into the pores as conical projections. Within each tiny cone, as seen from above in decalcified preparations, is a minute, crater-like depression, that contains a pore plug (or sieve plate). The sieve plates are circular in outline and lenticular in cross-section. Arnold's paper contains an account of techniques, and a brief review of earlier descriptions of wall structure.

METHODS AND TECHNIQUES

Some of the methods used in this project are standard, as in the preparation of samples, but a few techniques require explanation, being somewhat different from those often employed.

Measurements and chamber counts

Specimens were measured with a stereoscopic microscope, at relatively low magnification (ca. 75X), using a camera-lucida and calibration with a stage micrometer. Measurements and proportions, as listed in the Systematic Descriptions, were obtained from graphs constructed for the various suites of specimens. Although the number of specimens was not consistent, some species being relatively scarce, the measurements for several forms were taken from as many as 45 individuals.

The method of counting whorls and chambers is that of Frizzell (1945). A line, bisecting the second chamber, is extended backward through the proloculum. The first whorl begins with the proloculum and ends with the first chamber to touch the line. It is not a complete volution. The second whorl is an entire volution, begining and ending with chambers that touch the line. Chambers of the last whorl are counted from the ultimate chamber, posteriorly to the first exposed chamber of the whorl. The last whorl seldom coincides exactly with the whorls numbered from the proloculum.

Sectioning and mounting

Many oriented thin sections, both vertical and median, were prepared and examined. In addition, both horizontal and vertical serial sections were made for each species.

Thin sections and serial sections often were prepared with Canada balsam. A small amount of balsam was placed on a biological-type glass slide (one inch by three inches). The specimen was placed beside the balsam, covered with a drop of xylene to remove contained and adherent air, and quickly thrust into the balsam. The slide was heated, to evaporate the solvent from the mounting medium, and the specimen was oriented with a heated needle under the stereoscopic microscope.

Because of the brittleness of Canada balsam, after prolonged heating, Lakeside 70 (a thermoplastic) was found to be more easily used. A chip of that material was placed on a slide, heated to the melting point, and allowed to run over the specimen. A disadvantage in using Lakeside 70 lies in its insolubility in xylene, with consequent difficulty in securing penetration of porous tests.

Sections were ground on a frosted glass plate, using a mixture of levigated alumina, soap powder, and water. Thin sections were cut to the median plane. Serial sections, however, were ground a short distance, the exposed structures were sketched, followed by successive grinding and sketching until the entire specimen had been ground away. Although the serial sketches are not included in the illustrations for this report, they contributed a great deal to an understanding of the species studied.

Unfilled cavities within specimens often were encountered in the process of grinding sections. In these cases, it was necessary to wash and dry the slide, to reheat the mounting medium, and to fill the cavity with the liquified medium. Reorientation, of course, was required.

Cover slips were cemented in place with "liquid" Canada balsam (dissolved in xylene), whether the specimen had been mounted in balsam or Lakeside 70. Whole mounts made with castor oil (Refractive Index: 1.47) showed details of exterior, pores, and sieve plates to advantage, allowing "optical sections" of the test to be seen. Castor oil mounts, however, are not suited to photomicrography. Crushed tests were examined in castor oil and in Canada balsam, the latter having given better results in the study of sieve plates.

Decalcification

Specimens were decalcified with a very dilute solution of acetic acid. Four drops of glacial acetic acid, added to a Syracuse watch glass of water, gave the most effective results. Very weak hydrochloric acid was tried, but decalcification was too rapid, rupturing the delicate chitinoid layers of the test.

Whole and crushed specimens were decalcified on a glass slide, beneath a cover slip, the acid solution having been introduced with a pipette. (Failure to use a cover slip could injure the microscope.) In this way, the progress of decalcification was observed under the compound microscope, at magnifications ranging to 550 diameters.

Wall structure was studied most successfully by the use of relatively thick median sections made with Canada balsam. After grinding, the balsam was removed with xylene, and the section was decalcified under a cover slip. After partial or complete decalcification of the sections, the cover slip was removed, and the specimen was washed with water. After drying, the specimen was mounted in balsam. (Transfer through various concentrations of alcohol, into a suitable mounting medium, would have resulted in less distortion of the chitinoid membranes.) Sections prepared with Lakeside 70, and those mounted in castor oil, gave less satisfactory results.

Decalcification of tests impregnated with Canada balsam or Lakeside 70, to show relationships of pores and chamber cavities, were unsuccessful. Part of the difficulty was caused by the matrix filling many of the tests, but at least part of trouble seems due to the blocking action of the sieve plates in preventing the medium from penetrating the pores.

Drawing techniques

All exterior views were drawn, at relatively low magnification, with the stereoscopic microscope and camera lucida, as were a few of the sections. Horizontal and vertical serial sections of all species, not included in the accompanying illustrations, also were drawn with the camera lucida. Most median and vertical sections were drawn with the compound microscope, with the aid of an ocular grid.

SOURCES OF MATERIAL

Unwashed bulk samples were available in the micropaleontological collections of the Geology Department. Three samples of Cretaceous age were selected, with one from the Paleocene and another from the Eocene. The collecting localities for these are listed below.

Locality 1. Eocene, Claiborne group, Wheelock formation.

Brazos County, Texas; Texas Highway 21, bridge over Brazos River, 10.4 miles west of city limits of Bryan; one foot above first ledge above base of formation.

Collected by D. L. and H.E. Frizzell, October 19, 1951.

Cibicidina danvillensis (Howe and Wallace).

Locality 2. Paleocene, Midway group.

"Limerock Dairy," Sec. 8, T1S, R13W, Pulaski County, Arkansas; first five feet above limestone member.

Collected by L. M. Sherman.

Anomalina acuta Plummer, *A. midwayensis* (Plummer), *A. vulgaris* (Plummer), *Cibicides alleni* (Plummer).

Locality 3. Upper Cretaceous, Navarro group, Kemp clay.

Travis County, Texas; Willow Creek at crossing of Kimbro and Elgin roads, roughly 0.8 miles north of Kimbro.

Collected by D. L. Frizzell, F. H. Putlitz, and I. J. Anderson, May 2, 1948.

Anomalina pseudopapillosa Carsey, Planulina correcta (Carsey).

Locality 4. Upper Cretaceous, Navarro group equivalent, Selma chalk.

One mile northeast of Livingston, Alabama; Highway 11, east side of road in large cut.

Collected by N. E. Crockett, J. A. Martin, L. C. Martin, and A. F. Vondrasek, February 22, 1954.

Cibicides harperi (Sandidge), Stensioina americana Cushman and Dorsey.

Locality 5. Upper Cretaceous, Taylor group, Pecan Gap chalk.

Williamson County, Texas; abandoned quarry on east side of blacktop road, 0.8 miles southward from U.S. Highway 79, road intersection 1.2 miles westerly from intersection of U.S. Highway 79 and Texas Highway 95 at town of Taylor (speedometer distances); chalk facies of Pecan Gap chalk (as opposed to chalk-marl of vicinity of Austin).

Collected by D. L. and H. E. Frizzell, October

19, 1951.

Planulina dumblei (Applin), *Cibicides beaumontianus* (d'Orbigny), *Anomalinoides pinguis* (Jennings).

RESULTS AND CONCLUSIONS

The objective data of the project are recorded in some detail in the section of Systematic Descriptions and in the accompanying illustrations. A number of conclusions have been based on that evidence, some new, some corroborating previous work, as indicated on the following pages.

Variability

The species studied in this project showed only normal variability among adult individuals (see Systematic Descriptions for ranges). This conclusion is opposed to a commonly held belief that members of the Anomalinidae are highly variable. Some ontogenetic changes were noted, but dimorphism was not encountered, the microspheric generation apparently being relatively rare among anomalinid species.

Ontogenetic variation: The species of *Anomalina* and *Anomalinoides* are quite consistent from young to mature stages. Chambers increase uniformly in size, becoming slightly more inflated in later whorls. The immature forms usually are involute, with a slight increase in evoluteness with maturity. These differences are not marked, and the specimens at various growth stages are easily identifiable.

Planulina shows ontogenetic variation in both species. The young of _P_. _dumblei_ is slightly more biconvex and involute, the mature form adding chambers of rapidly increasing size, and the test becoming more compressed and evolute. In many specimens of _P_. _correcta_, the early chambers are low and broad, with later chambers becoming rapidly much higher and increasing greatly in size. Other individuals continue the addition of low chambers throughout.

The species of _Cibicides_ are not consistent in their ontogenetic development. In _C_. _alleni_, the chambers are added uniformly throughout, the test retaining its shape throughout the ontogeny. The young stage of _C_. _harperi_ is more biconvex than the adult, becoming more compressed with the addition of chambers of rapidly increasing height. Immature forms of _C_. _beaumontianus_ add chambers of uniformly increasing size. In older specimens, however, the chambers increase rapidly in size, and in many specimens become very irregular.

Cibicidina develops in much the same way as as Anomalina and Anomalinoides, but becomes somewhat more involute, dorsally, in the last few chambers.

Internal morphology

In all species considered in this report, the test consists essentially of three elements:

1. Revolving laminae -- the primary walls that bound the chambers, exclusive of the septa.

2. Septa -- the divisions between chambers, which contain the foramina; in the last chamber, this structure is called the septal face, and its opening is the aperture.

3. Secondary deposits -- clear material deposited at the umbonal and umbilical areas (ventral and dorsal centers), including ornamentation of the test in some forms.

These elements of the test are the basis for all discussions of the gross internal morphology and of the detailed structures of the wall.

Plan of growth: All of the species are initially trochoid, with a later trend toward planispiral coiling in most of them. Development of the planispiral pattern differs widely. Cibicides beaumontianus is trochoid nearly throughout its ontogeny, whereas *Planulina dumblei*, at the other extreme, is almost planispiral in all but the first few chambers. The anomalinine forms usually are more planispiral in the examples studied, and the cibicidine species more trochoid, although *Anomalinoides pinguis*, *Cibicides alleni*, and *C. harperi* are exceptions.

Whorls and chambers: The number of whorls, ranges from about two to four and a half. *Cibicides beaumontianus* contains the least, whereas the larger individuals of *C. harperi* reach the maximum.

The number of chambers in the first whorl is more consistent than in later volutions, ranging from five to seven. The second whorl is more variable, with eight to 14 chambers. *Cibicides beaumontianus* contains the least, with *Anomalina acuta* and *Planulina dumblei* having the maximum number. The third and fourth whorls, where present, usually consist of one more chamber than in the second. The number of chambers in the last volution ranges from about six to 12. *Cibicides beaumontianus* has least (six to eight), whereas *Anomalina acuta* and *A. pseudopapillosa* usually have 12, and *A. acuta* may contain as many as 14.

Median sections: The peripheral outline usually is subcircular, and the last few chambers in most forms are slightly scalloped. Cibicides beaumontianus is an exception, the later chambers sometimes showing distortion. In general, and persistently in Anomalina, the chambers are of uniformly increasing height as added. The septa usually curve gently backward to the periphery although, as in Anomalina acuta, the septa of early chambers may be straight. Forms that most closely approach planispiral coiling show most of the foramina of the last whorl, as in Planulina dumblei, where as many as 14 have been observed. The wall, in all species, increases in thickness from the proloculum through the last chamber of the penultimate whorl, then thins to the last chamber of the test. This thickening and thinning is persistent in all species, but the maximum thickness varies. In Cibicides harperi, for example, the wall is relatively thick in the penultimate whorl, but in other forms the wall at that location is somewhat thinner.

Vertical sections: The vertical outline reflects the nature of coiling and degree of inflation of the chambers. In species with inflated chambers and nearly planispiral pattern, as *Anomalina midwayensis* and *Anomalinoides pinguis*, the early chambers are semicircular and the last chambers almost circular. Chambers of compressed and nearly planispiral forms, as *Planulina dumblei* and *P. correcta*, are triangular and elongate. *Cibicides beaumontianus* and *Cibicidina danvillensis* are flattened to depressed on the dorsal side. Their later chambers are somewhat triangular, and overlap the earlier semicircular chambers on the ventral side.

The wall is thickened on both sides of the test, in all species, with the wall of later chambers becoming thin. Bosses and plugs are visible as protruding areas at the dorsal and ventral centers. *Cibicides harperi* and *C. alleni* show an irregular thickened umbonal plug (dorsal) and a clear, arched umbonal plug (ventral). In *Planulina dumblei* and *Anomalina acuta*, the umbonal plug of the dorsal side is rounded, and a series of multiple umbilical plugs is present ventrally. Vertical sections often show the wall of *Anomalina midwayensis* to be grotesquely thickened where portions of the very high sutures have been intersected.

The foramina are arched openings, at the base of the septa, extending varying distances dorsally or ventrally. A supplementary aperture in cibicidine forms is exposed at the dorsal margin of the chamber, a corresponding opening in the anomalininae test occurring at the ventral margin. The supplementary apertures are not visible in early chambers, having been filled by secondary deposits.

Wall structure

The wall of the anomalinid test is described in detail for the basic elements listed above: Revolving laminae, septa, and secondary deposits. For clarity, the crystalline structure and pores are treated under separate headings.

Crystalline structure: All species have the thin to acicular, radially oriented crystals that characterize Wood's (1948) hyaline type of wall. The material presumably is calcite, although neither chemical nor x-ray tests have ~~not~~ been made to check the possibility of aragonite. The crystals are normal to the surface of the foraminiferal test, except for the septum, where the crystals are normal to the surface of the septum.

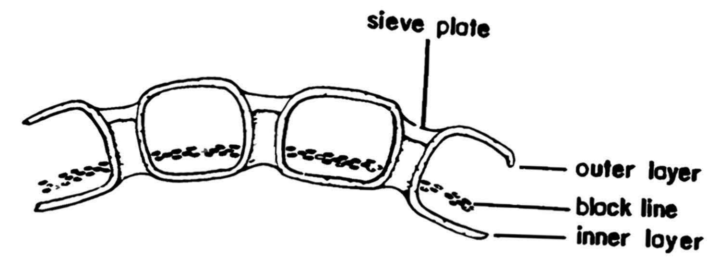
Septa: The septum (figure 3) consistently is composed of the maximum number of differentiated layers: the inner and outer chitinoid layers, the calcareous wall, and the black line. These are described as follows:

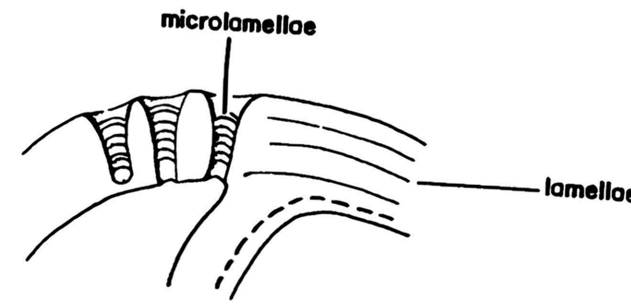
EXPLANATION OF FIGURES

Figure 1. Semidiagrammatic sketch of a portion of a specimen of Anomalina vulgaris (Plummer), showing component parts of the wall and sieve plates; sketched at high magnification during decalcification of a crushed fragment.

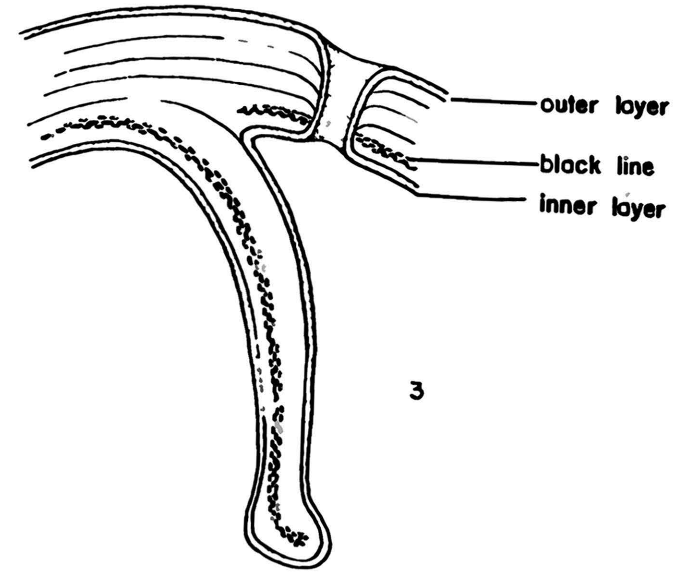
Figure 2. Semidiagrammatic sketch of a portion of a specimen of Cibicides harperi (Sandidge), showing laminations of the calcareous portion of the wall; sketched at high magnification from an undecalcified median thin section.

Figure 3. Diagrammatic sketch of a section through the anomalinid wall, showing relation of septum to wall of revolving lamina.





2



3

A colorless to yellowish, transparent chitinoid layer is present on the rear side of the septum, with an identical layer of the forward side. Where pores are present, as on the septal face of some forms, the chitinoid layer lines the pores, being continuous with the posterior and anterior layers. The layers are thickest in Anomalina vulgaris, and in some specimens the layer apparently is thickened on the anterior part of the last septum. The organic layers of the anomalinid test are tightly joined to the calcareous wall, and are visible only after decalcification. The chitinoid film is inert to acid, and optically is isotropic. Arnold (1954) found a similar layer in the discorbid genus Discorinopsis to be susceptible to biological stains, but that technique was not attempted in the present study.

The septal wall is composed of clear crystalline calcium carbonate. It is narrow and nearly uniform throughout the test, becoming only slightly thicker as larger chambers are added. The septa never show lamination, and the pores (in species with perforate septal face) are obliterated by secondary deposits. A septum is divided, by its contained black line, into forward and rear portions. The anterior division joins with the lamellae of the revolving laminae; the posterior division joins the wall of the chamber, extending backward a variable distance below the black line of the chamber wall.

The black line is a conspicuous feature of the septa, extending through each septum and for a varying distance into the chamber wall above. Decalcification shows the structure to be made up of fragmental and very loosely associated particles of presumably chitinoid material.

Septal pores were observed in several species, beginning a short distance above the aperture and becoming more numerous toward the periphery. They are visible on the septal face and sometimes on the septa of the last two chambers, but never occur on earlier septa, having been obliterated by a filling of clear secondary material. Septal pores were noted in *Anomalina pseudopapillosa*, *A. vulgaris*, *Planulina correcta* (infrequent), *Cibicides harperi* (infrequent), *Cibicidina danvillensis* (infrequent), and *Anomalinoides pinguis*.

Revolving laminae: The dorsal ventral walls of the test, exclusive of keel and central plugs, are termed the revolving laminae. They may be continuous at the periphery, or they may be separated by a keel. The unqualified term wall of the test (or chamber) is synonymous with wall of the revolving laminae. The anomalinid chamber wall has the same basic structure as in the septum, except for the abundance and permanence of pores, the inconsistent development of the black line, and the presence of lamination.

The chitinoid layers of the revolving laminae are identical with those of the septum. The relative thickness of the organic film varies with different species, and within the various genera. It is somewhat thickened in *Anomalina vulgaris*, appearing rapidly when decalcification begins. *Cibicides harperi*, in contrast, has a very thin film that is retained with difficulty in decalcified preparations.

The calcareous wall of the revolving laminae is composed of a series of more or less discrete lamellae, that in turn are made up of extremely thin microlamellae (figure 2). The lamellae, in general, were visible only at high magnifications (ca. 550X) and in extremely thin sections, but they were observed in all species except *Anomalina acuta*. They are not equal in thickness although the variation is small, nor do they increase in thickness as the test grows. Many lamellae bend inward toward the pores, perhaps explaining the external flaring of many pore openings. The microlamellae were visible only in sectioned pores in one specimen of Cibicides harperi, where a black mineral deposit coated the internal surface of the pores and revealed the ultra-fine structure of the wall. They apparently are combined to form the more conspicuous lamellae.

The laminations of the wall (lamellae and microlamellae) reflect a rhythmic secretion of calcium carbonate, during growth of the test, and show that, except for the secondary filling of pores and supplementary apertures, deposition of shell material is always external. Each lamella envelopes the exterior of exposed parts of the test. A somewhat indefinite relationship exists between the number of chambers in the test and maximum number of lamellae: at least one lamella is deposited during formation of each chamber. The number of lamellae, however, often exceeds the total number of chambers. Moreover, a section of Cibicides harperi shows three lamellae in the wall of the penultimate chamber, indicating secretion of an extra lamella during the time between initiation of that chamber and completion of the last chamber.

Smout (1954, p. 10) believed that foraminifera of the Superfamily Discorbidea, in which he placed the anomalinid species, secrete exactly one lamella with formation of each chamber, the lamellae having the general relationship to the test described above. The writer's observations agree with Smout's general interpretation of wall structure, except for the absence of a definite chamber-lamella relationship.

A paradoxical relationship exists between the exterior chitinoid layer and the lamellae. The organic film is present in specimens of all ages and sizes, and no trace was found of the layer between the lamellae. Yet the continuous external deposition of lamellae seems unquestionable. The obvious conclusion is that secretion of a lamella is preceded by resorption of the external chitinoid layer, but this postulate must remain unproved until confirmed by observations of living foraminifera.

The black line, described above for the septum, was never seen in vertical sections, and is irregularly developed at the periphery in median sections. It is variable, even from chamber to chamber within a single individual. The black line always extends into the wall, frequently disappearing against its lower surface. Occasionally it continues backward to the preceding septum, but in only one example did it appear to join the black line of the preceding septum.

Secondary deposits: The lamellae of the test form structures, apart from the revolving wall and septum, that are considered to be secondary deposits. In the Anomalinidae, these include: umbonal (dorsal) and umbilical (ventral) plugs, sometimes projecting as bosses, spirals, or beads; peripheral keels; raised and thickened sutures; and the clear shell material filling and obliterating the early pores and supplementary apertures.

Umbonal plugs, extending as rounded bosses, are present in *Anomalina acuta*, *A. pseudopapillosa*, *Planulina correcta*, and *P. dumblei*. Irregular umbonal plugs, forming an irregular raised spiral on the exterior, were observed in *Anomalina vulgaris*, *Cibicides beaumontianus*, and *Anomalinoides pinguis*. In the remaining species, the dorsal plug did not protrude conspicuously.

Umbilical plugs, forming raised spiral projections on the exterior, occur in *Anomalina vulgaris* and *Planulina dumblei*. In *Anomalina acuta* and *A. pseudopapillosa*, somewhat similar projections are formed by the beaded inner ends of sutures.

Umbilical plugs are prominent and project outward in _Cibicides alleni_ and _C. harperi_, but are less conspicuous in _Cibicidina danvillensis_.

Secondary thickening of the sutures, as noted above, sometimes results in formation of raised beads at the umbilicus. Some thickening of the sutures is found in all species, but it is most marked in _Anomalina midwayensis_, where the thickening is extreme.

Keels are present in many of the anomalinid species, but are usually low and inconspicuous.

Pores: Pores, in the Anomalinidae, occur in the revolving laminae, in the umbonal and umbilical plugs, frequently on the septal face, and sometimes in the keel. As noted above, they are filled by secondary deposits in the earlier parts of the test.

Anomalinid pores are large, as compared to those of most other groups of foraminifera, being visible at a magnification of 70 diameters. Within the family limits, however, they are classes as small, of medium size, or large. They vary within the different genera, only _Cibicidina_ being characterized by uniformly small pores (see also Bandy, 1949). Size and distribution, however, are consistent for species.

In the majority of species studied, pores are of the same size, and equally numerous, in both dorsal and ventral walls of the test. *Anomalina acuta* and *A. pseudopapillosa*, however, have larger and more numerous pores on the ventral wall. In *Cibicides beaumontianus*, the pores are the same size on both walls, but are numerous on the ventral side. The pores of the dorsal and ventral plugs show differences in various genera: *Anomalina* is rather consistent, with larger and more numerous pores in the umbilical plug. *Planulina*, in contrast, has more abundant and larger pores in the umbonal plug. *Cibicides* usually has more pores in the umbonal area, as does *Anomalinoides*, although in *C. beaumontianus* they are more frequent in the umbilical area. The maximum distribution of central pores, in *Cibicidina*, is in the umbilical plug.

Pocket-pores (figure 21) are found in the keel and central plugs of *Planulina dumblei*, *Cibicides alleni*, and *C. harperi*. These begin with very large flask-shaped cavities, continuing through narrowed necks to the exterior. No examples were observed that connected with the interior. The function and method of formation of these modified pores are not understood. In so far as the writer is aware, pocket-pores have not been recorded previously.

It is to be stressed that Hofker's (1951) deuteropores are no more than typical large pores with attached sieve plates. Hofker supposed that a series of extremely small pores join abruptly to form a single large pore. His illustrations, however, especially his figure 253c, simply show sieve plates as seen from the exterior of the test. His careful sketches of vertical sections demonstrate the complete absence of any such fusing of pores within the wall.

Sieve plates: A thin porous plate was observed to cover each pore in a number of species. These sieve plates, never more than one to a pore, are situated at various levels near the exterior of the wall. In *Anomalina vulgaris* and *Cibicides alleni*, with large and flaring pores, the sieve plate usually is attached where the pores flare outward. The plates apparently are composed of calcareous and chitinoid material, remaining as thin films after decalcification. They are porous, having very fine openings without any definite pattern. The sieve plates are loosely attached to the chitinoid lining of the pores, breaking away readily when the wall is broken, and they did not remain in place during the preparations of thin sections.

Sieve plates were observed in Anomalina acuta, A. pseudopapillosa, A. vulgaris, Planulina correcta, Cibicides alleni, C. harperi, and Anomalinoides pinguis. Similar plates may be present in the other species, although their presence in the very fine pores was not confirmed.

The function of sieve plates has not been determined, although their presence in Tretomphalus, Discorbis, and Discorinopsis has been recorded, and various explanations have been offered (Arnold, 1954, 1954A). Their purpose obviously is to screen, or perhaps block, entry to the test and exit from it, except through the apertures and foramina. But whether this control is aimed at nuclear and cytoplasmic elements of the cell, gametes, food particles, or undesirable external material, remains a problem for the marine biologist.

Classification

Taxonomic conclusions about the Family Anomalinidae, in so far as they can be formulated from a study of a very few species and genera, may be summarized as follows:

1. Species are readily recognized entities, with normal variability, characterized by:

Number of whorls and chambers.

Outline of test.

Minor differences in plan of growth.

Sculpture.

Size.

Size and distribution of pores.

2. Genera are groups of species that, although converging in some characters, appear to be relatively easily identified. Diagnostic characters are:

Plan of growth.

Pores (rarely, as is Cibicidina).

/Apertural characters apparently are of value in some of the more advanced cibicidine genera that were not treated in this project./

3. Two definite subfamily groups are recognized, based on the dorsal or ventral position of the supplementary aperture.

4. The subfamilies combine to constitute a coherent family, based on:

Trochoid to nearly planispiral coiling.

Large pores.

Major aperture peripheral; in genera studied, with supplementary apertures above or below.

5. The family falls within the Superfamily Discorbidea because of its laminar calcareous wall structure, single septa, and lack of canals; details of the wall (chitinoid layers and black line), as well as the initial trochoid pattern, suggest a close affinity with the Family Discorbidae.

A synopsis of the family as emended, restricted to forms studied in this project, is as follows:

SUPERFAMILY DISCORBIDEA

Family ANOMALINIDAE

Subfamily ANOMALININAE -- with ventral supplementary apertures.

Genus *Anomalina* -- initially trochoid, becoming planispiral; more inflated biconvex.

Genus *Planulina* -- nearly planispiral throughout; greatly compressed.

Subfamily CIBICIDINAE -- with dorsal supplementary apertures [advanced forms with altered plan of growth and modified apertures in adult].

Genus *Cibicides* -- trochoid nearly throughout; bi- or plano-convex.

Genus Cibicidina -- trochoid nearly throughout; plano- to concavo-convex; uniformly with relatively small pores.

Genus Anomalinoides -- initially trochoid becoming planispiral; inflated biconvex; (identical with Anomalina, except for dorsal supplementary aperture).

The classification of the Anomalinidae, as outlined above, is basically that of Cushman (1948), but modified in the light of contributions of Galloway (1933), Glaessner (1945), and Smout (1954), as well as from the writer's own observations.

Cushman's definitions of Anomalina and Planulina are erroneous (cf. Galloway, 1933, and Glaessner, 1945) in ignoring the supplementary apertures, and his inclusion of Anomalinoides in the Anomalininae is untenable. Gavelinella, that he placed in the Discorbinae (= Discorbidae), seems to be identical with Anomalina.

Cushman's Subfamily Cibicidinae seems to be a natural group of species, including simple forms, as defined above, with the addition of descendent and more advanced genera (becoming uniserial, biserial, annular, or irregular in later stages, or degenerate). His Subfamily Anomalininae, in contrast, is heterogeneous, requiring revision in detail.

Hofker's (1951) classification of foraminifera is not acceptable on several grounds: He ignores the basic principles of the International Rules of Zoological Nomenclature; he stresses single characters, avoiding the obvious similarities shown by groups of characters; and he coalesces genera in a manner that obscures relationships. Consequently, his taxonomic conclusions cannot be used -- in spite of his masterful studies in comparative morphology -- without re-evaluation of his basic evidence.

Comparison with a discorbid species, *Stensioina americana*

Stensioina americana was selected for study because of its similarity to members of the Anomalinidae, having been referred to *Cibicides*, and because it is an easily identified member of the Family Discorbidae.

The species is small, trochoid, plano-convex (flat above), and nearly circular in outline. The dorsal surface is ornamented with raised radial and spiral sutures, with irregular raised ridges of secondary material between the radial sutures.

The ventral side is smooth, with a small, slightly depressed umbilicus. At the base of the septal face, the aperture is situated about midway between the periphery and umbilicus. No ontogenetic changes in shape or plan of growth were noted.

The wall of Stensioina is radially crystalline, with lamellar structure in the calcareous part of the wall. External and internal chitinoid layers are present, as is the black line of the septum. Pores are sparse in the ventral wall, absent from the dorsal wall except for a few in the last exposed chambers, and infrequent on the septal face; they are moderately small. The ventral wall of the test overlaps in successive whorls, so that no umbilical plug is formed.

Stensioina americana resembles the anomalinid species studied in composition and structure of the wall, and in its plan of growth. It differs in the position of the aperture and lack of supplementary openings, and the absence of planispiral coiling, characters that seem to be of familial value. Minor differences are in the prominent dorsal sculpture and ventral overlapping of chambers.

Comparison of Stensioina americana with the various anomalinid species emphasizes the superfamily relationship of the Discorbidae and Anomalinidae, and indicates a close affinity between the families.

SYSTEMATIC DESCRIPTIONS

Superfamily DISCORBIDEA Smout, 1954

Family ANOMALINIDAE

Cushman, 1948, Foraminifera, etc., ed. 4, p. 331; Galloway, 1933, Man. of Foraminifera, pp. 287-299; Glaessner, 1945, Principles of Micropaleontology, pp. 145-148.

Description: Test calcareous-perforate (radial-crystalline), free or attached, biconvex, plano-convex to slightly concavo-convex; chambers arranged initially in a trochoid spiral, sometimes becoming planispiral; both sides of young nearly involute, usually becoming more evolute with maturity; pores of wall may be equal size dorsally and ventrally or somewhat restricted and unevenly distributed, pores visible at magnifications of about 70X; aperture a slit-like opening at base of septal face, extending either dorsally or ventrally for varying distances, with a supplementary aperture at dorsal or ventral chamber margin.

Subfamily ANOMALININAE

Diagnosis: Test biconvex to nearly plano-convex; initially trochoid, becoming planispiral; involute in young, becoming less involute with maturity; aperture at base of septal face, extending ventrally for varying distances, with a supplementary aperture at the ventral chamber margin.

Genus ANOMALINA d'Orbigny

Anomalina d'Orbigny, 1826, Ann. Sci. Nat., 7:282.

?Aspidospira Ehrenberg, 1844, K. Akad. Wiss. Berlin, Ber., 1844, p. 75.

?Porospira Ehrenberg, 1844, K. Akad. Wiss. Berlin, Ber., 1844, p. 75.

Rosalina (in part) of authors (not d'Orbigny).

Rotalia (in part) of authors (not Lamarck).

Discorbina (in part) of authors (not Parker and Jones).

Planorbulina (in part) of authors (not d'Orbigny).

Truncatulina (in part) of authors (not d'Orbigny).

Gavelinella Brotzen, 1942, Sver. Geol. Unders., /Ser. C/451:7.

Description: Test calcareous-perforate, free, young trochoid, becoming almost planispiral with maturity; involute in young, slightly less involute at maturity; usually quite biconvex and inflated, ventral side usually a little more convex than dorsal; main aperture an arched slit at base of septal face, extending a short distance ventrally, with a supplementary aperture at umbilical region.

ANOMALINA ACUTA Plummer

Text figures 4a, 4b, 4c, 5, 6

Anomalina ammonoides (Reuss) var. acuta Plummer, 1927, Univ. Texas, Bull., 2644:149, pl. 10 fig. 2.

A. acuta Plummer. Glaessner, 1937, Univ. Moscow, Problems of Paleontology, 2-3:386, pl. 5, fig. 40.---Toulmin, 1941, Jour. Paleontology, 15:608, pl. 82, figs. 9-10. ---Cushman and Renz, 1942, Cushman Lab. Foram. Research, Contr., 18:12, pl. 3, fig. 6.---Kline, 1943, Miss. Geol. Surv. Bull., 53:59, pl. 5, figs. 3-4.---Cooper, 1944, Jour. Paleontology, 18:353, pl. 54, figs. 3-5.---Cushman and Todd, 1946, Cushman Lab. Foram. Research, Contr., 22:64, pl. 11, figs. 13-14.---Cushman, 1951, U.S. Geol. Surv., Prof. Papers, 232:62-63, pl. 18, figs. 3-6.

Locality: No. 2; Pulaski Co., Arkansas.

Stratigraphic position: Paleocene, Midway group.

External morphology (figures 4a, 4b, 4c): Test calcareous-perforate, free, small, low trochoid; outline subcircular, periphery smooth, subacute to very slightly scalloped in mature forms, with narrow keel becoming reduced toward last chamber; typically biconvex, very slightly flattened above; dorsal side more evolute, ventral side less evolute, both becoming slightly evolute with age; about 2½ whorls in adult, 11 to 15 chambers in last whorl (typically 12); chambers increase gradually in size, becoming slightly inflated; sutures moderately and evenly arched, narrow, smooth, very slightly limbate; first visible sutures raised, becoming smooth in most of test, ventral sutures begin abruptly in a series of beads which surround umbilicus; umbilicus with low spiral knot of irregular translucent material; wall smooth, medium perforate ventrally, slightly finer dorsally, absent dorsal center; aperture an arched slit at base of septal face, extending slightly ventrally with a slight lip, with a supplementary aperture at ventral margin of chamber and extending slightly into the septal face. Dimensions: greater diameter 0.15 to 0.43 mm. (typically 0.30 mm.); lesser diameter/greater diameter 72% to 92% (typically 83%); thickness/greater diameter 31% to 45% (typically 39%).

Internal morphology: Median sections (figure 5) show a subcircular outline, with a maximum of 2½ whorls. The first whorl has 6 chambers, with 14 chambers in the second whorl. The septa are initially quite straight and very slightly limbate; later septa are straight for about half their length, then curve backward to the periphery. Each septum is imperforate and distinctly thickened above its foramen, protruding forward to form a slight lip. The black line extends from just above the foramen, through the septum, usually through the revolving lamina near the inner surface to the previous septum, but not connecting with the black line of that septum. The wall of the revolving lamina is quite thin around the proloculum, increasing in thickness through the penultimate whorl, then thins to the last chamber. The approximate ratio from proloculum to last chamber of penultimate whorl to last chamber is 1:4:2. The keel is clear and without pores, being slightly thicker than the lateral walls. The foramina are low, and of uniformly increasing height. Polarized light shows the wall to consist of radially oriented crystals. The diameter of the proloculum is approximately 0.015 to 0.02 mm. The ratios of shape of test are: <u>height last chamber first whorl/greater diameter</u>, approximately 14%; <u>height last chamber second whorl/greater diameter</u>, approximately 26%.

The vertical section (figure 6) is an elongated ellipse, with chambers of the inner whorls being semicircular, and the chambers of the last whorl are somewhat triangular. The test is greatly thickened in the vicinity of the proloculum, on both dorsal and ventral sides, with the dorsal boss showing as a clear rounded protuberance. Foramina are arched openings at the base of the septa, extending ventrally about half the distance to the umbilicus under a slight lip. At this point there is a closure caused by an extension of the septal face, beyond which a narrow arched slit opens into the umbilical region. Lamination was not seen at high magnification (ca. 550X).

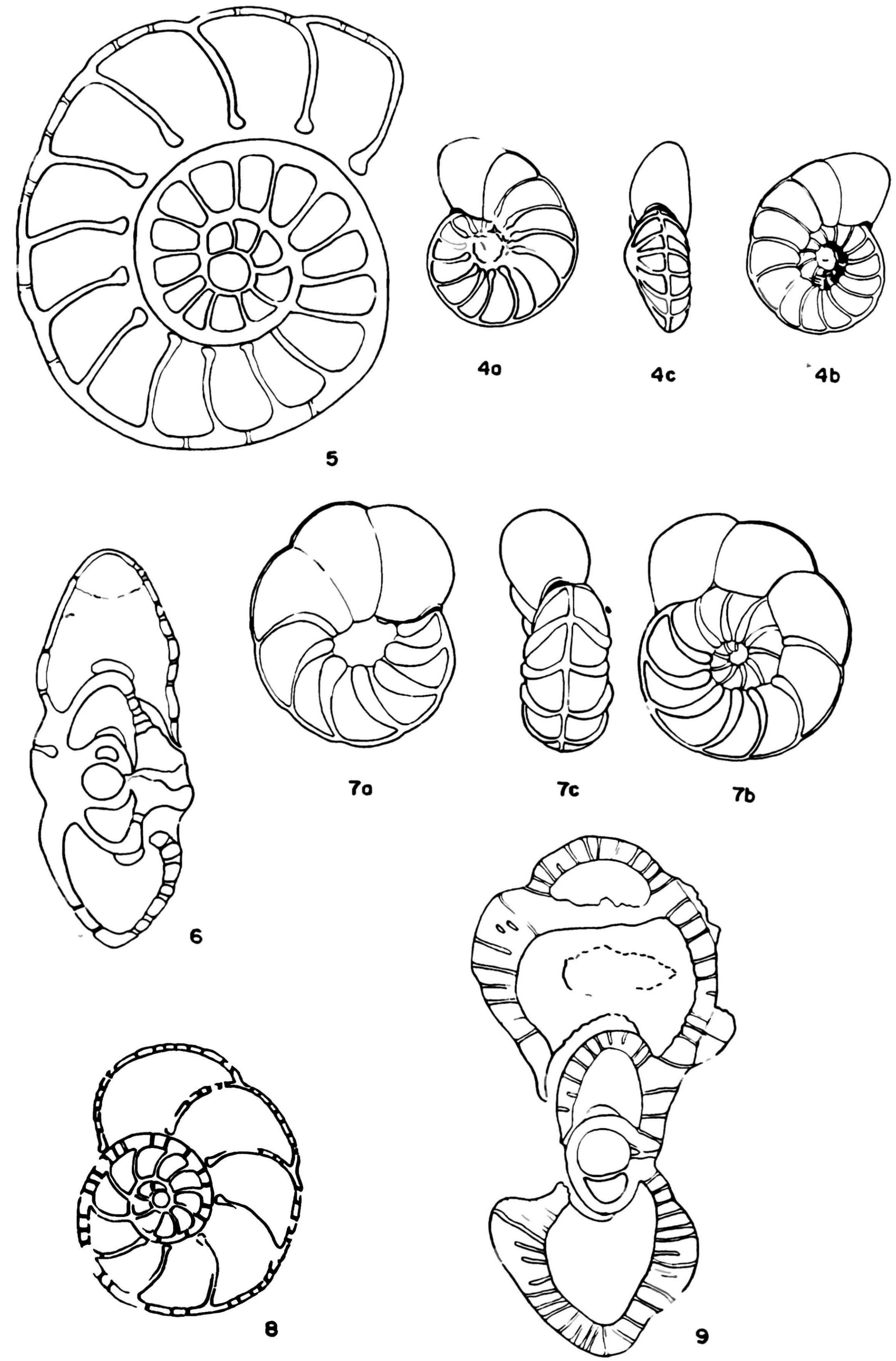
Characters of the wall: Decalcified preparations were used to study the structure of the wall. A chitinoid layer was found covering internal and external surfaces and lining the pores. This layer, in some decalcified specimens, is thicker than usual, a condition that seems to be indicated before decalcification by the yellowish-brown color of many tests. The sieve plates apparently contain some calcium carbonate, as upon decalcification they usually are partly destroyed, leaving a thin chitinoid film.

The following features were observed in undecalcified thin sections: The pores are of medium

EXPLANATION OF FIGURES

Figures 4-6. Anomalina acuta Plummer. 4. External views; greater diameter, 0.40 mm.; 4a, ventral view; 4b, dorsal view; 4c, apertural view. 5. Median section; greater diameter, 0.36 mm. 6. Vertical section; height, 0.31 mm.

Figures 7-9. Anomalina midwayensis (Plummer). 7. External views; greater diameter, 0.51 mm.; 7a, ventral view; 7b, dorsal view; 7c, apertural view. 8. Median section; greater diameter 0.43 mm. 9. Vertical section; height, 0.41 mm.



size, but are almost entirely restricted to the ventral side. Pores are absent in the dorsal wall near the center and few, and of smaller size, in the wall of later chambers of the dorsal side. In the vicinity of the proloculum and chambers of the first whorl, the pores extending to the ventral surface are larger, flaring outward. Sieve plates are present in pores of the ventral side and near the external surface.

ANOMALINA MIDWAYENSIS (Plummer)

Text figures 7a, 7b, 7c, 8, 9

Truncatulina midwayensis Plummer, 1927, Univ. Texas, Bull., 2644:141, pl. 9, fig. 7; pl. 15, fig. 3.

Anomalina midwayensis (Plummer). Cushman, 1940, Cushman Lab. Foram. Research, Contr., 16:73, pl. 12, fig. 18.---Kline, 1943, Miss. Geol. Surv., Bull., 53:60, pl. 6, figs. 17-18.---Cooper, 1944, Jour. Paleontology 18:354, pl. 54, figs. 15-17.---Cushman and Todd, 1946, Cushman Lab. Foram. Research, Contr., 22:64, pl. 11, figs. 18-19.---Cushman, 1951, U.S. Geol. Surv., Prof. Papers, 232:62, pl. 17, figs. 17-19 (synonymy).

Locality: No. 2; Pulaski Co., Arkansas

Stratigraphic position: Paleocene, Midway group

External morphology (figures 7a, 7b, 7c): Test calcareous-perforate, free, of medium size, trochoid; outline subcircular, periphery smooth, rounded, becoming reduced toward last chamber; typically biconvex, becoming somewhat flattened above with age; both sides involute in young, dorsal side becoming increasingly evolute with maturity; with 2 to 3¼ whorls (typically 2½), 7 to 9 chambers in last whorl (typically 8), last 2 to 3 chambers being quite inflated; sutures moderately and evenly arched, wide, smooth strongly limbate, and raised in most of test, becoming flush, incised between inflated chambers, ventral sutures slightly more raised, umbilical region depressed; wall smooth, perforations abundant and of medium size, septal face perforate; aperture a low arched slit at base of septal face, extending ventrally about half distance to margin, with a supplementary aperture at ventral margin of chamber; aperture of young forms sometimes extends slightly dorsal of periphery. Dimensions: greater diameter, 0.25 to 0.54 mm. (typically 0.42 mm.); lesser diameter/greater diameter, 74% to 94% (typically 84%); thickness/greater diameter, 34% to 50% (typically 40%).

Internal morphology: Median sections (figure 8) show a subcircular outline with a smooth margin, except the last 2 to 3 chambers, which are scalloped. The first whorl has 6 chambers, with 11 in the second whorl. Septa are of uniformly increasing thickness, with those of the first whorl being slightly thinner. They curve gently backward to the periphery. The septa are thickened above the foramina, in many cases the thickening is toward the previous septa. A septum contains an intermediate darkened area (the black line), which extends through the septum from just above the foramen into the wall, sometimes extending almost to the previous septum. The foramina are of uniformly increasing height, and the height of the aperture of the adult is about 0.01 mm. The wall increases in thickness from proloculum to penultimate whorl, then thins to the last chamber. The approximate ratio of wall thickness from proloculum to last chamber of penultimate whorl to the last chamber is 1:4:2. The keel is slightly thicker than the lateral walls, and is very clear. Polarized light shows the wall to consist of radially oriented crystals. The diameter of the proloculum is 0.013 to 0.027 mm.; height of last chamber of first whorl, 0.06 mm.; height of last chamber of second whorl, 0.11 mm.

In vertical sections (figure 9) the chambers appear inflated, especially those of the last whorl, which show an almost circular outline. The test is very thick on either side of the first whorl (umbilical and umbonal plugs), the thickness being somewhat exaggerated where the raised sutures have been sectioned. The ventral chambers of the last whorl partly overlap those of the preceding whorl, but leave a depressed umbilicus, indicating the initial trochoid coiling. Foramina in chambers of the last whorl (where visible) are arched openings at the base of the septa, extending ventrally for about half the width of the chamber, with a supplementary aperture opening into the umbilicus under a very thin flap. In earlier chambers the foramina do not open into the umbilicus, being closed by secondary shell material. In many cases, large pores are situated in the position formerly occupied by the supplementary apertures. Faint lamination was seen in the vertical thin section (ca. 550X magnification).

Characters of the wall: Upon decalcifying, a thin chitinoid layer was found, which borders the external and internal surfaces and lines the connecting pores. Satisfactory results were obtained only with decalcification of the crushed test. The chitinoid layer is exceedingly thin, and with complete decalcification the latter is ruptured, and much is lost.

Undecalcified thin sections show the perforations of the wall. The pores are fine and very numerous; in most cases they taper, being smaller at the internal surface and flaring outward. They are of uniform size, although in the vicinity of the first whorl outward to the ventral surface a few pores are of slightly larger size. Pores of the dorsal side are uniform in size and numerous, except in the vicinity of the proloculum and the first whorl. In this region pores are less numerous. Pores are present in the last septa but usually are absent in all other septa. Sieve plates were not found in this species.

ANOMALINA PSEUDOPAPILLOSA Carsey

Text figures 10a, 10b, 10c, 11, 12

Anomalina pseudopapillosa Carsey, 1926, Univ. Texas, Bull., 2612:47, pl. 1, figs. 6 a-c.---Cushman, 1940, Cushman Lab. Foram. Research, Contr., 16:29, pl. 5, figs. 6 a-c.---Cushman and Todd, 1943, idem, 19: 72, pl. 12, fig. 14.---Cushman, 1946, U.S. Geol. Surv., Prof. Papers, 206:154-155, pl. 64, fig. 1 (synonymy).

A. navarroensis Plummer, 1927, Univ. Texas, Bull., 2644:38, pl. 2, fig. 6.

Locality: No. 3; Travis Co., Texas.

Stratigraphic position: Cretaceous, Navarro group, Kemp clay.

External morphology (figures 10a, 10b, 10c): Test calcareous-perforate, free, small, depressed trochoid; margin smooth, slightly scalloped in last 2 to 5 chambers, with very narrow keel becoming reduced toward last chamber; almost equally biconvex, dorsal center somewhat flattened in some, periphery subacute; both sides very involute with dorsal side slightly less involute, somewhat evolute at maturity; with 2 to 3¼ whorls (typically 2½), chambers narrow, numerous, last whorl with 11 to 13 (typically 12); sutures raised, smooth, limbate, slightly higher ventrally in many specimens, arched gently to periphery; ventral sutures end abruptly near center, ends being somewhat beaded; bead-like extremities of preceding sutures visible within umbilical region; with small clear boss at dorsal center; wall smooth, somewhat granular, with medium sized perforations; aperture a moderately high arched opening at base of septal face, extending ventrally about half way to margin, with slight lip, with supplementary aperture at ventral margin of chamber. Dimensions: greater diameter, 0.17 to 0.35 mm. (typically 0.30 mm.); lesser diameter/greater diameter, 78% to 91% (typically 82%); thickness/greater diameter, 31% to 39% (typically 33%).

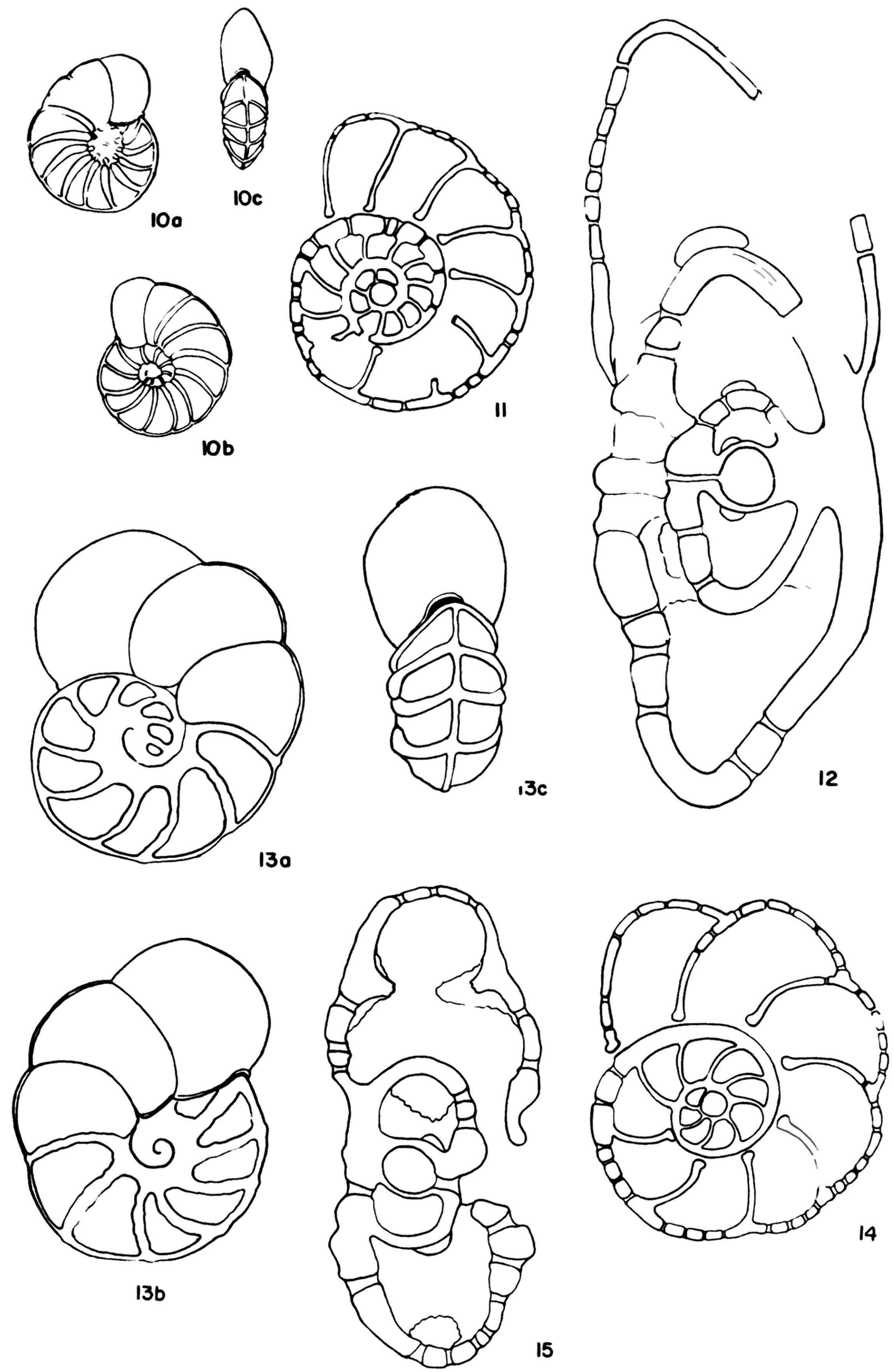
Internal morphology: Median sections (figure 11) show a subcircular outline, with the margin smooth to slightly scalloped in the last 2 to 4 chambers. There is a maximum of $3\frac{1}{4}$ whorls, with an average of 7 chambers in the first whorl, and 12 to 13 chambers in the second and third whorls when present. The septa of the first whorl are straight, with the later septa curving gently backward to the periphery. They are narrow and sometimes slightly limbate, thickening slightly as later chambers are added. The end of the septum above the foramen is thickened and extends forward, forming a slight lip. The septa show the intermediate darkened area (black line), which extends from just above the foramina through the septa and usually into the wall near its internal surface, in some chambers disappearing at the internal surface or extending to the preceding septum. The wall thickens from the initial part of the proloculum to the last whorl, then thins to the last chamber. The ratio of wall thickness from proloculum to last chamber of the penultimate whorl to last chamber is 1:3:1. In some sections, the keel is slightly thicker than the wall and thickens with about the same ratio, but is absent on the last chamber. The foramina (where visible) are of low and uniformly increasing height. The diameter of the proloculum is 0.013 to 0.020 mm.; height last chamber first whorl/greater diameter, approximately 9%; height last chamber second whorl/greater diameter, approximately 22%.

Vertical sections (figure 12) show the test to be almost equally biconvex, but somewhat compressed. The slight dorsal position of the proloculum and chambers of the first whorl, partly overlapping ventrally, demonstrates the slight initial trochoid coiling. Chambers of later whorls partly overlap both dorsally and ventrally, becoming almost planispiral. The wall is thickened at both dorsal and ventral centers, with the wall of the last visible chamber being quite thin. Foramina (where visible) are arched openings at the base of the septa, extending ventrally about a quarter the distance to the margin. At this point there is a closure of the septal face, be-

EXPLANATION OF FIGURES

Figures 10-12. *Anomalina pseudopapillosa* Carsey. 10. External views; greater diameter, 0.33 mm.; 10a, ventral view; 10b, dorsal view; 10c, apertural view. 11. Median section; greater diameter, 0.22 mm. 12. Vertical section; height, 0.29 mm.

Figures 13-15. *Anomalina vulgaris* (Plummer). 13. External views; greater diameter, 0.69 mm.; 13a, dorsal view; 13b, ventral view; 13c, apertural view. 14. Median section; greater diameter, 0.55 mm. 15. Vertical section; greater diameter, 0.38 mm.



yond which a narrow arched slit opens into the umbilical region. Lamellae are visible at high magnification (ca. 550X).

Characters of the wall: Decalcification revealed a chitinoid layer covering the internal and external surfaces and lining the pores. This layer is relatively thick, and usually is discolored by pyritic material.

Pores, shown in undecalcified thin sections, are numerous in the ventral wall and of medium size, flaring slightly both internally and externally. In the ventral center, some pores are larger and flare more toward the external surface. Pores are almost completely lacking in the dorsal wall, except in chambers of the last whorl. The keel is perforate, but the pores are fewer than in the wall. The septa are usually imperforate, although an occasional pore may be seen in the last septum. Sieve plates were found in pores of the ventral side, and situated near the exterior of the pore. Very few pores, however, contained plates that were recognized, as many of the pores were filled with matrix.

ANOMALINA VULGARIS (Plummer)

Text figures 13a, 13b, 13c, 14, 15

Truncatulina vulgaris Plummer, 1927, Univ.

Texas, Bull., 2644:145 pl. 10, fig. 3.

Cibicides vulgaris (Plummer). Cushman, 1940, Cushman Lab. Foram. Research, Contr., 16:73, pl. 12, fig. 21.---Kline, 1943, Miss. Geol. Surv., Bull., 53:63, pl. 6, figs. 19-20.---Cooper, 1944, Jour. Paleontology, 18:354, pl. 54, figs. 28-29.---Cushman and Todd, 1946, Cushman Lab. Foram. Research, Contr., 22:65, pl. 11, figs. 22-23.---Cushman, 1951, U.S. Geol. Surv., Prof. Papers, 232:66, pl. 19, figs. 7-11 (synonymy).

Locality: No. 2; Pulaski Co., Arkansas.

Stratigraphic position: Paleocene, Midway group.

External morphology figures 13a, 13b, 13c): Test calcareous-perforate, free, of medium size, trochoid; outline subcircular, periphery smooth, rounded, last 1 to 3 chambers scalloped, with narrow thick keel becoming reduced toward last chamber; typically biconvex, slightly more flattened above in mature forms; dorsal side a little less involute becoming more evolute with age, ventral side completely involute; with 2 to 2 3/4 whorls (typically $2\frac{1}{4}$, 7 to 9 chambers in last whorl (typically 8), last 1 to 3 chambers becoming more inflated in adult; sutures raised, especially near center, becoming flush, and last 1 to 3 sutures incised, with somewhat irregular surface, moderately and evenly arched; with raised irregular umbilical and umbonal bosses, forming spirals, more strongly developed on ventral side; wall smooth, coarsely and abundantly perforate, with less abundant pores in septal face; aperture an arched slit at base of septal face, extending ventrally about half way to margin, supplementary aperture at ventral margin of chamber. Dimensions: greater diameter, 0.37 to 0.66 mm. (typically 0.52 mm.); lesser diameter/greater diameter, 75% to 84% (typically 79%); thickness/greater diameter, 36% to 51% (typically 43%).

Internal morphology: Median sections (figure 14) show a subcircular outline with last 2 to 5 chambers scalloped. The first whorl has 6 chambers with 9 in the second. The septa are straight for about 1/8 of their length, then curve backward to the periphery. They are thickened just above the aperture, and project slightly forward, forming the external lip. The septa increase gradually in thickness as chambers are added and show an intermediate darkened area (the black line), which extends through the septum from just above the foramen into the wall, near the internal surface, sometimes reaching the previous septum but not joining with the black line of that septum. Foramina (where visible) are of uniform height, increasing gradually in height as later chambers are added. Usually all foramina of the last whorl are visible, in median sections cut through the center of the proloculum, indicating the planispiral pattern of the last whorl. The wall increases in thickness from proloculum to the last chamber of the penultimate whorl, then decreases to the last chamber with a ratio of approximately 1:4:2. At high magnification (ca. 550X), faint lamination is visible. Polarized light shows the wall to consist of radially oriented crystals.

Vertical sections (figure 15) show the test to be inflated, with chambers of the last whorl virtually circular in outline. In some specimens, later chambers are somewhat planispiral, with the proloculum near the dorsal side. The wall is greatly thickened at the dorsal and ventral centers (umbilical and umbonal plugs), the ventral side adjacent to the proloculum being very thick. Foramina in chambers of the last whorl are arched openings at the base of the septa, extending ventrally about half distance to the margin, supplementary apertures at the chamber margin in the vicinity of the umbilicus. Foramina of earlier chambers do not show the slit-like supplementary openings, but their position sometimes is occupied by enlarged pores.

Characters of the wall: Decalcification reveals a thin chitinoid layer covering the external and internal surfaces of the test and lining the pores. This layer is usually thicker than in most of the species studied, and in many cases seems to be thicker at the external surface. When partly decalcified, the intermediate darkened area (black line) of the septa and wall shows fragmental material which is resistant to decalcification. This appears to be chitinoid material which although not forming a layer, is distributed along the intermediate area as very minute particles. In undecalcified thin sections, pores are very coarse and numerous, being of uniform size in dorsal and ventral walls of the last chambers. Pores are almost absent in the umbonal plug, but are numerous in the umbilical plug. These pores are slightly larger than normal. They flare slightly toward the interior and exterior, usually a little more toward the exterior. Pores are visible although less numerous in the septa, but in-variably are absent for a very short distance above the aperture. The keel contains relatively few pores. Sieve plates are present in many of the pores, usually attached where the pores start to flare toward the external surface. In some cases the plates may be nearer the exterior, but have not been seen near the internal surface.

Discussion: This species cannot be included in the genus Cibicides. The position of the major aperture is characteristic of Anomalina, being restricted to the periphery and extending ventrally, but never appreciably on the dorsal side of the test. The biconvex test, being almost equally biconvex in many specimens, is also typical of Anomalina. The large size of the pores is suggestive of Cibicides to some workers, but this character does not seem to be of generic significance in the species studied.

Genus PLANULINA d'Orbigny

Truncatulina (in part) of authors (not d'Orbigny, 1826 = Cibicides Montfort).

Planulina d'Orbigny, 1826, Ann. Sci. Nat., 7:280.

Anomalina (in part) of authors (not d'Orbigny).

Description: Test calcareous-perforate, free, slightly trochoid in young, becoming nearly planispiral in adult; adult much compressed, becoming evolute; aperture a slit at base of se tal face, extending ventrally for varying distances, with a supplementary aperture at the ventral chamber margin.

PLANULINA CORRECTA (Carsey)

Text figures 16a, 16b, 16c, 17, 18

Discorbis correcta Carsey, 1926, Univ. Texas, Bull., 2612:45, pl. 3, fig. 5.---Plummer, 1931, idem, 3101:188, pl. 14, figs. 1-4.

Planulina correcta (Carsey). Cushman, 1940, Cushman Lab. Foram. Research, Contr., 16:36, pl. 6, figs. 11 a-c.---Cushman and Todd, 1943, idem, 19:72, pl. 12, figs. 15 a-c.---Cushman, 1946, U.S. Geol. Surv., Prof. Papers, 206:158, pl. 65, fig. 1 (synonymy).

Locality: No. 3; Travis Co., Texas.

Stratigraphic position: Cretaceous, Navarro group, Kemp clay.

External morphology (figures 16a, 16b, 16c): Test calcareous-perforate, free, of medium size, very low trochoid; outline subcircular, periphery smooth to slightly scalloped, with very low and narrow keel becoming reduced toward last chamber; typically convex above and somewhat concave below (occasionally reversed); dorsal side more evolute, ventral side less evolute, both becoming more evolute with age; with 2 to 3¼ whorls (typically 2½), 6 to 10 chambers in last whorl (typically 8), last 3 to 4 chambers of adult increasing rapidly in size; sutures moderately and evenly arched, wide, smooth, slightly limbate, raised in most of test, flush toward last chambers, becoming incised at last two to three chambers; wall smooth, finely and abundantly perforate (perforations visible at 72X magnification); aperture a low slit at base of septal face, extending ventrally about half distance to margin, with slight lip, with a supplementary aperture at ventral margin of chamber. Dimensions: greater diameter, 0.27 to 0.53 mm.; lesser diameter/greater diameter, 78% to 92% (typically 83%); thickness/greater diameter 18% to 31% (typically 22%).

Internal morphology: Median sections (figure 17) usually show a subcircular outline. In larger specimens the last few chambers may be enlarged and show a very scalloped margin. The first whorl has 5 chambers with 9 in the second. Septa curve gently backward to the periphery. They are very slightly thickened above the aperture, extending forward to form a slight lip. The septa are narrow and contain the black line extending through their length and usually into the wall. Foramina (where visible) are low and of uniform height, increasing gradually in height as later chambers are added. The wall increases gradually in thickness from proloculum through the penultimate whorl, then decreases to the last chamber, where the wall is exceedingly thin. The ratio of thickness of the wall from the proloculum to the last chamber of the penultimate whorl to the last chamber is 1:3:1. A very thin keel is slightly thicker than the wall, which narrows to the last chamber and is absent on the last chamber. Lamination is faintly visible at high magnification (ca. 550X). Polarized light shows a wall consisting of radially oriented crystals. The diameter of proloculum is 0.01 to 0.015 mm. Height of last chamber, first whorl is 0.03 mm.; height of last chamber, second whorl is 0.09 mm.

Vertical sections (figure 18) show the test to be very much elongated, especially the chambers of the last whorl. Early chambers are usually semicircular in outline. The test is usually quite convex at the dorsal center, the ventral side being slightly concave. The concentric arrangement of the chambers indicates the planispiral pattern of the test. The proloculum usually lies slightly further dorsally, indicating a change from trochoid to planispiral. The wall is quite thick at the dorsal center (umbonal plug), with the ventral center being a little less thickened (umbilical plug). Foramina (where visible) are arched openings at the base of the septa, extending ventrally about half the distance to the margin. A supplementary aperture at the umbilicus is covered by an extension of the chamber wall, forming a flap which bends to the wall for complete closure in many specimens. The supplementary aperture is visible only in the last few chambers.

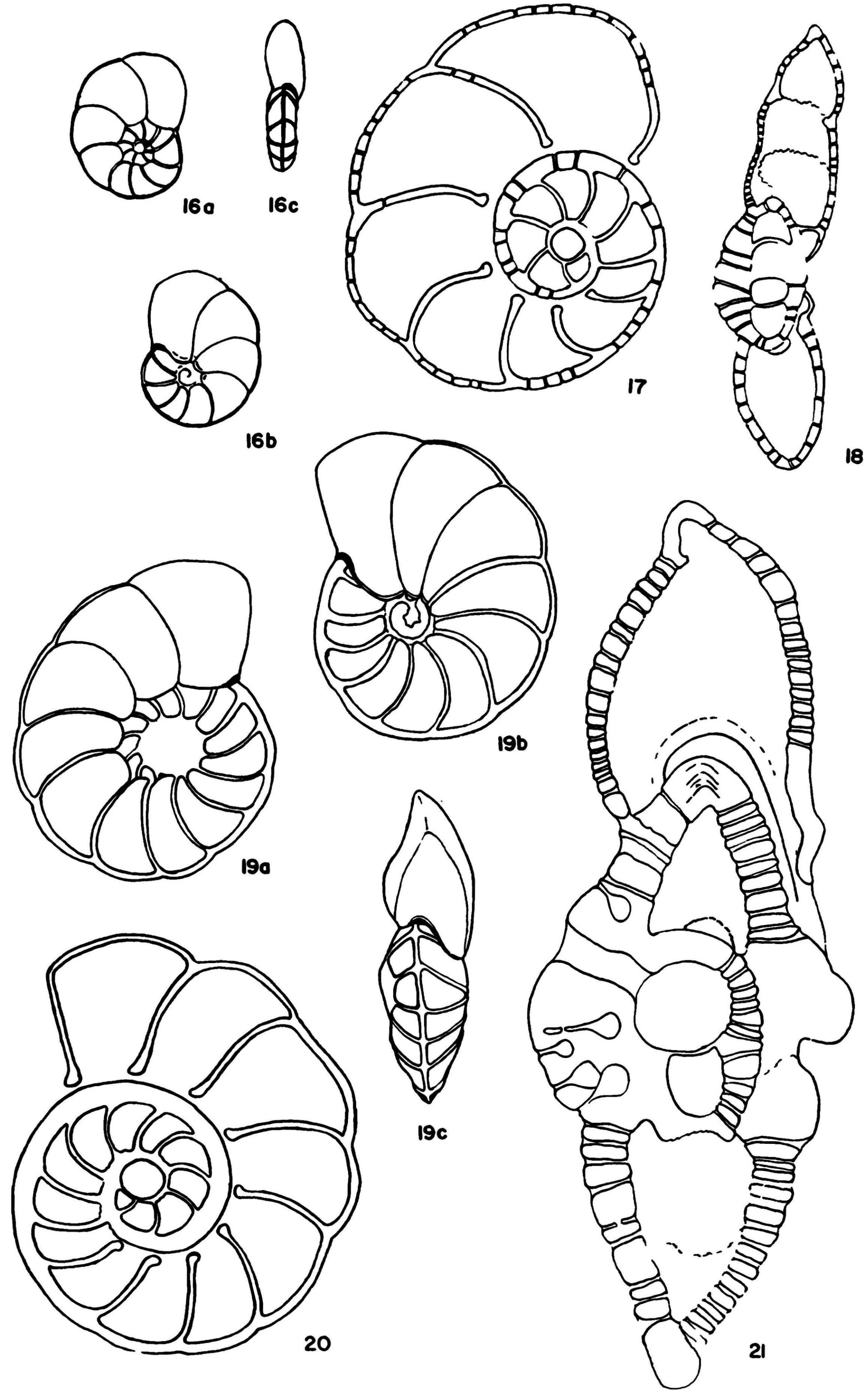
Characters of the wall: With decalcification a chitinoid layer was found, covering the external and internal surfaces, with the pores lined with the same material.

Pores in undecalcified thin sections are very fine and numerous, being slightly more numerous in the dorsal wall. They are straight and flare only toward the exterior at the dorsal center. Pores are less frequent in the wall of early chambers of the ventral side. The keel is perforate, as are the last few septa, but pores are less frequent in both structures. Sieve plates are present, and in many pores are situated about a quarter the distance from the exterior. This position, however,

EXPLANATION OF FIGURES

Figures 16-18. Planulina correcta (Carsey). 16. External views; greater diameter, 0.33 mm.; 16a, dorsal view; 16b, ventral view; 16c, apertural view. 17. M dian section; greater diameter, 0.33 mm. 18. Vertical section; height, 0.35 mm.

Figures 19-21. Planulina dumblei (Applin). 19. External views; greater diameter, 0.67 mm.; 19a, dorsal view; 19b, ventral view; 19c, apertural view. 20. Median section; greater diameter, 0.69 mm. 21. Ventral section; height, 0.68 mm.



is not always consistent. The plates are always nearer the exterior, but may be at varying distance from the surface.

PLANULINA DUMBLEI (Applin)

Text figures 19a, 19b, 19c, 20, 21

Anomalina taylorensis Dumble and Applin, 1924, Pan-Amer. Geol., 41:342 (nomen nudum).----Carsey, 1926, Univ. Texas, Bull., 2612:47, pl. 6, figs. 1 a-b.

Truncatulina dumblei Applin, 1925, in Applin, Ellisor and Kniker, Amer. Assoc. Petrol. Geol., Bull., 9:99, pl. 3, fig. 6 (reworked in Miocene strata).

Planulina taylorensis (Carsey). Cushman, 1931, Tenn. Dept. Ed., Div. Geol., Bull., 41: 62, pl. 12, figs. 5 a-c.

Planulina dumblei (Applin). Frizzell, 1954, Univ. Texas, Bur. Econ. Geol., Rept. Invest., 22:132, pl. 21, figs. 12 a-c.

Locality: No. 5; Williamson Co., Texas.

Stratigraphic position: Cretaceous, Taylor group, Pecan Gap chalk.

External morphology (figures 19a, 19b, 19c): Test calcareous-perforate, free, large, very low trochoid (nearly planispiral); outline subcircular, periphery smooth, slightly scalloped in last 2-5 chambers, subacute, with clear keel becoming reduced toward last chamber; typically more flattened above, both sides being much compressed although biconvex; dorsal side more evolute, ventral side less evolute, both sides becoming more evolute with age; with 2 to 3¼ whorls (typically 2½), 9 to 13 chambers in last whorl (typically 11); chambers of uniform shape, gradually increasing in size as added; center of dorsal side contains clear raised boss, ventral center with raised spiral of clear shell material; sutures distinct, raised, slightly limbate, becoming smooth to depressed in last 2 to 3, arched gently to periphery, ventral sutures slightly less raised than dorsal; wall smooth, finely and abundantly perforate; aperture an arched slit at base of septal face, extending ventrally to chamber margin. Dimensions: greater diameter, 0.44 to 0.93 mm. (typically 0.72 mm.); lesser diameter/greater diameter, 79% to 89% (typically 83%); thickness/greater diameter, 17% to 34% (typically 25%).

Internal morphology: Median sections (figure 20) show a subcircular outline, with the last 2 to 5 chambers scalloped. There are 6 chambers in the first whorl, 12 in the second whorl when present. The septa are narrow and of uniform thickness, curving gently backward to the periphery. They show a definate thickening above the aperture, and extend forward with a somewhat club-like projection that forms the external lip. The black line is distinct, extending from the forward basal part of the septa, through the septa, and into the wall near the internal surface, sometimes extending to the previous septum, at other times disappearing against the internal wall. Foramina (where visible) are of uniformly increasing height, but are relatively low. The diameter of the proloculum usually ranges from 0.046 to 0.053 mm. The wall increases gradually in thickness from proloculum through the penultimate whorl, then decreases to the last chamber. The approximate ratio of the wall thickness from proloculum to last chamber of the penultimate whorl to the last chamber is 1:4:2. A prominent clear keel is slightly thicker than the wall, and increases and decreases with the same ratio, but is absent on the last chamber. Lamellae are visible at high magnification (ca. 550X). Polarized light shows the wall to consist of radially oriented crystals.

Vertical sections (figure 21) show the test to be usually quite inflated at both dorsal and ventral center (umbonal and umbilical plugs).

The test is nearly planispiral, with only a very slight trochoid pattern in the first few chambers; later chambers overlap slightly more on the ventral side. The wall usually is very thick opposite the first whorl dorsally, and slightly less thickened ventrally, with the wall of the last chambers being very thin. Foramina in later chambers extend ventrally from the base of the septa to the margin. There is apparently fusion of the major aperture and the supplementary aperture. In early chambers, the foramina also extend slightly ventrally but do not open at the margin, being closed by later shell deposition.

Characters of the wall: Decalcification showed a very thin chitinoid layer, which envelopes the external and internal surface and lines the pores. This layer is easily ruptured, and much is lost with complete decalcification, necessitating use of very dilute acid. The test was always filled with secondary calcite, so the time for complete decalcification was usually long (four hours or more).

Other structures are seen in undecalcified thin sections: In chambers of the last whorl, pores are numerous, of small and equal size both dorsally and ventrally, flaring very slightly toward the external surface. Pores of the early whorls, on the dorsal side, are very large but infrequent. Also, on the dorsal side are large pocket-shaped pores, which taper to small openings at the external surface, but do not open into the interior. The ventral center often lacks pores, although they are found in chambers of early whorls in that area. The keel is nearly free of pores, although a few pocket-shaped pores are sometimes present. Pores do not penetrate the septa. Sieve plates were not found in this species, but may be present and unrecognizable because of the small size of the pores.

Subfamily CIBICIDINAE Galloway

Cibicidinae Galloway, 1933, Man. Foram., p. 290 (used as a subfamily of the Rotaliidae).

Diagnosis: Biconvex to slightly concavo-convex; initially trochoid, sometimes approaching planispiral in adult; sometimes becoming more evolute with maturity; aperture at base of septal face, extending dorsally for varying distances, with a supplementary aperture at dorsal margin of chamber.

Genus CIBICIDES Montfort

Cibicides Montfort, 1808, Conch. Syst., 1:123.

?Storilus Montfort, 1808, ibid., 1:131.

?Polyxenes Montfort, 1808, ibid., 1:139.

Truncatulina d'Orbigny, 1826, Ann. Sci. Nat., 7:279.

Lobatula Fleming, 1828, Hist. Brit. Anim., p. 232.

Rosalina (in part) of authors (not d'Orbigny).

Rotalina (in part) of authors (not d'Orbigny).

?Aristeropora Ehrenberg, 1858, K. Preuss. Akad. Wiss. Berlin, Monatsber., p. 11.

Heterolepa Franzenau, 1884, Termes. Furzetek, 8:181.

Pseudotruncatulina Andreae, 1884, Abh. geol. Spezialk Elsass-Loth., Bd. 2, Heft 3, p. 122.

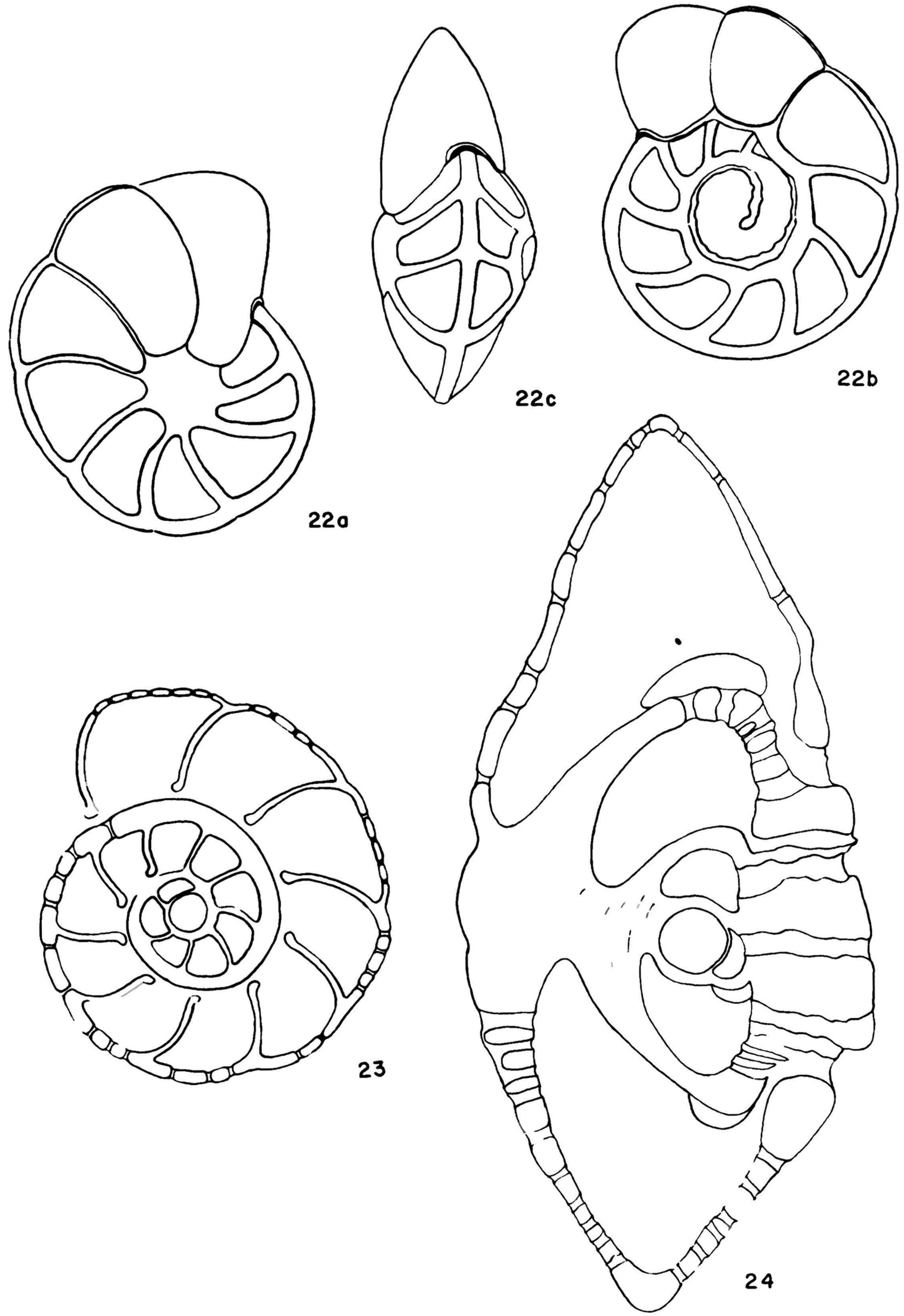
Description: Test free or loosely attached, plano-convex or biconvex; wall calcareous-perforate (radially crystalline); test trochoid to nearly planispiral; aperture a slit at base of septal face, extending dorsally, with a supplementary aperture at dorsal margin of chamber.

CIBICIDES ALLENI (Plummer)

Text figures 22a, 22b, 22c, 23, 24

Truncatulina alleni Plummer; 1927, Univ. Texas, Bull., 2644:144, pl. 10, fig. 4.

Cibicides alleni (Plummer). Plummer, 1933, Univ. Texas, Bull., 3201:54, 61 (lists).



EXPLANATION OF FIGURES

Figures 22-24. Cibicides alleni (Plummer). 22. External views; greater diameter, 0.73 mm.; 22a, ventral view; 22b, dorsal view; 22c, apertural view. 23. Median section; greater diameter, 0.61 mm. 24. Vertical section; height, 0.65 mm.

---Cushman, 1940, Cushman Lab. Foram. Research, Contr., 16:73, pl. 12, fig. 19.---Kline, 1943, Miss. Geol. Surv. Bull. 53:61, pl. 6, figs. 21-22.---Cooper, 1944, Jour. Paleontology, 18: 354, pl. 54, figs. 24-25.---Cushman, 1951, U.S. Geol. Surv., Prof. Papers, 232:66, pl. 18, figs. 16-17.

Locality: No. 2; Pulaski County, Arkansas.

Stratigraphic position: Paleocene, Midway group.

External morphology (figures 22a, 22b, 22c): Test calcareous-perforate, free, of medium size, trochoid; outline subcircular, periphery smooth, very slightly scalloped in last 1 to 3 chambers, rounded to subacute, with a thick and moderately wide keel becoming reduced toward last chamber; typically biconvex, more biconvex in young, slightly more convex below; dorsal side more evolute, becoming slightly more evolute with maturity, ventral side less evolute; with about 2 3/4 whorls in adult, 7 to 9 chambers in last whorl (typically 8), chambers increase uniformly in size as added; sutures smooth, arched gently to periphery, raised, becoming flush, last 1 to 3 slightly incised; earlier whorls of dorsal side concealed by raised clear umbonal boss, ventral center with large raised umbilical plug; wall smooth, coarsely perforate, with larger pores at dorsal center; aperture an arched opening at base of septal face, extending dorsally about ¼ width of chamber under slight lip, with a supplementary aperture at the dorsal margin. Dimensions: greater diameter, 0.19 to 0.73 mm. (typically 0.50 mm.); lesser diameter/greater diameter, 80% to 91% (typically 86%); thickness/greater diameter, 34% to 56% (typically 44%).

Internal morphology: Median sections (figure 23) show a subcircular outline, with last 2 to 3 chambers showing a very slight degree of scalloping. The first whorl has 5 chambers, with 10 in the second whorl. Septa curve very gently backward to the periphery, and are thin, with the initial part above the aperture showing a slight forward thickening. They increase very gradually as added, and show an intermediate darkened area (the black line) extending from the aperture to the preceding septum in many specimens. This darkened area lies close to the internal surface. Apertures are usually visible in all chambers of the last whorl when the section is cut through the center of the proloculum, characterizing the trend toward planispiral coiling in the last whorl. The wall increases gradually in thickness from the proloculum through the penultimate whorl, then decreases in thickness to the last chamber. The ratio of the wall thickness from the proloculum to the last chamber of the penultimate whorl to the last chamber is approximately 1:5:2. A clear keel is slightly thicker than the wall, and is imperforate. Faint lamination is visible in the wall when viewed at high magnification (ca. 550X).

Vertical sections (figure 24) show the test to be inflated, especially in the vicinity of the central region. The last chambers are ogival in outline, with earlier chambers semicircular. Initial chambers lying close to the dorsal side show the trochoid coiling, with chambers of later whorls overlapping the earlier chambers. The wall is very thick in the vicinity of the ventral umbilical plug, and also in the dorsal umbonal plug. Foramina (when visible) are arched openings at the base of the septa, and extend dorsally about a quarter the distance to the margin. Later chambers contain a supplementary aperture at the margin of the chamber on the dorsal side. This opening, however, does not occur in earlier chambers, being closed by later shell deposition.

<u>Characters of the wall</u>: Decalcified preparations were used to determine the presence of organic material in the wall. A chitinoid layer was found, covering the external and internal surfaces and lining the connecting pores. The septa also are enclosed in this chitinoid layer.

Pores in the chambers of the last whorl are of uniformly large size on both dorsal and ventral sides. They are nearly straight, flaring slightly near the interior and exterior surfaces, but slightly more toward the exterior. In earlier whorls, pores are absent in the ventral wall, but numerous and large in the dorsal wall. These dorsal pores taper outward to the exterior, and in many instances several small pores unite to form very large pores. The keel is relatively free of pores, those that were seen being pocket-like. They do not penetrate the internal surface, being enlarged within the keel and having a narrow opening at the external surface. The pores contain minutely porous sieve plates, which lie very near the external surface. The sie e plates seem to be partly destroyed after decalcification, apparently containing some calcium carbonate embedded in the chitinoid plate.

CIBICIDES BEAUMONTIANUS (d'Orbigny)

Text figures 25a, 25b, 25c, 26, 27

Truncatulina beamontiana d'Orbigny, 1840, Soc. Geol. France, Mem., [1]4:35, pl. 3, figs. 17-19.

Cibicides involuta (Reuss). Cushman, 1931, Jour. Paleontology, 5:315, pl. 36, figs. 10 a-c (not Rotalina involuta Reuss).

C. beaumontiana (d'Orbigny). Brotzen, 1936, Sver. Geol. Unders., Afl.[ser. C,no.396] 30(3):188.

C. beaumontianus (d'Orbigny). Cushman, 1940, Cushman Lab. Foram. Research, Contr., 16(2):39-40, pl. 7, fig. 9; 1946, U.S. Geol. Surv., Prof. Papers, 206:160, pl. 65, fig. 12 (synonymy).---Frizzell, 1954, Univ. Texas, Bur. Econ. Geol., Rept. Invest., 22:132, pl. 21, figs. 19 a-c.

Locality: No. 5; Williamson Co., Texas.

Stratigraphic position: Upper Cretaceous, Taylor group, Pecan Gap chalk.

External morphology (figures 25a, 25b, 25c): Test calcareous-perforate, free, large, low trochoid; outline subcircular to irregular, periphery acute and smooth to irregular; typically flat to slightly concave above and very convex below; dorsal side evolute, ventral side involute and becoming less involute with age; about $2\frac{1}{4}$ whorls in adult, 5 to 8 chambers in last whorl (typically 6), last 2 to 3 chambers of adult increasing rapidly in size and somewhat irregular; sutures slightly raised, smooth, strongly arched, ventral sutures slightly incised in later portion; wall smooth, with a slightly umbonal thickening on dorsal side, with medium sized perforations; aperture a low slit at base of septal face, extending dorsally about two-thirds distance to margin. Dimensions: greater diameter, 0.43 to 0.97 mm. (typically 0.71 mm.); lesser diameter/greater diameter, 71% to 88% (typically 76%); thickness/greater diameter, 25% to 37% (typically 29%).

Internal morphology: Median sections (figure 26) show a subcircular to irregular outline, with later chambers of mature specimens being quite irregular in outline. There is an a erage of 5 chambers in the first whorl and 7 in the second whorl. The diameter of the proloculum range from 0.037 to 0.047 mm. The septa of early chambers curve gently backward to the periphery. The later septa are somewhat irregular, however, and usually curve slightly forward for about a quarter of their length, then curve backward. They are of uniformly increasing thickness, the early ones being quite thin. The dark line is distinct, and extends through the septa and, in many instances, into the wall near the internal surface, sometimes disappearing at the internal surface. A club-like thickening, above the aperture, extends slightly forward in some septa. The wall increases gradually in thickness from the proloculum through the penultimate whorl, then thins to the last chamber, with a ratio of approximately 1:5:2. A keel is visible in sections cut near the dorsal side, and is almost without pores and not greatly thicker than the wall. Foramina usually show in all chambers of the last whorl, in sections cut through the proloculum, showing the planispiral pattern. The foramina are of uniformly increasing height and moderate size. All specimens examined were filled with secondary calcite.

Vertical sections (figure 27) show the test to be convex ventrally and flattened to concave dorsally, with the wall much thicker at the dorsal center and around chambers of the first whorl (umbonal plug). The proloculum lies near the dorsal wall, and later chambers completely overlap early chambers on the ventral side. Later chambers are usually much larger and are generally somewhat irregular. The supplementary aperture shows as an opening at the dorsal margin, at the base of the chamber. Foramina were not seen, the septa being obscured by deposits of calcite matrix.

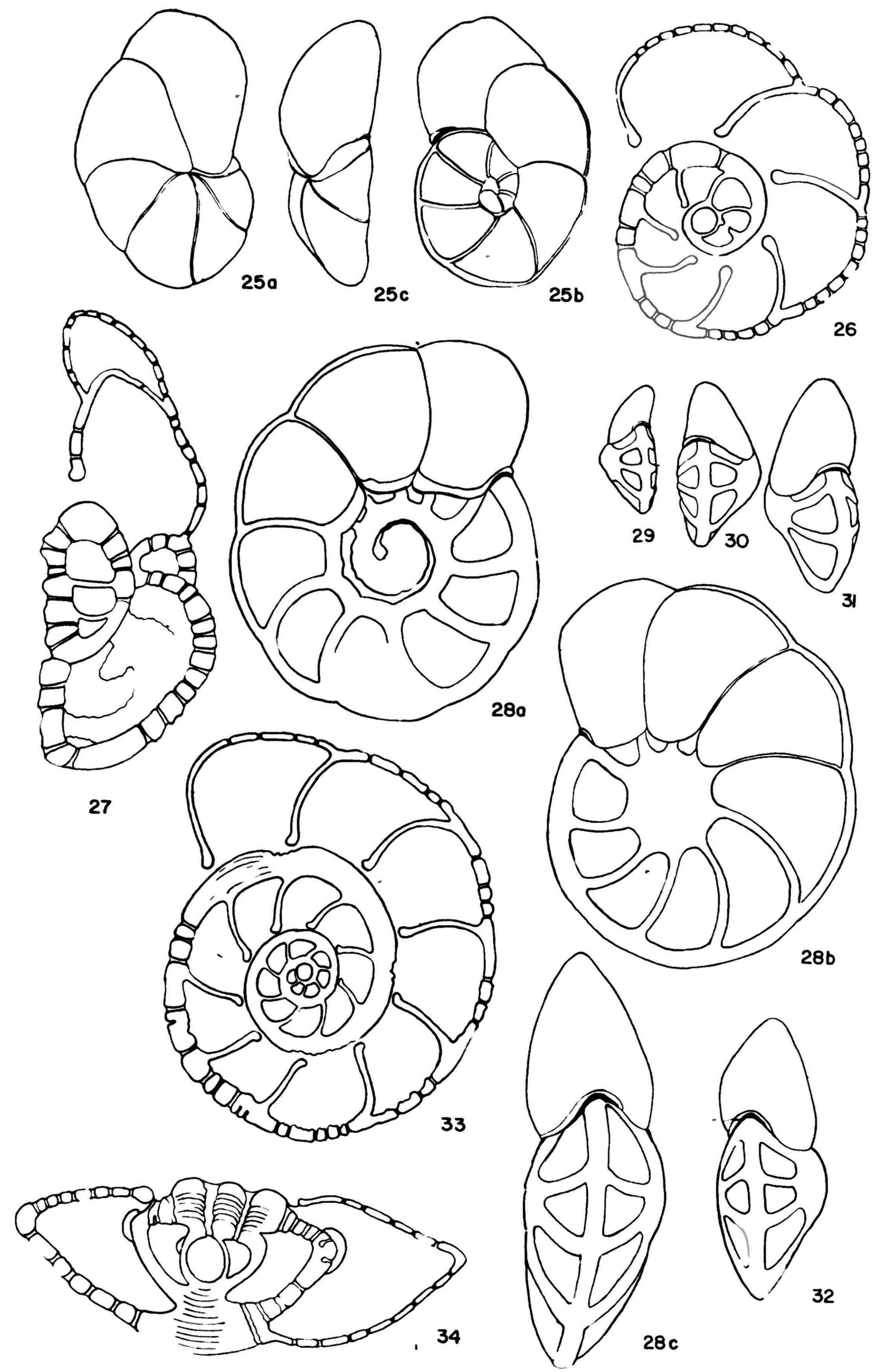
Characters of the wall: On decalcification, a chitinoid layer was found in the test, both externally and internally, with the pores line with the same material. Tests were always filled with secondary calcite, so complete decalcification usually took some time. With the extended decalcifying period, the chitinoid layer usually became badly ruptured and pore plates were destroyed. The layer, although still visible, was very fragmental.

Pores as seen in undecalcified sections, are much more abundant in the ventral than in the dorsal wall. In one vertical section, 79 pores penetrate the ventral wall and only 31 the dorsal. The pores are of medium size, but frequently are slightly larger on the ventral side. They flare slightly more toward the external surface than the internal. Pores of the dorsal umbonal plug flare from interior to exterior. Sieve plates were visibly in some of the pores during decalcification.

EXPLANATION OF FIGURES

Figures 25-27. Cibicides beaumontianus (d'Orbigny). 25. External views; greater diameter, 0.61 mm.; 25a, ventral view; 25b, dorsal view; 25c, apertural view. 26. Median section; greater diameter, 0.53 mm. 27. Vertical section; height, 0.77 mm.

Figures 28-34. Cibicides harperi (Sandidge). 28. External views; greater diameter, 0.88 mm.; 28a, dorsal view; 28b, ventral view; 28c, apertural view. 29. Apertural view; height, 0.28 mm. 30. Apertural view; height, 0.37 mm. 31. Apertural view; height, 0.48 mm. 32. Apertural view; height, 0.63 mm. 33. Median section; greater diameter, 0.91 mm. 34. Vertical section; height, 0.78 mm.



Their nature was not ascertained, however, as they were not visible after complete decalcification.

CIBICIDES HARPERI (Sandidge)

Text figures 28a, 28b, 28c, 29, 30, 31, 32, 33, 34

<u>Anomalina</u> <u>harperi</u> Sandidge, 1932, Am. Mid. Nat. 13:316, pl. 29, figs. 1-2.

<u>Cibicides</u> <u>ripleyensis</u> (W. Berry). Sandidge, 1932, Am. Mid. Nat. 13:199, pl. 19, figs. 17-19 (not <u>Truncatulina</u> <u>ripleyensis</u> W. Berry).

<u>C</u>. <u>harperi</u> (Sandidge). Cushman, 1946, Cushman Lab. Foram. Research, Contr., 16 (2):38, pl. 7, figs. 3-5; 1946, U.S. Geol. Surv., Prof. Papers, 206:159, pl. 65, figs. 5-7.---Frizzell, 1954, Univ. Texas, Bur. Econ. Geol., Rept. Invest., 22:133, pl. 21, figs. 22 a-b.

<u>Locality</u>: No. 4; Livingston, Alabama.

<u>Stratigraphic position</u>: Cretaceous, Navarro group, Selma chalk.

<u>External morphology (figures 28a, 28b, 28c, 29, 30, 31, 32)</u>: Test calcareous-perforate, free, large, depressed trochoid; outline subcircular, periphery subacute, with keel, last 3 to 5 chambers scalloped; keel wide, thick, becoming reduced

toward last chamber; typically biconvex in larger forms, with dorsal center flattened, younger forms with ventral side somewhat conical, with dorsal side tending to be flattened; ventral side involute, dorsal side becoming more evolute with age; with 2½ to 4¼ whorls (typically 3), 7 to 10½ chambers in last whorl (typically 9), chambers increasing uniformly in size; sutures moderately and evenly arched, wide, smooth, raised in most of test, becoming smooth and slightly depressed in last 1 to 3 chambers, ventral sutures less raised than dorsal, early chambers of dorsal side concealed by moderately high irregular spiral of clear shell material, ventral side with raised umbilical plug; wall smooth, very coarsely perforate, with larger pores in umbilical plug and dorsal spiral; aperture an arched opening at base of septal face, extending dorsally about half distance to margin under slight lip, with a supplementary aperture at the dorsal margin of the chamber. Dimensions: greater diameter, 0.20 mm. to 1.2 mm. (typically 0.73 mm.); <u>lesser diameter/greater diameter</u>, 76% to 92% (typically 85%); <u>thickness/greater diameter</u>, 30% to 57% (typically 44%).

<u>Internal morphology</u>: Median sections (figure 33) show a subcircular outline, with the last 3 to

6 chambers scalloped. The first whorl usually has 6 chambers with 9 in the second, 10 in the third and 10 in the fourth. The septa curve gently backward to the periphery, and are thickened above the aperture, being somewhat club-like. They are quite narrow, and increase slightly in size as later chambers are added. The black line is very distinct, extending from the forward basal part of the septum, through its length and into the wall of the chamber, sometimes reaching the previous septum, and in some specimens apparently joining the dark line of that septum. Foramina (where visible) increase uniformly in height as chambers are added. Large specimens, cut through the center of the proloculum, show as many as 14 foramina in the younger whorls of the test, demonstrating the planispiral trend with increase in age. The wall increases gradually in thickness from proloculum through the penultimate whorl, then decreases to the last chamber. The approximate ratio of the wall thickness from the proloculum to the last chamber of the penultimate whorl to the last chamber is 1:6:2. A very prominent clear keel is slightly thicker than the wall, and increases and decreases with the same ratio; it is absent on the last chamber. Lamellae are visible at low mag-

nification (ca. 72X). Polarized light shows the wall to consist of radially oriented crystals.

Vertical sections (figure 34) show the test to be inflated, especially in the smaller forms. The early chambers show a flattened dorsal and convex ventral side, with later chambers tending to be more equally biconvex but somewhat compressed. The slightly more dorsal position of the early chambers, with the later chambers over-lapping more ventrally, indicates the trochoid coiling; in many specimens, the coiling is practically planispiral throughout. The wall is greatly thickened at the dorsal and ventral centers (umbonal and umbilical plugs). Lamillae are very distinct, being quite numerous opposite the proloculum. In one specimen, a minimum 23 lamellae were counted on either side of the proloculum. Foramina (where visible) are arched openings at the base of the septal face extending dorsally about half the distance to the margin. There is a supplementary aperture in the last chambers at the dorsal margin. This supplementary aperture is not present in earlier chambers, being closed by later shell material.

<u>Character of the wall:</u> On decalcification, a very thin chitinoid layer was found, which envelopes the external and internal surfaces of the

test and septa. This material is thinner than that found associated with Cibicides vulgaris. After complete decalcification the chitinoid material, although still visible, is always ruptured in many places and widely distributed on the slide. The organic lining of the pores apparently holds the pore plates in position. The plates seem to be partly destroyed with decalcification, perhaps being partly composed of calcium carbonate.

Pores as seen in undecalcified thin sections, are large, numerous, and of uniform size in both dorsal and ventral walls of the last whorls. They flare slightly as they approach the exterior and interior surface. Pores of the dorsal center usually are enlarged and taper outward. In this region, the lamellae show a definite tendency to bend inward, where they are cut by the pores. The ventral center is nearly free of pores, with chambers of the second whorl also being almost without pores in the ventral wall. The keel is free of ordinary pores, but an infrequent pocket-shaped pore is present. These do not open to the interior, being large within the wall and narrowing to the exterior surface. The septa are usually free of pores, although a few were observed in the last septum of a few specimens. In many of the larger pores, sieve plates were observed, apparently lying near the exterior surface. These plates apparently are minutely perforate, although the nature of the perforation could not be determined.

Genus CIBICIDINA Bandy

Cibicides (in part) of authors (not Montfort, 1808).

Anomalina (in part) of authors (not d'Orbigny, 1826).

Cibicidina Bandy, 1949, Bulls. Amer. Pal., 32(131):121(91).

Description: Test calcareous-perforate (radially crystalline), trochoid; plano-convex to slightly concavo-convex, becoming very slightly planispiral; ventral side involute, dorsal side slightly more evolute; perforations fine and numerous; aperture a small arched opening at the base of the septal face, extending dorsally, with a supplementary aperture at the dorsal margin of the chamber under a flap-like extension of the chamber wall.

CIBICIDINA DANVILLENSIS (Howe and Wallace)

Text figures 35a, 35b, 35c, 36, 37

Cibicides danvillensis Howe and Wallace, 1932, La. Dept. Cons., Geol. Bull., 2:77, pl. 14, fig. 5.---Cushman and Herrick, 1945, Cushman Lab. Foram. Research, Contr., 21:72, pl. 11, fig. 14. ---Cushman, 1946, Cushman Lab. Foram. Research, Special Publ., 16:39, pl. 8, figs. 7-8.

Cibicidina danvillensis (Howe and Wallace). Bandy, 1949, Bulls. Amer. Paleontology, 32(131):92, pl. 14, figs. 7 a-c.

Locality: No. 1; Brazos Co., Texas.

Stratigraphic position: Eocene, Claiborne group, Wheelock fm.

External morphology (figures 35a, 35b, 35c): Test calcareous-perforate, free, small, low trochoid; outline subcircular, periphery smooth, subacute, with low and narrow keel becoming reduced toward last chamber; typically flat to slightly concave above, convex below; both sides involute, dorsal side tending to be less involute with age; with 2 to 3 whorls (typically 2½), 7 to 9 chambers in last whorl (typically 9); chambers moderately narrow, increasing uniformly in size as added; sutures moderately and evenly arched, smooth, narrow, slightly limbate, flush in most of test, first sutures visible on dorsal side very slightly raised, with small clear umbilical plug ventrally, with clear low boss on dorsal side; wall smooth, finely perforate, pores more numerous below; aperture a low arched slit at base of septal face, extending dorsally about half distance to margin, with supplementary aperture along dorsal margin of chamber. Dimensions: greater diameter, 0.13 to 0.31 mm. (typically 0.23 mm.); lesser diameter/greater diameter, 76% to 86% (typically 79%); thickness/greater diameter, 26% to 41% (typically 31%).

Internal morphology: Mediam sections (figure 36) show a subcircular outline, with the last 3 to 5 chambers slightly scalloped. The first whorl has 6 chambers, with 8 or 9 in the second. The septa of the first whorl usually are quite straight, with later septa curving gently backward to the periphery. The last 3-5 septa curve forward for about a quarter their length, then curve backward. The ends of septa, above the aperture, extend slightly forward, forming the external lip. The septa are quite narrow, thickening very little as added, and show the intermediate black line extending into the chamber wall. The wall increases gradually in thickness from the proloculum through the penultimate whorl, then decreases to the last chamber. The ratio of wall thickness from the proloculum to last chamber of the penultimate whorl to the last chamber is 1:4:2. Foramina (where visible) are moderately high, increasing gradually in height in later chambers. The wall in polarized light is shown to be of radially oriented crystals; in one specimen the structure was found to be acicular.

Vertical sections (figure 37) show a somewhat flattened to slightly concave dorsal side, with a convex ventral side. Chambers are somewhat triangular in outline, with convex ventral sides. The proloculum usually lies close to the dorsal wall, indicating the initial trochoid coiling. The wall of the last chamber visible is very thin. Foramina (where visible) are well arched openings at the base of the septa, extending dorsally a short distance. Dorsal supplementary apertures are present in the last 3 or 4 chambers, but are filled in earlier chambers. At high magnification (ca. 550X), faint lamellae are visible, both dorsally and ventrally of the proloculum.

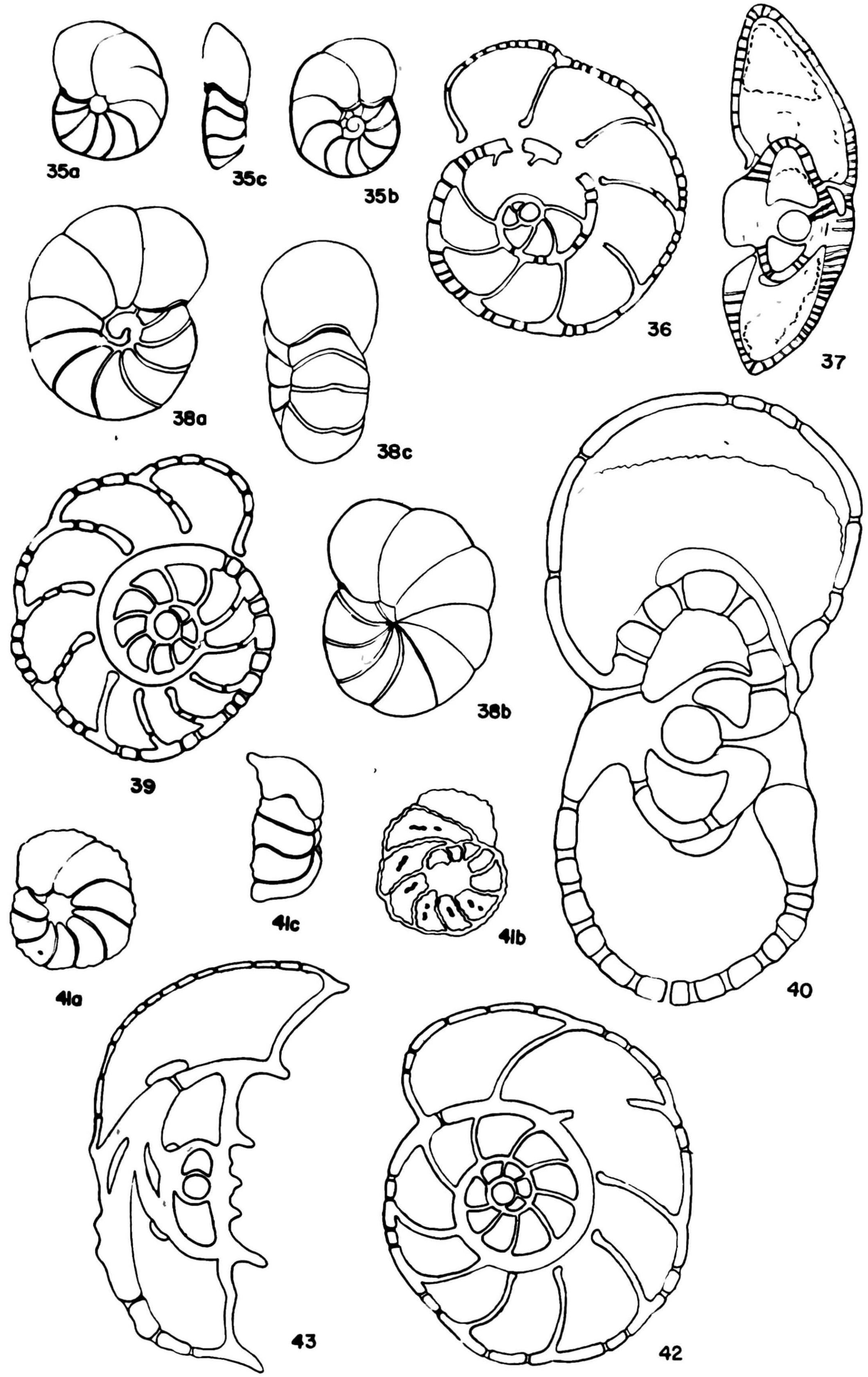
Characters of the wall: Decalcification revealed a thin chitinoid layer, covering the internal and external surfaces and lining the pores. This layer usually is stained in places to a deep reddish-brown, and the pores sometimes are filled.

EXPLANATION OF FIGURES

Figures 35-37. Cibicidina danvillensis (Howe and Wallace). 35. External views; greater diameter, 0.30 mm.; 35a, ventral view; 35b, dorsal view; 35c, apertural view. 36. Median section; greater diameter, 0.24 mm. 37. Vertical section; height, 0.29 mm.

Figures 38-40. Anomalinoides pinguis (Jennings). 38. External views; greater diameter, 0.47 mm.; 38a, dorsal view; 38b, ventral view; 38c, apertural view. 39. Median section; greater diameter, 0.50 mm. 40. Vertical section; height, 0.51 mm.

Figures 41-43. Stensioina americana Cushman and Dorsey. 41. External views; greater diameter, 0.31 mm.; 41a, ventral view; 41b, dorsal view; 41c, apertural view. 42. Median section; greater diameter, 0.29 mm. 43. Vertical section; height 0.32 mm.



The filling and discoloration seem to be caused by the presence of pyritic material within the test, and are resistant to decalcification.

Pores are best studied in undecalcified thin sections. They are fine and very numerous in both the dorsal and ventral walls of the last whorl, being straight and of very uniform size. At the dorsal center, pores are practically absent, although the ventral center contains many pores which usually curve slightly to the left or right of the umbilical plug. Pores are present in the septa but very infrequent. Sieve plates were not proved to be present in this species, although some pores exhibited closure near the external surface of the wall. The pores are quite small, and the presence of sieve plates was not demonstrated.

Genus ANOMALINOIDES Brotzen

Anomalina (in part) of authors (not d'Orbigny, 1826).

Anomalinoides Brotzen, 1942, Sver. Geol. Unders., [ser. C]451:23.

Description: Test calcareous-perforate (radially crystalline), free, slightly trochoid becoming planispiral; completely involute on ventral side, nearly involute on dorsal side; biconvex, considerably inflated, young forms sometimes very slightly flattened on dorsal side; aperture an arched slit at base of septal face, extending dorsally, with a supplementary aperture at dorsal margin of chamber.

ANOMALINOIDES PINGUIS (Jennings)

Text figures 38a, 38b, 38c, 39, 40

Anomalina grosserugosa (Gümbel). Carsey, 1926, Univ. Texas, Bull., 2612:46-47, pl. 3, figs. 3 a-b.---Plummer, 1931, Univ. Texas, Bull., 3101:201, pl. 14, figs. 9 a-c. (not Truncatulina grosserugosa Gümbel).

A. pinguis Jennings, 1936, Bull. Amer. Paleontology, 23(78):37, pl. 5, fig. 1.---Cushman, 1946, U.S. Geol. Surv., Prof. Papers, 206:156.

Anomalinoides plummerae Brotzen, 1942, Sver. Geol. Unders., Afl. /ser. C,no.451/36 (8):23.

Anomalinoides pinguis (Jennings). Frizzell, 1954, Univ. Texas, Bur. Econ. Geol., Rept. Invest , 22:131, pl. 21, figs. 8 a-c.

Locality: No. 5; Williamson Co., Texas.

Stratigraphic position: Cretaceous, Taylor group, Pecan Gap chalk.

External morphology (figures 38a, 38b, 38c): Test calcareous-perforate, free, of medium size, low trochoid; outline subcircular, periphery smooth to slightly scalloped, without keel; typically biconvex, immature forms slightly flattened dorsally; ventral side completely involute, dorsal side slightly more evolute; about 2½ whorls in adult, 7 to 10 chambers in last whorl (typically 9), last 3 to 4 chambers inflated; dorsal sutures raised, evenly arched to periphery, starting from a raised spiral of clear shell material, flush toward last chambers, becoming incised at last one to two chambers; ventral sutures raised, limbate, becoming incised; wall smooth, coarsely perforate, with pores in septal face; aperture an arched slit at base of septal face, joining smoothly with dorsal supplementary opening and extending nearly to penultimate chamber. Dimensions: greater diameter, 0.31 to 0.65 mm. (typically 0.52 mm.); lesser diameter/greater diameter, 74% to 86% (typically 79%); thickness/greater diameter, 37% to 46% (typically 41%).

Internal morphology: Median sections (figure 39) show a subcircular outline, with the peripheral margin of the whorls well rounded except for the last 3-5 chambers, where a slight scalloping occurs. There is an average of 2½ whorls, with 6 chambers in the first whorl and 11 in the second. The wall increases in thickness from the proloculum through the last chamber of the penultimate whorls, then thins to the last chamber. The ratio of wall thicknesses in proloculum, last chamber of penultimate whorl, and last chamber is 1:4:2. Laminations are faintly visible at high magnification (ca. 550X) throughout the thickened wall. The septa are thick and fairly uniform, being straight for about a quarter their length in later chambers, then curving slightly backward to the periphery. A club-like thickening above the foramen forms the external lip. The darkened intermediate area (black line) is present, extending from the forward part of the septum above the foramen into the wall of the chamber. Dimensions: Diameter of proloculum, 0.030 to 0.045 mm.; height of last chamber of first whorl, 0.045 to 0.055 mm.; height of last chamber, 0.09 to 0.13 mm.

Vertical sections (figure 40) show the test to be inflated, being very thick on the dorsal and ventral sides opposite the proloculum (umbonal and umbilical plugs). In some sections, the final whorl completely overlaps the previous whorls on the ventral side. This is more pronounced in smaller specimens, showing, the increase of evoluteness with maturity. Foramina in the last chambers are arched openings at the base of the septa, extending dorsally as slits almost to the margin and joining the dorsal supplementary opening. In earlier chambers, the foramina are arched openings extending dorsally almost to the margin of the chamber, the supplementary aperture being closed by secondary shell deposition.

Characters of the wall: After complete solution of the calcareous test, an interior and exterior chitinoid layer was observed, with pores also lined with the chitinoid material. This layer was thinner than found in Anomalina vulgaris and quite easily ruptured. All the specimens of this species, sectioned or decalcified, were found to be filled with secondary calcite, therefore requiring longer periods of decalcification.

Pores were studied in undecalcified thin sections. They are straight, large, and numerous, flaring slightly as they approach the exterior and interior surfaces. They penetrate the septal face in all its area, except for a distance about a quarter the length of the face above the aperture.

Sparser pores of larger than average size penetrate the dorsal wall from the surface to the proloculum. Pores are practically absent in the ventral side of earlier chambers. Sieve plates were seldom observed, although in a few instances they seemed to be situated near the external surface of pores. The nature of these plates could not be observed.

Family DISCORBIDAE

Glaessner (1945), p. 145.

Subfamily DISCORBINAE

Glaessner (1945), pp. 145-146.

Genus STENSIOINA Brotzen

Rotalia (in part) of authors (not Lamarck, 1804).

Cibicides (in part) of authors (not Montfort, 1808).

Truncatulina (in part) of authors (not d'Orbigny, 1826).

Gyroidina (in part) of authors (not d'Orbigny, 1826).

Stensioina Brotzen, 1936, Sver. Geol. Unders., /ser. C/396:164.

Stensioina is included in this study to show the similarities, differences, and apparent relationship of a discorbid species with the anomalinid forms studied. Its structures support the interpretation that the genus belongs to the Discorbidae, rather than the Anomalinidae, but a genetic relationship (possibly of superfamily rank) is indicated by the wall structure of these forms.

STENSIOINA AMERICANA Cushman and Dorsey

Text figures 41a, 41b, 41c, 42, 43

Cibicides excolata (Cushman). Cushman, 1931, Jour. Paleontology, 5:315, pl. 36, figs. 8 a-c (not Truncatulina excolata Cushman).

Stensioina excolata (Cushman). Cole, 1938, Florida Geol. Surv., Bull., 16:35, pl. 3. figs. 2-3 (not of Cushman).

S. americana Cushman and Dorsey, 1939, Cushman Lab. Foram. Research, Contr., 16 (1):5-6, pl. 1, fig. 7.---Cushman, 1946, U.S. Geol. Surv., Prof. Papers, 206:141-142, pl. 65, fig. 14 (synonymy).

Locality: No. 4, Livingston, Alabama.

Stratigraphic position: Cretaceous, Navarro group, Selma chalk.

External morphology (figures 41a, 41b, 41c): Test calcareous-perforate, free, small, trochoid; outline circular, periphery very slightly irregular; with low, moderately wide, keel, becoming reduced toward last chamber, predominatly visible from dorsal side; typically flat to concave above and convex below, dorsal side evolute, ventral side involute; with about 2½ whorls in the adult, 7 to 9 chambers in last whorl (typically 8); dorsal sutures raised, marked by irregular, broken, gently curving costae; ventral sutures slightly raised, becoming flush, last 2 to 3 very slightly depressed, arching gently to periphery from a smooth to slightly depressed umbilicus plug; wall with medium size perforations, ventral side smooth, dorsal side marked by irregular raised shell material between the sutures; aperture a low arched slit at base of septal face, about midway between umbilicus and periphery. Dimensions: greater diameter, 0.20 to 0.34 mm. (typically 0.27 mm.); lesser diameter/greater diameter, 85% to 91% (typically 89%); thickness/greater diameter, 46% to 53% (typically 50%).

Internal morphology: Median sections (figure 42) show an almost circular outline, with the margin in some cases slightly irregular, and the last 1 to 3 chambers very slightly scalloped. The first whorl has 5 chambers, with 9 in the second whorl, with a maximum of 2½ whorls. The septa curve backward to the periphery, and the later septa are usually quite sharply curved. They are narrow and smooth, although when viewed from the dorsal exterior are usually quite irregular. The ends of the septa are thickened, projecting forward just above the aperture. The black line is visible in median sections, extending through the septa and into the wall, but not joining the black line of the previous septum. Foramina (where visible) are low and of uniform height, but few are seen in any single section. The wall of the test increases gradually in thickness from proloculum through the penultimate whorl, then thins to the last chamber. The ratio of the wall from the proloculum to last chamber of the penultimate whorl to the last chamber is 1:4:2. Faint lamellae are visible at high magnification (ca. 550X). Polarized light shows the wall to consist of radially oriented crystals. Dimensions: Diameter of proloculum 0.010 to 0.015 mm., height of last chamber first whorl/greater diameter approximately 9%; height last chamber/greater diameter approximately 23%.

Vertical sections (figure 43) show a concavo-convex outline, with later chambers overlapping the earlier chamber at the ventral center, although there is very little overlap on the dorsal side.

On the dorsal side, the margin of each whorl extends upward from the dorsal surface as a conspicuous flange, and tends to flare outward. The wall is thickened at the dorsal center and adjacent to the first whorl ventrally, but becomes very thin at the last visible chamber. Foramina (where visible) are small arched openings, which in the last chambers are about half way between the ventral center and periphery; in earlier chambers, the foramina are slightly nearer the ventral center, migrating toward the periphery with maturity.

<u>Characters of the wall</u>: Upon decalcification, a thin chitinoid layer was found, bordering the external and internal surfaces, with the pores lined with the same material. Pore plates were not found in the decalcified specimens, nor in crushed tests.

Details of perforation of the test are seen in undecalcified thin sections. Pores are of medium size but less numerous than in the anomalinid species. They are generally restricted to the ventral side, although rarely a few pores are present in the last formed chambers of the dorsal side. The majority of the septa are imperforate, although a few pores are usually present in the last septum.

The pores flare toward the external and internal surfaces, flaring slightly more toward the exterior.

LIST OF REFERENCES

(Exclusive of synonymic entries.)

Arnold, Z. M., 1954. Discorinopsis aguayoi (Bermudez) and Discorinopsis vadescens Cushman and Bronnimann: A study of variation in cultures of living foraminifera. Cushman Lab. Foram. Research, Contr., 5(1):4-13, pls. 1-2, fig. 1.

_____1954-A. A note on foraminiferan sieve plates. Cushman Lab. Foram. Research, Contr., 5(2):77.

Bandy, O. L., 1949. Eocene and Oligocene foraminifera from Little Stave Creek, Clarke County, Alabama. Bulls. Am. Paleontology, 32 (131):1-211, pls. 1-27, figs. 1-2, table 1.

Carpenter, W. B., 1862. Introduction to the study of the foraminifera. London (Hardwicke), pp. 1-319, pls. 1-22, figs. 1-47.

Cushman, J. A., 1948. Foraminifera, their classification and economic use. ed. 4, Cambridge (Harvard Univ. Press), pp. 1-605, pls. 1-55, text pls. 1-31, text figs. 1-9.

Frizzell, D. L., 1945. Dimensions, whorls, and chamber counts in foraminiferal family Camerinidae. Jour. Paleontology, 19(1):75.

Galloway, J. J., 1933. A manual of foraminifera. Bloomington (Principia Press), pp. 1-483, pls. 1-42.

Glaessner, M. F., 1945. Principles of micropalaeontology. New York (Wiley), pp. 1-296, pls. 1-14, figs. 1-64, tables 1-7.

Hofker, J., 1951. The foraminifera of the Siboga Expedition, part 3. Siboga Expeditie, Mon. 4a, pp. 1-513, text figs. 1-348.

Smout, A. H., 1954. Lower Tertiary foraminifera of the Qatar Peninsula. Norwich (Jarrold and Sons), pp. 1-96, pls. 1-15, figs. 1-44.

Wood, A., 1948. The structure of the wall of the test in foraminifera; its value in classification. Quart. Jour. Geol. Soc., London, 104(2):229-255, pls. 13-15.

Vita

Billy G. Deaver was born November 24, 1925, in Huntington, West Virginia. He received his elementary education in the Huntington area, and graduated from Huntington East High School in January, 1944.

He served in the Army Infantry in the European Theater, from September, 1944, to May, 1946.

In 1946, upon discharge from the Army, he enrolled in Marshall College, and graduated in June, 1950, receiving the degree of Bachelor of Science.

He was called to active duty with the Navy in December, 1950, and served with the Atlantic Fleet until discharge in September, 1952.

In 1953, he enrolled in Missouri School of Mines and Metallurgy and graduated in August, 1954, receiving a second degree of Bachelor of Science, in geology. He enrolled as a graduate student in September, 1954.

He was married to Mona Lou Long, in 1949, and has one child.