Calcareous Nannoplankton and Stratigraphy of Late Turonian, Coniacian, and early Santonian Age of the Eagle Ford and Austin Groups of Texas

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By CHARLES C. SMITH

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This report covers a discussion of the stratigraphy of the area, the descriptions and illustrations of the calcareous nannoplankton flora, their occurrence, range zones, and biostratigraphic significance

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CALCAREOUS NANNOPLANKTON AND STRATIGRAPHY OF LATE TURONIAN, CONIACIAN, AND EARLY SANTONIAN AGE OF THE EAGLE FORD AND AUSTIN GROUPS OF TEXAS

By CHARLES C. SMITH

ABSTRACT

This report deals with the lithostratigraphy, biostratigraphy, and calcareous nannoplankton floras of the upper part of the Eagle Ford and lower part of the Austin Groups (Upper Cretaceous) of Texas. These strata are structurally simple and, in general, abundantly fossiliferous and offer an excellent opportunity for detailed biostratigraphic investigation. Furthermore, previous studies of Upper Cretaceous strata throughout Texas involving both the planktonic Foraminifera and megafossils have resulted in existing detailed zonal sequences, into which biostratigraphic data based on other fossil forms may be interrelated.

Strata within the upper part of the Eagle Ford Group, lithologically consisting of interbedded calcisiltite and calcareous shale, and massive calcareous shale or mudstone, are assigned to the Boquillas Formation of southwest Texas, the South Bosque Formation of central Texas, and the Arcadia Park Formation within the north-central and north Texas areas. The lower part of the overlying Austin Group, generally consisting of thin-bedded calcisiltite and indurated chalky limestone interbedded with gray calcareous shale and mudstone, is assigned to the Atco Formation. Within northern Texas, however, the lowermost part of the Austin Group is assigned to the Ector Chalk. Within the area of investigation, the Eagle Ford-Austin contact is conformable in southwestern and northern Texas, although the contact is disconformable in the central and north-central Texas areas. Separate sections of this report are devoted to the regional stratigraphy of these units, as well as to the detailed local lithostratigraphy and biostratigraphy at each of the collecting localities.

The major part of this text deals with the systematic paleontology of the calcareous nannoplankton floras. Methods of sample collection, processing techniques, and methods of slide preparation are outlined. Additionally, certain taxonomic problems unique to the study of the calcareous nannoplankton are presented in separate parts of the text. These problems include relating the different images produced by transmission electron or scanning electron microscopy as compared with images produced through the transmitted light microscope, difficulties involving the entirely different images as observed in proximal or distal aspect of the same nannofossil, and problems involving polymorphism. Certain of these problems have been overcome by the use of a new technique: the same nannofossil is studied first through the scanning electron microscope and then through the transmitted light microscope. This new method has proven invaluable in correlating the entirely different images produced through electron and transmitted light optical systems, as well as in relating surface morphology as observed in the scanning electron microscope to that observed in polarized and plane transmitted light. In addition, this new technique permits the light optical examination of both proximal and distal views of the same nannofossil.

Strata assigned to the upper part of the Eagle Ford Group and lower part of the Austin Group of Texas are abundantly fossiliferous and contain a diverse and well-preserved nannofossil assemblage consisting of 49 species assigned to 26 genera. Diagnoses of each taxon, its description based on electron and light optical images, its known range, the type locality, the worldwide occurrence data, and pertinent remarks are presented in the systematic descriptions. The plates accompanying this text consist of illustrations of 123 different specimens of calcareous nannofossils, including 93 scanning electron and nearly 600 transmitted light photomicrographs. Furthermore, many taxa are illustrated by both scanning electron and transmitted light photomicrographs of the same specimen.

Detailed examination of the nannoplankton flora has permitted the recognition of a new calcareous nannoplankton zone, the *Lucianorhabdus cayeuxii* Zone within the lower part of the Austin Group of Texas. This zone is defined by the initial (earliest) appearance of *Cylindralithus asymmetricus* Bukry, *Kamptnerius magnificus* Deflandre, and *Lucianorhabdus cayeuxii* Deflandre. The top of the *L. cayeuxii* Zone is marked by the initial (earliest) appearance of the calcareous nannofossil *Tetralithus obscurus* Deflandre. This new nannofossil zone has been recognized within the lower part of the Austin Group throughout Texas and thus should be an important biostratigraphic interval in establishing a detailed nannoplankton zonal sequence for the Gulf Coastal area.

On the basis of an evaluation of existing stratigraphic data involving the calcareous nannoplankton and the planktonic Foraminifera, the boundaries of the *Lucianorhabdus cayeuxii* Zone are used herein to mark the lower and upper limits of the Coniacian Stage within the Texas area. Although certain discrepancies exist between the microfossil and megafossil data regarding the Coniacian-Santonian boundary, the disagreement in age involves relatively short stratigraphic intervals in Texas, and could involve no more than the poorly defined limits of the type European stages. These discrepancies further emphasize the need for a thorough reevaluation of the type European stages and for more detailed and integrated investigations involving both microfossils and megafossils from Upper Cretaceous strata of the Gulf Coastal Plain.

INTRODUCTION

The calcareous nannoplankton rank with the planktonic Foraminifera, Radiolaria, ammonites, and other pelagic groups of fossils as outstanding biostratigraphic indices. Their cosmopolitan nature, rapid floral change during Mesozoic and Cenozoic time, great diversity, and extreme abundance in the smallest of samples make them superb biostratigraphic indicators for developing detailed systems of zonation applicable to the worldwide correlation of marine strata.

From the inception of the current JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling) Deep Sea Drilling Project, the nannoplankton have proven particularly valuable in deciphering the biostratigraphy and chronostratigraphic relations of the oceanic crust. The application of Cenozoic nannoplankton zonations to deep-sea strata during the course of the Deep Sea Drilling Project by Gartner, Bukry, Hay, Percival, Thierstein, and others has proven highly successful. Although a detailed nannofossil zonation has been proposed for the Cenozoic (Hay and others, 1967; Martini, 1971) and integrated within the zonal framework of planktonic Foraminifera and Radiolaria, a detailed and integrated calcareous nannoplankton zonation has yet to be proposed for the Mesozoic.

This study has four principal objectives: (1) to examine in detail the calcareous nannoplankton of strata of late Turonian, Coniacian, and early Santonian Age of Texas by both transmitted light and scanning electron microscopy; (2) to define a nannoplankton zonal scheme for these strata; (3) to relate the nannoplankton zonation to the zonal framework of planktonic Foraminifera (Pessagno, 1967; 1969) and ammonites (Young, 1963); and (4) to relate the Coniacian nannoplankton zonation to the Santonian zonation proposed by Bukry (1969).

ACKNOWLEDGMENTS

I express sincere thanks to the faculty and staff of the Institute for Geological Sciences at the University of Texas at Dallas where I conducted my initial investigations of Mesozoic calcareous nannoplankton and planktonic Foraminifera. I am especially indebted to Emile A. Pessagno, Jr., for his enthusiastic support and encouragement, and for the unselfish sharing of his knowledge throughout all phases of this study. Appreciation is expressed to Charles L. McNulty (Department of Geology, The University of Texas at Arlington) for his valued discussions on the stratigraphy of the Eagle Ford and Austin Groups of northern and north-central Texas. Keith Young (Department of Geology, The University of Texas at Austin) and Erle G. Kauffman (University of Colorado, Boulder, Colo.) identified the megafossil collections and gave freely of their time in valued discussions on Upper Cretaceous biostratigraphy. Special thanks are extended to Jan E. Van Hinte (Esso Production Research Co., Houston, Tex.), Norman F. Sohl (U.S. Geological Survey, Washington, D.C.), and Mrs. Elaine R. Padovani (Dallas, Tex.) for so generously collecting samples from the type sections of the European Turonian, Coniacian, and Santonian Stages. Acknowledgment is also extended to Ross Foster (Ross Foster Ranch) and W. B. (Red) Smith (Rancho Rio Grande) for their assistance to me during my field investigations in the west Texas area.

My colleagues in the U.S. Geological Survey, David Bukry (La Jolla), Peter A. Scholle (Denver), and Norman F. Sohl (Washington), critically reviewed the manuscript. Stefan Gartner, Jr. (Texas A and M University), Stephen F. Percival (Mobil Field Research Laboratory, Dallas), Hans R. Thierstein (Scripps Institution of Oceanography), J. Dan Powell (Union Carbide Corp., Grand Junction, Colorado), and the late M. N. Bramlette (Scripps Institution of Oceanography) also generously offered their comments and constructive criticisms. Although these gentlemen, as well as others, gave freely of their advice, their review does not constitute an endorsement of, nor any responsibility for, the views expressed herein.

AREA OF INVESTIGATION

Upper Cretaceous strata of Texas crop out in a northeast-southwest trending belt extending from northern Bowie County in northeastern Texas, through the central part of the State, into Val Verde, Kinney, and Maverick Counties in southwestern Texas (fig. 1). These strata are structurally simple and, in general, extremely fossiliferous and offer excellent opportunity for detailed biostratigraphic investigation. Furthermore, the previous detailed examination of the planktonic foraminiferal faunas by Pessagno (1967; 1969) from Upper Cretaceous strata throughout Texas provides a unique

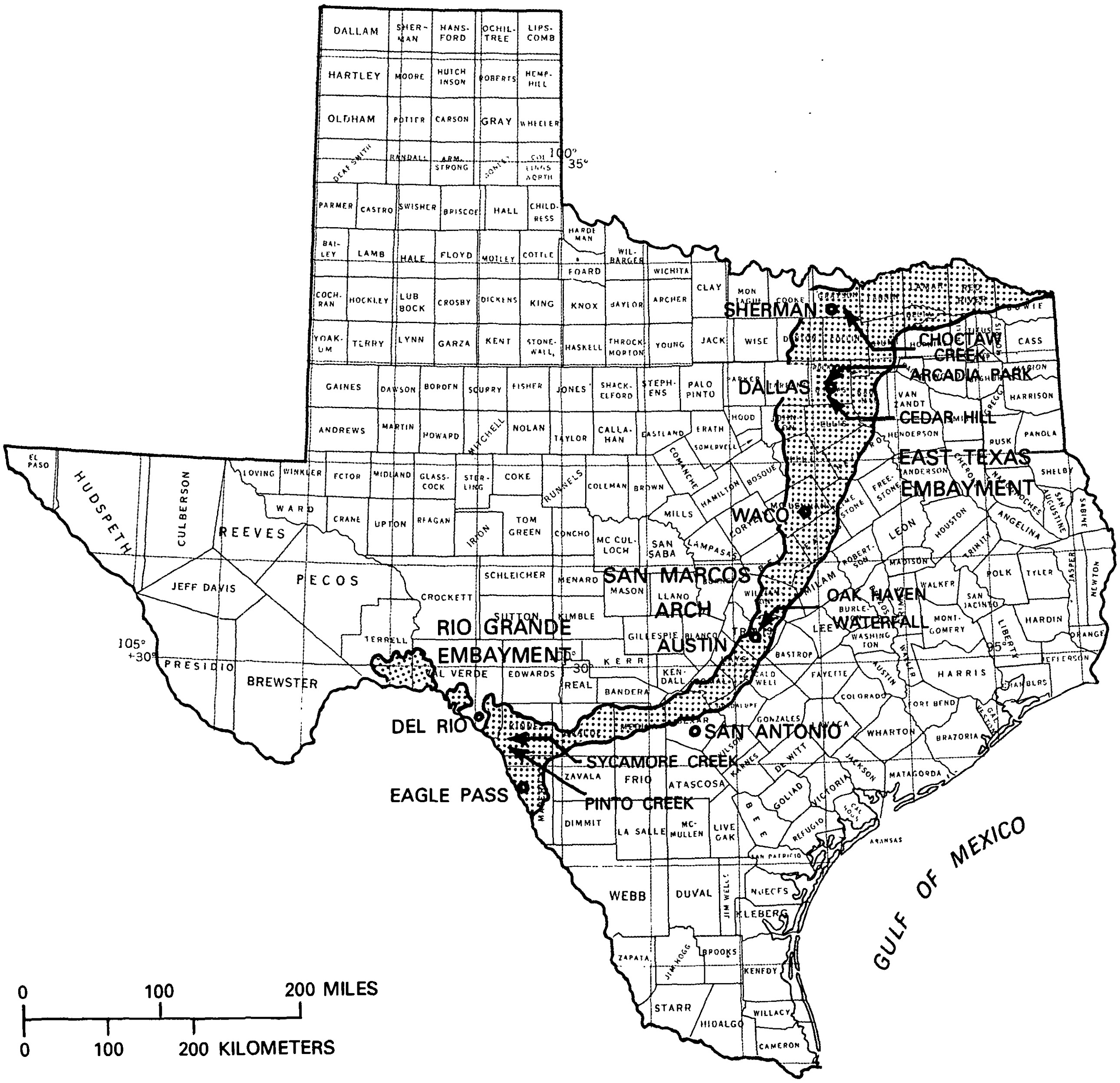

FIGURE 1.—Generalized distribution of Upper Cretaceous strata of Texas (stipple pattern) and the location of measured sections.

and detailed zonal sequence into which biostratigraphic data based on other fossil forms may be interrelated.

During this investigation, samples were collected from strata of late Turonian through early Santonian Age exposed along Pinto and Sycamore Creeks in Kinney County, the Oak Haven Waterfall site in Travis County, Cedar Hill and Arcadia Park exposures in Dallas County, and the Choctaw Creek locality of Grayson County (fig. 1).

TECTONIC SETTING

This investigation focuses on Upper Cretaceous strata of Texas that extend 500 miles from near Del Rio in Val Verde County to near Sherman in Grayson County (fig. 1). Although the regional structural geology relating to this broad area is much too complex for discussion here, a few cursory remarks are presented. King (1959), Murray (1961), Eardley (1962), and others, gave comprehensive discussions of the regional and local structural geology of Texas.

Murray (1961, p. 128) noted that the Rio Grande Embayment (fig. 1) is the most dominant structural feature of the western Gulf Coastal area. The embayment probably originated in the late Paleozoic or early Mesozoic during renewed Ouachita orogenies. Although definite Jurassic strata crop out in the marginal fold province of Coahuila and Nuevo Leon, most of the embayment consists of Upper Cretaceous and Paleocene sediment probably exceeding 40,000 feet (12.2 km) in thickness (Murray, 1961, p. 130).

Toward the east, the Rio Grande Embayment merges with the San Marcos Arch, which effectively separated the Rio Grande and East Texas Embayments. The San Marcos Arch, an extension of the Llano Uplift, is a broad, southeastward plunging structural high. Lower and Upper Cretaceous strata, as well as pre-Miocene lithic units, thin appreciably over the arch. To the north and northeast, the Upper Cretaceous outcrop approximates the western margin of the East Texas Embayment. This broad negative area is probably genetically related to the broad band of the buried Ouachita Mountain fold belt. The embayment seems to have been a negative area since the Jurassic (or pre-Jurassic), for Jurassic through Eocene sediments thicken from the north, west, and south into the center of the basin. The East Texas Embayment was not entirely open gulfward, as was the Rio Grande Embayment, but it appears to have been alternately opened and closed toward the south. Murray (1961, p. 124) noted that the southern margin was probably constricted by piercement salt domes and an associated broad belt of Cretaceous reefs.

In the vicinity of Grayson County, the Lower Cretaceous through middle Eocene outcrop belt bends sharply from a predominantly north-south to an east-west direction, coinciding with the northern limit of the East Texas Embayment. As along the western margin of the basin, the presently exposed outcrop pattern is probably related to the buried Ouachita fold belt.

REGIONAL STRATIGRAPHY

The following brief comments regarding the regional stratigraphy of the Eagle Ford and Austin Groups of Texas are intended to familiarize the reader with the general stratigraphy of these units. This study deals with only the uppermost part of the Eagle Ford Group and the lower part of the Austin Group.

Lithologic descriptions, thicknesses, and stratigraphic relations of these units are discussed more completely under the sections dealing with the respective local geographic areas investigated. A more detailed and comprehensive discussion of regional lithostratigraphy of the Eagle Ford and Austin Groups is presented in Adkins (1933, p. 422–455), Murray (1961, p. 342–352), and Pessagno (1969, p. 60–82).

EAGLE FORD GROUP

The earliest mention of the term "Eagle Ford" in geological literature was by Ferdinand Roemer. In 1852, he included "black Eagle Ford shales with fish remains" in his "Formation at the foot of the highland" in the New Braunfels area, Comal County, Tex. The name "Eagle Ford shales" was formally applied to these strata by R. T. Hill in 1887 (p. 296–298). Hill (1887) derived the name from the community of Eagle Ford along the Texas and Pacific Railway about 6 miles west of Dallas where the upper part of these strata are typically exposed. Calcareous sandstone, siltstone, calcareous shale, and flaggy limestone overlying the Woodbine Formation and conformably or disconformably overlain by the Austin Group are recognized herein as the Eagle Ford Group. Within Dallas County, the Eagle Ford Group unconformably overlies the Woodbine Formation and is disconformably overlain by the Austin Group (Pessagno, 1969, p. 66). Adkins (1933, p. 424–425) defined three formal units within the Eagle Ford Group of north-central Texas. In ascending order, these units were termed the Tarrant, Britton, and Arcadia Park Formations. These units are herein adopted. According to Brown and Pierce (1962, p. 2135), the Eagle Ford Group in Dallas County is 474 feet (114.5 m) thick.

Northward, in the vicinity of Sherman, Grayson County, the Eagle Ford Group is estimated to be about 350 feet (106.7 m) thick (Adkins, 1933, p. 428). In northern Collin County, and throughout Grayson and Fannin Counties, McNulty (1966) recognized two new lithostratigraphic units which were assigned to his Eagle Ford Formation. These units were termed the Bells Sandstone Member and the overlying Maribel Shale Member. As used and herein adopted, the Bells and Maribel are assigned as members of the Arcadia Park Formation. These members are considered in greater detail within the discussion of the local lithostratigraphy of Choctaw Creek. Within northeastern Texas, the Eagle Ford Group is apparently unconformable with the underlying Woodbine Formation, but is conformably overlain by the Austin Group.

In the vicinity of Austin, Travis County, the Eagle Ford thins considerably, presumably owing to the proximity of the San Marcos Arch. Within this area, the Eagle Ford disconformably overlies the Woodbine Formation and is unconformably overlain by the Austin Group. In Travis County, the Eagle Ford Group is about 40 feet (12.2 m) thick and is divided into a lower Lake Waco Formation and an upper South Bosque Formation. The Lake Waco Formation, herein adopted, was defined by Adkins and Lozo (1951, p. 120) from exposures near Waco in McLennan County. The overlying South Bosque Formation, also adopted herein as a valid lithostratigraphic unit, was initially defined by Prather (1902, p. 121–122) from exposures near South Bosque Station in southern McLennan County, Tex. However, as a result of their studies of the Woodbine and Eagle Ford strata of central Texas, Adkins and Lozo (1951, p. 119–120) later emended Prather's (1902) original definition of the South Bosque Formation. The emended definition of Adkins and Lozo is followed herein (refer to local lithostratigraphy of the Oak Haven Waterfall locality).

Farther westward, in the vicinity of Del Rio, strata equivalent to the Eagle Ford Group of central and north-central Texas have been termed the Boquillas Formation (=Boquillas Flags of Udden, 1907, p. 29–33). The type locality of the Boquillas Formation is about 7.5 miles northwest of the present village of Boquillas, along Tornillo Creek in the Big Bend National Park, Brewster County, Tex. (Maxwell and others, 1967, p. 55). South of Del Rio, in the vicinity of Pinto and Sycamore Creeks, Kinney County, the Boquillas Formation is not exposed in its entirety, although Pessagno (1969, p. 61–62) reported 188 feet (57.3 m) of continuous section measured at Lozier Canyon, Terrell County, Tex. The Boquillas Formation of the Lozier Canyon area is divided by Pessagno into a lower Rock Pens Member and an upper Langtry Member. Both members are lithologically distinct and readily recognized throughout the southwest Texas area. The names Rock Pens and Langtry Members of the Boquillas Formation are herein adopted.

AUSTIN GROUP

The name Austin was first applied in a lithostratigraphic sense by B. F. Shumard in 1860 to the limestone typically exposed in the vicinity of Austin, Travis County, Tex. Shumard correctly placed the Austin above the Eagle Ford, but incorrectly determined that it was overlain by the Comanche Peak, a formation now recognized as being Early Cretaceous ("Fredericksburgian") in age.

The sequence of interbedded chalky limestone and marl overlying the Eagle Ford Group and underlying the Taylor Marl is herein referred to as the Austin Group. Lithologically, the Austin Group is the most distinctive and easily recognizable sequence of strata in the Cretaceous of Texas. It consists of massive chalk, or more properly a chalky limestone or calcarenite, containing interbedded bluish-gray marl. Where fresh, the chalk is pale blue gray to dark gray, and in weathered exposures is light tan to white.

The Austin Group in its type area of Travis County consists of about 360 feet (109.7 m) of chalk and marl which rest with slight disconformity on the Eagle Ford Group, being overlain disconformably by the Taylor Marl (=Sprinkle Formation of Young, 1965). Within its type area, the Austin Group consists of the following lithostratigraphic units (from bottom to top): (1) Atco Chalk; (2) "Vinson Chalk;" (3) "Jonah Chalk;" (4) Dessau Chalk; (5) Burditt Marl, and (6) "Big House Chalk;" (see Pessagno, 1969, p. 71–74). For this report, the names "Vinson Chalk," "Jonah Chalk," and "Big House Chalk" will remain informal lithostratigraphic units of local usage within the Austin Group of the central Texas area. The lower part of the Austin Group, extending geographically from the Rio Grande area northward into Dallas County, is known as the Atco Chalk. The name Atco was initially proposed by C. O. Durham, Jr., in 1957 and remained an informal lithostratigraphic unit until the name was first published by Murray (1961). Pessagno (1969, p. 77) formally defined and adopted the name Atco Chalk Member of the Austin Formation in his report on the Upper Cretaceous strata of the western Gulf Coastal Plain area. The name Atco Chalk is adopted herein as the Atco Formation, raised from member to formational rank, and assigned as the lowest formation within the Austin Group throughout north-central, central, and southwest Texas. Both the Dessau Formation, defined by Durham (1955, p. 57; see also Pessagno, 1969, p. 72–73), and Burditt Marl, as defined by Adkins (1933, p. 449–450) and herein restricted to exclude the "Big House Chalk" of local usage (Durham, 1957, unpub. Ph.D. dissertation, Columbia University), are also adopted.

Westward, in the vicinity of Del Rio in the Rio Grande area, the Austin Group ranges in thickness from 275 to 600 feet (83.8 to 182.8 m), and consists, in ascending order, of the: (1) Atco Formation, (2) Dessau Formation, (3) Burditt Marl, and (4) "Big House Chalk" of local usage. Within the Del Rio area, the Austin Group conformably overlies the Langtry Member of the Boquillas Formation and, according to Pessagno (1969, p. 69), is disconformably overlain by the Upson Clay.

Northward from the type area, near Waco in McLennan County, the Austin Group consists of the Atco Formation conformably overlain by the Bruceville Chalk. As most other lithostratigraphic units within the central Texas area, the name Bruceville was initially proposed by Durham in his Ph.D. dissertation. Although Murray (1961) was the first to use the name Bruceville, Pessagno (1969, p. 78) designated a type locality near Waco and formally adopted the name for use in his report on the stratigraphy of Upper Cretaceous strata of Texas. The name Bruceville Chalk is adopted herein as the Bruceville Formation and designated the upper formation within the Austin Group of the McLennan County area of central Texas. According to Pessagno, the Austin Group of McLennan County is about 232 feet (70.6 m) thick and rests with pronounced disconformity on the South Bosque Formation of the Eagle Ford Group, and is disconformably overlain by the Taylor Marl, or Sprinkle Formation of Young, 1965.

In the vicinity of Dallas County, the Austin Group consists of, in ascending order: (1) Atco Formation, (2) Bruceville Formation, and (3) "Hutchins Chalk." For this report, the name "Hutchins Chalk" (of Durham, 1957) will remain an informal lithostratigraphic unit of local usage. Within Dallas County, the Austin Group is about 600 feet (182.8 m) thick, and rests disconformably on the Arcadia Park Formation of the Eagle Ford Group, and is disconformably overlain by the Taylor Marl, which may be in part equivalent to the Sprinkle Formation of Young (1965).

Farther northward near Sherman in Grayson County, the Austin Group consists of the following units (ascending): (1) Ector Chalk, (2) Bonham Marl, (3) Blossom Sand, (4) Brownstown Marl, and (5) the Gober Chalk (see remarks herein under "Local Lithostratigraphy," "Choctaw Creek"). Within Grayson County, the Austin Group conformably overlies the Arcadia Park Formation of the Eagle Ford Group. The lithostratigraphic nomenclature and stratigraphic relationships of units overlying the Austin Group of northeastern Texas are very poorly known and were not studied during this investigation. Whether the name Ozan Formation, as used by the Texas Bureau of Economic Geology (see Barnes, 1967), is appropriate, or whether the Sprinkle Formation of Young (1965) can be applied to these strata overlying the Gober Chalk is unknown at present, and satisfactory resolution of this problem must await future investigations.

LOCAL LITHOSTRATIGRAPHY

PINTO CREEK

The Pinto Creek section consists of exposures in three bluffs south and southwest from the bridge along U.S. Highway 277 over Pinto Creek, 2 miles northwest of the intersection of Texas Highway 693 and U.S. Highway 277, or about 20 miles southeast of Del Rio, in Kinney County, Tex. (fig. 1).

The first bluff, 0.5 miles S. 40° W. of the Pinto Creek Bridge, consists of the upper 26 feet (7.9 m) of the Langtry Member of the Boquillas Formation, and the lower 21 feet (6.4 m) of the Atco Formation of the Austin Group. The second bluff, 1.1 miles S. 49° W. of the Pinto Creek Bridge, consists of exposures of Atco strata extending from 5 feet (1.5 m) to 66 feet (20.7 m) above the base of the Atco Formation. The third bluff, 2.25 miles S. 3° W. of the Pinto Creek Bridge exposes the upper 80 feet (24.4 m) of the Atco Formation, extending from 71 feet (21.6 m) to about 150 feet (45.7 m) above its contact with the underlying Boquillas Formation.

A total of 32 samples (USGS 30810–30841) were collected for calcareous nannoplankton investigation from exposures at this locality, although because of overlap in sampling the three bluffs, only 26 samples are incorporated within this study. The stratigraphic distribution of these samples is shown on the measured section at this site (fig. 2). The distribution, abundance, and biostratigraphic significance of the nannoplankton and other microfossils and megafossils within these strata are discussed under the section title "Biostratigraphy."

At Pinto Creek, the Langtry Member consists of thin-bedded, 2- to 4-inch thick lenses or buff dense calcisiltite interbedded with 1- to 4-inch thick lenses of gray and buff fissile calcareous shale and blocky-fracturing marl. Individual dense limestone beds are laterally discontinuous and often wedge out within 2 to 3 feet, or they are replaced by interbedded marl. The Langtry Member is conformable and gradational with the overlying Atco Formation. The upper boundary of the Langtry Member is arbitrarily placed at the base of the first 1- to 3-foot thick massive chalky limestone bed.

Strata assigned to the Atco Formation of the Austin Group consists of 151.5 feet (about 46.2 m) of thick-bedded light tan to white indurated chalky limestone, or calcarenite, ranging from 2 to 5 feet in thickness. The chalky limestone is interbedded with thin lenses, generally 2 to 4 inches thick, of gray to buff marl. From about 80 to 106 feet (24.4 to 32.3 m) above the base of the Atco Formation

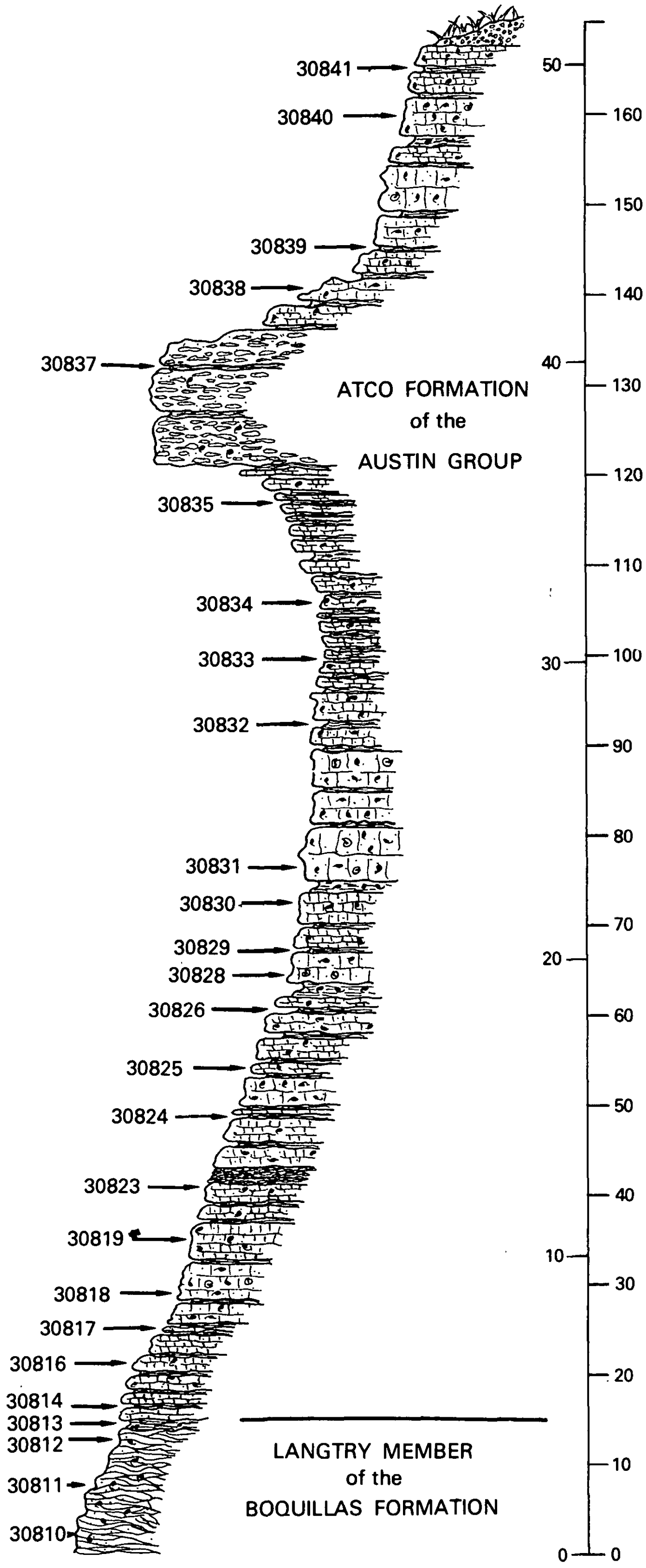

FIGURE 2.—Profile of measured section at Pinto Creek showing lithology and stratigraphic position of samples.

(fig. 2), the limestone becomes thinner, averaging only 1 to 2 feet in thickness, and stratigraphically contains a larger proportion of interbedded gray marl. The overlying 12 feet (3.7 m) of section, although consisting of more thickly bedded limestone, is distinctly nodular, more resistant than the underlying or overlying units, and forms a large overhang in the bluff near the top of the measured section.

SYCAMORE CREEK

The Sycamore Creek section consists of exposures in bluffs along the southern bank of Sycamore Creek, 12 miles southeast of Del Rio, Tex., (fig. 1) and 1.5 miles S. 43° W. from the bridge along U.S. Highway 277 over Sycamore Creek, Kinney County, Tex. Exposures at this site consist of the upper 100 feet (30.5 m) of the Boquillas Formation and about 14 feet (4.3 m) of the overlying Atco Formation. Figure 3 shows sampled part of this exposure. The basal 62 feet (18.9 m) of strata at this site are assigned to the Rock Pens Member of the Boquillas Formation. The Rock Pens Member was not sampled for nannoplankton, nor was it measured or described (for description and biostratigraphy, see Pessagno, 1969, p. 62–63). The overlying Langtry Member of the Boquillas Formation consists of 38 feet (11.6 m) of strata lithologically identical to the Langtry Member as exposed along Pinto Creek. The contact between the Boquillas Formation and the overlying Atco Formation is both conformable and gradational, as at Pinto Creek. Similarly, the 14 feet of Atco strata present at Sycamore Creek is identical lithologically to that exposed in the lower part of the Atco Formation at Pinto Creek.

Five samples (USGS 30803–30807) were collected from the Langtry Member, and two samples (USGS 30808–30809) were collected from the lower part of the Atco Formation for nannoplankton investigation. The stratigraphic distribution of these samples is indicated on the measured section (fig. 3). The biostratigraphic significance of the nannoplankton, planktonic Foraminifera, inoceramids, and ammonites found in the Sycamore Creek locality are discussed under the section "Biostratigraphy."

OAK HAVEN WATERFALL

Adkins (1933, p. 431) reported the Eagle Ford Group to be only 42 to 47 feet (12.8 to 14.3 m) thick in Travis County. Along Bouldin Creek in Austin (see Pessagno, 1967, p. 378, samples TX 103–108; 1969, p. 72; Stenzel, 1953, p. 55), the Eagle Ford

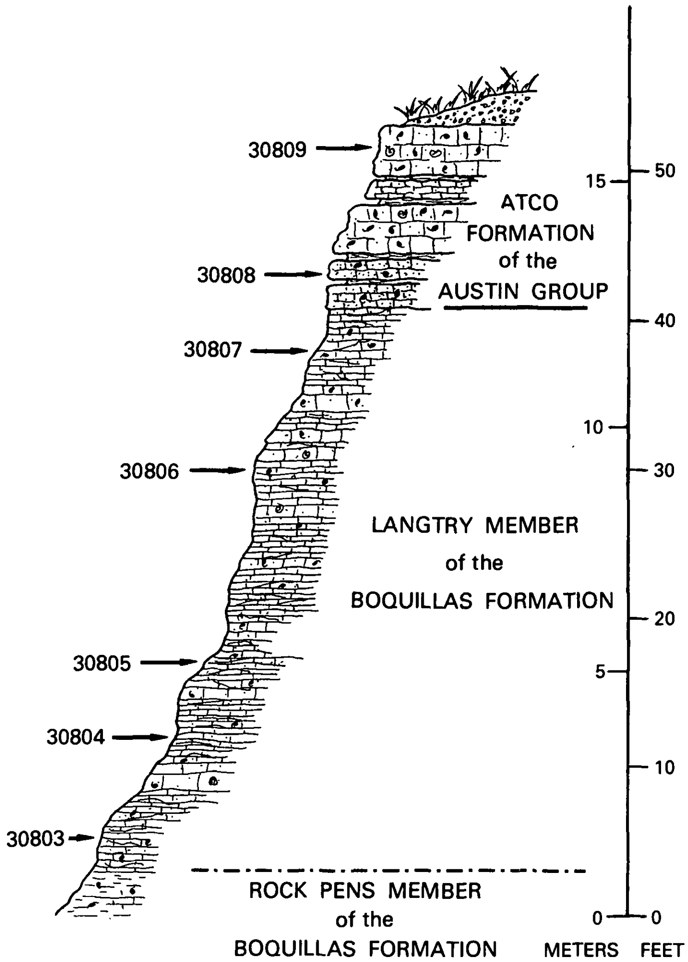

FIGURE 3.—Profile of measured section at Sycamore Creek showing lithology and stratigraphic position of samples.

is 41.2 feet (12.5 m) thick; and according to Stenzel (1953), the lower 19.7 feet (6.0 m) is assignable to the Lake Waco Formation and the upper 21.5 feet (6.6 m) is correlative with the South Bosque Formation of the Eagle Ford Group. Although the Bouldin Creek locality was sampled for nannoplankton investigation, it is not included in this study because only the lower 5 feet (1.5 m) of Atco strata are present at this site.

The Oak Haven Waterfall locality (fig. 1) consists of exposures along the bank and at the waterfall of a northward flowing branch of Walnut Creek on the Oak Haven Estate. This site is about 0.25 miles northeast of the Oak Haven Gate, 0.2 miles southeast from the intersection of Oak Haven Lane (gravel) with Farm Road 1325 (Burnet Road), an intersection which is about 1.4 miles north of the Balcones Research Center along Farm Road 1325 north of Austin, Travis County, Tex.

This section consists of about 7 feet (about 2.1 m) of strata correlative with the South Bosque Formation, disconformably overlain by 27 feet (about 8.2 m) of strata assigned to the Atco Formation of the Austin Group (fig. 4). The South Bosque Formation at this site consists of light gray to black massive and blocky-fracturing (thinly laminated on weathering) calcareous mudstone. The overlying 3½ feet (about 1.1 m) of strata consists of light to dark gray chalky marl with an abundance of ferruginous oolites, dark-green glauconite, reworked phosphatic pebbles, clams, small *Baculites* fragments, and shark teeth. This condensed zone is included herein within the lower part of the Atco Formation. The remainder of the Atco at the Oak Haven locality consists of 23.5 feet (7.2 m) of thick-bedded light-tan to white indurated chalky limestone, ranging from 2 to 6 feet in thickness, interbedded with thin, 2- to 4-inch thick lenses of fissile calcareous shale and marl (fig. 4).

Two samples (USGS 30796–30797) were collected from the South Bosque Formation of the Eagle Ford Group and five samples (USGS 30798–30802) were

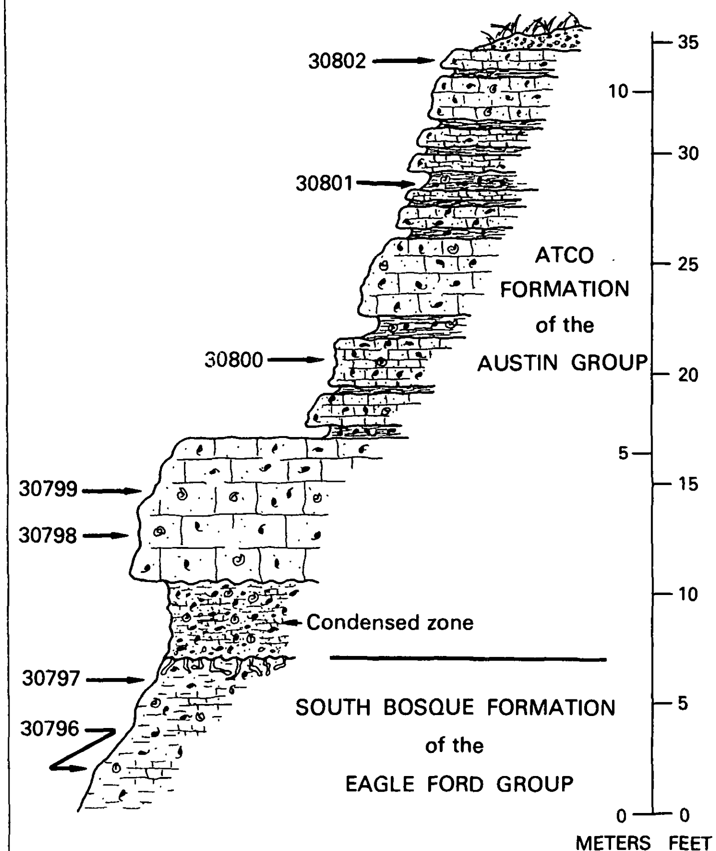

FIGURE 4.—Profile of measured section at the Oak Haven Waterfall locality showing lithology and stratigraphic position of samples.

collected from the lower part of the Atco Formation for calcareous nannoplankton investigation. The stratigraphic distribution of these samples is shown on the measured section (fig. 4). The distribution and abundance of nannoplankton at this site are discussed under the section titled "Biostratigraphy."

CEDAR HILL

The most prominent topographic feature in Dallas County is the White Rock Escarpment, a well-defined cuesta formed by the indurated chalky limestone of the Austin Group. The cuesta extends almost north-south through the western part of Dallas County, reaching its maximum elevation about 850 feet (259 m) above sea level near the community of Cedar Hill. The cuesta has an average relief of about 300 feet (91.4 m). The valley to the west is formed in the less resistant Britton and Arcadia Park Formations of the Eagle Ford Group.

The Cedar Hill site (fig. 1) consists of exposures along the northern side of Mansfield Road in a highway cut through the White Rock Escarpment, 0.6 to 0.85 miles west of the intersection of Mansfield Road with Belt Line Road, or about 1.8 to 2.1 miles west of the community of Cedar Hill in southwestern Dallas County, Tex.

Exposures at this site consist of about the upper 90 feet (27.5 m) of the Arcadia Park Formation of the Eagle Ford Group unconformably overlain by the lower 70 feet (21.3 m) of the Atco Formation of the Austin Group. The upper part of the Arcadia Park Formation at this site (fig. 5) consists of light to dark gray massive and blocky-fracturing to fissile calcareous shale and mudstone. This unit is locally gypsiferous, and on weathered slopes small crystals of selenite may be observed in great abundance. The lower part of the Atco Formation consists of buff to dark gray chalky marl, often ferruginous-stained, containing abundant reworked phosphatic nodules, fishbones, shark teeth, and pelecypod fragments. This condensed zone ranges laterally from 6 inches to 1 foot in thickness (fig. 5). The overlying 45.5 feet (about 13.9 m) of the Atco Formation is continuously exposed at the Cedar Hill locality. This unit consists predominately of thick-bedded light-gray to white indurated chalky limestone, generally 2 to 6 feet in thickness, interbedded with 6- to 18-inch thick lenses of light to dark gray fissile calcareous shale and blocky-fracturing marl.

Many samples were collected from the upper part of the Eagle Ford Group at Cedar Hill as well as from several other localities in the Dallas area. All

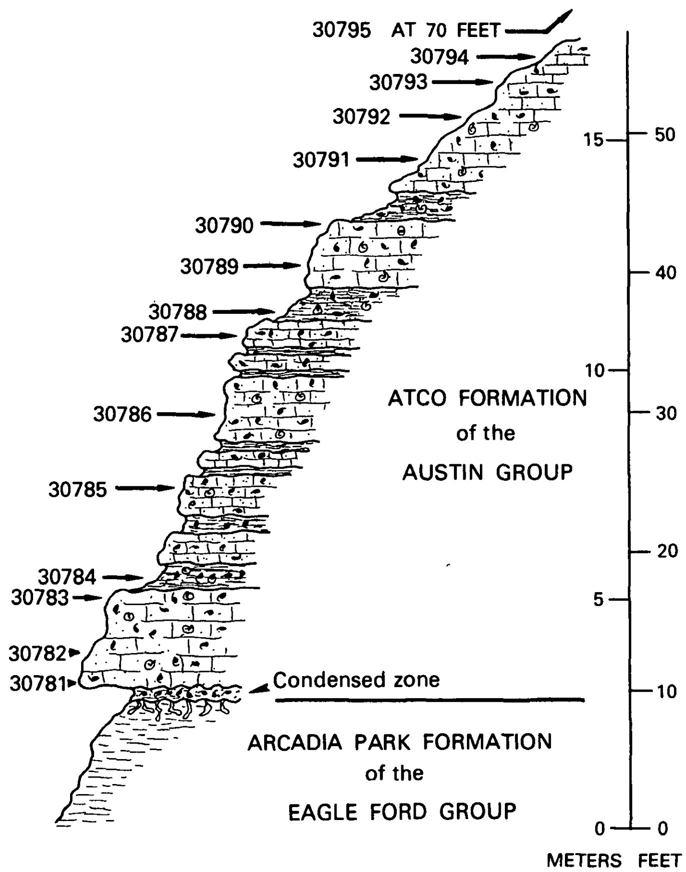

FIGURE 5.—Profile of measured section at Cedar Hill showing lithology and stratigraphic position of samples.

these samples proved to be devoid of calcareous nannoplankton as well as calcareous Foraminifera. According to J. Dan Powell (Union Carbide Corp., Grand Junction, Colorado, written commun., 1975), strata within the upper part of the Arcadia Park Formation of Dallas County were deposited in a shallow marine environment. His evidence for this interpretation includes the presence of thin, discontinuous lenses of glauconitic and phosphatic calcarenite containing both attached and reworked oysters identified as *Lopha bellaplicata* (Shumard, 1860), many in living position and having both valves in place. Furthermore, Powell observed corroded and abraded ammonite steinkerns bored by pholadid clams, thin calcarenite and quartzose sand lenses containing inoceramids and a large molluscan infauna, as well as calcareous concretions that contained an abundant inner neritic molluscan megafaunal assemblage. On the basis of these data, as well as his analysis of the regional stratigraphic relationships of the upper strata of the Eagle Ford, Powell suggested that the upper sediments of the Eagle Ford were deposited in a shallow, inner neritic marine environment. Of particular importance to the present investigation in his observation of Foraminifera, including rare planktonic species assignable to the genera *Hedbergella* and *Heterohelix,* within some of the thin calcarenitic units in the upper part of the Arcadia Park Formation. Unfortunately, these thin microfossiliferous lenses evidently were not sampled during this study. Thus, the potential presence of nannoplankton within these lenses must await future investigation.

The absence of calcareous microfossils and megafossils throughout most of the upper strata of the Arcadia Park is somewhat puzzling. A possible explanation is that the calcareous fauna and flora may have been postdepositionally removed by acidic ground-water percolation. As noted previously, the upper part of the Arcadia Park Formation contains common and occasionally abundant selenite. Additionally, this unit, as well as the overlying Atco Formation, contains finely disseminated pyrite. Oxidation of the pyrite would produce sulfuric acid and iron dissolved as ferrous ions, or more likely as ferrous sulfate. Further oxidation of the ferrous sulfate would yield limonite or ferric hydroxide, which is present throughout the Arcadia Park and Atco Formations as the dominant stain in weathered exposures of these units. Sulfuric acid would be present to dissolve the calcareous microfossils and other calcium carbonate grains within the upper part of the Eagle Ford, and perhaps yield calcium sulfate as gypsum or selenite. These comments are presented here as a likely method, however unproven, for explaining the absence of calcareous organisms in samples collected within the upper part of the Arcadia Park Formation at localities investigated in the Dallas County area.

Fifteen samples (USGS 30781–30795) were collected from the lower part of the Atco Formation at the Cedar Hill locality for detailed nannoplankton investigation. The stratigraphic distribution of samples from this site is shown on the measured section (fig. 5), and their biostratigraphic significance is discussed under "Biostratigraphy."

ARCADIA PARK

The Arcadia Park site (fig. 1) consists of strata exposed in a westward-facing hill slope along the the eastern side of Loop 12, 0.8 miles south of the intersection of Loop 12 with Jefferson Boulevard in the western part of Dallas, Dallas County, Tex. This site consists of about 30 feet (9.1 m) of strata assigned to the upper part of the Arcadia Park Formation unconformably overlain by about 10 feet (about 3.1 m) of strata correlative with the lower part of the Atco Formation. Figure 6 shows the sampled part of exposure. The respective lithologies are similar to those in the section exposed at the Cedar Hill locality; and, as at Cedar Hill, the contact between the two units is unconformable at both localities. The upper part of the Arcadia Park Formation is completely devoid of calcareous microfossils.

The Arcadia Park locality is included in this study because it is the same site from which Gartner (1968, p. 50, sample 5) collected and described several new species of calcareous nannofossils from the lower part of the Atco Formation. Additionally, it has provided a check on the presence or absence of several key species restricted to the lower part of the Atco. Four samples (USGS 30777–30780) were collected from the Atco Formation at this locality (fig. 6). The distribution, the abundance, and the biostratigraphic significance of the nannoplankton are discussed under "Biostratigraphy."

CHOCTAW CREEK

The Eagle Ford Group has been estimated (Adkins, 1933, p. 428) to be about 350 feet (106.7 m) thick within the northeastern Texas area. In northern Collin County and throughout Grayson and Fannin Counties, McNulty (1966) distinguished two members within the upper part of his Eagle Ford Formation (the lower part remains undifferentiated). The Bells Sandstone Member, within the upper 50 to 100 feet of the Eagle Ford, consists of from 15 to about 50 feet (4.6 to 15.2 m) of yellow, gray, and brown clayey and quartzose silty, fine to medium-grained quartz arenite (McNulty, 1966, p. 375). Conformably overlying the Bells Sandstone

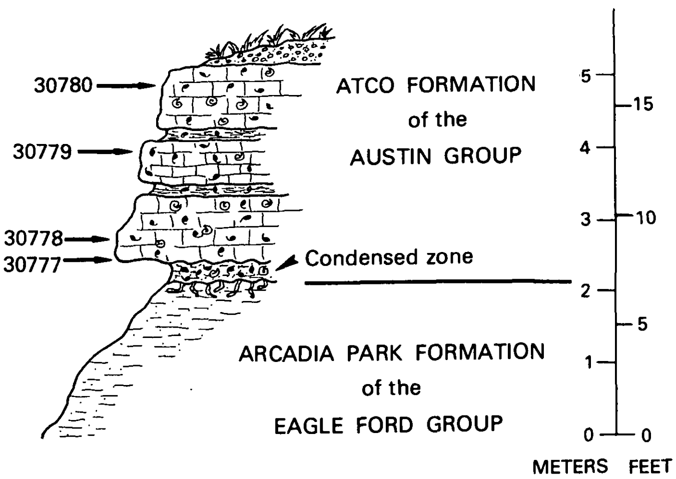

FIGURE 6.—Profile of measured section at the Arcadia Park locality showing lithology and stratigraphic position of samples.

Member is about 10 to 20 feet (3.1 to 6.1 m) of dark-gray to black massive and blocky-fracturing mudstone and fissile calcareous shale named by McNulty (1966, p. 378) the "Maribel Shale Member." Both units are assigned herein to the Arcadia Park Formation of the Eagle Ford Group.

The lithostratigraphy and stratigraphic relations of units overlying the Eagle Ford Group in the northeastern Texas area are very poorly known. I am not aware of any comprehensive study of the various units or a study in which the lithologic units of northeastern Texas have been correlated stratigraphically with the Austin Group of Dallas or Collin Counties. The Texas Bureau of Economic Geology, on the explanation accompanying the Sherman Sheet of the Geologic Atlas of Texas (see Barnes, 1967), included the following units (ascending) within the Austin Group: (1) Ector Chalk, (2) Bonham Marl, (3) Blossom Sand, (4) Brownstown Marl, and (5) the Gober Chalk. This usage is followed in this report. During the present study, only the lower part of the Ector Chalk was measured and sampled for nannoplankton investigation. Although the Ector Chalk or "Ector Tongue" of the Austin Chalk of former usage may prove to represent a chalky wedge extending from the lower part of the Austin of north-central Texas (as originally suggested by Stephenson, 1918, p. 149), the stratigraphic relationships between formations of the Austin Group in the Dallas County area and those of the northeastern Texas area have not been adequately demonstrated. The Ector Chalk consists of argillaceous chalky limestone conformably overlying the Maribel Shale Member of the Arcadia Park Formation of the Eagle Ford Group and is conformably overlain by the Bonham Marl of the Austin Group in northeastern Texas.

The Choctaw Creek locality (fig. 1) consists of exposures in a southern-facing hill slope, small abandoned quarry, and gully, about 0.2 miles south of U.S. Highway 82 along a gravel road where the road curves at a sharp right-angle turn from a predominately south to east direction. This site is 7.9 miles S. 87° E. of the intersection of U.S. Highway 82 with U.S. Highway 75 in Sherman, Grayson County, Tex. (see McNulty, 1966, p. 378, sec. 3).

The section exposed at this locality (fig. 7) consists of about 11 feet (3.4 m) of the uppermost part of the Maribel Shale Member of the Arcadia Park Formation, conformably overlain by about 45 feet (13.7 m) of the Ector Chalk. The lower 9 feet (2.7 m) of the Ector Chalk consists of thick-bedded bluish-gray to white indurated chalky limestone, or

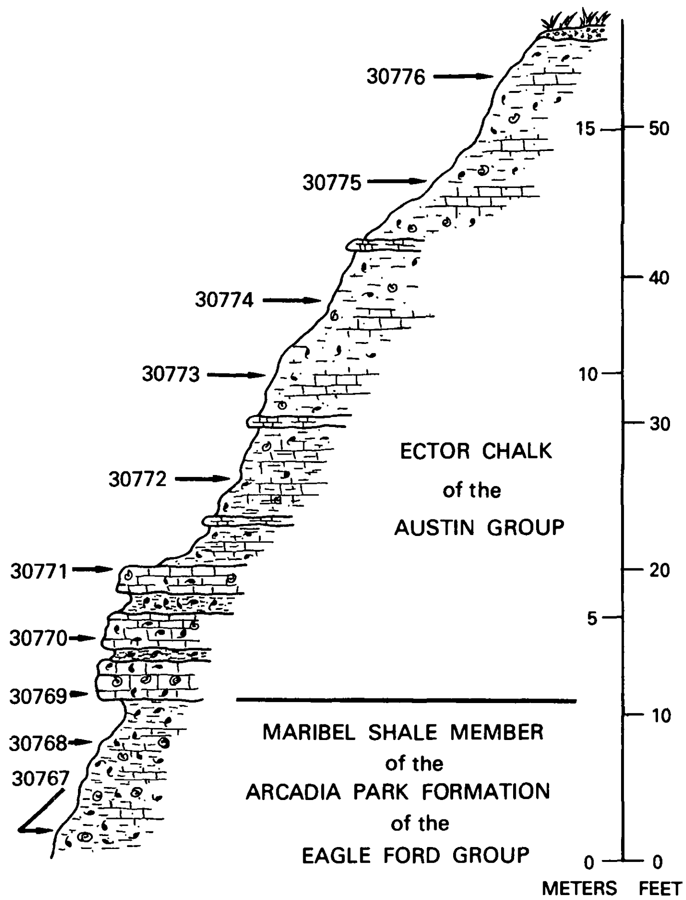

FIGURE 7.—Profile of measured section at the Choctaw Creek locality showing lithology and stratigraphic position of samples.

calcarenite, generally 1 to 3 feet in thickness, interbedded with 2- to 4-inch thick lenses of fissile calcareous shale. The overlying 36 feet (11.0 m) of strata consists of light gray to buff blocky-fracturing mudstone and calcareous shale and can be equated with the so-called middle marl of the Ector Chalk (C. L. McNulty, Jr., oral commun., 1973).

Ten samples (USGS 30767–30776) were collected from the upper part of the Maribel Shale Member and lower part of the Ector Chalk at the Choctaw Creek locality. The stratigraphic position of samples from this site is shown on the measured section (fig. 7). The distribution, abundance, and biostratigraphic significance of nannofossils, planktonic Foraminifera, and megafossils is discussed under "Biostratigraphy."

BIOSTRATIGRAPHY

A number of detailed studies have been previously conducted on Upper Cretaceous calcareous nannoplankton (Deflandre, 1959; Stradner, 1963; Bramlette and Martini, 1964; Reinhardt, 1966a; Stover, 1966; Gartner, 1968; Manivit, 1968; Perch-Nielsen, 1968; Bukry, 1969; Cepek and Hay, 1969; Noel, 1970; Cita and Gartner, 1971; Pienaar, 1969; Shumenko, 1976; Thierstein, 1971a, 1976; Verbeck, 1976b.) Only four investigations have involved material from the Eagle Ford and Austin Groups or their stratigraphic equivalents within the Gulf Coastal Plain area (Gartner, 1968; Bukry, 1969; Cepek and Hay, 1969; and Thierstein, 1976).

Cepek and Hay (1969) presented a calcareous nannoplankton zonation of the Upper Cretaceous that was based on two sections, one in Russell County, Kans., and the other from exposures along the Alabama River in Dallas and Wilcox Counties, Ala. Unfortunately, none of the 12 nannoplankton zones were referred either to the existing standard or reference sections of European stages or to the existing (Murray, 1961, p. 324–363) sequence of Gulf Coastal area provincial stages. Additionally, no mention was made of the relation between the nannofossil zones and existing foraminiferal or megafossil zones. The sequence of proposed zones was related only to the lithostratigraphic units from which the samples were collected.

Gartner (in Cita and Gartner, 1971, text-fig. 5) reproduced the zonal succession proposed by Cepek and Hay (1969) and indicated probable correlations with European Upper Cretaceous stages. Considerable difference exists in the age assignments proposed by Gartner and in the ages established from existing microfossil and megafossil data for both the sections exposed in Kansas as well as in central Alabama. I recently completed a comprehensive evaluation (Smith, 1975b) of the zonation proposed by Cepek and Hay (1969; 1970), including an integration with existing zonations that was based on other fossil groups and their age assignments within the standard European stages. Of interest within the present investigation is the fact that Cepek and Hay (1969, figs. 2, 4; 1970) did not study sequences representing the interval between the middle Turonian through the early Campanian.

The lower part of the nannoplankton zonation proposed by Cepek and Hay terminates in Russell County, Kans., in strata assigned to the lower part of the Fairport Chalk Member of the Carlile Shale (Cepek and Hay, 1969, fig. 2). Hattin (1962, p. 23–58; 1965, p. 16–17) reported the presence of the ammonite *Collignoniceras woollgari* (Mantell) associated with numerous specimens of a broad form of *Inoceramus labiatus* Schlotheim, and numerous other fossils, from the Fairport Chalk Member in Russell County, Kans. Many authors, including Cobban and Reeside (1952 (chart 10b), Reeside (1957, p. 522, table 1), Hattin (1962, p. 52–58), and Cobban and Scott (1972, p. 31, tables 3–4), referred this assemblage to European strata assigned to the early middle Turonian.

The upper part of the nannoplankton zonation proposed by Cepek and Hay (1969; 1970) is resumed in Dallas County, Ala., in strata assigned to the Tombigbee Sand Member of the Eutaw Formation (Cepek and Hay, 1969, fig. 4). Megafossils and microfossils from the Tombigbee Member of Dallas County are very poorly known, although N. F. Sohl (U.S. Geological Survey, Washington, D.C.) and I are conducting investigations on the Eutaw Formation, as well as other lithostratigraphic units, throughout its outcrop from central Alabama through northeastern Mississippi and southern Tennessee. Nevertheless, on the basis of previous field investigations and existing megafossil collections, Sohl (oral commun., 1975) regarded the Tombigbee Sand Member at Plymouth Bluff as both biostratigraphically and chronostratigraphically equivalent to the Tombigbee Member as exposed in Dallas County, Ala.

Numerous megafossils have been reported from the classic sections of the Tombigbee Sand Member exposed at Plymouth Bluff along the Tombigbee River in Lowndes County, Miss. These exposures (Stephenson and Monroe, 1940, p. 72–73; Young, 1963, p. 30–31) contain the ammonites *Menabites densinodosus* (Renz), *Texanites roemeri* (Yabe and Shimizu), *Placenticeras planum* Hyatt, *Stantonoceras* aff. *S. guadalupae* (Romer), and other fossils. Young (1963, p. 30) assigned this fauna to the upper part of his *Submortoniceras tequesquitense* Zone and to the lower part of his *Delawarella delawarensis* Zone of the standard central Texas sequence. On the basis of Young's data (1963, text-fig. 4), the Tombigbee Sand Member at Plymouth Bluff is chronostratigraphically correlative with European strata that are of the middle early Campanian Age. As noted previously, a more comprehensive discussion of the age relations of the stratigraphic units studied by Cepek and Hay (1969; 1970) was presented by Smith (1975b).

There can be little doubt that the zonal sequence proposed by Cepek and Hay terminates in Kansas in strata of early middle Turonian Age, and is resumed in Alabama in strata of middle early Campanian Age. Within Texas, this missing interval is represented by strata assigned to the Arcadia Park Formation of the Eagle Ford Group, and very nearly the entire Austin Group. None of the results of the present investigation, and little of the data presented by either Gartner (1968) or Bukry (1969), can be satisfactorily integrated, at least at present, within the zonal framework proposed by Cepek and Hay (1969; 1970). The assignment by Cepek and Hay of samples studied by both Gartner and Bukry from the Eagle Ford and Austin Groups of Texas to their (Cepek and Hay, 1969) proposed Upper Cretaceous nannoplankton zonal sequence must be considered with a great deal of uncertainty. Studies in progress may resolve many of the existing questions regarding the biostratigraphy and chronostratigraphic relationships of these strata.

PALEONTOLOGY OF STRATA OF LATE TURONIAN AGE OF TEXAS

The Turonian Stage was defined by d'Orbigny (1847) for strata found in the vicinity of Touraine, France. The lithology and paleontology of the type Turonian were presented by Lecointre (1959, p. 415–423). A summary of Lecointre's ammonite zonation of the Turonian, and its intergration within Young's (1963) ammonite zonal sequence and Pessagno's (1967) planktonic foraminiferal zonation for Upper Cretaceous strata of Texas was presented by Pessagno (1969, p. 21–24).

Megafossils, particularly the ammonites, are common throughout the Eagle Ford Group of Texas, and extensive lists were presented by Adkins (1928, p. 32–33; 1931, p. 35–71; 1933, p. 422–439), Moreman (1927; 1942), Adkins and Lozo (1951, p. 155–157), Powell (1965, p. 517), and others. The upper part of the Eagle Ford Group was assigned by these workers to strata correlative with the European Turonian Stage. McNulty (1966, p. 378) noted the rare occurrence of *Prionocyclus wyomingensis* Meek from the upper part of the Bells Sandstone Member of the Arcadia Park Formation in northern Collin and southern Grayson Counties. The presence of this species in the uppermost part of the Eagle Ford Group is again in accord with a late Turonian Age for these strata.

On the basis of palynologic correlations within north-central Texas, Brown and Pierce (1962, p. 2146) noted that "Upper Eagle Ford palynomorph assemblages have strong Turonian affinities when compared with assemblages described by Krutzsch (1957) from Europe." The best evidence, however, for the chronostratigraphic correlation of the upper part of the Boquillas Formation and Eagle Ford Group with the upper part of the European type Turonian Stage is the recent integration (Pessagno, 1969, p. 23–24) of the planktonic foraminiferal zones with ammonite data from the Eagle Ford Group of Texas, and the correlation of the ammonite data with Lecointre's (1959, p. 415–423) megafossil zones of the European Turonian.

Studies of the planktonic Foraminifera (Pessagno, 1967; 1969) show that the base of the late Turonian is marked by the initial appearance (base) of the planktonic Foraminifera *Marginotruncana angusticarenata* (Gandolfi), *M. canaliculata* (Reuss), *M. coronata* (Bolli), *M. pseudolinneiana* Pessagno, and *M. renzi* (Gandolfi). The upper limit of the Turonian is defined by the latest appearance (top) of the planktonic Foraminifera *Marginotruncana helvetica* (Bolli) and *M. sigali* (Reichel). On the basis of Pessagno's data, and on studies conducted during this investigation utilizing the planktonic Foraminifera from the various collecting localities, strata assigned to the late Turonian include the Langtry Member of the Boquillas Formation as exposed in the Pinto Creek and Sycamore Creek localities (figs. 2, 3), the South Bosque Formation as exposed at the Oak Haven Waterfall site (fig. 4), and the Maribel Shale Member of the Arcadia Park Formation at the Choctaw Creek locality (fig. 7).

Calcareous nannoplankton from the upper part of the Eagle Ford Group of central and north-central Texas, and from the lithostratigraphic equivalent Boquillas Formation of southwestern Texas, are extremely abundant and diversified, consisting of 49 species assigned to 26 genera (fig. 8). The distribution and relative abundance of nannoplankton species within Kinney, Travis, and Grayson Counties is shown in figures 9–12. Although the lower ranges of species within these strata were not studied during this investigation, all species present in the Boquillas Formation and Eagle Ford Group have been observed to range into the lower part of the Atco Formation of the Austin Group. Because of the objectives of this study and the long-ranging nature of most nannoplankton species within the lithostratigraphic units investigated, no nannoplankton zones could be defined within the late Turonian.

Of significance is the total absence of calcareous nannofossils, as well as planktonic Foraminifera, in outcrop samples within the upper part of the Arcadia Park Formation of Dallas County (refer to "Local Lithostratigraphy" at the Cedar Hill locality). Gartner (1968) examined a single sample from the middle(?) part of the Eagle Ford Group of Dallas County. Of the 23 species reported from this sample (Gartner, 1968, text-fig. 2), 4 species were restricted to the Eagle Ford, *Coccolithus coronatus* Gartner,

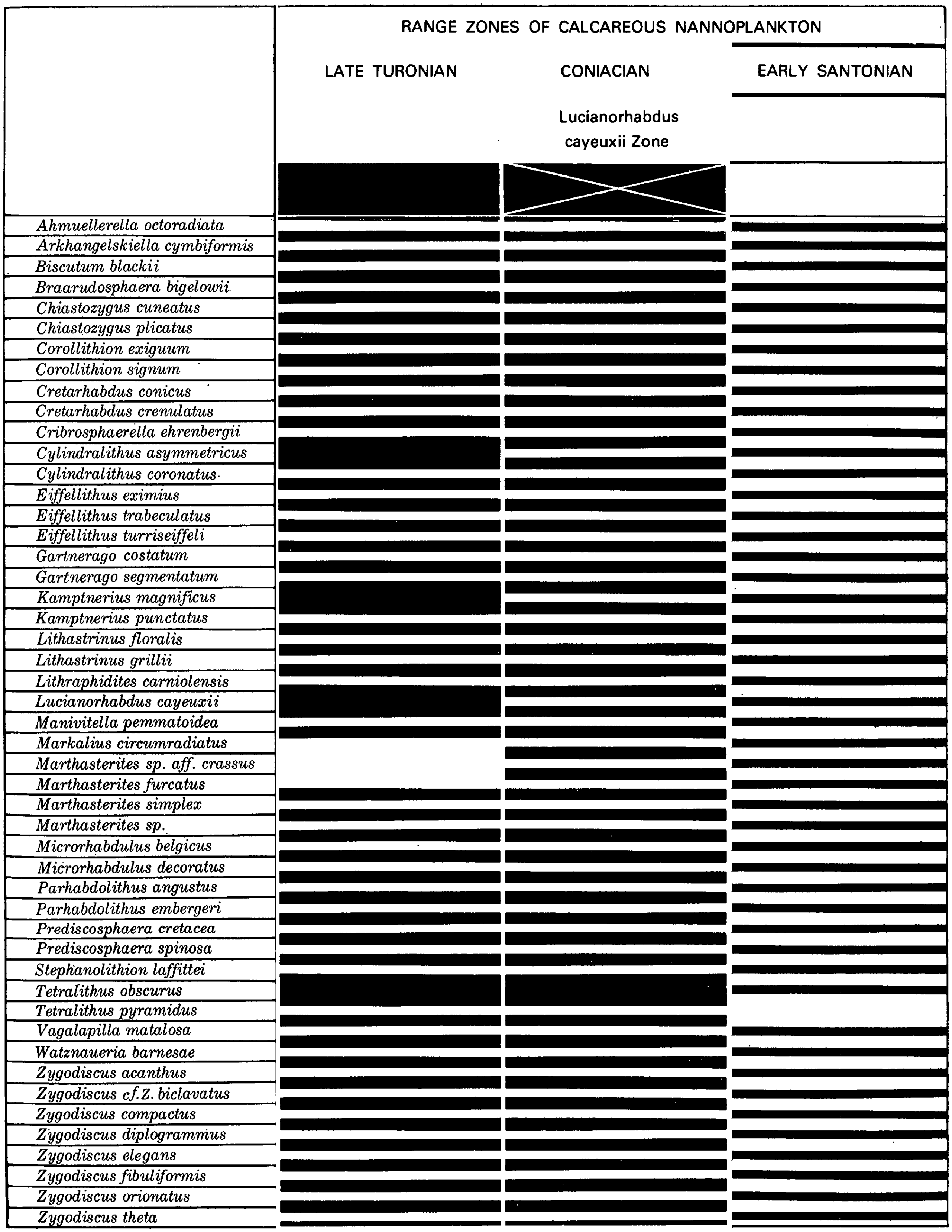

FIGURE 8.—Range zones of calcareous nannoplankton occurring in strata of late Turonian, Coniacian, and early Santonian Ages of Texas.

R=RARE (1–5 SPECIMENS)
C=COMMON (6–20 SPECIMENS)
A=ABUNDANT (>21 SPECIMENS)
▬ ▪ ▬ TOP OF *L. cayeuxii* Zone
▪▪▪▪▪▪▪ BASE OF *L. cayeuxii* Zone

	30810	30811	30812	30813	30814	30816	30817	30818	30819	30823	30824	30825	30826	30828	30829	30830	30831	30832	30833	30834	30835	30837	30838	30839	30840	30841
Arkhangelskiella cymbiformis	C	R	R			R	R	R	R	R	R	R		R		R	R	R	R	R	R	R	R	R	C	R
Biscutum blackii	C		C	R	R	C	C	R	R	R	R	R	R		R	C	A	R		R	C	R	R	C	R	
Braarudosphaera bigelowii	R	R	R			R	R	R	R			R		R	R	R	R	R	R	C	C		R	R		R
Chiastozygus plicatus	C	R	R	R	R	R	C	C		R	R	R	R	C	R	R	R	A	C	C	R		C	R	R	C
Corollithion exiguum	R	R	R		R		R	R		R	R		R			R	R	R		R		R			R	R
Corollithion signum	R		R			R	R	R	R	R		R														
Cretarhabdus conicus	R	R	R	R	C	C	C	R	C	A	R	C	C	C	C	C	C	C	R	C	C	R	R	C	R	R
Cretarhabdus crenulatus	C	C	C	R	R	A	A	A	A	A	A	C	C	C	A	C	C	C	R	C	C	C	C	C	R	C
Cribrosphaerella ehrenbergii	C	R	R	R		A	R	R	R	C	C	A	C	R	A	C	C	R	R	R	R		R	R	C	
Cylindralithus asymmetricus					R	R	R	C	R	R	R	C	R	R	C	R	C	R	R	C	C	R	C	R	R	C
Cylindralithus coronatus	C	R	A	C	C	A	C	A	A	A	A	A	A	C	C	C	R	A	C	C	C	R	C	C	C	C
Eiffellithus eximius	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	C	A	A	C	A
Eiffellithus trabeculatus	R	R	C		R	A	C	R	R	C	R	R	R	R	C	C	C	R	R	R	R	R	R	R		R
Eiffellithus turriseiffeli	C	R	R	R	R	R	R	R	R	C	C	C	R	C	R	C	R	C	R	C	C	C	R	C	R	R
Gartnerago segmentatum	C	R	C		R	C	C	R	R	A	R	C	R	R	R	R	C	C	R	R	C	R	C	C	C	R
Kamptnerius magnificus					R	R		R	R	R	R	R	R		R		R	R		R		R	R	R	R	R
Lithastrinus floralis	C	C		R	C	C	C	R	C	C	R	R		R	C		R			R	C	R			R	R
Lithraphidites carniolensis	R		R		R	C	C		R	R	C	R	R		R	R	R	R		R	R	R	R	C	R	R
Lucianorhabdus cayeuxii						R		R	R	R			R	R	R	R	C	R	A	C	C	R	C	R	C	C
Manivitella pemmatoidea	C	R	R	R	R		R	R	R	R	R	C		R	C	R	R		R	R	R	R	R	R	R	R
Markalius circumradiatus	C	R	C			C		R	R	C	R	R		R	R	R	R	R		R	R		R	R	R	R
Marthasterites sp. aff. crassus						R		R		R	R		R		R	R	R	R		R	R	R		R		R
Marthasterites furcatus	R	R	C	R		R	R	A	R	C		R	C	C	C	R	C	R	R	A	C	R	R	R	R	R
Marthasterites simplex	R		R			R			R		R				R	R	R	R		R				R	R	
Marthasterites sp.					R	R	R		R	R			R	R		R		R		R	R		R	R	R	R
Microrhabdulus belgicus	R	R				R	R			R					R	R			R		R	R		R		R
Microrhabdulus decoratus		R	R		R	C	R		R	R		R			R		C	R			R	R	R		R	R
Parhabdolithus angustus					R	C	R	R		R	R	R	R	R	R		R	R		R	R	R		R	R	
Parhabdolithus embergeri	C	R	C	R	R	C	R	R	C	C		C		R	R	R		R		R	C	R				R
Prediscosphaera cretacea	A	C	A	A	C	A	A	C	A	A	C	A	A	C	C	A	A	A	C	C	C	C	C	C	R	R
Prediscosphaera spinosa	R		R			R	R			R		R	R			R		R		R	R	R		R		R
Stephanolithion laffittei	C	R	R	R		R	R	R	R		R					C		R	R	R	R	R		R	R	R
Tetralithus obscurus																		C	R	C	C	R		R		C
Tetralithus pyramidus	R	C	R	C	A	C	C	A	A	C	R	R	C	C	C	R	R									
Vagalapilla matalosa	R	R	C	R	R	C	C	R	R	R	R		C		R		C	C		R		R		R		R
Watznaueria barnesae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Zygodiscus acanthus	R	R	R			R	R		R	R	R		R	R		R	R	R		R		R	R		R	
Zygodiscus cf. Z. biclavatus			R																							
Zygodiscus compactus	C	C	C	C	R	A	C	C	R	C	A	C	R	R	C	C	A	R		C	R	R	C	C		R
Zygodiscus diplogrammus	R	R	R			C	R	R	R	R	C	C	R	C	C	C	R	R		R	R	R	R			R
Zygodiscus elegans	R	R	C		R	C	A	R	R	R	R	C	C		R	R	A	R		R	R	R	R	C	C	R
Zygodiscus fibuliformis	R	C	C			R	R	C	C	C	R	R	R		C	R	R		R		C				R	
Zygodiscus orionatus	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	R	A
Zygodiscus theta				R		R					R			R		R		R				R	R			

FIGURE 9.—Distribution and relative abundance of calcareous nannoplankton, Pinto Creek, Kinney County, Tex.

R=RARE (1–5 SPECIMENS)
C=COMMON (6–20 SPECIMENS)
A=ABUNDANT (>21 SPECIMENS)
⁞⁞⁞⁞⁞⁞⁞ BASE OF *L. cayeuxii* Zone (between 30807 and 30808)

	30803	30804	30805	30806	30807	30808	30809
Ahmuellerella octoradiata	R	R	R	R	R		
Biscutum blackii		R	R	R	R	C	R
Braarudosphaera bigelowii	R	R	R	R	R	R	
Chiastozygus plicatus	R	R		R	R	R	R
Corollithion exiguum	R		R		R	R	
Corollithion signum	R	R		R		R	R
Cretarhabdus conicus	R	R	R	R	C	C	C
Cretarhabdus crenulatus	R	C	R	R	C	A	C
Cribrosphaerella ehrenbergii	R		R	C	C	C	R
Cylindralithus asymmetricus						R	C
Cylindralithus coronatus	C	C	A	A	A	C	R
Eiffellithus eximius	A	A	A	A	A	A	A
Eiffellithus trabeculatus	R	C	R	R	C	A	R
Eiffellithus turriseiffeli	R	R	R	R		R	
Gartnerago segmentatum	R	R	R	C	R	R	R
Kamptnerius magnificus						R	R
Lithastrinus floralis	R	R		C	R	R	R
Lithraphidites carniolensis	R	R		R	R	R	R
Lucianorhabdus cayeuxii						C	R
Manivitella pemmatoidea	C	R	A	R	R	R	R
Markalius circumradiatus	R		R	R	R		
Marthasterites furcatus	R	C	R	C	C	R	R
Marthasterites simplex	R	R			R		R
Marthasterites sp.						R	R
Microrhabdulus decoratus					R	R	R
Parhabdolithus angustus		R	R	R	R	C	R
Parhabdolithus embergeri	R	R	R	R	R	R	R
Prediscosphaera cretacea	A	A	A	A	A	A	A
Prediscosphaera spinosa	R	R	R	R	R		
Stephanolithion laffittei	R	R	C	R			R
Tetralithus pyramidus	C	R	C	C	C	C	R
Vagalapilla matalosa	R	R		R	R	C	C
Watznaueria barnesae	A	A	A	A	A	A	A
Zygodiscus acanthus	R	R		R	R	R	R
Zygodiscus compactus	C	R		R	C	A	C
Zygodiscus diplogrammus		R		C		C	R
Zygodiscus elagans	R	R	R	R	R	R	R
Zygodiscus fibuliformis	R	C	C	C	C	R	R
Zygodiscus orionatus	A	A	C	A	C	A	C
Zygodiscus theta	R		R	C	C	C	R

FIGURE 10.—Distribution and relative abundance of calcareous nannoplankton, Sycamore Creek, Kinney County, Tex.

R=RARE (1–5 SPECIMENS)
C=COMMON (6–20 SPECIMENS)
A=ABUNDANT (>21 SPECIMENS)
⁞⁞⁞⁞⁞⁞⁞ BASE OF *L. cayeuxii* Zone (between 30797 and 30798)

	30796	30797	30798	30799	30800	30801	30802
Ahmuellerella octoradiata	C	R					
Biscutum blackii	R	R	R	R	R	R	R
Braarudosphaera bigelowii	R	C	C	C	R	R	R
Chiastozygus plicatus	R	C	R	C	C	C	C
Corollithion exiguum	R	R		R	R	R	
Corollithion signum	R	R					
Cretarhabdus conicus	C	C	R	R	C	C	R
Cretarhabdus crenulatus	A		C	C	R	R	C
Cribrosphaerella ehrenbergii	C	C		R	R	R	R
Cylindralithus asymmetricus					R	C	R
Cylindralithus coronatus	C	A	A	A	C	C	A
Eiffellithus eximius	A	A	C	A	C	A	A
Eiffellithus trabeculatus		R		R	R	R	R
Eiffellithus turriseiffeli	R	R	R		R	R	R
Gartnerago segmentatum	A	C	R	R	C	C	C
Kamptnerius magnificus			R	R	R	R	R
Lithastrinus floralis	C	C	C	R	R	R	R
Lithastrinus grillii	R	R		R		R	R
Lithraphidites carniolensis	R	R	R	R	R	R	R
Lucianorhabdus cayeuxii			R	C	A	A	A
Manivitella pemmatoidea	C	C		R	R	R	R
Markalius circumradiatus	R	R	R	R	R		R
Marthasterites furcatus	R	C			C	C	C
Marthasterites simplex	R	R	R	R	R	R	R
Marthasterites sp.		R			R	R	R
Microrhabdulus decoratus	R			R	R	R	R
Parhabdolithus angustus	R	R	R		R	R	R
Parhabdolithus embergeri	C	C	C	R	R	R	R
Prediscosphaera cretacea	A	C	C	A	A	A	C
Prediscosphaera spinosa	R	R					
Stephanolithion laffittei		R		R		R	R
Tetralithus pyramidus	R	C	C	C	C	R	R
Vagalapilla matalosa	A	C	C	R	R	R	R
Watznaueria barnesae	A	A	A	A	A	A	A
Zygodiscus acanthus		R		R		R	R
Zygodiscus compactus	C	R		R	R	R	R
Zygodiscus diplogrammus	C		R	R		R	R
Zygodiscus elegans	R	R	R	R	R	R	R
Zygodiscus fibuliformis	R		R			R	
Zygodiscus orionatus	A	A	C	A	A	A	R
Zygodiscus theta	A	C	C	C	R	C	C

FIGURE 11.—Distribution and relative abundance of calcareous nannoplankton, Oak Haven Waterfall, Travis County, Tex.

Cretarhabdus loriei Gartner, *Pontilithus obliquicancellatus* Gartner, and *Prediscosphaera orbiculofenestra* Gartner. As none of these four species were observed during this investigation, the relation of this sample to the flora within the strata of late Turonian Age of southwestern, central, and northeastern Texas cannot be satisfactorily resolved at present.

R=RARE (1–5 SPECIMENS)
C=COMMON (6–20 SPECIMENS)
A=ABUNDANT (>21 SPECIMENS)
–·–·–·– TOP OF *L. cayeuxii* Zone
·············· BASE OF *L. cayeuxii* Zone

	30767	30768	30769	30770	30771	30772	30773	30774	30775	30776
Arkhangelskiella cymbiformis	C	C	C	A	A	R	A	C	C	R
Biscutum blackii	C		R	A			C	C	A	C
Braarudosphaera bigelowii	R		R			R	R		R	R
Chiastozygus plicatus	A	C	A	C	A	C	C	C	A	C
Corollithion exiguum	R		R			R	R	A	R	C
Corollithion signum	R			R		R	R		C	C
Cretarhabdus conicus	C	C	R	R	C		R	R	C	C
Cretarhabdus crenulatus					R	R	R	R		R
Cribrosphaerella ehrenbergii	C	R	R	R	C		C	R	A	R
Cylindralithus asymmetricus			R	R	R	C	R	C	C	C
Cylindralithus coronatus	C	C	C	C	C	R	C	C	C	C
Eiffellithus eximius	A	C	A	A	A	A	A	A	A	A
Eiffellithus trabeculatus	R	R	R	R		R	C	R	C	C
Eiffellithus turriseiffeli	C	R	R		R	R		R	R	R
Gartnerago costatum	C	C	R	R	C	R	C	R	C	R
Gartnerago segmentatum	A	C	C	A	C	R	C	C	A	R
Kamptnerius magnificus			R	R	R	R	R	R	R	R
Kamptnerius punctatus	C	C	C	R	R	R	C	R	C	R
Lithastrinus floralis	C	R	C	C	R	R	R	C	R	R
Lithastrinus grillii	C	R	C	R				C		R
Lithraphidites carniolensis	R	R	R	C	R	R	R	R	C	C
Lucianorhabdus cayeuxii			R	R	R	R	R	R	R	R
Manivitella pemmatoidea	R	R	R	R	R	R	R	R	R	R
Markalius circumradiatus			R	R	R	R	R	R	R	R
Marthasterites sp. aff. crassus			R	R		R	R		R	R
Marthasterites furcatus	A	A	C	A	R	C	C	R	A	C
Marthasterites simplex	R	R	R	R		R	R		R	R
Microrhabdulus belgicus	R			R			R		R	R
Microrhabdulus decoratus	R		R	C		R	R		R	R
Parhabdolithus angustus	R	R	R	R			R		R	R
Parhabdolithus embergeri	R	R	R	R	R	R	R	R		
Prediscosphaera cretacea	C	C	A	A	C	C	C	A	A	C
Prediscosphaera spinosa	C	R	R	C		R	C	R	C	C
Stephanolithion laffittei	C	R	C	C	C	C	R	R	C	C
Tetralithus obscurus								R	C	C
Tetralithus pyramidus	R	R		R	A	R	R			
Vagalapilla matalosa	C	R	C	C	C	C	R	R	R	R
Watznaueria barnesae	A	C	A	A	A	A	A	A	A	A
Zygodiscus acanthus	C	R	C	R		R			R	
Zygodiscus compactus	A	C	A	R	C	C	R	C	R	R
Zygodiscus diplogrammus	R			R	R	R	R		R	R
Zygodiscus elegans	C	C	R	C	C	R	R	R	C	R
Zygodiscus fibuliformis	C		R	R	R		R			R
Zygodiscus orionatus	A	C	A	C	C	C	C	A	C	C
Zygodiscus theta	R	R	C	R	R	R	R	A	R	R

FIGURE 12.—Distribution and relative abundance of calcareous nannoplankton, Choctaw Creek, Grayson County, Tex.

Additionally, the lack of biostratigraphic control from surface exposures on the basis of the calcareous nannoplankton within the upper strata of the Eagle Ford Group of Dallas County further hinders the biostratigraphic placement of Gartner's sample.

Pessagno (1967, p. 380; 1969, p. 66–68) examined the planktonic Foraminifera from the Mobil Oil Co. core of the type Eagle Ford Group of Dallas County and assigned the upper part of the Britton Formation and the entire Arcadia Park Formation to the late Turonian. Until fossiliferous parts of the uppermost strata of the Eagle Ford within the Dallas area are sampled in surface outcrop and the nannoplankton flora are described, or until the Mobil Oil Co. core is examined for its nannoplankton floras, the foraminiferal data presented by Pessagno (1967; 1969) give perhaps the best biostratigraphic ties based on microfossils with strata of late Turonian Age in other areas.

PALEONTOLOGY OF STRATA OF CONIACIAN AGE OF TEXAS

In 1856, Coquand published the results of his initial investigations on the Upper Cretaceous strata within the Charente province of southwestern France; he recognized three "etages," the lower "etage" being divided into three "sous-etages." In 1857, Coquand provided additional descriptions of the lithology and paleontology of the various units and proposed the name Coniacian for strata previously assigned to the lower two "sous-etages" of his first or lower "etage." The third "sous-etage" of the lower "etage" was elevated to the rank of "etage" and named "the Santonian." Within his publications of 1856 and 1857, Coquand mentioned several localities for his Coniacian and Santonian "etages," although in 1858 he described both "sous-etages" of the Coniacian occurring in one locality, in the escarpment below the wall of Parc Francois I in the city of Cognac. This locality was selected by Seronie-Vivien in 1959 to serve as the type locality for the Coniacian Stage.

During this study, several samples from the type area of the Coniacian Stage were examined for the presence of calcareous nannoplankton. These samples included material from the type locality at Cognac and from Coniacian strata which crop out in the vicinity of the villages of Richemont and Javresac, north and northwest of Cognac. Unfortunately, the entire collection of samples was barren of calcareous nannoplankton (Manivit, 1971; 1972). More comprehensive studies must be undertaken on the lithostatigraphy and biostratigraphy of the type Coniacian that are based on other fossil organisms and integrated with the nannoplankton and planktonic Foraminifera, as direct correlation into the type area of the Coniacian Stage by the calcareous nannofossils, at least at present, appears to be impossible.

Further discussions involving the lithology and paleontology of the type Coniacian Stage were presented by Seronie-Vivien (1959, p. 581), Dalbiez (1959, p. 862–863), and Van Hinte (1965, p. 9–12).

An integration of the European Coniacian megafossil and microfossil zones within the Upper Cretaceous of Texas was presented by Young (1963, p. 5–34) and Pessagno (1969, p. 23–25). Within his discussions regarding the age of the typical Austin sections in Travis County, Young (1963, p. 16) noted that, on the basis of collections of ammonites studied by earlier workers, "Although the superposition of the sequence was confused, there was never any argument about the Coniacian age of the lower part of the Austin Chalk."

Strata within the lower part of the Austin Group in its type area of central Texas were studied by Pessagno (1967; 1969) and referred to his *Marginotruncana renzi* Assemblage Zone. As noted by Pessagno (1969, p. 24), the *M. renzi* Assemblage Zone is generally correlative with European strata of Coniacian Age. On the basis of the planktonic Foraminifera, the lower limit of the *M. renzi* Assemblage Zone is characterized by the absence of *Marginotruncana helvetica* (Bolli) and *M. sigali* (Reichel), the two species that are characteristic of strata of late Turonian Age throughout Texas. The upper limit of the *M. renzi* Assemblage Zone, generally correlative with the Coniacian-Santonian boundary, is characterized by the absence of several species diagnostic of the early Santonian, including abundant *Marginotruncana concavata* (Brotzen), and *Archaeoglobigerina blowi* Pessagno, *A. cretacea* (d'Orbigny), *Globotruncana bulloides* (Vogler), *G. fornicata* Plummer, and *G. lapparenti* Brotzen. As the Coniacian part of the Austin Group throughout Texas is recognized by the absence of planktonic Foraminifera diagnostic of the late Turonian and absence of other species characteristic of the early Santonian, a major objective of the present study is the examination of the calcareous nannoplankton within this "negative zone."

The distribution and relative abundance of calcareous nannoplankton from the lower part of the Austin Group throughout Texas is shown in figures 9–14. On the basis of the stratigraphic distribution of species within the lower part of the Austin Group, a new nannoplankton zone, the *Lucianorhabdus cayeuxii* Zone is proposed. The base of the *L. cayeuxii* Zone is defined by the initial appearance of *Cylindralithus asymmetricus* Bukry, *Kamptnerius magnificus* Deflandre, and *Lucianorhabdus cayeuxii* Deflandre. The top of the *L. cayeuxii* Zone is marked by the earliest appearance of the calcareous nannoplankton *Tetralithus obscurus* Deflandre, and is closely approximated by the initial appearance of the planktonic Foraminifera *Marginotruncana concavata* (Brotzen). The boundaries of the *Lucianorhabdus cayeuxii* Zone mark the lower and upper boundaries of the Coniacian Stage within the Texas area.

Both the lower and the upper limits of the *L. cayeuxii* Zone are present in continuous exposures in the Pinto Creek locality, Kinney County, Tex. (figs. 2, 9). The lower boundary (equivalent to the late Turonian-Coniacian boundary on the basis of

R=RARE (1–5 SPECIMENS) C=COMMON (6–20 SPECIMENS) A=ABUNDANT (>21 SPECIMENS) -·-·- TOP OF *L. cayeuxii* Zone	30781	30782	30783	30784	30785	30786	30787	30788	30789	30790	30791	30792	30793	30794	30795
Ahmuellerella octoradiata				R	R			R		R	R		R	R	
Arkhangelskiella cymbiformis	C	C	C	C	C	A	R	R	R	R	R		C	R	C
Biscutum blackii	C	R	A		C	C	R	C	C	C	C	R	C	C	C
Braarudosphaera bigelowii		R				R			R						
Chiastozygus cuneatus		R	R		R	R	R			R					
Chiastozygus plicatus	A	C	C	C	A	A	A	C	A	A	C	C	C	A	C
Corollithion exiguum	R		R	R		R		R				R			R
Corollithion signum	C		R	R	C	C	R	R	C	C	R		C	C	C
Cretarhabdus conicus	R	C	C	C	R	A	C	R	C	R	R	R	R	C	C
Cretarhabdus crenulatus	C	C	R	R	R	R			C			R	C	R	R
Cribrosphaerella ehrenbergii	A	C	A	C	C	A	C	R	C	C	R	R	C	C	C
Cylindralithus asymmetricus	C	R	C	R	R	C	R	R	C	R	R	R	R	C	R
Cylindralithus coronatus	A	A	C	C	A	A	A	A	C	C	C	R	C	C	R
Eiffellithus eximius	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Eiffellithus trabeculatus	R	C	R	C	R	R	C	R	C	C	R	C	A	A	R
Eiffellithus turriseiffeli	C	R	R	C	C	R	C	R	C	C	R	C	R	R	C
Gartnerago segmentatum	C	C	C	A	A	A	A	R	C	C	R	C	C	C	R
Kamptnerius magnificus	C	C		C	R		A	R	C	C		R	C	R	R
Lithastrinus floralis	R	R	C	C	C	C	R	R	R	R	R	R	R	R	R
Lithastrinus grillii	R			R		C	R					R		R	R
Lithraphidites carniolensis	C			R	R	R	R	R	C	C	C	C	A	C	C
Lucianorhabdus cayeuxii	C	R		R		R		R		R			R	C	C
Manivitella pemmatoidea	C	C	C	R	R	C	R		R	C	R		R	R	R
Markalius circumradiatus	R	R	R	R		R	R	R						R	
Marthasterites sp. aff. crassus		C	R	C		R	R	R		R		R		R	
Marthasterites furcatus	R	A	A	A		R	A	C	R	C	R	C	R	R	
Marthasterites simplex	R	R		R	R		R	R		R		R	R		R
Marthasterites sp.		R	R		R	R	R		R				R	R	
Microrhabdulus belgicus	R	R		R		R			R	R			R		R
Microrhabdulus decoratus	R	C	R	R	R	R	C		C	R	R		R	R	R
Parhabdolithus angustus	C	R	R	R		R	R		R		R	R		R	
Parhabdolithus embergeri	R	R	R	R	C	C		R	R	R			R	R	R
Prediscosphaera cretacea	A	A	A	A	A	C	C	A	A	A	C	C	A	C	C
Prediscosphaera spinosa	R	R	C	R	C	C	C	C	C	C	R	R	C	R	R
Stephanolithion laffittei	C		R	R	C	C	R	R	C	C	C		C	R	R
Tetralithus obscurus											R	R	R	R	R
Tetralithus pyramidus	R		C	C	C	A	R	C	A	A					
Vagalapilla matalosa	C	A	A	C	C	A	C	R	C	C		R	R	C	R
Watznaueria barnesae	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Zygodiscus acanthus	R		R	R	R	C	C	R		R	R	R	R	R	R
Zygodiscus compactus	A	A	A	C	C	C	C	C	C	C	R		A	A	A
Zygodiscus diplogrammus	C	R		C	R	R	R	R	C	R	C	C	R	C	R
Zygodiscus elagans	C	R	R	R	R	R	R	R	C	C	C	R	C	A	C
Zygodiscus fibuliformis	R	R	R	C	C	C	R		R	R	R	R	R	R	R
Zygodiscus orionatus	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Zygodiscus theta	A	C	A	A	C	C	C	R	R	R		R	C	R	C

FIGURE 13.—Distribution and relative abundance of calcareous nannoplankton, Cedar Hill, Dallas County, Tex.

R=RARE (1–5 SPECIMENS)
C=COMMON (6–20 SPECIMENS)
A=ABUNDANT (>21 SPECIMENS)

	30777	30778	30779	30780
Ahmuellerella octoradiata	R	R	R	R
Arkhangelskiella cymbiformis	C	C	R	R
Biscutum blackii	C	A	C	C
Braarudosphaera bigelowii		R		R
Chiastozygus plicatus	C	A	A	C
Corollithion exiguum	R	R	R	R
Corollithion signum	C	R	R	R
Cretarhabdus conicus	A	A	C	A
Cretarhabdus crenulatus		R	C	C
Cribrosphaerella ehrenbergii	R	C	C	C
Cylindralithus coronatus	A	C	A	C
Eiffellithus eximius	A	A	A	A
Eiffellithus trabeculatus	A	C	C	R
Eiffellithus turriseiffeli	R	R	R	R
Gartnerago segmentatum	C	C	C	C
Kamptnerius magnificus	C	C	C	R
Lithastrinus floralis	R	R	R	R
Lithastrinus grillii	C	R	R	C
Lithraphidites carniolensis	R	R	R	C
Lucianorhabdus cayeuxii	R	R	R	R
Manivitella pemmatoidea	R	R	C	R
Markalius circumradiatus		R	R	R
Marthasterites sp. aff. crassus		R		R
Marthasterites furcatus	A	C	C	C
Marthasterites simplex	R	R	R	R
Microrhadulus belgicus		R	R	R
Microrhabdulus decoratus		R	C	
Prediscosphaera cretacea	R		R	R
Parhabdolithus angustus	A	C	A	A
Parhabdolithus embergeri	R	R	R	R
Prediscosphaera spinosa	C	R	C	C
Stephanolithion laffittei		R	C	R
Tetralithus pyramidus	R	R	R	C
Vagalapilla matalosa	C	C	C	C
Watznaueria barnesae	A	A	A	A
Zygodiscus acanthus	R		R	R
Zygodiscus compactus	A	A	C	C
Zygodiscus diplogrammus	R	R		R
Zygodiscus elegans	R	R		R
Zygodiscus fibuliformis	R	R	R	R
Zygodiscus orionatus	A	A	A	A
Zygodiscus theta	C	C	C	C

FIGURE 14.—Distribution and relative abundance of calcareous nannoplankton, Arcadia Park, Dallas County, Tex.

megafossils and Foraminifera coincides with the conformable contact between the Langtry Member of the Boquillas Formation and the Atco Formation of the Austin Group. The upper boundary is between 62 and 78 feet (18.9 and 23.8 m) above the base of the Atco Formation. Owing to the lack of intervening sample control within the Pinto Creek locality, the upper limit of the *L. cayeuxii* Zone (equivalent to the Coniacian-Santonian boundary on the basis of foraminiferal data) can, at present, be defined no more precisely than within 62 to 78 feet above the base of the Atco. The collection and examination of intervening samples will help to define more accurately the upper limit of the Coniacian Stage within this section.

Both the lower and the upper boundaries of the *L. cayeuxii* Zone are also present in the conformable and continuous exposures at the Choctaw Creek locality, Grayson County (figs. 7, 12). At this site, the base of the *L. cayeuxii* Zone corresponds to the conformable boundary between the Maribel Shale Member of the Arcadia Park Formation and the Ector Chalk. The top of the *L. cayeuxii* Zone is between 22 and 27 feet (6.7 and 8.2 m) above the base of the Ector Chalk. The lower 32 to 37 feet (9.8 to 11.3 m) of the Atco strata exposed at Cedar Hill (figs. 5, 13), as well as the lower part of the Atco exposed at Sycamore Creek (figs. 3, 10), Oak Haven Waterfall (figs. 4, 11), and Arcadia Park (figs. 6, 14) localities are assigned to the *L. cayeuxii* Zone, and are of Coniacian Age.

Gartner (1968) examined a single sample from the lower part of the Austin Group of Dallas County. He (1968, text–fig. 2) reported the initial appearance of *Kamptnerius magnificus* Deflandre and final appearance of *Tetralithus gothicus* Deflandre (= *T. pyramidus* Gardet 1955) and *Zygodiscus crassicaulis* Gartner (=*Parhabdolithus embergeri* (Noël, 1958) Stradner, 1963) within the lower part of the Atco Formation from data based on his (Gartner, p. 50) sample 5. Gartner did not refer his nannoplankton floras to biostratigraphic zones. Although he presented no evidence for his chronostratigraphic assignment, he correctly referred his sample to European strata of the Coniacian Stage (Gartner, 1968, text–fig. 1). The same site from which Gartner collected his sample 5 was studied in detail during this investigation (figs. 6, 14). Although samples from the upper part of the Eagle Ford Group are barren of calcareous nannoplankton, samples from the lower part of the Atco contain a well-preserved nannoplankton flora including *Lucianorhabdus cayeuxii* Deflandre and *Kamptnerius magnificus* Deflandre, which is assigned to the L. *cayeuxii* Zone.

Bukry (1969) studied the calcareous nannoplankton from the Austin Group and Taylor Marl of Dallas, Ellis, and Travis Counties, Tex., and samples from European strata of Albian through Maastrichtian Age. Unfortunately, the presence or absence of species was determined from the transmission electron microscopic examination of prepared samples; in many instances, the size of the sample available for study utilizing electron microscopy appears too small to accurately determine the presence of rare or even some common species. For instance, Bukry examined a sample that was found 3.5 feet above the base of the Atco Formation exposed along Bouldin Creek, Travis County, Tex. (Bukry, 1969, p. 9, sample C–4). Bukry (1969, table 1) indicated a total floral of only seven species from this sample. Examination of a sample from this same locality and interval utilizing transmitted light optics revealed the presence of a minimum of 40 to 45 distinct forms. Thus, some combination of both transmitted light and electron optical examination by Bukry would have shown the presence of numerous forms not recorded in his range charts.

Bukry (1969, p. 18–19) defined four nannoplankton zones for strata of early Santonian through early Campanian Age of Texas. Although these zones were based on what he believed to be the first and last occurrences of species, zonal boundaries were not indicated on his occurrence and range charts (Bukry, 1969, table 1), and the zonal assignment of a particular sample is difficult to determine. Additionally, because Bukry did not recognize *Kamptnerius magnificus* Deflandre, *Lucianorhabdus cayeuxii* Deflandre, or *Tetralithus obscurus* Deflandre (as well as other species) in samples from the lower part of the Atco Formation of Dallas County, his data are difficult to relate to the zonal scheme proposed herein. Essentially on the basis of the presence of *Cylindralithus asymmetricus* Bukry, admittedly rather poor evidence, the lower part of Bukry's "*Cyclagelosphaera? chronolitha* Zone" seems to correspond, at least in part, to the *Lucianorhabdus cayeuxii* Zone.

Stover (1966, text–fig. 3) reported the initial appearance of *Lucianorhabdus cayeuxii* Deflandre from strata of early Coniacian Age of France and the Netherlands, providing further evidence for correlation of the *L. cayeuxii* Zone, at least in part, with European strata of Coniacian Age.

PALEONTOLOGY OF STRATA OF EARLY SANTONIAN AGE OF TEXAS

The Santonian Stage was defined by Coquand in 1857 for strata occurring in the vicinity of Saints, Charente, France. Seronie-Vivien (1959, p. 581–582), Dalbiez (1959, p. 865), and van Hinte (1965, p. 9–14) presented discussions of the lithology and paleontology of the type Santonian, which Young (1963) incorporated in his study of the late Cretaceous ammonite succession of the Gulf Coastal area. According to Young (1963, p. 15–34, text–fig. 4, table 13), the Coniacian-Santonian boundary is placed in the lower part of his formation B (equivalent to the "Vinson Chalk" of Durham, 1957) of the standard central Texas sequence.

On the basis of studies of the planktonic Foraminifera of late Cretaceous Age of Texas, Pessagno (1969, p. 11, 25; pl. 45) noted that the early Santonian Age derived from megafossil zones is in agreement with planktonic Foraminiferal data. The early Santonian part of the Austin Group is referred by Pessagno to his *Globotruncana bulloides* Assemblage Zone, *Marginotruncana concavata* Subzone. The base of the *M. concavata* Subzone is characterized by the presence of abundant *M. concavata* (Brotzen), and *Archaeoglobigerina blowi* Pessagno, *A. bosquensis* Pessagno, *A. cretacea* (d'Orbigny), *Globotruncana bulloides* (Vogler), *G. fornicata* Plummer, and *G. lapparenti* Brotzen. Although strata assigned to the middle and upper parts of the Santonian Stage were not studied during this investigation, the top of the *M. concavata* Subzone (boundary between the early and late Santonian) is marked by the extinction of all species of the genus *Marginotruncana*, and an accompanying increase in abundance of the species *Globotruncana bulloides* (Vogler), *G. fornicata* Plummer, and *G. lapparenti* Brotzen.

During this investigation, strata assigned to the lower part of the Santonian Stage were sampled and studied for their nannoplankton floras. On the basis of the calcareous nannoplankton, the lower limit of the Santonian corresponds to the top of the *Lucianorhabdus cayeuxii* Zone, which is marked by the earliest appearance of the calcareous nannofossil *Tetralithus obscurus* Deflandre. The distribution and relative abundance of calcareous nannoplankton in strata assigned to the lower part of the Santonian Stage is shown in figures 9, 12, and 13.

At the Pinto Creek locality, lower strata of the Atco between 62 and 78 feet (18.9 and 23.8 m) above the base of the Atco Formation to the top of the exposure at 151.5 feet (46.2 m) are assigned to the lower Santonian (see figs. 2, 9). Similarly, the upper 37 feet (11.3 m) of Atco strata at the Cedar Hill locality (figs. 5, 13), and the upper 19 feet (5.8 m) of Ector strata at the Choctaw Creek locality (figs. 7, 12) are assigned to the lower Santonian Stage.

As noted previously, the upper range of nannoplankton species within the early Santonian was not determined during this study (the top of the early Santonian as used herein is determined by planktonic foraminiferal data). It is impossible, therefore, to integrate the previous nannoplankton data presented by Gartner (1968) and Bukry (1969) from the middle and upper part of the Austin Group. However, on the basis of the ranges of nannoplankton species presented by Gartner (1968, p. 50, text-fig. 2, samples 9 and 12) and all of the samples collected by Bukry (1969, p. 8–10, tables 1, 2) from the middle and upper part of the Austin Group within the Dallas area, the Santonian Stage can be divided into at least two, perhaps more, nannoplankton zones. Unfortunately, it is beyond the scope of this study to examine the nannofossils of the entire Austin Group of Texas.

Both ammonites and inoceramids are common throughout the Austin Group, particularly in central and southwest Texas. Young (1960; 1963) presented a comprehensive and detailed examination of the ammonite faunas of Texas and recognized three ammonite zones within the lower part of the Austin Group (1963, p. 10–34, text-figs. 3–4). On the basis of correlations with the type European sections, Young assigned his formation A (equivalent to the Atco Formation herein) and the lower part of his formation B (the "Vinson Chalk" of Durham, 1957) of the central Texas section to the Coniacian Stage of the standard European sequence.

Ammonites were collected throughout this investigation and were identified by Keith Young (Dept. of Geology, Univ. of Texas at Austin) and W. A. Cobban (U.S. Geological Survey, Denver, Colo.). *Prionocycloceras gabrielense* Young was collected 10 feet (3.1 m) above the base of the Atco Formation exposed along Pinto Creek (fig. 2), and 10 feet above the basis of the Atco Formation at Sycamore Creek (fig. 3). Additionally, *Peroniceras westphalicum* (Schluter) was collected 65 feet (19.8 m) above the base of the Pinto Creek section. The assignment of these ammonites to the European Coniacian Stage (Young, 1963, p. 69–71, text-fig. 3) provides excellent evidence for the assignment of the *Lucianorhabdus cayeuxii* Zone to the European Coniacian.

A third, small, damaged ammonite was collected 143 feet (43.6 m) above the base of the Atco Formation in the Pinto Creek exposures. This individual was questionably identified as *Protexanites* (?) sp. indet. by Young, and questionably as a juvenile of *Peroniceras haasi* Young by Cobban (written commun., 1975). Young (1963, text-fig. 3, table 12) listed *Protexanites* as characteristic of the late Coniacian and *Peroniceras* as diagnostic of Texas Gulf Coast strata of early Coniacian Age. According to the "Treatise on Invertebrate Paleontology," on a global scale, the genus *Protexanites* ranges from the early Coniacian through the early Santonian, whereas *Peroniceras* is restricted to strata of Coniacian Age. The assignment of strata at 143 feet (43.6 meters) above the base of the Pinto Creek appears to be in conflict with the early Santonian Age of these beds on the basis of the planktonic Foraminifera and calcareous nannoplankton.

In addition to the ammonites, a rather large group of inoceramids was collected from the lower part of the Austin Group from numerous localities throughout southwestern Texas. These specimens were identified by Erle G. Kauffman (U.S. National Museum, Washington, D.C.), and were placed in the collections of the National Museum. The following inoceramids were collected from sites studied herein.

Pinto Creek Locality

18.5 feet (5.6 m)—above base of Atco Formation
Mytiloides sp. ex. gr. "*problematicus*" (Schlotheim) (usage of Meek, 1876; non Schlotheim)
Mytiloides striatoconcentricus (Gümbel)
58 feet (17.7 m)—above base of Atco Formation
Cremnoceramus inconstans (Woods) s.l., aff. subsp. *woodsi* (Fiege)
68 feet (20.7 m)—above base of Atco Formation
"*Inoceramus*" *stantoni* Sokolow
143–147 feet (43.6–44.8 m)—above base of Atco Formation
Cremnoceramus (juvenile), probably *C. inconstans* (Woods)
"*Inoceramus*" indet. (could be *inconstans*)
Inoceramus sp. aff. *I. (Magadiceramus) subquadratus* Schluter

Sycamore Creek Locality

8 feet (2.4 m)—above base of Atco Formation
"*Inoceramus*" n. sp. ancestral to "*I.*" *deformis*–"*I.*" *erectus* lineage
10 feet (3.1 m)—above base of Atco Formation
Mytiloides aviculoides (Meek and Hayden)
Mytiloides sp. aff. *M. confertimannulatus* (Roemer)

Kauffman assigned the Pinto Creek collection at 18.5 feet (5.6 m) to the latest Turonian or possibly earliest Coniacian; the collections at 58 feet (17.7 m) to the latest early to middle Coniacian; 68 feet (20.7 m) to the middle to late Coniacian; and the collection at 143–147 feet (43.6–44.8 m) to the latest Coniacian. Both collections from the Sycamore Creek locality are referred to European strata of latest Turonian or earliest Coniacian Age. As indicated previously, the ammonite *Prionocycloceras gabrie-*

lense Young was collected 10 feet (3.1 m) above the base of the Atco Formation at both the Pinto Creek and Sycamore Creek localities. Ammonities indicate these lower strata of the Atco to be of Coniacian Age, whereas inoceramids indicate the same strata to be latest Turonian to earliest Coniacian Age. Lower strata of the Atco at both the Pinto Creek and Sycamore Creek localities thus appear to be very low in the Coniacian on the basis of the collective megafossil data.

A comment must be made regarding the apparent discrepancy between the ammonite-inoceramid and planktonic foraminiferal age assignments of strata within the upper part of the Pinto Creek section. On the basis of megafossil data, the collections at 143–147 feet (43.6–44.8 m) above the base of the Atco Formation at Pinto Creek are assigned to European strata of latest Coniacian Age.

According to Pessagno (1969), the first abundant occurrence of the planktonic Formainifera *Marginotruncana concavata* (Brotzen) is regarded by most micropaleontologists as an early Santonian zone fossil. Furthermore, Pessagno (1969, p. 75) stated, "The early Santonian age of *M. concavata* (Brotzen) is rather well substantiated by megafossil data from a number of places in the world." Pessagno (1969, p. 75–76) presented documentation supporting this conclusion. Within the Pinto Creek section, *M. concavata* has been found to be a common-to-abundant element of the fauna. It makes its initial appearance at 83 feet (25.3 m) above the base of the Atco Formation and ranges to the top of the exposure at 151 feet (46.0 m). Therefore, on the basis of the abundant occurrence of *M. concavata,* these strata within the upper part of the Pinto Creek section are herein regarded as early Santonian, rather than late Coniacian Age.

The discrepancy in the ammonite, planktonic Foraminiferal, and inoceramid ages is not great and involves relatively short lithostratigraphic intervals in southwestern Texas. The disagreement in ages could be due to no more than the very imperfect and poorly defined limits of the European type Turonian, Coniacian, and Santonian Stages. These discrepancies emphasize the need for a thorough reevaluation of the type European stages, as well as for more detailed and integrated investigations involving both the microfossils and megafossils from Upper Cretaceous strata of the Gulf Coastal Plain.

METHODS OF INVESTIGATION

SAMPLE COLLECTION

Calcareous nannoplankton constitute the bulk of both the thick indurated chalky limestone and the thin marly layers throughout the Austin Group. Preliminary examination of several samples indicated that, although the coccoliths were perhaps more abundant in the chalky limestone, the nannoplankton from the marly layers were almost equally abundant, easier to extract, and in many instances showed better preservation and fewer effects due to recrystallization. On the basis of these observations (see also Rezak and Henry, 1975), the bulk of the sample material utilized herein was collected, where possible, from thin marly lenses within the Austin Group.

During this study, samples were collected for both foraminiferal and nannoplankton investigations. Owing to the small size of the calcareous nannofossils and the resulting ease of their contamination, extraordinary precautions were taken during both sample collection and processing. Nannoplankton samples, each consisting of about 1 cm^3 in volume, were stored in sealed manila coin envelopes throughout the period of field investigation.

PROCESSING TECHNIQUES

Foraminiferal samples were processed following the procedure outlined by Pessagno (1967, p. 357). All samples were processed by geographic locality and in order of their stratigraphic position, from bottom to top, at each of the several sites. The nannoplankton samples were pulverized by using mortar and pestle, and the powder stored in small glass sample vials as permanent reference material. All implements, such as mortar and pestle, beakers, stirring rods, and so forth, were washed in a dilute solution of hydrochloric acid and were thoroughly rinsed following each use in order to eliminate contamination from sample to sample.

The following technique is the result of several trial-and-error experiments utilizing both centrifugation and various settling schemes. About one-half gram of the powder was placed in a 150-ml glass beaker, about 6 cm in diameter, and distilled water added to a depth of 25 mm. The beaker was then placed in an ultrasonic vibrator for 15 seconds, which resulted in the separation and cleaning of the coccoliths, but little or no noticeable effect of breaking or separation of the plates. After sonification, the beaker was covered and allowed to sit undisturbed for 90 seconds. During this time, the coarse noncoccolith fraction (>20 μm) settled to the bottom of the beaker. The decantant, containing the coccolith and fine-clay fraction (<20 μm), was carefully poured into a second beaker, covered, and allowed to settle for 12 minutes. The residue remaining in the bottom of the second beaker contained the coccolith-size fraction, consisting of particles of about 1 to 20 μm in diameter.

A second or third period of resettling was occasionally necessary to further remove <1 μm debris. This was accomplished by adding about 60 ml of distilled water to the residue, followed by stirring for a short period to resuspend the coccolith-size fraction, then letting it resettle for 12 minutes. After the settling and decanting, the residue was resuspended in a few milliliters of distilled water and transferred to small glass vials. Both the coarse (>20 μm) and fine (<1 μm) fractions were occasionally examined in order to minimize the removal of excessively large or small coccoliths. The settling times were varied to suit individual samples. This resulted in an almost pure concentrate of nannofossils (also see Burns, 1974).

SLIDE PREPARATION

Two types of slide preparations were utilized during this investigation. Permanent slides were prepared for light microscopic investigation, and a second, new double coverslip technique was developed that permitted the examination of the same nannofossil by using the scanning electron microscope and then by transmitted light optics. Both techniques were extensively utilized and proved invaluable during this investigation.

LIGHT MICROSCOPY

Permanent light-microscope slide preparations were used in organizing occurrence, distribution, and abundance data for each species from each of the various samples. The slides were prepared by first placing two drops of distilled water on a 22 by 30 mm rectangular coverglass. The water was then spread over the coverslip by using a toothpick. The vial containing the nannofossil concentrate was agitated, and one drop of the suspension was allowed to fall from an eyedropper onto the center and one drop at either end of the coverglass. No further mixing or spreading of the suspension was necessary because each droplet rapidly spread over the previously wetted coverslip. After about 1 minute, during which time the platy nannofossils settled to the surface of the coverglass, the edges of small pieces of absorbent paper towels were applied to the suspension to remove the excess water. The coverglass was then transferred to a warm hotplate, and the suspension was allowed to dry. Next, one or two drops of Caedax were placed on a standard 1- by 3-inch-glass slide and allowed to cure on a hotplate at about 120°C for 10 minutes. After curing, which removes the volatile xylene from the Caedax, the glass slide was removed from the hotplate, and the coverglass was immediately mounted in the cured Caedax. This standard preparation technique of permanent mounts for light-microscope examination was used throughout this investigation with no noticeable movement of the coverglass during subsequent examination, cleaning, and storage.

ELECTRON MICROSCOPY

During this study, a new method was developed that permitted, first, scanning electron microscopy and then transmitted light examination of the same nannoplankton specimen (Smith, 1975a). This technique is important because it (1) removes the uncertainty in correlating the quite different images produced by the scanning electron and transmitted light microscopes; (2) allows the direct relating of surface morphology as observed in the scanning electron microscope to polarized and transmitted light images; and (3) permits the study of the same specimen in both proximal and distal aspects using transmitted light photomicrographs, and the slide serves as a permanent mount of potential type nannofossils specimens. Because of the importance of this new technique and its applicability in studies of nannoplankton proven throughout the present investigation, the method is outlined in detail.

A drop of distilled water was placed on a 13 mm diameter circular microscope coverglass, and was spread to a uniform film with a toothpick. Next, a single drop of concentrated nannofossil suspension was placed onto the water film. After allowing the nannofossils to settle to the surface of the coverslip (a period of 15 to 20 seconds was sufficient), the edges of small strips of absorbent paper towels were applied to the suspension droplet to remove excess water.

After drying, the coverglass was fitted into the recessed area of a T-shaped metal plug and transferred to a vacuum evaporator for metal coating (Urban and Padovani, 1970, fig. 3). Experimentation showed that a 1.5-cm length of 8 mil diameter alloy, consisting of 60 percent gold/40 percent palladium, applied to both the low- and high-angle filaments (Urban and Padovani, 1970, fig. 5), resulted in excellent secondary electron emission and provided a sufficiently thin coating for light microscopy.

Low-power photographic mapping of the distribution of nannofossils on the coverglass surface may be achieved by using either scanning electron or light microscopes. If a scanning electron microscope is used, the coverslip is removed from the T-shaped coating plug, inserted into a spring-loaded plug (Urban and Padovani, 1970), and mapped at a magnification of × 1,000 or less. Low-power photographic mapping using a light microscope is achieved by transferring the coverslip from the coating plug, carefully placing it on a 1×3 inch glass slide, and photographically scanning the coverglass by using either transmitted or reflected light optics. Either method is satisfactory and allows the relocation of the same nannofossil specimen after scanning electron microscopy.

After the scanning electron examination and the proper labeling on the coverslip map of each photographed specimen, the coverglass is removed from the spring-loaded plug, inverted, and permanently mounted on a 22 mm diameter circular coverglass. Excellent results have been achieved by using a 70 percent Caedax/30 percent Xylene solution as a mounting medium. The mounting medium should be of sufficiently low viscosity to produce a thin preparation. Otherwise, the combined thickness of the coverslip and mounting medium, as observed through the 22 mm diameter coverslip, will be too great for focusing with × 100 oil-immersion objectives.

Care in slowly lowering the nannofossil coated coverglass onto the Caedax-solution droplet will eliminate air bubbles and insure no movement of individual nannofossils. No pressure should be applied to either coverslip, as any attempt to "squeeze" the coverglasses into closer proximity will result in movement of the mapped specimens.

Holders for the double coverslip mounts have been constructed of aluminum, although other available sheet metal, or Plexiglas, should be satisfactory. The metal slide is 1 inch wide, 3 inches long, and 0.050 inches thick (for compatible storage in standard microscope slide storage boxes), with a 0.875-inch-diameter circular hole drilled through the center of the slide. The double coverslip mount is inserted into the metal slide, and the edge of the 22 mm diameter coverslip is temporarily cemented to the opening in the slide with a small amount of quick-drying household cement. After 2 or 3 minutes of drying, epoxy, Caedax, or other strong bonding material is applied along the contact between the coverglass mount and metal holder, and the slide placed in a warm oven to cure. Experience has shown that 4 days (preferably 7 to 10 days) at 65°C is required to properly cure the Caedax mount and to insure no movement of the coverslips during subsequent handling and cleaning.

After curing, the double coverslip may be examined under a light microscope with oil-immersion objectives. The same nannofossil specimen studied in the scanning electron microscope is relocated by referring to the previously labeled maps of the coverglass surface.

MICROSCOPES

Light microscopic examination was conducted by using an American Optical Reichert Zetopan Microscope adapted to a Leitz Aristophot Photomicrograpic Apparatus [1] fitted with a 35 mm Exakta camera back, and a Zeiss Photomicroscope III with Polaroid 4×5 camera attachments. Both microscopes were equipped with 12 volt 100 watt quartz halogen light sources, with polarizing, phase, and interference phase contrast systems. All light microscope photographs were taken on 35 mm panatomic-X film at an original magnification of about × 2,000. The JEOLCO JSM–1 and Cambridge S4–10 Scanning Electron Microscopes were utilized throughout this investigation. Negatives were taken on Tri-X Pan film at magnifications ranging from × 4,000 to × 30,000.

TAXONOMIC PROBLEMS

NOMENCLATURE

Living coccolithophorids possess some of the characters of both plants and animals. Examination of living coccospheres that were collected from the open oceans, or from maintained laboratory cultures, indicates that most of the coccospheres have a flagellate motile stage, are free swimming, and propel themselves by a pair of flagella at one pole of the cell. Parke and Adams (1960, p. 265) observed the Protista-like attributes of ingestion and assimilation of bacteria and plant cells up to a diameter of 5 μm in size. Unlike the Protista, however, living coccolithophores possess chromatophores and synthesize their food from the energy of sunlight.

Although recent studies have shown that the majority of living coccolithophorids belong to the Division Phaeophyta rather than the Protozoa, paleontologists have with almost equal frequency adopted

[1] Any trade names in this publication are used for descriptive purposes only, and do not constitute endorsement by the U.S. Geological Survey.

either botanical or zoological codes of nomenclature. Since the two codes share large areas of agreement, the problems of a dual system of nomenclature are not necessarily great, if consistency is maintained in the use of a particular code.

During the Symposium on Calcareous Nannoplankton, Second Planktonic Conference, held in Rome on September 23–28, 1970, a series of proposed recommendations were approved (see Farinacci, 1971, p. 1345), including proposition 1, "That in the future the International Code of Botanical Nomenclature should be followed by all workers on calcareous nannoplankton." This recommendation, as well as others approved by the Symposium, is followed herein.

POLYMORPHISM

The life histories of living coccolith-bearing algae are very poorly known, and from the few that have been studied in detail, the results have been quite unexpected. Parke and Adams (1960) conducted a study of *Crystallolithus hyalinus* Gaarder and Markali, 1956, collected as motile, free-swimming coccospheres from the northeastern Atlantic. In culture, *C. hyalinus* was found to undergo fission, producing motile daughter cells identical to the parent. After a few weeks, the daughter cells ceased to swim, settled to the bottom of the flask, grew in size, and ultimately secreted coccoliths in a form regarded as a separate and distinct genus and species, *Coccolithus pelagicus* (Wallich, 1877) Schiller 1930. Observations conducted over a 12-month period showed a regular alternation between the motile *C. hyalinus* and nonmotile *C. pelagicus* phases, each phase producing coccospheres bearing coccoliths of an entirely different nature from the opposite phase, so different in fact, that they had been thought to belong to entirely different families.

Coccoliths produced by the nonmotile phase of a two-stage life cycle have been termed heterococcoliths because of the varying sizes and shapes of the constituent elements. Almost without exception, all fossil coccoliths are of the heterococcolith type. The motile stage in the life cycle produces coccoliths constructed of elements of uniform size and shape, and these have been termed holococcoliths. The holococcoliths are very rarely preserved in a fossil state, presumably because of their fragile nature and ease of disaggregation. Notwithstanding the selective preservation of the heterococcoliths, it should be borne in mind that this type of nomenclatoral problem directly affecting the taxonomy of the coccolithophorids will continue.

Another and perhaps more serious problem that complicates the classification of the calcareous nannoplankton is the existence of two completely different types of coccoliths—for example, *Gephyrocapsa oceanica* Kamptner, 1943, and *Emiliania huxleyi* (Lohmann, 1902), Hay and others, 1967, borne on a single coccosphere (Clocchiatti, 1971). The assignment of isolated fossil coccoliths to generic and higher taxonomic categories is, thus, even more artificial than was previously evident. Although the problems of polymorphism present difficulties in nannoplankton taxonomy, they should not detract from the use of isolated coccoliths as distinct morphologic entities in stratigraphic paleontology.

DIFFERENCE IN ASPECT

Of more immediate importance to paleontological studies are the difficulties presented in the entirely different aspects of proximal and distal sides of coccoliths. Because only a single view may be examined by electron microscopy, it is often difficult and occasionally impossible to properly correlate isolated proximal and distal views. As an example, the genus *Favocentrum* Black 1964 (type species =*F. laughtoni* Black 1964) was based on transmission electron micrographs of isolated distal views. A second species, *F. matthewsi* Black 1964 was described from electron micrographs of isolated proximal views. More recent studies have shown that both *F. laughtoni* and *F. matthewsi* represent no more than distal and proximal views of the same species. In this case, however, additional taxonomic problems exist because both species are junior subjective synonyms of *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912) Deflandre 1952a; thus, the genus *Favocentrum* Black 1964 is a junior synonym of *Cribrosphaerella.* Future problems of this nature could be significantly reduced if the double coverslip method described herein, or similar techniques described by Thierstein, Franz, and Roth (1971), Moshkovitz (1974), or Hansen, Schmidt, and Mikkelsen (1975) were used during scanning electron and transmitted light investigation. Furthermore, Perch-Nielsen (1967) described a technique for examining the same nannoplankton specimen by utilizing transmitted light and then transmission electron microscopy. These methods, or a combination of techniques, should eliminate many of the problems in image correlation.

LIGHT AND ELECTRON MICROSCOPY

Transmission and scanning electron microscopy of calcareous nannoplankton have shown complexity of surface structure beyond the limit of resolution of light optical systems. Indeed, many of the so-called major structural features observed in electron microscopy, on which specific as well as generic (and suprageneric!) taxa have been based, are occasionally only inferred through light optical examination. The present investigation has substantiated the difficulty of relating the entirely different images produced in electron and light optical systems. Although few paleontologists would disagree that emphasis should be placed on overall morphologic features distinct in both electron and light microscopes, far too few taxonomists are willing to abide by this concept in actual practice.

The development and utilization herein of the technique of examining the same specimen in both scanning electron and light microscopes have been of immense value in removing this uncertainty of image correlation. However, until this or some similar technique gains more widespread acceptance, there is, and will unfortunately continue to be, countless new taxa based on isolated light and electron photomicrographs.

SYSTEMATIC PALEONTOLOGY

DEFINITION OF MORPHOLOGIC TERMS

The following abbreviated list of terms commonly used in describing the architecture of calcareous nannoplankton has been taken largely, and with little modification, from the works of Bukry (1969, p. 8) and Perch-Nielsen (see Farinacci, 1971, Round Table on Calcareous Nannoplankton, p. 1348–1349):

Arm.—Portion of crossbar between rim and center of coccolith.

Bar.—Skeletal element crossing central area that does not pass through center of coccolith.

Central area.—Central region of a coccolith, but not including parts of a shield or wall. It can be open or partly or completely covered by elements.

Central process.—A protuberant part of the central area.

Central structure.—The arrangement of elements within the central area.

Clockwise inclination.—Sutures of elements inclined rightward as they proceed to periphery.

Coccolith.—General term for any calcified skeletal element of Coccolithophyceae.

Coccolith center.—Center of coccolith symmetry in proximal and distal view.

Coccolithophores.—Any chromatophore-bearing protist which at some phase of its life-cycle produces coccoliths.

Coccosphere.—Entire spherical test of a coccolithophore, composed of interlocking coccoliths.

Counterclockwise inclination.—Sutures of elements inclined leftward as they proceed to periphery.

Cycle.—Concentric rows of elements in a shield or central area. Numbers of cycles are listed from the outer towards the inner part of the coccolith.

Dextral imbrication.—Each element overlapping one to right when viewed from center of cycle.

Distal view.—Outward-facing convex side of coccolith.

Element.—Basic structural unit of coccolith skeleton consisting of a single calcite crystallite.

Perforation.—A small opening in a coccolith that is surrounded by or between few elements.

Proximal view.—Inward-facing concave side of coccolith.

Radial.—Suture corresponding to radius in circular form or to straight line drawn through nearest focus or line connecting foci of elliptical form.

Rim.—Peripheral cycle or cycles of elements in coccolith skeletons surrounding central area.

Shield.—The part of the coccolith, excluding the central area, that is more or less horizontal. It is composed of one or several cycles.

Sinistral imbrication.—Each element overlapping one to left when viewed from center of cycle.

Stem.—Complex of elements in form of cylinder or prism, which may be hollow or solid, and extends from center of distal side of some coccoliths.

Suture.—Boundary between skeletal elements.

Wall.—The part of the coccolith, excluding the central area, that is more or less vertical. Walls should be numbered from the outer towards the inner part of the coccolith.

SUPRAGENERIC CLASSIFICATION

The assignment of isolated coccoliths to even generic categories is much more artificial than we previously believed. Dimorphic two-stage life cycles in which the coccospheres produce two entirely different types of coccoliths have become increasingly well known. Other living species have skeletal elements surrounding the apical pole, quite different from the coccoliths on the remainder of the sphere. In other living forms, certain coccoliths possess a central stem completely lacking in other forms on the same coccosphere. Additionally, coccospheres are known to possess two entirely distinct forms of coccoliths on the same spherical body (Clocchiatti, 1971). The usual difficulties in assigning fossil forms to generally dissimilar modern taxa are, therefore, increased.

The objective and entirely artificial classification of isolated coccoliths to specific and generic taxa does not seem to justify, at least at present, their assignment to elaborate and taxonomically cumbersome suprageneric hierarchies. Additionally, there appears to be little phylogenetic significance, either real or implied, in any of the existing schemes involving late Cretaceous suprageneric taxa. Finally, that there are known biological relationships between morphologically different fossil nannoplankton species has yet to be proved.

Inherent in the International Code of Botanical Nomenclature (see Stafleu, 1972) is the concept of form genera, expressly provided for the naming and organization of taxa consisting of isolated, fragmentary fossil parts lacking known relationships to other fossil parts or to the specific parent organism. To convert potentially valuable biostratigraphic fossil forms into an oppressive, illogical, and endless array of reshuffled categories does not seem necessary; therefore, an artificial classification based on morphological similarities characterizing form-genera will be used herein. Genera and included species are arranged in alphabetical order.

SYSTEMATIC DESCRIPTIONS

Genus AHMUELLERELLA Reinhardt 1964

Type species.—*Discolithus octoradiatus* Gorka 1957.

Diagnosis.—Elliptical forms consisting of a single cycle distal rim tier composed of imbricate elements that are strongly inclined proximally, and an open central area lined by a narrow proximal cycle and spanned by crossbars slightly asymmetrical to the major and minor axes of the ellipse.

Ahmuellerella octoradiata (Gorka 1957) Reinhardt 1966

Plate 1, figures 1–9, 10–15

1957. *Discolithus octoradiatus* Gorka, p. 259, pl. 4, fig. 10.
1963. *Zygolithus octoradiatus* (Gorka 1957), Stradner, p. 180, pl. 5, figs. 2–2a.
1964. *Zygolithus? octoradiatus* (Gorka 1957), Bramlette and Martini, p. 304, pl. 4, figs. 15–16.
1964. *Ahmuellerella limbitenuis* Reinhardt, p. 751, pl. 1, fig. 6; pl. 2, fig. 6; text-fig. 1.
1966a. *Ahmuellerella octoradiata* (Gorka 1957), Reinhardt, p. 24, pl. 22, figs. 3–4.
1966a. *Ahmuellerella limbitenuis* Reinhardt 1964, Reinhardt, p. 24, pl. 14, figs. 1a–b, 3, 4a–b; text-fig. 16.
1967. *Zygrhablithus octoradiatus* (Gorka 1957), Lyul'eva, p. 92, pl. 1, figs. 9–9a.
1967. *Ahmuellerella octoradiata* (Gorka 1957), Reinhardt, p. 166, figs. 1, 7 (1–3).
1967. *Ahmuellerella octoradiata* (Gorka 1957), Reinhardt and Gorka, p. 242, pl. 31, figs. 1, 4; pl. 32, fig. 2.
1967. *Zygolithus octoradiatus* (Gorka 1957), Sales, p. 305, pl. 3, figs. 15a–b.
1967. *Zygolithus? octoradius* (Gorka 1957), Vangerow and Schloemer, (error for *octoradiatus*), p. 456, table 1, fig. 23.
1968. *Eiffellithus octoradiatus* (Gorka 1957), Gartner p. 25, pl. 2, figs. 17–21; pl. 3, figs. 11a–c; pl. 5, fig. 20; pl. 12, figs. 10a–c.
1968. *Ahmuellerella octoradiata* (Gorka 1957), Perch-Nielsen, p. 23–24, pl. 2, figs. 1, 2, 12–15.
1969. *Vagalapilla octoradiata* (Gorka 1957), Bukry, p. 58, pl. 33, figs. 5–7.
1969. *Ahmuellerella octoradiata* (Gorka 1957), Čepek and Hay, p. 331, text-fig. 2, no. 3, text-fig. 4, no. 7.
1969. *Ahmuellerella octoradiata* (Gorka 1957), Pienaar, p. 82, pl. 4, fig. 7; pl. 10, fig. 8.
1970. *Zygolithus octoradiatus* (Gorka 1957), Čepek, p. 244, pl. 25, figs. 7, 8a–c.
1970a. *Ahmuellerella octoradiata* (Gorka 1957), Hoffmann, p. 849, pl. 1, fig. 5; pl. 3, figs. 1, 2.
1970a. *Ahmuellerella octoradiata* (Gorka 1957), Reinhardt, p. 11–12, pl. 1, figs. 9, 10; text-figs. 12, 13.
1971a. *Ahmuellerella* sp. cf. *A. octoradiata* (Gorka 1957), Black, p. 618, pl. 45.4, fig. 42.
1971. *Ahmuellerella octoradiata* (Gorka 1957), Manivit, p. 93–94, pl. 1, figs. 1, 2–3, 4–5.
1971. *Ahmuellerella octoradiata* (Gorka 1957), Shafik and Stradner, p. 80, pl. 23, figs. 1–4.
1971a. *Ahmuellerella octoradiata* (Gorka 1957), Thierstein, p. 35, pl. 1, figs. 13–14.
1972. *Ahmuellerella octoradiata* (Gorka 1957), Forchheimer, pl. 23, figs. 3, (?)6.
1972. *Ahmuellerella octoradiata* (Gorka 1957), Grün and others, p. 166, pl. 28, figs. 9a–b, 10a–b.
1972a. *Ahmuellerella octoradiata* (Gorka 1957), Hoffmann, p. 35–37, pl. 4, fig. 5; pl. 5, figs. 1, 2, 3; text-figs. 17, 18.
1972. *Ahmuellerella octoradiata* (Gorka 1957), Lauer, p. 166, pl. 28, figs. 9a–b, 10a–b (note: listed in error as *Vagalapilla octoradiata* (Gorka) in explanation of plate figures).
1972. *Ahmuellerella octoradiata* (Gorka 1957), Locker, p. 753, pl. 10, figs. 7–8.
1973. *Ahmuellerella octoradiata* (Gorka 1957), Priewalder, p. 12, pl. 1, figs. 1, 2, 3, 4, 5.
1973. *Ahmuellerella octoradiata* (Gorka 1957), Risatti, p. 19, pl. 8, figs. 18, 19.
1974. *Ahmuellerella octoradiata* (Gorka 1957), Totten, p. 84, pl. 1, figs. 31–32, 33–34.
1975. *Eiffellithus octoradiatus* (Gorka 1957), Krancer, p. 11, pl. 2, fig. 3.
1975. *Ahmuellerella octoradiata* (Gorka 1957), Stapleton, p. 55, pl. 4, figs. 5a–b.
1976. *Ahmuellerella octoradiata* (Gorka 1957), El-Dawoody and Zidan, p. 419–420, pl. 5, figs. 1a–b, (?)2a–b.
1977. *Ahmuellerella octoradiata* (Gorka 1957), Pavšič, p. 38, pl. 2, figs. 1, 2, 3, 4.
1978. *Ahmuellerella octoradiata* (Gorka 1957), Proto Decima, Medizza, and Todesco, p. 602, pl. 15, figs. 14a–c, (?)15a–c.
1978. *Ahmuellerella octoradiata* (Gorka 1957), Shafik, p. 223, fig. 6, Oa–Ob.

Diagnosis.—Elliptical coccoliths consisting of a single cycle distal rim tier constructed of 45 to 60 dextrally imbricate elements. Distally, the interelement sutures are radially inclined, becoming very strongly clockwise inclined near the inner margin of the cycle. The broad and open central area is spanned by four double crossbars that are offset a few degrees sinistrally from the major and minor axes of the ellipse. Each crossbar becomes strongly divergent as it approaches the inner margin of the distal rim cycle.

Description.—This species was not observed under the scanning electron microscope during this study. Plane transmitted and phase contrast light images show *Ahmuellerella octoradiata* to consist of a narrow, elliptical rim cycle and large, open central area spanned by four biserial crossbars. The crossbars are not alined perfectly with the longitudinal and transverse axes of the elliptical central area, but are slightly rotated sinistrally in distal view. Each crossbar consists of two members which are parallel and adjacent near the middle of the central opening, but are strongly diverging at their contact with the inner margin of the rim cycle. In cross-polarized light, when oriented with the major axis parallel to either nicol, the four pairs of diverging crossbars appear bright, each pair of crossbars bisected by a thin, dark interference-extinction line.

Remarks.—*Ahmuellerella octoradiata* is distinct in transmitted light as well as in electron optical systems and is easily distinguished from other species.

Known range.—Middle Turonian through Maastrichtian.

Type locality.—Maastrichtian strata of Gora Pulawska, Poland.

Occurrence.—This species is well documented from Turonian through Maastrichtian strata of Europe and Africa (see synonymy). Within the United States, it has been reported from the lower to middle Campanian part of the Ladd Formation of Orange County, Calif. (Totten, 1974); Pfeifer Shale Member of the Greenhorn Limestone, and Fairport Chalk Member of the Carlile Shale of Russell County, Kans. (Čepek and Hay, 1969); upper part of the Niobrara Chalk, Knox County, Nebr. (Bukry, 1969); Mooreville Chalk and Demopolis Chalk of Mississippi (Newell, 1968); Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Mississippi (Risatti, 1973); Tombigbee Sand Member of the Eutaw Formation, Mooreville Chalk, Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Alabama (Čepek and Hay, 1969); Ripley Formation, Prairie Bluff Chalk of Alabama, and the Arkadelphia Marl of Arkansas (Bramlette and Martini, 1964); and from the lower and middle part of the Austin Group, Taylor Marl, and Corsicana Marl of Texas (Gartner, 1968; Bukry, 1969).

During this study, *Ahmuellerella octoradiata* was observed in samples from upper Turonian strata exposed along Sycamore Creek and at the Oak Haven Waterfall sites, Kinney and Travis Counties, and from Coniacian and lower Santonian strata exposed in Dallas County, Tex.

Genus ARKHANGELSKIELLA Vekshina 1959

Type species.—*Arkhangelskiella cymbiformis* Vekshina 1959.

Remarks.—The description presented by Gartner (1968, p. 37) is followed herein. *Arkhangelskiella* Vekshina differs from *Gartnerago* Bukry by (1) having three rim cycles at three distinct levels in proximal view, (2) having a fewer number of elements in each cycle, and (3) having interelement sutures which maintain the same inclination across each cycle of elements.

Arkhangelskiella cymbiformis Vekshina 1959

Plate 1, figures 16–24, 25–31, 32–34

1912. "Coccoliths of uncertain affinity," Arkhangelsky, pl. 6, fig. 24.
1959. *Arkhangelskiella cymbiformis* Vekshina, p. 66, pl. 2, figs. 3a–b.
1963. *Arkhangelskiella cymbiformis* Vekshina 1959, Stradner, p. 178, pl. 1, figs. 4a–c.
1964. *Arkhangelskiella cymbiformis* Vekshina 1959, Bramlette and Martini, p. 297–298, pl. 1, figs. 3–5, 6(?), 7, 8, 9.
1964. *Arkhangelskiella cymbiformis* Vekshina 1959, Stradner, p. 137, text-fig. 42.
1965. *Arkhangelskiella cymbiformis* Vekshina 1959, Reinhardt, pl. 2, fig. 6.
1966a. *Arkhangelskiella cymbiformis* Vekshina 1959, Reinhardt, p. 31–32, pl. 6, figs. 1, 2, 3a–b; pl. 22, figs. 14–19.
1966. *Arkhangelskiella cymbiformis* Vekshina 1959, Stover, p. 137, pl. 1, fig. 18; pl. 8, fig. 8; *not* pl. 1, figs. 17a–b.
1966. *Discolithus octocentralis* Stover, p. 143, pl. 3, figs. 1a–c, 2; pl. 8, fig. 18.
1967. *Arkhangelskiella cymbiformis* Vekshina 1959, Moshkovitz, p. 146, pl. 1, figs. 6–6a, 7, 8; pl. 5, figs. 1, 2a–b.
1967. *Arkhangelskiella cymbiformis* Vekshina 1959, Reinhardt, p. 174, text-figs. 8, 12a–c.
1967. *Arkhangelskiella cymbiformis* Vekshina 1959, Vangerow and Schloemer, p. 456, table 1, fig. 1.
1968. *Arkhangelskiella cymbiformis* Vekshina 1959, Forchheimer, p. 22–23, pl. 2, figs. 6a–6b; fig. 4, no. 6.
1968. *Arkhangelskiella cymbiformis* Gartner, p. 38, pl. 1, figs. 1–6; pl. 4, figs. 2, 3; pl. 6, figs. 1a–c; *not* pl. 4, figs. 1, 4; *not* pl. 27, figs. 2a–b.
1968. *Arkhangelskiella scapha* Gartner, p. 39, pl. 14, fig. 1; pl. 15, figs. 1a–d; pl. 17, figs. 8a–d; pl. 20, figs. 1–3.
1968. *Arkhangelskiella cymbiformis* Vekshina 1959, Perch-Nielsen, p. 57–59, pl. 19, figs. 1, 2; pl. 20, figs. 3–8; text-figs. 24, 25, 26a–b.
1969a. *Arkhangelskiella cymbiformis* Vekshina 1959, Bukry, p. 21, pl. 1, figs. 1–3.
1969. *Arkhangelskiella cymbiformis* Vekshina 1959, Čepek and Hay, p. 331, text-fig. 4, no. 9.
1969a. *Arkhangelskiella cymbiformis* Vekshina 1959, Noël, p. 195, text-figs. 1a–b.
1969b. *Arkhangelskiella cymbiformis* Vekshina 1959, Noël, p. 479–482, pl. 2, figs. 1–3; text-fig. 4.

1969. *Arkhangelskiella cymbiformis* Vekshina 1959, Pienaar, p. 84–85, pl. 1, figs. 2, 3; pl. 6, figs. 6, 7; pl. 11, fig. 1.
1970. *Arkhangelskiella cymbiformis* Vekshina 1959, Iaccarino and Follini, p. 589, pl. 39, (?)figs. 7, 8; *not* pl. 40, figs. 6. 7.
1970. *Discolithus octocentralis* Stover 1966, Čepek, p. 241, pl. 22, figs. 7, 8a–c; pl. 26, fig. 6.
1971. *Arkhangelskiella cymbiformis* Vekshina 1959, Manivit, p. 103, pl. 1, figs. 6, 7, 8–9, 10–11.
1971a. *Arkhangelskiella cymbiformis* Vekshina 1959, Thierstein, p. 38, pl. 2, figs. 33–34.
1972. *Arkhangelskiella cymbiformis* Vekshina 1959, Báldiné Beke, p. 217, pl. 3, figs. 2a–b.
1972. *Arkhangelskiella cymbiformis* Vekshina 1959, Grün and others, p. 152, pl. 23, figs. 3a–b, 4a–b.
1972. *Arkhangelskiella cymbiformis* Vekshina 1959, Lauer, p. 152, pl. 23, figs. 3a–b, 4a–b.
1972. *Arkhangelskiella cymbiformis* Vekshina 1959, Locker, p. 770, pl. 10, figs. 17, 18.
1973. *Arkhangelskiella cymbiformis* Vekshina 1959, El-Dawoody and Barakat, p. 107–108, pl. 10, figs. 1a–b.
1973. *Arkhangelskiella cymbiformis* Vekshina 1959, Priewalder, p. 12–13, pl. 3, figs. 1, 2, 3, 4.
1973. *Arkangelskiella cymbiformis* Vekshina 1959, Risatti, p. 25, pl. 1, figs. 21–23.
1973. *Arkhangelskiella cymbiformis* Vekshina 1959, Roth, p. 715, pl. 19, figs. 1, 3, 5, 7; pl. 20, fig. 1.
1974. *Arkangelskiella cymbiformis* Vekshina 1959, Totten, p. 83, pl. 1, figs. 29–30.
1975. *Arkhangelskiella cymbiformis* Vekshina 1959, Čepek, p. 98–99, pl. 1, fig. 4; pl. 3, figs. 1a–d.
1975. *Arkhangelskiella cymbiformis* Vekshina 1959, Jafar, pl. 13, figs. 12–13.
1975. *Arkhangelskiella cymbiformis* Vekshina 1959, Proto Decima, Roth, and Todesco, p. 44, pl. 1, figs. 1a–b.
1976. *Arkhangelskiella cymbiformis* Vekshina 1959, El-Dawoody and Zidan, p. 410–411, pl. 1, figs. 1a–b, 2a–b, 3a–b, 4a–b, 5a–b, (?)6a–b.
1976b. *Arkhangelskiella cymbiformis* Vekshina 1959, Verbeek, p. 142–143, pl. 3, fig. 3.
1977. *Arkhangelskiella cymbiformis* Vekshina 1959, Pavšič, p. 39, pl. 3, figs. 1, 2, 3, 4.
1978. *Arkhangelskiella cymbiformis* Vekshina 1959, Shafik, p. 213, figs. 2, Qa–Qb, Ra–Rb.

Diagnosis.—Elliptical discoliths with narrow rim cycles and a broad cribrate central area divided into quadrants by four ribs, two alined with the major axis and two slightly rotated dextrally to the minor axis. In cross-polarized light, the central area is divided into alternately light and dark, equal radial wedges, two wedge-shaped areas to each quadrant.

Description.—The description of this species by Gartner (1968, p. 38) is based on electron micrographs and is followed herein. In plane transmitted and phase contrast light, this species appears to have a rather broad outer rim and large central area. In plane transmitted light, the central area appears granular and the rim somewhat indistinct. Phase contrast images show a bright outer rim and central area indistinctly divided into eight equal radial wedges. *Arkhangelskiella cymbiformis* is most distinctive in cross-polarized light in which the central area appears sharply divided into eight radially arranged, alternately light and dark, wedge-shaped regions. Each quadrant of the central area contains one light and one dark region. In distal view, the bright wedges are adjacent and dextral to the major and minor axes of the central elliptical area. When viewed proximally, the bright wedge-shaped regions are adjacent and sinistral to the axes. In both proximal and distal views, two narrow, rather sharply defined, interference-extinction lines extend across the bright outer rim at either end of the elongate ellipse.

Remarks.—The light optical images of *Arkhangelskiella cymbiformis* differ from those of *Gartnerago segmentatum* (Stover 1966) in (1) having a wider and much more distinct outer peripheral rim, (2) having the more sharply defined, wedge-shaped radial elements, and (3) lacking distinct sutures bisecting the central area.

The form figured by Stover (1966, pl. 1, figs. 17a–b) as *Arkhangelskiella cymbiformis* should probably be assigned to *Broinsonia parca* (Stradner 1963) Bukry 1969. It differs from *A. cymbiformis* is having a very narrow central area traversed by sutures alined with the major and minor axes of the ellipse, and in having a much wider outer peripheral rim.

The forms figured by Gartner as *Arkhangelskiella cymbiformis* (1968, pl. 4, figs. 1, 4; pl. 27, figs. 2a–b) are herein assigned to *Gartnerago costatum* (Gartner 1968) Bukry 1969. Gartner's figures show perforations which are arranged in a single row adjacent to and along either side of the central sutures. The pores are also bisected by a single transverse bar. Both of these features are diagnostic of *Gartnerago costatum*.

Known range.—Late Cenomanian through Maastrichtian.

Type locality.—Maastrichtian strata from the West Siberian Shelf near Lucinkino, U.S.S.R.

Occurrence.—*Arkhangelskiella cymbiformis* has been well documented to have a worldwide occurrence in upper Cenomanian through Maastrichtian strata (see synonymy). This species was observed throughout the upper Turonian, Coniacian, and lower Santonian strata of Texas. It was not, however, observed in any of the samples from the Sycamore Creek or Oak Haven Waterfall localities.

Genus BISCUTUM Black 1959

Type species.—Biscutum testudinarium Black 1959.

Diagnosis.—Small elliptical placoliths consisting of two closely appressed shields. The distal shield is slightly larger than the proximal, and both are constructed of a small number of radial or nearly radially arranged elements. The small central area is constructed of irregularly shaped elements.

Remarks.—Biscutum Black 1959 differs from *Bidiscus* Bukry 1969 in having an elliptical, rather than circular, outer peripheral outline. It differs from *Watznaueria* Reinhardt 1964 in having a single cycle distal shield constructed of radially arranged elements.

Biscutum blackii Gartner 1968

Plate 1, figures 35–40, 41–44, 45–47

1968. *Biscutum blacki* Gartner, p. 18–19, pl. 1, fig. 7; pl. 6, figs. 2a–c; pl. 8, figs. 8, 9, 10; pl. 11, figs. 8a–c; pl. 15, figs. 2a–c; pl. 16, fig. 8.
1969. *Biscutum blacki* Gartner 1968, Bukry, p. 28, pl. 7, fig. 12; pl. 8, figs. 1, 2, 3.
1969. *Biscutum blackii* Gartner 1968, Pienaar, p. 85, pl. 3, fig. 6.
1971a. (?)*Biscutum blacki* Gartner 1968, Thierstein, p. 39, pl. 2, figs. 39–40.
1972. *Biscutum blackii* Gartner 1968, Black, p. 27, pl. 2, figs. 5, 6, 7, 8.
1972. *Biscutum blacki* Gartner 1968, Forchheimer, p. 32, pl. 8, figs. 3, 4; pl. 9, fig. 5.
1972. *Biscutum kennedyi* Bukry 1970, Forchheimer, p. 32, pl. 6, figs. 3, 5.
1972a. *Biscutum blacki* Gartner 1968, Hoffmann, p. 68, pl. 15, fig. 6; pl. 19, fig. 5.
1972. *Biscutum constans* (Gorka 1957), Lauer, p. 153, pl. 23, figs. 7a–b, 8a–b; *not* pl. 23, figs. 6a–b.
1973. *Biscutum blacki* Gartner 1968, Risatti, p. 26, pl. 3, figs. 2–3.
1973. (?)*Markalius* sp. Risatti, p. 27, pl. 3, fig. 1.
1975. *Biscutum blackii* Gartner 1968, Krancer, p. 6, pl. 1, fig. 2.
1978. *Biscutum blacki* Gartner 1968, Shafik, p. 219, fig. 4, Aa–Ab.

Diagnosis.—Broadly elliptical placoliths with symmetrical proximal and distal shields constructed of from 16 to 22 rather broad, wedge-shaped elements having straight, radial sutures.

Description.—Although this species was not observed in images produced by the scanning electron microscope, light microscopic examination showed close agreement with the light photomicrographs of Gartner (see synonymy). Where observed in phase contrast light, the two shields of the placolith appear dark. The irregularly sutured central area, as observed in electron micrographs (Gartner, 1968, pl. 1, fig. 7), is bright and bisected by a thin, dark line in phase contrast images. This dark line is more or less parallel to the long axis of the ovate central area and appears to be slightly expanded into a narrow, fusiform-shaped area in the center of the placolith. In cross-polarized light, the two shield cycles are dark because of the near radial arrangement of shield elements, although the central area remains bright. With the long axis of the ovate placolith parallel to either nicol, the central area is bisected by two narrow closely spaced dark lines that expand somewhat near the margin of the central area with the inner rim of the proximal shield. When rotated about 45° from the plane of either nicol, the central area is bisected by an acute X-shaped interference-extinction figure.

Remarks.—Photomicrographs of *Biscutum blackii* Gartner resemble the light photomicrographs of *Biscutum constans* (Gorka 1957) of Perch-Nielsen (1968, pl. 27, figs. 6–7, 8–9, 10–11). However, electron micrographs of *B. constans* in Perch-Nielsen (1968, figs. 1–5) and Noël (1970, pl. 33, figs. 1–10; pl. 34, figs. 1a–g, 2a–b) are significantly different and readily differentiated from *B. blackii.* Since neither *B. blackii* nor *B. constans* were observed in images from the scanning electron microscope during this study, separation of the two species on the basis of their corresponding photomicrographs remains uncertain.

Known range.—Albian through middle Maastrichtian.

Type locality.—Taylor Marl near Gastonia, Kaufman County, Tex.

Occurrence.—Biscutum blackii has been reported from type lower Albian strata near Dienville, France (Bukry, 1969a); middle and upper Albian of England (Black, 1972); upper Albian and lower Santonian strata of north-central Germany (Hoffman, 1972a); Santonian strata of western Australia (Shafik, 1978); Campanian strata of Austria (Lauer, 1972); Santonian sedimentary rocks of eastern Switzerland (Thierstein, 1971a); Maastrichtian strata of Zululand, South Africa (Pienaar, 1969); Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi (Newell, 1968); Demopolis, Ripley, and Prairie Bluff Formations of Mississippi (Risatti, 1973); and from the Austin Group, Taylor Marl, and Corsicana Marl of Texas, and the Arkadelphia Marl of Arkansas (Gartner, 1968). This species was observed throughout the upper Turonian, Coniacian, and lower Santonian strata of Texas during this investigation.

Genus BRAARUDOSPHAERA Deflandre 1947

Type species.—*Pontospaera bigelowi* (Gran and Braarud 1935).

Diagnosis.—Pentagonal calcareous plates consisting of five segments, each segment constructed of a single crystallographic unit, joined along straight, radial sutures.

Braarudosphaera bigelowii (Gran and Braarud 1935) Deflandre 1947

Plate 1, figures 48–50

1935. *Pontosphaera bigelowi* Gran and Braarud, p. 388, text-fig. 67.
1947. *Braarudosphaera bigelowi* (Gran and Braarud 1935), Deflandre, p. 439, text-figs. 1–5.
1968. *Braarudosphaera bigelowi* (Gran and Braarud 1935), Gartner, p. 45, pl. 15, fig. 3; pl. 16, fig. 9; pl. 19, figs. 7a–c; pl. 20, fig. 4; pl. 21, fig. 8; *not* pl. 4, fig. 5.
1969. *Braarudosphaera bigelowi bigelowi* (Gran and Braarud 1935), Bukry, p. 62, pl. 36, figs. 11–12.
1970a. *Braarudosphaera bigelowi* (Gran and Braarud 1935), Reinhardt, p. 21–22, text-fig. 37.
1972. *Braarudosphaera bigelowi* (Gran and Braarud 1935), Báldiné Beke, p. 217, pl. 3, figs. 7a–b, 8a–b.
1972b. *Braarudosphaera bigelowi* (Gran and Braarud 1935), Hoffmann, p. 43–46, pl. 3, fig. 1.
1973. *Braarudosphaera bigelowi* (Gran and Braarud 1935), Risatti, p. 27, pl. 3, fig. 23; pl. 10, figs. 3–4.
1977. *Braarudosphaera bigelowi* (Gran and Braarud 1935), Pavšič, p. 42, pl. 3, figs. 5, 6, 7.
1978. *Braarudosphaera bigelowi* (Gran and Braarud 1935), Shafik, p. 219, fig. 4, Sa–Sb.

Diagnosis.—Pentaliths consisting of five nonimbricate segments having straight radial sutures which meet the peripheral margin at the midpoints between adjacent apices.

Remarks.—This species differs from *Braarudosphaera africana* Stradner 1961 in that the regular pentagonal outline has uniform and straight sides, rather than indentions in each side at the juncture with each radial suture. The subspecies described by Bukry (1969, p. 62) as *B. bigelowi imbricata* differs in having sinistrally imbricate elements as observed in proximal view. Neither of the forms described by Stradner or Bukry were observed during the present investigation.

Known range.—Tithonian through Holocene.

Type locality.—Holocene plankton from the Bay of Fundy off southwestern Nova Scotia.

Occurrence.—Reinhardt (1970a, p. 21–22; and Hoffmann, 1972b, p. 43–44) presented extensive synonymies indicating the worldwide distribution of *B. bigelowii* throughout its known range. It was observed in samples throughout the upper Turonian through lower Santonian strata examined during this study.

Genus CHIASTOZYGUS Gartner 1968

Type species.—*Zygodiscus? amphipons* Bramlette and Martini 1964.

Diagnosis.—Elliptical forms consisting of a single cycle distal rim constructed of imbricate elements, a narrow inner proximal cycle, and a large open central area spanned by X-shaped crossbars symmetrically or slightly asymmetrically alined with the major and minor axes of the ellipse. The crossbars may or may not support a distal stem.

Chiastozygus cuneatus (Lyul'eva 1967) Čepek and Hay 1969

Plate 1, figures 51–57, 58–60

1967. *Zygolithus cuneatus* Lyul'eva, p. 93, pl. 1, fig. 13.
1969. *Chiastozygus cuneatus* (Lyul'eva 1967), Čepek and Hay, p. 325, text-fig. 2, no. 7, text-fig. 4, no. 1.
1970. *Chiastozygus irregularis* Čepek *in* Čepek and Hay, p. 337–338, pl. 20, fig. 2.
1972. *Chiastozygus cuneatus* (Lyul'eva 1967), Forchheimer, p. 46–47, pl. 18, figs. 1, 2, 3, 4.
1972. *Chiastozygus cuneatus* (Lyul'eva 1967), Roth and Thierstein, pl. 12, figs. 1–6.
1978. *Chiastozygus cuneatus* (Lyul'eva 1967), Čepek, p. 677, pl. 2, fig. 6.

Diagnosis.—Broadly elliptical forms with the rim constructed of two rather narrow cycles of imbricate elements. The large, open elliptical central area is spanned by four X-shaped, asymmetrically arranged crossbars. The crossbars do not merge at a common point in the central region, but are offset along the longitudinal axis of the elliptical central area. The sides of the crossbars are concave and broadly flaring at their contact with the inner rim cycle.

Remarks.—The description of this species by Čepek (in Čepek and Hay, 1970, p. 337) is based on photomicrographs and is followed herein. The species was not observed under the scanning electron microscope during the present investigation and, to my knowledge, it has not been previously figured by electron micrographs.

Thierstein (1971a, p. 36) regarded *Chiastozygus cuneatus* as a junior subjective synonym of *Eiffellithus trabeculatus* (Gorka 1957) Reinhardt and Gorka 1967. It differs from *E. trabeculatus* in having more narrow X-shaped crossbars asymmetrically arranged with respect to the longitudinal and transverse axes of the elliptical central area, and in having four rather large subcircular openings between the arms of the crossbars.

Known range.—Late Cenomanian through middle Santonian.

Type locality.—Turonian strata of the Dnieper-Don Basins, U.S.S.R.

Occurrence.—This species has been reported from the middle and upper part of the Greenhorn Limestone and lower part of the Carlile Shale of Russell County, Kans., and the upper part of the Tombigbee Sand Member of the Eutaw Formation, Clay County, Miss., and Dallas and Wilcox Counties, Ala. (Čepek and Hay, 1969; 1970). During this investigation, *Chiastozygus cuneatus* was observed only from the lower part of the Atco Formation (Coniacian) as exposed at Cedar Hill, Dallas County, Tex.

Chiastozygus plicatus Gartner 1968

Plate 2, figures 1–9, 10–12

1966. *Zygolithus* sp. cf. *Z. concinnus* Martini 1961, Stover, p. 149, pl. 4, figs. 18a–c.
1967. *Zygodiscus*? *amphipons* Bramlette and Martini 1964, Moshkovitz, p. 150, pl. 1, figs. 9, 10.
1968. *Chiastozygus plicatus* Gartner, p. 27, pl. 16, figs. 10, 11; pl. 17, figs. 9a–d; pl. 19, figs. 9a–d; pl. 20, fig. 6; pl. 21, figs. 9a–d; pl. 22, fig. 12.
1969. *Chiastozygus plicatus* Gartner 1968, Bukry, p. 50–51, pl. 28, fig. 3.
1971. *Chiastozygus amphipons* (Bramlette and Martini 1964), Manivit, p. 92, pl. 4, figs. 6–7, 8–9.
1971b. *Chiastozygus litterarius* (Gorka 1957), Thierstein, p. 476, pl. 2, figs. 17–19, 20, 21.
1971a. *Zygolithus litterarius* (Gorka 1957), Thierstein, p. 34, pl. 1, figs. 3–4.
1972. *Helicolithus stillatus* Forchheimer, p. 48, pl. 11, figs. 1, 2, 3, 4; pl. 16, figs. 5, 6.
1972. *Chiastozygus litterarius* (Gorka 1957), Grün and others, p. 164, pl. 25, figs. 11a–b, 12a–b.
1972. *Chiastozygus plicatus* Gartner, Iaccarino and Rio, p. 654, pl. 72, figs. 14a, 14b.
1972. ?*Chiastozygus litterarius* (Gorka 1957), Lauer, p. 164, pl. 25, figs. 11a–b, 12a–b.
1972. *Chiastozygus bifarius* Bukry 1969, Lauer, p. 164–165, pl. 25, figs. 10a–b.
1972. *Chiastozygus litterarius* (Gorka 1957), Roth and Thierstein, pl. 1, figs. 1–6.
1972. *Chiastozygus amphipons* (Bramlette and Martini 1964), Wilcoxon, p. 431, pl. 10, figs. 7, 8.
1973. *Zygolithus litterarius* (Gorka 1957), Priewalder, p. 28, pl. 23, figs. 3, 4, 5, 6.
1974. *Chiastozygus litterarius* (Gorka 1957), Totten, p. 83, pl. 1, figs. 16–17.
1974. *Chiastozygus plicatus* Gartner 1968, Totten, p. 83, pl. 1, fig. 20.
1975. *Chiastozygus* sp. cf. *amphipons* (Bramlette and Martini 1964), Čepek, p. 97, pl. 2, figs. 3a–c.
1975. *Chiastozygus amphipons* (Bramlette and Martini 1964), Krancer, p. 9, pl. 1, fig. 9.
1977. *Chiastozygus litterarius* (Gorka 1957), Pašvič, p. 37–38, pl. 1, figs. 14, 15.
1978. *Chiastozygus plicatus* Gartner 1968, Shafik, p. 225, fig. 7, Ga–Gb.

Diagnosis.—Elliptical coccoliths with the distal rim cycles constructed of a large number of dextrally imbricate elements. The broad, elliptical central area is spanned by four asymmetrical X-shaped crossbars, which form acute angles with the transverse axis of the central area. The arrangement of the crossbars results in two small circular openings along the transverse axis and two larger, subcircular openings along the longitudinal axis.

Remarks.—In electron micrographs this species is characterized by the (1) relatively large number, usually 60 to 70, of dextrally imbricate elements composing the distal rim cycle, (2) broad X-shaped crossbar, and (3) penetration of the crossbars into the narrow proximal cycle of elements.

Cross-polarized light images of *Chiastozygus plicatus* Gartner show that each of the four members of the X-shaped crossbar is constructed of two parallel series of elements. The extinction of the two adjacent parts of the doubled crossbar is evident during slight rotation in polarized light. Plane transmitted and phase contrast images show the somewhat flaring and broadened nature of the crossbars at their contact with the inner margin of the rim cycle. Penetration into the proximal rim cycle is evident in cross-polarized images.

Chiastozygus plicatus Gartner differs from *C. litterarius* (Gorka 1957) and *C. amphipons* (Bramlette and Martini 1964) in having more numerous elements in the distal rim cycle and broader, doubled, X-shaped crossbars.

Known range.—Early Aptian through middle Campanian.

Type locality.—Austin Group (lower Santonian) exposed along Interstate Highway 45 about 500 feet south of its intersection with Langdon Drive in the northwestern portion of Hutchins, Dallas County, Tex.

Occurrence.—This species was previously reported from upper Barremian through middle Albian cores recovered during Leg 11, Deep Sea Drilling Project, western North Atlantic Basin (Wilcoxon, 1972); Aptian through Albian strata of southeastern France, and from Albian cores, Leg 1, Deep Sea Drilling Project, sites 4 and 4A, Blake Bahama Basin area (Thierstein, 1971b); Aptian through Campanian cores, Leg 14, Deep Sea Drilling Project, from the eastern Atlantic Basin (Roth and Thierstein, 1972); Albian strata of Austria (Lauer, 1972); subsurface Albian samples from the Netherlands (Stover, 1966); Coniacian through Maastrichtian of France (Manivit, 1971); Santonian strata of eastern Switzerland (Thierstein, 1971a); Turonian and Campanian part of the Ladd Formation, Orange County, Calif. (Totten, 1974); Maastrichtian strata of Israel (Moshkovitz, 1967); upper part of the Niobrara Chalk, Knox County, Nebr. (Bukry, 1969); and from the Austin Group and Taylor Marl of Texas (Gartner, 1968; Bukry, 1969).

Genus COROLLITHION Stradner 1961, emended

Type species.—*Corollithion exiguum* Stradner 1961.

Original description.—"Flat, radiating, six-sided calcareous bodies with six diagonally oriented openings. A short stem extends distally from the middle of the body in the direction of the main axis. The margin of the calcareous body is sloping so that the proximal diameter is smaller than the distal."

Emended description.—Polygonal disks, generally hexagonal in outline, consisting of a narrow rim constructed of one or two cycles of elements lacking peripheral spines or projections. The large open central area of the disk is spanned by crossbar structures that may support a short stem distally.

Remarks.—*Corollithion* Stradner 1961 differs from *Stephanolithion* Deflandre 1939 in that it lacks radial, outer peripheral spines or projections.

Corollithion exiguum Stradner 1961

Plate 2, figures 13–18, 19–21

1961. *Corollithion exiguum* Stradner, p. 83, text-figs. 58–61.
1963. *Corollithion exiguum* Stradner 1961, Stradner, p. 178, pl. 1, figs. 12a–b.
1964. *Corollithion exiguum* Stradner 1961, Bramlette and Martini, p. 308, pl. 5, figs. 8–9.
1966. *Corollithion exiguum* Stradner 1961, Maresch, p. 381, pl. 3, fig. 4.
1966a. *Corollithion exiguum* Stradner 1961, Reinhardt, p. 41, pl. 19, fig. 5.
1967. *Corollithion exiguum* Stradner 1961, Sales, p. 305, pl. 3, figs. 24a–b.
1967. *Corollithion exiguum* Stradner 1961, Vangerow and Schloemer, p. 456, table 1, fig. 27.
1968. *Corollithion exiguum* Stradner 1961, Gartner, p. 35, pl. 10, fig. 26.
1968. *Stephanolithion* sp. aff. *S. laffitei* Noël 1956, Gartner (error for *laffittei*), p. 35, pl. 5, fig. 14; pl. 22, fig. 18.
1969. *Corollithion exiguum* Stradner 1961, Bukry, p. 40–41, pl. 18, fig. 12; pl. 19, fig. 1.
1969. *Corollithion exiguum* Stradner 1961, Čepek and Hay, p. 327, text-fig. 2, no. 14.
1969. *Corollithion exiguum* Stradner 1961, Pienaar, p. 90–91, pl. 2, fig. 1; pl. 7, fig. 9.
1970b. *Corollithion exiguum* Stradner 1961, Reinhardt, p. 44, text-fig. 3.
1971. *Corollithion exiguum* Stradner 1961, Manivit, p. 109, pl. 5, figs. 1–3.
1971. *Corollithion exiguum* Stradner 1961, Shafik and Stradner, p. 81, pl. 46, figs. 1–4; (?) pl. 47, fig. 1.
1972b. *Corollithion exiguum* Stradner 1961, Hoffmann, p. 49–50, pl. 4, figs. 5, 6; pl. 7, fig. 2.
1973. *Corollithion exiguum* Stradner 1961, Perch-Nielsen, p. 310–311, pl. 2, figs. 5, 8, 11, 14.
1973. *Corollithion exiguum* Stradner 1961, Priewalder, p. 16, pl. 6, fig. 1.
1973. *Corollithion exiguum* Stradner 1961, Risatti, p. 23, pl. 1, figs. 4–5.
1974. *Corollithion exiguum* Stradner 1961, Müller, p. 589, pl. 17, fig. 2.
1975. *Corollithion exiguum* Stradner 1961, Krancer, p. 13, pl. 2, fig. 8.
1975. *Corollithion exiguum* Stradner 1961, Stapleton, p. 55, pl. 4, figs. 7a–b.
1976. *Corollithion exiguum* Stradner 1961, Shumenko, p. 68–69, pl. 26, fig. 8.
1976a. *Corollithion exiguum* Stradner 1961, Verbeek, p. 75, pl. 1, figs. 4a–b.
1978. *Corollithion rhombicum* (Stradner and Adamiker 1966), Shafik, p. 221, fig. 5, Da–Db.
1980. *Corollithion exiguum* Stradner 1961, Barrier, p. 296, pl. 1, figs. 2–16.

Diagnosis.—Small, regularly hexagonal forms consisting of a narrow rim cycle and large open central area spanned by six bars extending radially from a common point in the center of the open frame to the midpoints of each side of the hexagonal frame.

Remarks.—The frame of *Corollithion exiguum* consists of a regular hexagonal rim, all six sides about equal in length. Six radial arms or spokes extend from the center of the open frame to the midpoints of each of the six sides of the frame. As previously noted, this species has a small distal stem at the center of the radial arms (Gartner, 1968, p. 35; Bukry, 1969, p. 41).

Owing to the low birefringence of images produced in phase contrast or plane transmitted light, as well as its small size, this species may be overlooked in the light microscope. The hexagonal frame and six radial arms, however, are usually distinct and are characteristic features of *Corollithion exiguum*. Bramlette and Martini (1964, p. 308) noted that the optical axis of calcite is normal to the length of the crossbars and radially oriented in the rim.

Known range.—Early Turonian through late Maastrichtian.

Type locality.—Upper Cretaceous (Senonian) strata near Salzburg, Austria.

Occurrence.—*Corrolithion exiguum* has been reported from the lower Turonian of Germany (Reinhardt, 1964); Turonian and lower Santonian strata of Germany (Hoffmann, 1972b); Turonian through Maastrichtian strata of France (Manivit, 1971); middle Campanian Aachen Marl near Aachen, Germany, and middle(?) Campanian chalk near Meudon, France (Bukry, 1969); Maastrichtian Tarawan Chalk of Egypt (Shafik and Stradner, 1971); Maastrichtian sedimentary rock from the subsurface of western Africa (Sales, 1967); type Maastrichtian of Maastricht, Holland, as well as the Maastrichtian of southwestern France and Tunisia (Bramlette and Martini, 1964); upper Maastrichtian strata of Austria (Priewalder, 1973); Maastrichtian cores from the western Indian Ocean (Müller, 1974); Jetmore Chalk and Pfeifer Shale Members of the Greenhorn Limestone, and Fairport Chalk Member of the Carlile Shale of Russell County, Kans. (Čepek and Hay, 1969); upper part of the Niobrara Chalk of Knox County, Nebr. (Bukry, 1969); Ripley Formation and Prairie Bluff Chalk of Alabama (Bramlette and Martini, 1964); Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi (Newell, 1968); Demopolis Chalk, Ripley Formation and Prairie Bluff Chalk of Mississippi (Risatti, 1973); and from the Austin Group, Taylor Marl, and Corsicana Marl of north-central Texas (Gartner, 1968; Bukry, 1969; Barrier, 1980).

During the present study, *Corollithion exiguum* was found to be sporadic in occurrence and generally rare in abundance. It was, however, present throughout the upper Turonian through lower Santonian samples.

Corollithion signum Stradner 1963

Plate 2, figures 22–24, 25–31, 32–36

1963. *Corollithion signum* Stradner, p. 177, pl. 1, figs. 13a–b.
1966. *Corollithion signum* Stradner 1963, Maresch, p. 381, pl. 3, fig. 3.
1967. *Corollithion signum* Stradner 1963, Sales, p. 305, pl. 3, figs. 25a–b.
1969. *Corollithion signum* Stradner 1963, Bukry, p. 41, pl. 19, figs. 5–8.
1969. *Corollithion signum* Stradner 1963, Čepek and Hay, p. 327, text–fig. 2, no. 13, text–fig. 4, no. 16.
1970. *Corollithion signum* Stradner 1963, Čepek and Hay, p. 335, pl. 20, fig. 3.
1970b. *Corollithion signum* Stradner 1963, Reinhardt, p. 45, text–fig. 5.
1971. *Corolithion signum* Stradner 1963, Manivit (error for *Corollithion*), p. 110–111, pl. 5, fig. 6; not pl. 5, figs. 7–8, 9–10.
1971b. *Corollithion signum* Stradner 1963, Thierstein, p. 480, pl. 8, figs. 18–22.
1972. Not *Corollithion signum* Stradner 1963, Bystricka, p. 170, pl. 9, fig. 5.
1972b. *Corollithion signum* Stradner 1963, Hoffmann, p. 52–53, pl. 5, fig. 6.
1973. *Corollithion signum* Stradner 1963, Black, p. 94–95, pl. 29, figs. 10, 11, 12.
1973. *Corollithion signum* Stradner 1963, Risatti, p. 23, pl. 1, figs. 2–3.
1974. *Corollithion signum* Stradner 1963, Müller, p. 589, pl. 17, fig. 1.
1974. Not *Corollithion signum* Stradner 1963, Totten, p. 83, pl. 1, figs. 18–19.
1976. *Corollithion signum* Stradner 1963, Hill, p. 131–132, pl. 4, figs. 21–23, 24; pl. 13, fig. 22.
1976. *Corollithion signum* Stradner 1963, Shumenko, p. 69, pl. 26, figs. 10, 11.
1978. *Corollithion signum* Stradner 1963, Čepek, p. 676, pl. 3, fig. 3.
1978. *Corollithion signum* Stradner 1963, Shafik, p. 221, fig. 5, Aa–Ab, Ba–Bb, Ca–Cb.

Diagnosis.—Small, irregularly shaped hexagonal forms, slightly greater in length than width, consisting of two parallel sides with each end of the frame constructed of two straight bars of slightly different length. The large open central area is spanned by four asymmetrical crossbars.

Remarks.—This species consists of an hexagonal frame, slightly longer than it is wide, and a large open central area spanned by slightly asymmetric, plus-shaped crossbars. The hexagonal frame consists of two parallel sides, the ends being gently rounded or more commonly composed of two straight bars of slightly different length. Opposing bars on each end of the frame are of the same length; that is, the shorter (or longer) bar at one end is diagonally opposite a short (or long) bar at the opposite end of the frame.

The hexagonal frame of *Corollithion signum* consists of an outer rim cycle of elements and an inner cycle that forms a frame to which the crossbars are attached. Bukry (1969, p. 41) noted that the long bar of the cross is narrower than the shorter transverse bar, and rather than being symmetrically arranged, the longer bar of the cross is rotated slightly clockwise, whereas the shorter bar is rotated counterclockwise in distal view.

Corollithion signum is distinct in both electron and light optical systems. Although *Corollithion signum* should not be confused with other species, Totten (1974) assigned *Prediscosphaera cretacea* to this taxon.

Known range.—Early Albian through early Maastrichtian.

Type locality.—Upper Turonian sedimentary rocks from near Klafterbrunn, Austria.

Occurrence.—*Corollithion signum* has been described from type lower Albian strata new Dienville, France (Bukry, 1969); upper Abian cores from Leg 1, Deep Sea Drilling Project, sites 4, 4a, and 5a, Blake Bahama Basin area, western North Atlantic, and from upper Albian sedimentary rocks of southeastern France (Thierstein, 1971b); Albian sedimentary rocks of England (Black, 1973); upper Albian strata of Germany (Hoffmann, 1972b); Turonian through Santonian strata from the subsurface of western Africa (Sales, 1967); upper Turonian through Campanian strata of Austria (Stradner, 1963); lower Campanian of northwestern Germany (Čepek, 1970); middle(?) Campanian chalk near Meudon, France (Bukry, 1969); Maastrichtian cores from the western Indian Ocean (Müller, 1974); Niobrara Chalk and Pierre Shale of Knox County, Nebr. (Bukry, 1969); Jetmore Chalk and Pfeifer Shale Members of the Greenhorn Limestone of Russell County, Kans. (Čepek and Hay, 1969; 1970); Tombigbee Sand Member of the Eutaw Formation and Ripley Formation of the Selma Group of Dallas and Wilcox Counties, Ala. (Čepek and Hay, 1969; 1970); Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi (Newell, 1968); Ripley Formation of Mississippi (Risatti, 1973); Albian and Cenomanian strata of Texas (Hill, 1976); and from the Austin Group and Taylor Marl of north-central Texas (Bukry, 1969).

Corollithion signum was rare in the upper Turonian through lower Santonian samples. It was not observed in samples from the Coniacian of the Austin Group of Travis County, nor was it observed in the upper Coniacian and lower Santonian of the Austin Group exposed along Pinto Creek, Kinney County, Tex. Its sporadic occurrence and rather rare abundance is undoubtedly due to its small size.

Genus CRETARHABDUS Bramlette and Martini 1964

Synonyms.—*Polypodorhabdus* Noël 1965; *Heterorhabdus* Noël 1970; *Retecapsa* Black 1971.

Type species.—*Cretarhabdus conicus* Bramlette and Martini 1964.

Diagnosis.—Elliptical forms with two distal cycles of essentially radial elements, the interelement sutures of the broad inner cycle being slightly offset from the interelement sutures of the narrow outer distal cycle. The central area is constructed of subradially arranged ribs that support axially or slightly subaxially oriented struts or crossbars. A single cycle of radial to subradial elements is present in the proximal rim.

Remarks.—*Stradneria* Reinhardt 1964 differs from *Cretarhabdus* Bramlette and Martini 1964 in having a broad outer cycle and a narrow inner cycle of elements as observed in distal view.

Cretarhabdus conicus Bramlette and Martini 1964

Plate 2, figures 37–44, 45–48;

plate 3, figures 1–9, 10–15, 16–19

1964. *Cretarhabdus conicus* Bramlette and Martini, p. 299, pl. 3, figs. 5–6, 7–8.

1965. *Cretarhabdus conicus* Bramlette and Martini 1964, Manivit, p. 193, pl. 1, figs. 2a–d.

1966. *Cretarhabdus conicus* Bramlette and Martini 1964, Stover, p. 140, pl. 1, figs. 19a–c, 20a–e; pl. 8, fig. 9.

1966a. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Reinhardt, p. 25–26, pl. 7, figs. 1–2; pl. 14, fig. 2; text-figs. 6a–b.

1967. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Sales, p. 305, pl. 3, figs. 9a–b.

1968. *Cretarhabdus conicus* Bramlette and Martini 1964, Gartner, p. 21–22, pl. 1, figs. 10–11; pl. 3, figs. 5a–c, (?)6a–c; pl. 4, figs. 9–12; pl. 6, figs. 3a–c, (?)4a–b; pl. 11, figs. 12a–c; pl. 15, figs. 9a–c; pl. 16, figs. 12–13; pl. 17, figs. 10a–c; pl. 20, figs. 8–9; pl. 22, figs. 20–21; pl. 24, figs. 11a–c; pl. 25, figs. 3(?), 4; *not* pl. 14, figs. 7–9; *not* pl. 16, fig. 14.

1968. *Cretarhabdus conicus* Bramlette and Martini 1964, Perch-Nielsen, p. 51–52, pl. 12, figs. 1–4.

1968. *Cretarhabdus conicus* Bramlette and Martini 1964, Newell, p. 40–41, pl. 4, figs. 1b, 1c, 1d; *not* pl. 4, fig. 1a.

1968. *Polypodorhabdus actinosus* (Stover 1966), Perch-Nielsen, p. 50–51, pl. 10, figs. 1–6; text-fig. 19.

1968. *Polypodorhabdus crenulatus* (Bramlette and Martini 1964), Perch-Nielsen, p. 48–50, pl. 11, figs. 2, 3, 4–5; text-fig. 18.

1969. *Cretarhabdus conicus* Bramlette and Martini 1964, Bukry, p. 35, pl. 13, figs. 7–12.

1969. *Cretarhabdus conicus* Bramlette and Martini 1964, Pienaar, p. 90–91, pl. 2, fig. 3; pl. 5, fig. 9.

1970. *Cretarhabdus conicus* Bramlette and Martini 1964, Iaccarino and Follini, p. 589–590, pl. 39, (?) fig. 22.

1970. *Cretarhabdus conicus* Bramlette and Martini 1964, Noël, p. 58–59, pl. 17, figs. 2, 4; text-fig. 14.

1970. *Stradneria crenulata* (Bramlette and Martini 1964), Noël, p. 55–57, pl. 13, fig. 5; pl. 17, figs. 3a–b.

1971. (?)*Cretarhabdus crenulatus* Bramlette and Martini 1964, Hoffman and Vetter, p. 1183–1184, pl. 8, figs. 1, 2.

1971. *Cretarhabdus conicus* Bramlette and Martini 1964, Manivit, p. 95, pl. 2, figs. 13, 14–15, 16, 17–18.

1971. *Cretarhabdus loriei* Gartner 1968, Manivit, p. 96, pl. 6, figs. 11–12, 13–14.

1971. *Stradneria crenulata* (Bramlette and Martini 1964), Manivit, p. 99, pl. 7, figs. 1(?), 2–3, 4–5, 6–7(?), 8–9(?).

1971. *Polypodorhabdus crenulatus* (Bramlette and Martini 1964), Shafik and Stradner, p. 85, pl. 12, figs. 1, 2; pl. 13, figs. 1, 2, 3, 4.

1971b. *Cretarhabdus conicus* Bramlette and Martini 1964, Thierstein, p. 447, pl. 6, figs. 7, 8, 9–11, 12.

1972. ?*Cretarhabdus actinosus* (Stover 1966), Forchheimer, p. 49, pl. 9, fig. 4.

1972. *Cretarhabdus biseriatus* Forchheimer, p. 50, pl. 19, figs. 5, 6; pl. 21, fig. 6.

1972. *Cretarhabdus conicus* Bramlette and Martini 1964, Forchheimer, p. 50–51, pl. 19, figs. 1, 2, 3.

1972. *Cretarhabdus octoperforatus* Forchheimer, p. 51–52, pl. 20, figs. 1, 2.

1972a. *Cretarhabdus conicus* Bramlette and Martini 1964, Hoffmann, p. 47–48, pl. 11, figs. 1, 2, 3, 4, 5.

1972. *Cretarhabdus conicus* Bramlette and Martini 1964, Iaccarino and Rio, p. 655, pl. 71, figs. 17a–b; *not* pl. 72, fig. 2.

1972. *Cretarhabdus ingens* (Gorka 1957), Locker, p. 771, pl. 10, fig. 11.

1972. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Wilcoxon, p. 431, pl. 7, fig. 1; *not* pl. 7, fig. 2.
1972. *Cretarhabdus conicus* Bramlette and Martini 1964, Lauer, p. 156–157, pl. 24, figs. 1a–b, 2a–b.
1973. *Cretarhabdus angustiforatus* (Black 1971), Bukry, p. 677, pl. 2, figs. 4–6, 7.
1973. *Cretarhabdus conicus* Bramlette and Martini 1964, Priewalder, p. 17, pl. 7, figs. 1, 2, 3, 4.
1973. *Cretarhabdus actinosus* (Stover 1966), Risatti, p. 24, pl. 6, figs. 3–4.
1974. *Cretarhabdus conicus* Bramlette and Martini 1964, Müller, p. 589, pl. 18, fig. 10.
1974. *Cretarhabdus conicus* Bramlette and Martini 1964, Proto Decima, p. 591, pl. 3, figs. 16–18.
1975. *Retecapsa crenulata* (Bramlette and Martini 1964), Grün and Allemann, p. 175–176, pl. 4, figs. 4, 5, 6; text–figs. 17a–b.
1975. *Cretarhabdus conicus* Bramlette and Martini 1964, Krancer, p. 9, pl. 2, figs. 1, 2.
1976. *Cretarhabdus conicus* Bramlette and Martini 1964, Burns, p. 283–284, pl. 2, fig. 6.
1976. *Cretarhabdus conicus* Bramlette and Martini 1964, El-Dawoody and Zidan, p. 411–412, pl. 3, figs. 1a–b.
1976. *Cretarhabdus conicus* Bramlette and Martini 1964, Hill, p. 132, pl. 4, figs. 25, 26, 27–30; pl. 13, figs. 23, 24.
1978. *Cretarhabdus conicus* Bramlette and Martini 1964, Shafik, p. 223, fig. 6, Ia–Ib, J.
1980. *Cretarhabdus conicus* Bramlette and Martini 1964, Siesser, p. 826, pl. 1, fig. 19; pl. 5, figs. 12–13.

Diagnosis.—Elliptical rhabdoliths with a rather narrow rim and large central area traversed usually by 12 subradially arranged struts that usually support crossbars alined with the transverse and longitudinal axes of the elliptical central area.

Description.—Forms belonging to this species are elliptical in outline and consist of three cycles of rim elements and a broad perforate or imperforate central area, which may be spanned by ribs or crossbars. In distal view, the rim consists of a narrow outer cycle and moderately broad inner cycle, each constructed of 25 to 40 elements with radial or slight counterclockwise inclination. In proximal view, the inner proximal cycle consists of rather elongate elements sinistrally imbricate with radial or slight counterclockwise inclination. Distally, the broad central area consists of a series of radially to subradially oriented ribs attached to, or overlapped onto, the inner margin of the inner distal cycle. The ribs support axial to subaxial crossbars or struts which support a central stem at their intersection. Proximally, the central area is composed of small rectilinear elements in apparent random orientation with numerous interelement voids.

Transmitted light images show a rather narrow rim and large, somewhat perforate central area. The axial or subaxial struts may or may not be distinct in transmitted light images. In cross-polarized light, the margin between the central area and rim cycles is distinctly crenulate, owing to the overlapping of central area ribs onto the distal cycle. The central area appears to consist of subradial rodlike elements.

Remarks.—Although both the transmitted light and electron images of *Cretarhabdus conicus* are distinct, there remains some confusion in the literature about the identity of this species (see synonymy). In transmitted light and in electron images, it differs from *Cretarhabdus crenulatus* Bramlette and Martini 1964 in having more narrow distal and proximal rim cycles and a much larger elliptical central area.

Known range.—Berriasian through Maastrichtian.

Type locality.—Arkadelphia Marl about 4 miles north of Hope, Hempstead County, Ark.

Occurrence.—Bramlette and Martini (1964, p. 299) reported *Cretarhabdus conicus* from the type Maastrichtian at Maastricht, Holland, as well as from equivalent strata in Denmark, France, Tunisia, the Ripley Formation and Prairie Bluff Chalk of Alabama, and the Arkadelphia Marl of Arkansas. It has since been reported from Berriasian through Albian strata of southeastern France, and from Hauterivian and Barremian cores from Leg 1, Deep Sea Drilling Project, sites 4, 4A, and 5A, Blake Bahama Basin area (Thierstein, 1971b); Barremian through Albian strata of Austria (Lauer, 1972); Berriasian strata of southern Spain (Grün and Allemann, 1975); type lower Albian from Dienville, France (Bukry, 1969); from the Aptian and Albian stratotypes of the Aquitaine Basin, France (Manivit, 1965); Albian through Maastrichtian sedimentary rocks from the subsurface of western Africa (Sales, 1967); upper Albian and lower Santonian of northern Germany (Hoffmann, 1972a); Turonian strata near Pasewalk, Germany (Hoffmann and Vetter, 1971); upper Turonian through Maastrichtian strata of France (Manivit, 1971); Campanian strata of France (Noël, 1970; Stover, 1966); lower and upper Maastrichtian of Denmark (Perch-Nielsen, 1968); Maastrichtian cores from the western Indian Ocean (Müller, 1974); Maastrichtian sedimentary rocks from the Isle of Rugen, northeastern Germany (Reinhardt, 1966a); upper Maastrichtian strata of Austria (Priewalder, 1973); and Maastrichtian strata of the Eastern Desert, Egypt, and from the subsurface of the Dnjepr-Donetz Region, Russia (Shafik and Stradner, 1971).

Within North America, *Cretarhabdus conicus* has been reported from the upper portions of the Niobrara Chalk of Knox County, Nebr. (Bukry, 1969); Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi (Newell, 1968); Demopolis

Chalk, Ripley Formation and Prairie Bluff Chalk of Mississippi (Risatti, 1973); Albian and Cenomanian strata of Texas (Hill, 1976); as well as from the Eagle Ford Group, Austin Group, Taylor Marl, and Corsicana Marl of Texas (Gartner, 1968; Bukry, 1969). This species was observed throughout the upper Turonian and through lower Santonian samples studied during this investigation.

Cretarhabdus crenulatus Bramlette and Martini 1964

Plate 3, figures 20–28;

plate 4, figures 1–9, 10, 11–17

1964. *Cretarhabdus crenulatus* Bramlette and Martini, p. 300, pl. 2, figs. 21–24.
1965. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Manivit, p. 193, pl. 1, figs. 3a–d.
1966a. Not *Cretarhabdus crenulatus* Bramlette and Martini 1964, Reinhardt, p. 25–26, pl. 7, figs. 1, 2; pl. 14, fig. 2; text–figs. 6a–b.
1966. *Coccolithus actinosus* Stover, p. 138–139, pl. 1, figs. 15a–c, 16a–b; pl. 8, fig. 7.
1966. *Coccolithites ficula* Stover, p. 138, pl. 5, figs. 5a–c, 6; pl. 9, fig. 11.
1968. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Gartner, p. 22, pl. 1, fig. 9; pl. 6, figs. 6a–c; pl. 19, figs. 11a–d; pl. 20, figs. 10, 11; *not* pl. 1, fig. 8.
1968. *Cretarhabdus conicus* Bramlette and Martini 1964, Gartner (part), p. 21–22, pl. 14, figs. 7, 8, 9; pl. 16, fig. 14.
1968. Not *Polypodorhabdus crenulatus* (Bramlette and Martini 1964), Perch-Nielsen, p. 48–50, pl. 11, figs. 2, 3, 4–5; text–fig. 18.
1969. *Cretarhabdus crenulatus crenulatus* Bramlette and Martini 1964, Bukry, p. 35, pl. 14, figs. 1–6.
1969. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Bukry and Bramlette, p. 375, pl. 1, fig. D.
1970. *Heterorhabdus sinuosus* Noël 1970, p. 48–49, pl. 13, figs. 1a–c, 2, 3, 4, 6; text–fig. 9.
1970. Not *Stradneria crenulata* (Bramlette and Martini 1964), Noël, p. 55–57, pl. 13, fig. 5; pl. 17, figs. 3a–b.
1971b. *Retecapsa angustiforata* Black, p. 409, pl. 33, fig. 4.
1971b. *Retecapsa brightoni* Black, p. 409, pl. 33, fig. 3.
1971b. *Retecapsa neocomiana* Black, p. 410, pl. 33, fig. 2.
1971. Not *Polypodorhabdus crenulatus* (Bramlette and Martini 1964), Shafik and Stradner, p. 85, pl. 12, figs. 1, 2; pl. 13, figs. 1, 2, 3, 4.
1971b. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Thierstein. p. 476, pl. 5, figs. 10–12, 13–14.
1971a. *Cretarhabdus ingens* (Gorka 1957), Thierstein, p. 37, pl. 3, figs. 60–61.
1972a. *Cretarhabdus ingens* (Gorka 1957), Hoffmann, p. 49–50, pl. 10, fig. 3; pl. 12, figs. 3, 4.
1972. *Cretarhabdus actinosus* (Stover 1966), Lauer, p. 158, pl. 24, figs. 11a–b.
1972. *Cretarhabdus crenulatus crenulatus* Bramlette and Martini 1964, Lauer, p. 157, pl. 24, figs. 3a–b, 4a–b, 5a–b.
1972. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Roth and Thierstein, pl. 5, figs. 10–12.
1972. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Wilcoxon, p. 431, pl. 7, fig. 2; *not* pl. 7, fig. 1.
1973. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Black, p. 52, pl. 17, fig. 7; pl. 19, figs. 5, 7, 8.
1973. Not *Cretarhabdus crenulatus* Bramlette and Martini 1964, Hekel, p. 227, pl. 1, fig. 6.
1973. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Priewalder, p. 17, pl. 6, (?) figs. 5, 6.
1973. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Risatti, p. 24, pl. 6, figs. 1–2.
1973. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Roth, p. 724, pl. 19, fig. 6.
1975. *Retecapsa angustiforata* Black 1971, Grün and Allemann, p. 173–174, pl. 4, figs. 1, 2, 3; text–figs. 16a–c.
1975. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Jafar, pl. 13, figs. 8–9.
1975. *Polypodorhabdus crenulatus* (Bramlette and Martini 1964), Stapleton, p. 55, pl. 5, figs. 12a–b(?), 13a–b.
1976. *Cretarhabdus crenulatus crenulatus* Bukry 1969, Burns, p. 284, pl. 2, figs. 7, 8, 9, 10.
1976. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Hill, p. 133, pl. 4, figs. 31–33, 34–35, 36–39, 40–42; pl. 13, figs. 25, 26.
1978. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Čepek, p. 676, pl. 3, fig. 7.
1978. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Shafik, p. 223, fig. 6, Fa–Fb, Ga–Gb, Ha–Hb.
1980. *Cretarhabdus crenulatus* Bramlette and Martini 1964, Siesser, p. 826, pl. 2, figs. 3, 4; pl. 5, figs. 14–15.

Diagnosis.—Elliptical rhabdoliths having a relatively broad rim and narrow central area spanned by four to eight subradially arranged struts that support crossbars alined with the axes of the elliptical central area.

Description.—The description of *Cretarhabdus crenulatus* by Bukry (1969, p. 35), based on transmission electron micrographs, is followed herein. In transmitted light images, this species has a broad outer rim which may appear finely striate, and a narrow, elongate elliptical central area. The axial or subaxial crossbars spanning the central area generally are not distinct in plane light images. In cross-polarized light, the margin between the central area and the broad outer rim may be crenulate or somewhat smooth. Two interference-extinction lines extend across the bright outer rim at either end of the elongate ellipse. The extinction lines are rather narrow and sharpy defined along the inner margin of the rim and become wider and more poorly defined along the outer peripheral margin of the rim. Although the interference-extinction lines are generally straight and near radial, they are occasionally curved sinistrally where observed in distal view, or curved dextrally in proximal view.

Remarks.—*Cretarhabdus crenulatus* differs from *C. conicus* Bramlette and Martini in having much broader distal and proximal rim cycles and a more narrow elliptical central area.

Known range.—Berriasian through Maastrichtian.

Type locality.—Upper Maastrichtian strata exposed in the streambed of the Gave de Pau River near Bellocq, southwestern France.

Occurrence.—This species has been reported from Valanginian through Albian strata of southeastern France, and Hauterivian and Barremian cores from Leg 1, Deep Sea Drilling Project, sites 4, 4A, and 5A, Blake Bahama Basin area (Thierstein, 1971b); Berriasian strata of southern Spain (Grün and Allemann, 1975); Barremian through Albian strata of Austria (Lauer, 1972); Barremian and Hauterivian strata of England (Black, 1971b); Albian cores from Leg 11, western North Atlantic Basin (Wilcoxon, 1972); type lower Albian near Dienville, France, type middle Santonian from Sens, France, middle (?) Campanian chalk from Meudon, France, type Campanian marl from Barbezieux, France, and middle Campanian Aachen Marl from near Aachen, Germany (Bukry, 1969); upper Albian strata of England (Black, 1973); upper Albian through Cenomanian of northern Germany (Hoffmann, 1972); Kjolby Gaard Chalk from Kjolby Gaard, Denmark (Bukry, 1969); type Maastrichtian at Maastricht, Holland, and in equivalent strata in Denmark and Tunisia (Bramlette and Martini, 1964).

Thierstein (1971a) reported this species as *Cretarhabdus ingens* (Gorka 1957) from Santonian strata of eastern Switzerland. It was figured as *Coccolithus actinosus* from Albian marl and as *Coccolithites ficula* from Turonian chalk of north-central France (Stover, 1966). Newell (1968) figured this species as *C. actinosus* from the lower part of the Mooreville Chalk of Mississippi.

Within North America, this species has been reported throughout the Niobrara Chalk of Knox County, Nebr. (Bukry, 1969); Ripley Formation and Prairie Bluff Chalk of Alabama, and the Arkadelphia Marl of Arkansas (Bramlette and Martini, 1964); Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Mississippi (Risatti, 1973); Albian and Cenomanian strata of Texas (Hill, 1976); and from the Eagle Ford Group, Austin Group, Taylor Marl and Corsicana Marl of central and north-central Texas (Gartner, 1968; Bukry, 1969).

During this investigation, *Cretarhabdus crenulatus* was observed throughout the upper Turonian through lower Santonian part of the Eagle Ford Group and Austin Group from all sites except the samples from the upper Turonian part of the Maribel Shale Member of the Arcadia Park Formation of the Eagle Ford Group as exposed along Choctaw Creek, Grayson County, Tex.

Genus CRIBROSPHAERELLA Deflandre 1952

Synonyms.—*Cribrosphaera* Arkhangelsky 1912; *Favocentrum* Black 1964; *Cretadiscus* Gartner 1968.

Type species.—*Cribrosphaera ehrenbergi* Arkhangelsky 1912.

Diagnosis.—Subcircular to elliptical forms constructed of two rim cycles and a broad central perforate or imperforate plate. Both the broad distal and more narrow proximal cycles consists of elements that are radial or slightly inclined counterclockwise.

Remarks.—According to article 45 of the ICBN, the name of a taxon must be available (see ICBN footnote, p. 45: = legitimate) in zoological nomenclature to be validly transferred to the plant kingdom. Since the name *Cribrosphaera* Arkhangelsky 1912 is a junior homonym of the radiolaria *Cribrosphaera* Popofsky 1906, *Cribrosphaera* Arkhangelsky is not available in the animal kingdom and, therefore, the name cannot be transferred for use in botanical nomenclature. The name *Cribrosphaerella* was introduced by Deflandre (1952a, p. 111; 1952b, p. 466) as a substitute name for use in zoological as well as botanical nomenclature. For this reason, the name *Cribrosphaerella* Deflandre is used herein.

Favocentrum Black 1964 was distinguished from *Cribrosphaera* Arkhangelsky 1912 (= *Cribrosphaerella* Deflandre 1952) by having a central area constructed of equidimensional granules. Black (1964, p. 313) noted, however, that "coccoliths of this genus are reminiscent of some that have been included in *Cribrosphaera*, but they differ in always being imperforate." *Favocentrum* is herein regarded as a junior subjective synonym of *Cribrosphaerella* because (1) the two genera are identical in both configuration and rim cycle construction, (2) slight amounts of secondary crystal growth could easily account for the closing of the central pores and recrystallization of the thin plate into equidimensional granules, and (3) the two genera are indistinguishable utilizing transmitted light microscopes.

Cretadiscus Gartner 1968 was distinguished from *Cribrosphaera* Arkhangelsky 1912 (= *Cribrosphaerella* Deflandre 1952) by having a single cycle of elements described as flaring distally so that the distal diameter was larger than its proximal diameter. Gartner (1968, p. 36) noted that the type species of *Cretadiscus*, *C. polyporus* Gartner 1968, could not be distinguished from *Cribrosphaerella* in either distal or proximal views. The distinction between the two genera can be made only in side views, and even then some doubt must remain as to coalescing of the two rims by recrystallization. *Cretadiscus* is, therefore, regarded as a junior subjective synoynm of *Cribrosphaerella* Deflandre 1952.

Cribrosphaerella ehrenbergii (Arkhangelsky 1912) Deflandre 1952

Plate 4, figures 18–27, 28–34, 35, 36, 37–42

1912. *Cribrosphaera ehrenbergi* Arkhangelsky, p. 412, pl. 6, figs. 19, 20.
1952a. *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912) Deflandre in Piveteau, p. 111, figs. 54a, 54b.
1952b. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Deflandre in Grasse, p. 466, text–figs. 362 (N–O).
1956. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Vekshina, p. 1057, fig. d.
1957. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Gorka, p. 280, pl. 4, fig. 12.
1957. *Discolithus numerosus* Gorka, p. 279, pl. 4, fig. 5.
1959. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Vekshina, p. 70–71, pl. 2, fig. 9.
1963. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Stradner, p. 179, pl. 2, figs. 1–1a.
1964. *Favocentrum laughtoni* Black, p. 313–314, pl. 53, figs. 1, 2.
1964. *Favocentrum matthewsi* Black, p. 314–315, pl. 53, figs. 5, 6.
1964. *Favocentrum laughtoni* Black 1964, Black and others, p. 504, pl. 43, fig. c.
1964. *Favocentrum matthewsi* Black 1964, Black and others, p. 504, pl. 43, fig. d.
1964. *Discolithina*? cf. *D. numerosa* (Gorka 1957), Bramlette and Martini, p. 301, pl. 1, figs. 23–24.
1964. *Cribrosphaerella romanica* Reinhardt, p. 756–757, pl. 2, fig. 1; text–fig. 7.
1964. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Stradner, p. 137, text–fig. 35.
1966. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Cohen, p. 30, pl. 4, figs. a, b.
1966. *Favocentrum laughtoni* Black 1964, Edwards, p. 487, figs. 20, 23.
1966a. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Reinhardt, p. 28, pl. 22, figs. 13, 26; text–fig. 8.
1966a. *Cribrosphaera matthewsi* (Black 1964), Reinhardt, p. 28, pl. 5, figs. 1a–b, 2a–b; pl. 12, fig. 5; text–fig. 7.
1966. *Discolithus venatus* Stover, p. 144, pl. 3, figs. 12a–c, 13a–b; pl. 8, fig. 21.
1967. *Cretadiscus* sp., Honjo and Minoura, pl. 50, figs. 1, 2.
1967. *Cretadiscus* sp., Honjo, Minoura, and Okada, pl. 52, figs. 1, 2.
1967. *Discolithina* cf. *D. numerosa* (Gorka 1957), Moshkovitz, p. 149, pl. 1, figs. 2–2a, 3, 4, 5; pl. 5, fig. 4.
1967. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Reinhardt, p. 171–172, text–fig. 7 (10–12).
1967. *Cribrosphaerella matthewsi* (Black 1964), Reinhardt, p. 171–172, text–figs. 6, 7 (13–15).
1967. *Cribosphaerella numerosa* (Gorka 1957), Reinhardt and Gorka, p. 243–244, pl. 31, figs. 7, 11; pl. 37, fig. 2; text–fig. 1.
1967. *Discolithus numerosus* Gorka 1957, Sales, p. 305, pl. 3, fig. 4.
1967. *Discolithus numerosa* (Gorka 1957), Vangerow and Schloemer, p. 456, table 1, fig. 14.
1968. *Discolithina*? cf. *numerosa* (Gorka 1957), Barbieri and Panicieri, p. 426, pl. 32, figs. 1, 2, 3, 4.
1968. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Gartner, p. 40, pl. 1, figs. 14, 15; pl. 3, figs. 2a–d; pl. 6, figs. 7a–c; pl. 12, figs. 2a–d; pl. 15, figs. 11a–d.
1968. *Cribrosphaerella pelta* Gartner, p. 41, pl. 10, figs. 24, 25.
1968. *Cribrosphaerella linae* Gartner, p. 40–41, pl. 1, fig. 16; pl. 3, figs. 4a–d; pl. 11, figs. 16a–c.
1968. *Cretadiscus colatus* Gartner, p. 36, pl. 10, figs. 7, 8; pl. 12, figs. 5a–c, 6a–b; pl. 19, fig. 10.
1968. *Cretadiscus polyporus* Gartner, p. 36, pl. 1, figs. 17, 18, 19; pl. 4, fig. 13; pl. 25, fig. 5.
1968. *Discolithus numerosus* Gorka 1957, Manivit, p. 284, pl. 2, figs. 8a–b.
1968. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Perch-Nielsen, p. 54–55, pl. 17, figs. 1–8.
1968. *Coccolithus cribosphaerella* Pienaar, p. 362–363, pl. 70, figs. 4–5.
1969. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Bukry, p. 44–45, pl. 22, figs. 7–12.
1969. *Cribrosphaera laughtoni* (Black 1964), Bukry, p. 45, pl. 23, figs. 1–9.
1969. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Pienaar, p. 93–94, pl. 1, fig. 4; pl. 2, fig. 5; pl. 6, fig. 3; pl. 7, fig. 8.
1969. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Shumenko, p. 1294, fig. 2–f.
1970. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Čepek, p. 239, pl. 22, figs. 1, 2a–b; pl. 26, fig. 1.
1970a. *Cribrosphaera arkhangelskii* (Shumenko 1962), Hoffmann, p. 856, pl. 4, fig. 1.
1970. *Discolithus numerosus* Gorka 1957, Iaccarino and Follini, p. 588–589, pl. 40, figs. 37, 38.
1970. *Discolithus venatus* Stover 1966, Iaccarino and Follini, p. 590, pl. 39, figs. 19, 20, 21.
1970. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Noël, p. 70–73, pl. 18, figs. 4a–c, 5, 6, 7; pl. 19, figs. 1a–c, 2, 3, 4; pl. 20, figs. 1a–c, 2, 3, 4.
1971a. *Cribrosphaera ehrenbergii* Arkhangelsky 1912, Black, p. 618, pl. 45.4, fig. 41.
1971. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Manivit, p. 101–102, pl. 8, figs. 1, 2, 3, 4–5, 6, 7–8, 9, 10–12, 13.
1971. *Cribrosphaera laughtoni* (Black 1964), Shafik and Stradner, p. 82, pl. 30, figs. 1–4; pl. 31, figs. 1–4.
1971a. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Thierstein, p. 37, pl. 1, figs. 7–8.
1972. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Forchheimer, pl. 9, figs. 1, 3, 4.
1972. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Grün and others, p. 158–159, pl. 25, figs. 7a–b, 8a–b, (?) 9a–b.
1972a. *Cribrosphaera arkhangelskii* (Shumenko 1962), Hoffmann, p. 56–58, pl. 15, figs. 3, 4; text–figs, 25, 26.
1972a. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Hoffmann, p. 54–55, pl. 15, figs. 1, 2.
1972. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Iaccarino and Rio, p. 655, pl. 71, fig. 1.
1972. *Cretarhabdus conicus* Bramlette and Martini 1964, Iaccarino and Rio, p. 655, pl. 72, fig. 2; *not* pl. 71, figs. 17a–b.
1972. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Lauer, p. 158–159, pl. 25, figs. 7a–b, 8a–b, *not* pl. 25, figs. 9a–b.
1972. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Locker, p. 769, pl. 10, figs. 12, 13–14.

1972. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Wilcoxon, p. 431, pl. 11, figs. 3, 4.
1973. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), El-Dawoody and Barakat, p. 107–108, pl. 11, figs. 1a–b.
1973. *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912), Hekel, p. 228–229, pl. 3, figs. 3–4.
1973. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Perch-Nielsen, p. 330, pl. 4, figs. 5, 6.
1973. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Priewalder, p. 18, pl. 8, figs. 3, 5.
1973. *Cribrosphaerella laughtoni* (Black 1964), Priewalder, p. 18, pl. 8, figs. 4, 6.
1973. (?)*Cribrosphaera ehrenbergi* Arkhangelsky 1912, Risatti, p. 24, pl. 2, figs. 3–4.
1973. *Cretadiscus colatus* Gartner 1968, Risatti, p. 25, pl. 2, figs. 1–2.
1973. *Cribrosphaera linea* (Gartner 1968), Risatti, p. 24, pl. 2, fig. 5.
1974. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Báldiné Beke, p. 77, pl. 6, figs. 9a–b.
1974. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Müller, p. 589, pl. 18, figs. 11, 12.
1975. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Čepek, p. 99, pl. 2, figs. 2a–c.
1975. *Cribrosphaera pelta* (Gartner 1968), Krancer, p. 15, pl. 3, fig. 2.
1975. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Proto Decima, Roth, and Todesco, p. 50, pl. 5, figs. 9a–b.
1975. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Stapleton, p. 55, pl. 4, figs. 12a–b.
1976. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Burns, p. 285, pl. 3, fig. 4.
1976. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), El-Dawoody and Zidán, p. 416, pl. 2, figs. (?)2a–b, 3a–b, (?)4a–b.
1976. *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912), Hill, p. 135, pl. 5, figs. 20–22, 23–25, 26–29, 30–32; pl. 13, figs. 29, 30.
1977. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Gašparíková, p. 163, pl. 74, fig. 2; pl. 76, figs. 1, 2.
1977. *Cribrosphaera laughthoni* (Black 1964), Gašparíková, p. 163, pl. 76, figs. 3, 4, 6.
1977. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Pavšič, p. 38–39, pl. 2, figs. 13, 14, 15, 16.
1978. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Čepek, p. 677, pl. 1, figs. 4, 5.
1978. *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912), Proto Decima, Medizza, and Todesco, p. 602, pl. 14, figs. 1–3.
1978. *Cribrosphaera ehrenbergi* Arkhangelsky 1912, Shafik, p. 219, fig. 4, Da–Db; p. 223, fig. 6, Da–Db.

Diagnosis.—Elongate elliptical coccoliths with two rim cycles, the smaller proximal cycle distinctly raised above the level of the proximal surface of the distal rim cycle. The central area structure consists of a broad elliptical plate constructed of small equidimensional granules and which is usually perforate.

Description.—Ovate to elliptical in outline, consisting of two cycles of rim elements with a central plate that may be perforate or imperforate. In distal view, the rim cycle is constructed of 15 to 30 rather broad elements radially oriented or inclined slightly counterclockwise, with little or no imbrication. In distal view, the rim cycle slopes toward the central area. The broad central plate is convex distally and may be either perforated by numerous small subcircular pores or constructed of small irregularly shaped crystals with little or no evidence of pores. In proximal view, two cycles are visible. The proximal cycle is distinctly raised above the level of the proximal surface of the distal cycle, and consists of 15 to 30 elements radially oriented or with slight clockwise inclination. The proximal cycle slopes toward the central area. The outer part of the distal cycle (in proximal view) is constructed of radial elements that slope toward the outer peripheral margin. Proximal views of the central area duplicate those observed in distal view.

In phase contrast light, the elliptical coccolith has a broad dark outer ring and narrow bright inner ring. Although pores were occasionally visible in scanning electron micrographs, transmitted light micrographs of the same coccolith show no distinctly perforate central plate, undoubtedly owing to the limit of resolution of the light microscope. Images produced in cross-polarized light have a narrow and indistinct dark outer ring and bright inner ring. Interference-extinction lines, two at either end of the elliptical rim cycles, curve dextrally in proximal view and sinistrally in distal view.

Remarks.—*Cribrosphaerella ehrenbergii* shows a considerable degree of variation in both electron and transmitted light optics. The peripheral outline varies from elongate elliptical to subcircular. Additional variation exists in the relative widths of the proximal and distal rim cycles as well as in the perforate or imperforate nature of the central plate.

Forms belonging to this species have been described previously under a variety of both generic and specific names (see synonymy). The multiplicity of names is in part due to the variation exhibited within this species, although much of its history is confused because of the differences in the state of preservation of the material being studied. Specific identity has also been based on differences in electron micrography between proximal and distal surfaces. *Favocentrum laughtoni* Black 1964 (=type species of *Favocentrum* Black 1964) was based on the distal surface, while *Favocentrum matthewsi* Black 1964 was described from micrographs of the proximal surface of *Cribrosphaerella ehrenbergii* Arkhangelsky 1912.

Known range.—Albian through Maastrichtian.

Type locality.—Upper Cretaceous strata of the U.S.S.R.

Occurrence.—This species has a worldwide geographic distribution through out its geologic range. Within the United States, *Cribrosphaerella ehrenbergii* has been reported throughout the Niobrara Chalk of Knox County, Nebr. (Bukry, 1969), Albian and Cenomanian strata of Texas (Hill, 1976); as well as from the Eagle Ford Group, Austin Group, Taylor Marl, and Corsicana Marl of Texas, and Arkadelphia Marl of Arkansas (Gartner, 1968; Bukry, 1969). Newell (1968) figured this species as *Cretadiscus colatus, C. polyporus, Cribrosphaerella ehrenbergi,* and *C. matthewsi* from the Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi. Risatti (1973) recorded this species under a variety of names (see synonymy) from the Demopolis Chalk, Ripley Formation and Prairie Bluff Chalk of Mississippi. This species was observed throughout the upper Turonian, Coniacian, and lower Santonian samples that were examined during this study.

Genus CYLINDRALITHUS Bramlette and Martini 1964

Type species—Cylindralithus serratus Bramlette and Martini 1964.

Diagnosis.—Forms having a tapering cylindrical body, in plan view circular to subcircular and flaring at both ends, with a broad longitudinal opening that may be spanned by symmetrical or asymmetrical crossbars at the smaller proximal end. The wall is constructed of a single cycle of broad elements more or less parallel to the longitudinal axis of the cylindrical body.

Cylindralithus asymmetricus Bukry 1969

Plate 4, figures 43–48; plate 5, figures 1–7, 8

1969. *Cylindralithus asymmetricus* Bukry, p. 42, pl. 19, figs. 9–12.
1970b. *Cylindralithus asymmetricus* Bukry 1969, Reinhardt, p. 54, text–figs. 27–28.
1970. (?)*Cylindralithus biarcus* Bukry 1969, Noël, p. 84–85, pl. 30, figs. 1a–f, 2, 3a–b, 4; pl. 31, figs. 1, 2, 5, 6.
1972. *Cylindralithus asymmetricus* Bukry 1969, Roth and Thierstein, pl. 12, figs. 19–22.
1975. *Cylindralithus asymmetricus* Bukry 1969, Krancer, p. 13, pl. 3, fig. 1.
1978. *Cylindralithus biarcus* Bukry 1969, Shafik, p. 221, fig. 5, Pa–Pb.
1978. *Cylindralithus asymmetricus* Bukry 1969, Shafik, p. 221, fig. 5, Qa–Qb.

Diagnosis.—Double-flaring cylindrical forms with a broad longitudinal opening spanned by two narrow X-shaped crossbars at its smaller proximal end.

Remarks.—Bukry (1969, p. 42) described *Cylindralithus asymmetricus* from examination of transmission electron micrographs. Although this species was described as having an elliptical central opening, it is certainly only very slightly eccentric (1.1 to 1.3 according to Bukry, 1969). Measurements of this nature can be made on only the rare individuals whose long axis is oriented almost perfectly perpendicular to the plane of the observer. The slender, acute X-shaped crossbars spanning the proximal end of the double-flaring cylinder is herein regarded as the most diagnostic characteristic of this species.

In transmitted light photomicrographs, *Cylindralithus asymmetricus* has an irregular and indistinct outer peripheral margin and a more or less sharply defined inner ring margin. Occasionally, the cylindrical body may appear to be constructed of a broad, dark, indistinct outer ring and a narrow, bright inner ring. As noted herein under *Cylindralithus coronatus* Bukry, the dark outer ring is produced by the flaring ends and the bright ring is a result of the more or less radial elements of the main cylinder body. The narrow, acute X-shaped crossbars are distinct in both plane transmitted and phase contrast light. In cross-polarized light, the cylindrical body appears as a bright, almost circular ring with four indistinct, interference-extinction lines. The crossbars cannot be observed owing to the optical axes of the elements being perpendicular to the plane of the nicols.

Known range.—Coniacian through early Campanian.

Type locality—Taylor Marl about 5 feet above its contact with the Austin Group in a gully near the southern end of the Lake Waxahachie spillway, Ellis County, Tex.

Occurrence.—*Cylindralithus asymmetricus* is known from Coniacian through (?) lower Maastrichtian cores recovered during Leg 14, Deep Sea Drilling Project, western Atlantic Basin (Roth and Thierstein, 1972); Santonian strata of western Australia (Shafik, 1978); the Santonian and Campanian strata of Germany (Reinhardt, 1970b); questionably from the Campanian near Arpenty, France (Noël, 1970); upper part of the Niobrara Chalk of Knox County, Nebr. (Bukry, 1969a); and the Austin Group of Travis and Dallas Counties, and the Taylor Marl of Ellis County, Tex. (Bukry, 1969). Newell (1968) recorded this species as *Stephanolithion* aff. *S. bigoti* Deflandre from the Eutaw Formation, Mooreville Chalk and Demopolis Chalk of Mississippi.

This species was not observed in any of the upper Turonian samples examined here. It was noted throughout the Coniacian and lower Santonian part of the Atco Chalk in the Pinto Creek, Sycamore Creek, Oak Haven, Cedar Hill, and Choctaw Creek localities.

Cylindralithus coronatus Bukry 1969

Plate 5, figures 9–17

1963. *Zygolithus maltanensis* (Gorka 1957), Stradner, p. 178, pl. 2, figs. 10–10a.
1968. *Cylindralithus achylosus* (Stover 1966), Gartner, p. 46, pl. 21, figs. 10a–d; pl. 22, fig. 23.
1969. *Cylindralithus coronatus* Bukry, p. 42, pl. 20, figs. 4, 5, 6.
1970b. *Cylindralithus coronatus* Bukry 1969, Reinhardt, p. 55, text–figs. 30, 31.
1972. *Cylindralithus coronatus* Bukry 1969, Roth and Thierstein, pl. 12, figs. 23–26; pl. 13, figs. 1–5.
1976. *Stephanolithion achylosum* (Stover 1966), Shumenko, p. 66, pl. 25, figs. 1(?), 2.
1978. *Cylindralithus coronatus* Bukry 1969, Čepek, p. 673, pl. 1, fig. 9.
1978. *Cylindralithus coronatus* Bukry 1969, Shafik, p. 221, fig. 5, Na–Nb.

Diagnosis.—Double-flaring cylindrical forms with a broad longitudinal opening, spanned at its proximal end by a rather broad, plus-shaped crossbar constructed of four arms which intersect at or near right angles.

Description.—*Cylindralithus coronatus* consists of a short tapering cylinder that flares at both the larger distal and smaller proximal ends. The wall is constructed of a single cycle of longitudinal elements, which appear ribbed or serrate in side view. A plus-shaped cross consisting of four bars extends from the center to the rim at the smaller proximal end of the cylinder. The cross may be symmetrical or asymmetrical, and the bars may meet at a common center or be somewhat offset. The larger distal end of the tapering cylinder is open.

Plane transmitted as well as phase contrast images of this species show a narrow irregular and indistinct dark outer ring and a bright inner ring, sharply defined along the interior of the cylinder. Scanning electron and transmitted light images of the same nannofossil indicate that the dark outer ring in transmitted light images represents the irregularly flaring ends of the cylinder wall, and the bright inner ring represents the more or less radial elements composing the main cylinder body. Owing to the length of the cylinder body, the crossbars may be seen only when the focal plane is adjusted to a level at or near the proximal end of the cylinder. In cross-polarized light, the cylinder body is seen as a bright ring with four narrow and indistinct, slightly curved, interference-extinction lines. The cross members are dark because the optical axes of calcite elements are at, or nearly perpendicular to, the circular plane of the cylinder.

Remarks.—Light photomicrographs show that *Cylindralithus coronatus* Bukry differs from *Chiphragmalithus achylosus* Stover 1966 in having (1) a longer cylinder body, (2) a much more irregular outer peripheral outline, (3) an indistinct rather than sharply defined contact between the dark outer and bright inner ring margins, and (4) wider crossbars that are dark in cross-polarized light.

Transmitted light photomicrographs of the cylindrical body of *Cylindralithus coronatus* differ only slightly from those of *C. asymmetricus* Bukry, although in *C. coronatus* the two rings produced by the flaring wall and main cylinder body are more sharply defined. *Cylindralithus coronatus* is distinct, however, in having broader crossbars which intersect at or near right angles.

Known range.—Late Turonian through middle Campanian.

Type locality.—Upper part of the Austin Group exposed near the intersection of White Rock Road with Shook Avenue in Dallas, Dallas County, Tex.

Occurrence.—*Cylindralithus coronatus* is known from Coniacian and Santonian cores recovered during Leg 14, Deep Sea Drilling Project, western North Atlantic Basin area (Roth and Thierstein, 1972); Santonian and Campanian strata of Germany (Reinhardt, 1970b); and from the Austin Group of Dallas County, and Taylor Marl of Ellis County, Tex. (Bukry, 1969). Gartner (1968, p. 46) noted that *C. achylosus* Stover (=*C. coronatus* Bukry 1969) was found in the lower part of the Austin Group (Coniacian) of Dallas County, but his distribution chart (Gartner, 1968, p. 15, text–fig. 2) shows this species present throughout the Austin Group and Taylor Marl of Dallas County, Tex.

During this investigation, *Cylindralithus coronatus* was observed to be common to abundant throughout the upper Turonian-lower Santonian strata of all sections sampled for nannoplankton.

Genus EIFFELLITHUS Reinhardt 1965

Synonyms.—*Clinorhabdus* Stover 1966.

Type species.—*Zygolithus turriseiffeli* (Deflandre 1954).

Diagnosis.—Elliptical forms having a rim constructed of a single cycle of imbricate elements. The central area is spanned by two intersecting crossbars, either symmetrically or slightly asymmetrically arranged with respect to the major and minor axes of the ellipse, which may or may not support a stem.

The central area between the crossbars may be either partially or completely filled by an inner cycle of large elements.

Eiffellithus eximius (Stover 1966) Perch-Neilsen 1968

Plate 5, figures 18–24, 25, 26–32, 33–35

1963. *Rhabdolithus turriseiffeli* (Deflandre 1954), Stradner, p. 180, pl. 5, figs. 9–9a.
1964. *Rhabdolithus turriseiffeli* (Deflandre 1954), Stradner, p. 137, text–figs. 39, 40.
1966. *Clinorhabdus eximius* Stover, p. 138, pl. 2, figs. 15a–c, 16a–b; pl. 8, fig. 15.
1968. *Eiffellithus turriseiffeli* (Deflandre 1954), Gartner, p. 26, pl. 16, fig. 2; pl. 17, figs. 3a–d; pl. 18, figs. 9–10; pl. 19, figs. 1a–d, 2a–c; pl. 22, fig. 4; pl. 23, figs. 9, 10, 11; pl. 24, figs. 2a–c.
1968. *Zygrhablithus turriseiffeli* (Deflandre 1954), Manivit, pl. 2, figs. 4a–b.
1968. *Clinorhabdus turriseiffeli* (Deflandre 1954), Newell, p. 33–35, pl. 2, figs. 1a, 1d; *not* pl. 1, figs. 3a, 3b–c, 3d–e; *not* pl. 2, figs. 1b, 1c.
1968. *Eiffellithus eximius* (Stover 1966), Perch-Nielsen, p. 30, pl. 3, figs. 8, 9–10; text–fig. 5d.
1969. *Eiffellithus augustus* Bukry, p. 51–52, pl. 28, figs. 10–11; pl. 29, fig. 1.
1970. *Eiffellithus eximus* (Stover 1966), Noël (error for *Eiffellithus eximius*), p. 40–41, pl. 6, figs. 4, (?) 5a–b, 7; pl. 7, figs. 1, 2, 3a–b, 4, (?) 5a–b, 7; pl. 7, figs. 1, 2, 3a–b, 4, 5a–c, 6, 7.
1970b. *Eiffellithus eximus* (Stover 1966), Reinhardt (error for *eximius*), p. 61, text–figs. 46a–c.
1970. *Zygolithus* aff. *biramiculatus* Stover 1966, Iaccarino and Follini, p. 594, pl. 40, fig. 19.
1971. *Eiffellithus eximius* (Stover 1966), Manivit, p. 91, pl. 11, figs. 10, 11.
1971. *Eiffellithus turriseiffeli* (Deflandre 1954), Manivit, p. 90–91, pl. 11, figs. 1, 2, 3, 4, (?) 13–14.
1971a. *Eiffellithus turriseiffeli* (Deflandre 1954), Thierstein, p. 36, pl. 1, figs. 5–6.
1972. *Eiffellithus eximius* (Stover 1966), Forchheimer, p. 47, pl. 15, figs. 1, 2, 3.
1972. *Eiffellithus eximius* (Stover 1966), Grün and others, p. 166–167, pl. 29, figs. 1a–e, 2a–b.
1972a. *Eiffellithus eximius* (Stover 1966), Hoffmann, p. 41–42, pl. 6, figs. 3, 4; text–fig. 22.
1972. *Eiffelithus eximius* (Stover 1966), Lauer (error for *Eiffellithus*) p. 166–167, pl. 29, figs. 1a–b, 2a–b.
1972. *Eiffellithus eximius* (Stover 1966), Locker, p. 771, pl. 5, fig. 11.
1972. *Eiffellithus* aff. *E. eximius* (Stover 1966), Perch-Nielsen, p. 1011, pl. 22, figs. 4, 6.
1973. *Eiffellithus eximius* (Stover 1966), Roth, p. 726–727, pl. 18, figs. 1a–d.
1976. Not *Eiffellithus eximius* (Stover 1966), El-Dawoody and Zidan, p. 420, pl. 4, figs. 5a–b.
1976. *Eiffellithus eximius* Stover 1966), Hill, p. 139, pl. 6, figs. 19–23, 24–29, 30–33.
1976b. *Eiffellithus eximius* (Stover 1966), Verbeek, p. 132, 135–136, pl. 1, fig. 3.
1977. *Eiffellithus eximius* (Stover 1966), Manivit and others, p. 175, pl. 1, fig. 12.
1978. *Eiffellithus eximius* (Stover 1966), Čepek, p. 677, pl. 1, figs. 10, 11.
1978. *Eiffellithus eximius* (Stover 1966), Schmidt, p. 713, pl. 5, figs. 7a–b.
1978. *Eiffellithus eximius* (Stover 1966), Shafik, p. 219, fig. 4, Wa–Wb.
1978. *Eiffellithus eximius* (Stover 1966), Thompson, Pervical, and Patricelli, p. 668, pl. 3, figs. 8, 12, 16.
1980. *Eiffellithus eximius* (Stover 1966), Barrier, p. 296, pl. 1, fig. 15.

Diagnosis.—Elongate elliptical rhabdoliths with a broad central area spanned by four crossbars alined, or in near alinement, with the transverse and longitudinal axes of the central area. The crossbars are broad, and bifurcate near their point of attachment with the distal rim cycle.

Description.—Elliptical in outline, consisting of a narrow rim cycle, broad inner cycle, and large central area spanned by four crossbars alined symmetrically or near symmetrically with the axes of the elliptical central area. In distal view, the outer rim cycle is constructed of 40 to 60 narrow elements that are dextrally imbricate and inclined slightly clockwise. The large elliptical central area is bordered by an inner cycle of 8 to 10 irregularly arranged and broad elements. The central area may be open, although it is commonly filled owing to slight recrystallization of the inner cycle elements. Each of the central area crossbars is constructed of numerous parallel elements that are attached to the outer rim cycle through gaps in the broad inner elements. The crossbars merge at a common point along the vertical axis of the elliptical central area, are raised above the level of the distal rim cycle, and form the support struts for a large, hollow, central stem. In proximal view, the outer rim cycle consists of 40 to 60 narrow, elongate elements, sinistrally imbricate and strongly inclined counterclockwise. The wide central area is distinctly concave and bordered by an inner cycle of counterclockwise inclined elements. The crossbars are visible only within the small ovate central area.

In plane transmitted and phase contrast light, the coccolith is elliptical and has an outer peripheral margin that may be smooth or somewhat serrate. The narrow outer rim cycle appears dark, the bright central area spanned by four rather broad crossbars symmetrically or slightly asymmetrically alined with respect to the axes of the ellipse. Images in cross-polarized light consist of a narrow outer rim separated from the bright elliptical central area by a dark and distinct narrow line. The crossbars are distinct and appear to be in near alinement with the longitudinal and transverse axes of the coccolith. When oriented about 45° to the plane of either nicol, however, the crossbars appear less distinct and are asymmetrically arranged about the transverse axis. In distal view, the crossbars are offset sinistrally from the longitudinal and transverse axes. In proximal view, the crossbars are offset dextrally.

Remarks.—*Eiffellithus eximius* (Stover 1966) has been previousy confused (see synonymy) with *E. turriseiffeli* (Deflandre 1954). This species differs from *E. turriseiffeli* in having broader crossbars alined, or in near alinement, with the major and minor axes of the elliptical coccolith.

Known range.—Turonian through Campanian.

Type locality.—Campanian chalk from a quarry near Sens, France.

Occurrence.—*Eiffellithus eximius* has been recorded from Turonian and lower Santonian strata of northern Germany (Hoffmann, 1972a); Turonian through Campanian strata of France (Manivit, 1968); Campanian strata near Arpenty, France (Noël, 1970); middle(?) Campanian chalk from Meudon, France (Bukry, 1969); Campanian and Santonian of north-central France (Stover, 1966); Santonian of eastern Switzerland (Thierstein, 1971a); type middle Santonian chalk from Saintes, France (Bukry, 1969); upper part of the Niobrara Chalk, Knox County, Nebr. (Bukry, 1969); Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi (Newell, 1968); and from the Austin Group and Taylor Marl of Dallas and Ellis Counties, Tex. (Gartner, 1968; Bukry, 1969).

Eiffellithus eximius is one of the most abundant species that was observed during this investigation. It occurs throughout the upper Turonian through lower Santonian part of the Eagle Ford Group and Austin Group of Texas.

Eiffellithus trabeculatus (Gorka 1957) Reinhardt and Gorka 1967

Plate 6, figures 1–7, 8–13, 14–17

1957. *Discolithus trabeculatus* Gorka, p. 277, pl. 3, fig. 9.
1966a. *Eiffellithus testaceus* Reinhardt, p. 39, pl. 19, fig. 2.
1966. *Discolithus disgregatus* Stover, p. 142, pl. 2, figs. 11a–b, 12a–b; pl. 8, fig. 12.
1967. *Eiffellithus trabeculatus* (Gorka 1957), Reinhardt and Gorka, p. 250, pl. 31, figs. 19, 23; pl. 32, fig. 1; text–fig. 5.
1968. *Discolithus* cf. *ornamentus* Caratini 1963, Forchheimer, p. 44, pl. 8, figs. 6a–b; fig. 4, no. 3.
1968. *Zygolithus* cf. *phacelosus* (Stover 1966), Manivit, p. 280, pl. 1, figs. 13a–b; *not* pl. 1, figs. 12a–b (note figs. 11 and 12 are reversed in plate explanation).
1969. *Chiastozygus disgregatus* (Stover 1966), Bukry, p. 49, pl. 27, figs. 1–4.
1969. *Chiastozygus planus* Bukry, p. 50, pl. 27, fig. 12; pl. 28, figs. 1–2.
1970. *Discolithus disgregatus* Stover 1966, Čepek, p. 241, pl. 23, figs. 1, 2a–c; pl. 26, fig. 4.
1970a. *Eiffellithus trabeculatus* (Gorka 1957), Hoffmann, p. 851, pl. 3, fig. 5.
1970a. *Eiffellithus disgregatus* (Stover 1966), Hoffmann, p. 850–851, pl 2, fig. 4; pl. 4, fig. 5.
1970b. *Eiffellithus trabeculatus* (Gorka 1957), Reinhardt, p. 61–62, pl. 4, fig. 3; text–figs. 49, 50.
1971. *Eiffellithus anceps* (Gorka 1957), Manivit, p. 91–92, pl. 11, figs. 7–8, 9.
1971. *Eiffellithus trabeculatus* (Gorka 1957), Shafik and Stradner, p. 83, pl. 43, fig. 2.
1971a. *Eiffellithus trabeculatus* (Gorka 1957), Thierstein, p. 36, pl. 3, figs. 54–55.
1972a. *Eiffellithus trabeculatus* (Gorka 1957), Hoffmann, p. 42–43, pl. 9, figs. 1, 2; text–fig. 23.
1972. *Eiffellithus trabeculatus* (Gorka 1957), Locker, p. 771, pl. 5, figs. 13–14.
1972. *Eiffellithus trabeculatus* (Gorka 1957), Roth and Thierstein, pl. 12, figs. 7–18.
1973. *Chiastozygus trabeculatus* (Gorka 1957), Risatti, p. 23, pl. 6, figs. 20–21.
1976. *Eiffellithus trabeculatus* (Gorka 1957), Burns, p. 289, pl. 3, fig. 7.
1976. *Eiffellithus trabeculatus* (Gorka 1957), Hill, p. 139, pl. 6, figs. 34–36; pl. 14, figs. 6, 7.

Diagnosis.—Elongate elliptical forms that have a wide central area largely filled by four broad double bars forming an asymmetrical, X-shaped centrally offset, crossbar. Each arm of the crossbar contains a distinct medial suture bordered by two rectilinear elements.

Description.—Elliptical in outline, consisting of a narrow rim cycle and large central area spanned by eight large plates. Distally, the rim is constructed of about 40 narrow dextrally imbricate elements with strong clockwise inclination. The large central area is spanned by four X-shaped crossbars that form acute angles with the transverse axis of the elliptical central area. Each of the four crossbars consists of two broad parallel rectilinear elements with a distinct medial suture. The four crossbars do not meet at a common point, but are slightly offset at the center of the elliptical opening. Openings may or may not occur in the central area between the four crossbars.

Plane transmitted light images show little beyond the elliptical outline of this species. In phase contrast and cross-polarized light, this form consists of a narrow dark outer rim and bright central area spanned by four cloverleaflike central crossbars. The contact between the dark rim cycle and central area is marked by a distinct dark narrow line. The medial suture bisecting each of the four crossbars may or may not be evident. The bright area between the crossbars is of variable width, and, in cross-polarized light, is bisected by a narrow radial interference-extinction line at both ends near the longitudinal axis.

Remarks.—*Eiffellithus trabeculatus* is distinct in both electron and light optical images and should not be confused with other species. *Chiastozygus planus* Bukry is herein assigned to *E. trabeculatus* as it differs only in possessing a wider rim cycle. Although Bukry (1969, p. 49, 50) stated that *C. disgregatus* (=*E. trabeculatus* s.s.) differed from *C. planus* in having definite gaps between the four crossbars, his illustrations of *C. disgregatus* (pl. 27, figs. 1–4) show both open (figs. 2, 3) and completely closed (figs. 1, 4) central areas. That one specimen may possess either an open or a closed central area is regarded herein as being the result of slight secondary recrystallization, and should, therefore, be of no taxonomic significance.

Known range.—Turonian through Maastrichtian.

Type locaity.—Upper Maastrichtian strata from near Mecmirez, Poland.

Occurrence.—Forms assigned to this species have been reported under a variety of names (see synonymy) from the lower Turonian of France (Manivit, 1968); upper Turonian sedimentary rocks from the subsurface of Sweden (Forchheimer, 1968); lower Coniacian through Maastrichtian of northwestern Germany (Čepek, 1970); Turonian and Maastrichtian of northern Germany (Hoffmann, 1972a); Santonian of eastern Switzerland (Thierstein, 1971a) and north-central France (Stover, 1966); middle(?) Campanian chalk from Meudon, France, and middle Campanian Aachen Marl from near Aachen, Germany (Bukry, 1969); lower Maastrichtian chalk from near Jasmund on the isle of Rugen, northeastern Germany (Hoffmann, 1970a); Maastrichtian of the Eastern Desert Region, Egypt, and from the subsurface of the Dnjepr-Donetz Region of Russia (Shafik and Stradner, 1971); from upper Maastrichtian strata of Poland (Gorka, 1957; Reinhardt and Gorka, 1967); and from reworked upper Miocene sedimentary rocks of Germany (Locker, 1972).

This species has been reported from the Maastrichtian Ripley Formation and Prairie Bluff Chalk of Mississippi by Risatti (1973). Newell (1968) recorded this form from the Santonian and Campanian Eutaw Formation, Mooreville Chalk and Demopolis Chalk of Mississippi as *Zygolithus* aff. *Z. dubius* Deflandre and Fert 1954. Bukry (1969) reported *E. trabeculatus* from the Coniacian and Santonian portions of the Austin Group of Dallas and Travis Counties, Tex. During the present investigation, it was found throughout the upper Turonian, Coniacian, and lower Santonian part of the Eagle Ford Group and Austin Group at all sample localities.

Eiffellithus turriseiffeli (Deflandre 1954) Reinhardt 1965

Plate 6, figures 18–24, 25–33

1954. *Zygolithus turriseiffeli* Deflandre *in* Deflandre and Fert, p. 149, pl. 13, figs. 15–16; text-fig. 65.

1959. *Zygrahablithus turriseiffeli* (Deflandre 1954), Deflandre, p. 135–136.

1959. *Rhabdosphaera elliptica* Vekshina, p. 74–75, pl. 1, fig. 10; pl. 2, figs. 14a–b.

1963. *Zygrhablithus turriseiffeli* (Deflandre 1954), Gorka, p. 9–11, text-pl. 1, figs. 5, 6.

1963. *Rhabdolithus turriseiffeli* (Deflandre 1954), Stradner, p. 175, pl. 5, fig. 5.

1964. *Zygrhablithus? turriseiffeli* (Deflandre 1954), Bramlette and Martini, p. 304, pl. 3, figs. 18–19, 20–21; pl. 4, figs. 1–2.

1965. *Zygrhablithus turriseiffeli* (Deflandre 1954), Manivit, p. 191, pl. 1, figs. 1a–d.

1965. *Eiffellithus turriseiffeli* (Deflandre 1954), Reinhardt, p. 32, 35.

1966. *Zygrhablithus? turriseiffeli* (Deflandre 1954), Cohen, p. 27, pl. 4, fig. g.

1966. *Zygrhablithus? turriseiffeli* (Deflandre 1954), Edwards, p. 489, figs. 32–33.

1966. *Zygrhablithus turriseiffeli* (Deflandre 1954), Lezaud, p. 42, pl. 1, fig. 14.

1966a. *Eiffellithus turriseiffeli turriseiffeli* (Deflandre 1954), Reinhardt, p. 38, pl. 23, fig. 1; text-fig. 18.

1966. *Clinorhabdus turriseiffeli* (Deflandre 1954), Stover, p. 138, pl. 3, figs. 7, 8a–c, 9a–b.

1967. *Eiffellithus turriseiffeli* (Deflandre 1954), Moshkovitz, p. 153, pl. 1, fig. 17; pl. 5, figs. 3a–b.

1967. *Zygrhablithus* cf. *turriseiffeli* (Deflandre 1954), Vangerow and Schloemer, p. 456, table 1, fig. 24.

1968. *Eiffellithus turriseiffeli* (Deflandre 1954), Black, pl. 149, fig. 6.

1968. *Eiffellithus turriseiffeli* (Deflandre 1954), Čepek, p. 677, pl. 1, fig. 12.

1968. *Eiffellithus turriseiffeli* (Deflandre 1954), Gartner, p. 26, pl. 2, figs. 22, 23; pl. 3, figs. 13a–c; pl. 5, fig. 19; pl. 7, figs. 5a–c; pl. 9, figs. 6–10; pl. 13, figs. 1a–c, 2a–c; pl. 16, fig. 1; pl. 18, fig. 11; pl. 23, figs. 7, 8(?); pl. 24, figs. 1a–c; pl. 25, fig. 15, 16(?); pl. 26, figs. 3a–c; *not* pl. 16, fig. 2; pl. 17, figs. 3a–c; pl. 18, figs. 9–10; pl. 19, figs. 1a–d, 2a–c; pl. 22, fig. 4; pl. 23, figs. 9–11; pl. 24, figs. 2a–c.

1968. *Eiffellithus turriseiffeli* (Deflandre 1954), Perch-Nielsen, p. 28, pl. 3, figs. 1–7; text-figs. 5b, 6.

1968. *Eiffellithus regularis* (Gorka 1957), Perch-Nielsen, p. 30–31, pl. 32, figs. 8–9.

1969. *Eiffellithus turriseiffeli* (Deflandre 1954), Bukry, p. 52, pl. 29, figs. 2–5.

1969. *Eiffellithus turriseffeli* (Deflandre 1954), Čepek and Hay, p. 326, 331, text-fig. 2, no. 1, text-fig. 4, no. 6.

1969. *Zygrhablithus turriseiffeli* (Deflandre 1954), Pienaar, p. 119–120, pl. 4, fig. 2; pl. 10, fig. 4.

1970. *Eiffellithus turriseiffeli* (Deflandre 1954), Iaccarino and Follini, p. 587, pl. 40, figs. 11, 12, 13.

1970. *Zygolithus* sp., Iaccarino and Follini, p. 592, pl. 39, fig. 12.

1970b. *Eiffellithus turriseiffeli* (Deflandre 1954), Reinhardt, p. 62–63, pl. 4, figs. 6, 7; pl. 5, figs. 1, 2; text-figs. 47–48.

1971. *Zygrhablithus turriseiffeli* (Deflandre 1954), Grigorovich, p. 86–88, pl. 3, fig. 8.
1971. *Eiffellithus regularis*? (Gorka 1957), Manivit, (no pagination), pl. 11, figs. 5–6.
1971b. *Eiffellithus turriseiffeli* (Deflandre 1954), Thierstein, p. 475, pl. 7, figs. 9–11.
1972. *Eiffellithus turriseiffeli* (Deflandre 1954), Báldiné Beke, p. 217, pl. 3, figs. 1a–b.
1972. *Eiffellithus turriseiffeli* (Deflandre 1954), Forchheimer, pl. 15, fig. 5; pl. 16, figs. 1, (?)3.
1972. *Eiffellithus turriseiffeli* (Deflandre 1954), Grün and others, p. 167, pl. 29, figs. 3a–b, 4a–b.
1972a. *Eiffellithus turriseiffeli* (Deflandre 1954), Hoffmann, p. 37–39, pl. 4, fig. 6; pl. 5, figs. 4, 6; text-fig. 19.
1972. *Eiffellithus turriseiffeli* (Deflandre 1954), Iaccarino and Rio, p. 654, pl. 71, figs. 23a–b.
1972. *Eiffelithus turriseiffeli* (Deflandre 1954), Lauer (error for *Eiffellithus*) p. 167, pl. 29, figs. 3a–b, 4a–b.
1972. *Eiffellithus turriseiffeli* (Deflandre 1954), Locker, p. 771, pl. 5, fig. 12.
1972. *Eiffellithus turriseiffeli* (Deflandre 1954), Roth and Thierstein, pl. 4, figs. 1–6, 9.
1973. *Eiffellithus parallelus* Perch-Nielsen, p. 315–316, pl. 6, figs. 2, 4; pl. 10, figs. 47–48.
1973. *Eiffellithus turriseiffeli* (Deflandre 1954), Perch-Nielsen, p. 330, pl. 6, fig. 7; pl. 10, figs. 49–50.
1973. *Eiffellithus regularis* (Gorka 1957), Priewalder, p. 18, pl. 9, fig. 5.
1973. *Eiffellithus turriseiffeli* (Deflandre 1954), Priewalder, p. 19, pl. 9, figs. 1, 2, 3, 4.
1974. *Eiffellithus turriseiffeli* (Deflandre 1954), Proto Decima, p. 592, pl. 3, figs. 5, 6–7.
1975. *Eiffellithus turriseiffeli* (Deflandre 1954), Burns, p. 472, figs. 7, 8, 9, 10.
1975. *Eiffellithus turriseiffeli* (Deflandre 1954), Čepek, p. 96–97, pl. 1, figs. 3a–c.
1975. *Eiffellithus turriseiffeli* (Deflandre 1954), Hill, p. 231, pl. 2, fig. 5.
1975. *Eiffellithus turriseiffeli* (Deflandre 1954), Jafar, pl. 13, figs. 4–5.
1975. *Eiffellithus turriseiffeli* (Deflandre 1954), Proto Decima, Roth, and Todesco, p. 49, pl. 5, figs. 1, 2a–b.
1975. *Eiffellithus turriseiffeli* (Deflandre 1954), Stapleton, p. 55, pl. 5, figs. 3a–b, 4a–b.
1976. *Eiffellithus turriseiffeli* (Deflandre 1954), Burns, p. 286, pl. 3, fig. 6.
1976. *Eiffellithus turriseiffeli* (Deflandre 1954), El-Dawoody and Zidan, p. 420–423, pl. 4, figs. 1a–d, (?)2a–b, 3a–b, 4a–b, *not* figs. 5a–b.
1976. *Eiffellithus turriseiffeli* (Deflandre 1954), Hill, p. 140, pl. 6, figs. 37–38, 39–42; pl. 14, figs. 8, 9.
1976a. *Eiffellithus turriseiffeli* (Deflandre 1954), Verbeek, p. 76, pl. 1, fig. 5.
1976b. *Eiffellithus turriseiffeli* (Deflandre 1954), Verbeek, p. 132, 134, pl. 1, fig. 1.
1976. *Eiffellithus turriseiffeli* (Deflandre 1954), Wind and Wise, p. 170, fig. 2i.
1977. *Eiffellithus turriseiffeli* (Deflandre 1954), Gašpariková, p. 159, pl. 72, fig. 2.
1977. *Eiffellithus turriseiffeli* (Deflandre 1954), Manivit and others, p. 172–173, pl. 1, fig. 5.
1977. *Eiffellithus turriseiffeli* (Deflandre 1954), Pašvič, p. 37, pl. 1, figs. 12, 13.
1978. *Eiffellithus turriseiffeli* (Deflandre 1954), Shafik, p. 217, fig. 3, Wa–Wb; p. 219, fig. 4, Ta–Tb, U; p. 221, fig. 5, Ia–Ib.
1980. *Eiffellithus turriseiffeli* (Deflandre 1954), Siesser, p. 826, pl. 7, fig. 17.

Diagnosis.—Elongate elliptical rhabdoliths with a broad central area spanned by narrow X-shaped crossbars in which the acute angles of the cross are alined with the transverse axis of the coccolith. The crossbars meet in the center of the elliptical opening to form a square base for attachment of the stem.

Remarks.—The description of this species based on transmission electron micrographs by Bukry (1969, p. 52) is followed herein. Transmitted light images of *Eiffellithus turriseiffeli* are similar to *E. eximius* (Stover 1966) but differ in having X-shaped crossbars in which the acute angles are alined with the transverse axis of the elliptical central area.

Known range.—Early Aptian through Maastrichtian.

Type locality.—Senonian chalk from Burham, Kent, England.

Occurrence.—This species has a worldwide geographic distribution throughout its geological range. Within North America, *Eiffellithus turriseiffeli* has been reported from the upper part of the Niobrara Chalk of Knox County, Nebr. (Bukry, 1969); Greenhorn Limestone and Carlile Shale of Kansas, and the Eutaw Formation including the Tombigbee Sand Member and the Ripley Formation and Prairie Bluff Chalk of Alabama (Čepek and Hay, 1969); Ripley Formation and Prairie Bluff Chalk of Alabama, and the Arkadelphia Marl of Arkansas (Bramlette and Martini, 1964); Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi (Newell, 1968); upper Albian and lower Cenomanian of Texas (Hill, 1976); and from the Eagle Ford Group, Austin Group, Taylor Marl, and Corsicana Marl of central and north-central Texas (Gartner, 1968; Bukry, 1969).

Eiffellithus turriseiffeli is one of the most abundant species found in the samples of the present investigation. It occurs throughout the upper Turonian through lower Santonian parts of the Eagle Ford Group and Austin Group of Texas.

Genus GARTNERAGO Bukry 1969

Synonyms.—*Laffittius* Noël 1969.

Type species.—*Arkhangelskiella concava* Gartner 1968 = *Discolithus segmentatus* Stover 1966.

Remarks.—The description of this genus by Bukry (1969, p. 24) is followed herein. *Gartnerago* differs from *Arkhangelskiella* Vekshina 1959 in having

(1) an inner cycle of narrow elements in proximal view, (2) interelement sutures more strongly inclined, and (3) a greater number of elements in each cycle.

Gartnerago costatum (Gartner 1968) Bukry 1969

Plate 6, figures 34, 35–42;
plate 7, figures 1–9, 10–13, 14

1963. Not *Arkhangelskiella obliqua* Stradner, p. 176, pl. 1, figs. 2–2a.
1964. Not *Arkhangelskiella obliqua* Stradner 1963, Stradner, p. 138, text-fig. 43.
1968. *Arkhangelskiella costata* Gartner, p. 37–38, pl. 8, figs. 1, 2, 3; pl. 11, figs. 1a–c; pl. 28, fig. 2.
1968. *Arkhangelskiella cymbiformis* Vekshina 1959, Gartner, p. 38, pl. 4, figs. 1, 4; pl. 27, figs. 2a–b; *not* pl. 1, figs. 1–6; *not* pl. 4, figs. 2, 3; *not* pl. 6, figs. 1a–c.
1969. *Gartnerago costatum costatum* (Gartner 1968), Bukry, p. 24, pl. 4, figs. 7–9.
1970. *Arkhangelskiella cymbiformis* Vekshina 1959, Iaccarino and Follini, p. 589, (?) *not* pl. 39, figs. 7, 8; pl. 40, figs. 6, 7.
1971. (?)*Arkhangelskiella cymbiformis* Vekshina, Shafik and Stradner, p. 80, pl. 5, figs. 1–3; *not* pl. 6, figs. 1–2; *not* pl. 7, figs. 1–2.
1971a. Not *Arkhangelskiella costata* Gartner 1968, Thierstein, p. 38, pl. 4, figs. 73–75.
1972. *Gartnerago costatum* (Gartner 1968), Forchheimer, p. 27–28, pl. 4, figs. 2, 4.
1972. *Gartnerago obliquum* (Stradner 1963), Forchheimer; p. 28, pl. 4, figs. 5, 6.
1974. *Gartnerago costatum costatum* (Gartner 1968), Bukry, p. 356, figs. 5I–J.
1974. *Gartnerago obliquum* (Stradner 1963), Thierstein, p. 640, pl. 5, figs. 3, 4, 5, 6–9; pl. 6, fig. 2; pl. 7, figs. 1–5, 7–10.
1975. *Gartnerago costatum* cf. *costatum* (Gartner 1968), Krancer, p. 5, pl. 1, fig. 1.
1978. *Gartnerago obliquum* (Stradner 1963), Shafik, p. 213, fig. 2, Aa–Ab, Ba–Bc, Ca–Cb; *not* Da–Db, E, F.

Diagnosis.—Large, elliptical coccoliths with a single row of perforations adjacent to and along either side of the longitudinal and transverse sutures of the central area. In electron micrographs, each pore is bisected by a single transverse bar, either partially or completely formed, each bar being parallel to the adjacent suture axis.

Description.—The description of this species based on transmission electron micrographs by Gartner (1968, p. 37–38) is followed herein. In transmitted light micrographs, this species appears to have a narrow rim and broad central area. The longitudinal and transverse sutures are distinct. The perforations along either side of the central area sutures are clearly visible, although the bars bisecting each pore are beyond the limit of resolution of light optics. In phase contrast light, and in cross-polarized light when the long axis of the ellipse is oriented at about 45° to the plane of either nicol, the central area is divided into eight, indistinct, radially arranged, and wedge-shaped, alternately light and dark regions. Each quadrant of the central area contains one light and one dark wedge-shaped region. In distal view, the bright wedges are adjacent and dextral to the major sutures of the central area. When viewed proximally, the bright wedge-shaped regions are adjacent and sinistral to each of the axes.

Remarks.—Thierstein (1974, p. 640) and several other workers (see synonymy) have referred forms of *Gartnerago* with a single row of perforations bordering both sides of the central area axes to *Arkhangelskiella obliquum* Stradner 1963. Examination of Stradner's figures of *A. obliquum* (1963, pl. 1, figs. 2–2a) definitely shows that central area perforations are not restricted to the borders of the central area sutures. Furthermore, within the description of *A. obliquum*, Stradner (1963, p. 176) made no reference to the restricted position of central area pores. Rather, he stated, "A varying number of pores perforate the sectors of the central area." As defined, the name *Arkhangelskiella costata* Gartner 1968 is the earliest validly published (ICBN Art. 32, par. 1) and available (ICBN Art. 45, footnote to par. 6) name to which forms with a single row of perforations bordering the central area axes may be assigned.

Gartnerago costatum differs from *G. segmentatum* (Stover, 1966) in having a single row of pores along either side of the longitudinal and transverse axes of the central area. The shape, cycle arrangement, and construction of the two species are otherwise similar.

Bukry (1969, p. 24) described *Gartnerago costatum porolatum* and distinguished it from *G. costatum costatum* by the presence of elongate elliptical pores spanned by two or three crossbars. Images of *Gartnerago porolatum* were not observed by means of the scanning electron microscope during this investigation, and, hence, its corresponding transmitted light images cannot be described. Neither the orientation of the elongate pores nor the nature or number of crossbars spanning each pore can be seen under light microscopes. There can be little doubt, therefore, that the two species (or subspecies) will be indistinguishable utilizing light optics. They are, however, herein regarded as separate and distinct species.

Known range.—Late Turonian through middle Campanian.

Type locality.—Base of Taylor Marl exposed along Cottonwood Creek at Millers Ferry Road, Dallas, Dallas County, Tex.

Occurrence.—This species has been recorded from the Austin Group, Taylor Marl, and Corsicana Marl of Texas (Gartner, 1968; Bukry, 1969). During this investigation, *Gartnerago costatum* was observed only in samples from the Maribel Shale Member of the Arcadia Park Formation of the Eagle Ford Group (upper Turonian) and Ector Chalk of the Austin Group (Coniacian and lower Santonian) as exposed at the Choctaw Creek locality, Grayson County, Tex.

Gartnerago segmentatum (Stover 1966) Thierstein 1974

Plate 7, figures 15, 16–26, 27

1963. *Discolithus decoratus* Caratini, pl. 1, figs. 7, 8, 9 (invalid ICBN Art. 34, par. 12).
1963. *Discolithus ornamentus* Caratini, p. 18, pl. 1, figs. 7, 8, 9 (invalid ICBN Art. 34, par. 12).
1965. Not *Arkhangelskiella inclinata* Reinhardt, p. 31, pl. 2, fig. 5.
1966. *Discolithus segmentatus* Stover, p. 143–144, pl. 3, figs. 3a–c, 4a–b, 5, 6a–b; pl. 8, fig. 19.
1967. *Arkhangelskiella obliqua* Stradner 1963, Reinhardt, p. 174–176, figs. 9, 10, 12d–e.
1967. Not *Arkangelskiella ornamenta* (Caratini 1963), Lyul'eva, p. 96, pl. 3, fig. 33.
1968. *Arkhangelskiella concava* Gartner, p. 37, pl. 14, figs. 2, 3; pl. 16, figs. 5, 6, 7; pl. 17, figs. 7a–d; pl. 18, figs. 22, 23; pl. 19, figs. 6a–d; pl. 21, figs. 7a–c; pl. 22, figs. 13, 14, 15.
1968. *Arkhangelskiella ornamentus* (Caratini 1963), Manivit, p. 278, pl. 1, figs. 2a–b.
1969. *Gartnerago concavum* (Gartner 1968), Bukry, p. 24, pl. 4, figs. 2–6.
1969a. *Laffittius confossus* Noël, p. 198–200, pl. 2, fig. 5; pl. 3, figs. 6a–b.
1969a. *Laffittius obliquus* (Reinhardt 1967), Noël, p. 197–198, pl. 3, figs. 1–5; text-figs. 3a–b.
1970. *Gartnerago obliquus* (Reinhardt 1967), Noël, p. 79–81, pl. 26, figs. 1–7; text-figs. 19–20.
1971a. *Arkhangelskiella ornamenta* (Caratini 1963), Thierstein, p. 38, pl. 1, figs. 15–16.
1971. *Gartnerago obliquus* (Stradner 1963), Manivit, p. 106–107, pl. 2, figs. 9–10, 11–12.
1972. *Gartnerago concavum* (Gartner 1968), Forchheimer, p. 26–27, pl. 3, fig. 5.
1972. *Gartnerago obliquum* (Stradner 1963), Locker, p. 770, pl. 10, fig. 16.
1972. *Gartnerago obliquus* (Reinhardt 1967), Noël, p. 2–3, pl. 1, figs. 4a, 4b; pl. 2, figs. 2, 3.
1973. *Gartnerago obliquum* (Stradner 1963), Priewalder, p. 19, pl. 10, figs. 1, 2, 3, 4.
1973. *Gartnerago obliquum* (Stradner 1963), Roth, p. 715, 718, pl. 22, figs. 1a–c.
1974. *Gartnerago segmentatum* (Stover 1966), Thierstein, p. 640, pl. 5, figs. 1, 2; pl. 6, figs. 1, 3–6, 7–10; pl. 7, fig. 6.
1975a. *Arkhangelskiella ornamenta* (Caratini 1963), Smith, p. 44, figs. 1–13.
1976. *Gartnerago concavum* (Gartner 1968), Burns, p. 289, pl. 3, fig. 8.
1977. *Gartnerago obliquum* (Stradner 1963), Manivit and others, p. 174, pl. 1, fig. 11.
1978. *Gartnerago obliquum* (Stradner 1963), Proto Decima, Medizza, and Todesco, p. 602, pl. 14, figs. 11a–b.
1978. *Gartnerago obliquum* (Stradner 1963), Shafik, p. 213, fig. 2, Da–Db, E, F; *not* Aa–Ab, Ba–Bc, Ca–Cb.

Diagnosis.—Large, elliptical coccoliths with a broad, imperforate central plate that has sutures on both distal and proximal surfaces. The sutures are recessed between low ridges formed by the sloping faces of central area elements. The longitudinal suture is alined with the major axis of the coccolith and the transverse suture, as observed in proximal view, is rotated about 5° degrees dextrally from the minor axis of the ellipse. *Gartnerago segmentatum* is the only known imperforate species belonging to this genus.

Description.—This species is rather strongly elliptical in outline and consists distally of two cycles and proximally of three cycles of elements. In distal view, the irregularly constructed convex distal cycle consists of elements that originate at the suture line along the major axis of the ellipse. The elements terminate more or less radially along the outer peripheral margin of the distal cycle. In distal view, a part of the first or outer proximal cycle is seen along the outer peripheral margin of the coccolith. The concave proximal surface is constructed of three cycles of elements, each progressively wider than the preceding (outer) cycle. The longitudinal suture spanning the broad central plate is alined with the major axis of the ellipse. The transverse suture, in proximal view, is rotated about 5° degrees dextrally from the minor axis of the ellipse. The sutures, both proximally and distally, are recessed between low ridges formed by the sloping faces of central plate elements.

In plane transmitted and phase contrast light, this species appears to have a narrow rim and large central area. Both the longitudinal and transverse sutures are distinct. In phase contrast light, and in cross-polarized light where the long axis of the ellipse is at about 45° to the plane of either nicol, the broad central area is divided into eight, radially arranged, alternatively light and dark regions. Each quadrant contains one light and one dark region; and when viewed distally, the bright wedges are dextral to the major and minor sutures of the ellipse. The orientation of the four bright wedges is sinistral to the axes when viewed proximally.

Remarks.—Loeblich and Tappan (1970a, p. 563–564) and Thierstein (1974, p. 640) noted that the name *Discolithus ornamentus* Caratini 1963 is invalid (1CBN Art. 34, par. 12) because Caratini inadvertently use the new name *Discolithus decoratus* in the explanation of the plate figures for the new species *D. ornamentus*. I am convinced that Caratini simply made a mistake in the explanation for the plate figures and did not purposely propose two different names for the same taxon. Article 34, paragraph 12 of the ICBN leaves little choice but to invalidate both names, and therefore, the names are not available for use in taxonomy. I believe that in instances such as this, paragraph 12 of Article 34 is excessively punitive and leads to further instability and confusion in botanical nomenclature. Nevertheless, in adherence to the botanical code, the names *Discolithus ornamentus* Caratini and *D. decoratus* Caratini are regarded herein as invalid names.

As noted by Thierstein (1974, p. 640), the holotype of *Arkhangelskiella inclinata* Reinhardt, a cross-polarized light micrograph, shows neither the extinction pattern characteristic of the form discussed herein nor the pattern diagnostic for other species assignable to *Gartnerago* Bukry 1969. Therefore, *Discolithus segmentatus* Stover 1966 represents the earliest validly described species whose name is available for imperforate forms of *Gartnerago*.

Noël (1969a, p. 197–198) noted that the name *Discolithus ornamentus* Caratini 1963 (=*Gartnerago segmentatum*) has priority over the name *Arkhangelskiella obliqua* Stradner 1963 because it has a prior effective date of publication. However, because Caratini's illustrations were of light micrographs and Stradner's figures were line drawings, Noël (1969a and 1970) chose to disregard both names and to use *Arkhangelskiella obliqua* Stradner 1963 of Reinhardt 1967, since Reinhardt was the first to publish electron micrographs of the species. Noël's obvious dual system of nomenclature (one for electron images and another for light optical images) and the granting of priority to the earliest published name accompanied by electron micrographs is not supported by codes of nomenclature and is not followed herein.

Gartnerago segmentatum (Stover 1966) differs from *G. costatum* (Gartner 1968) in that it lacks perforations along the longitudinal and transverse sutures, and generally has more distinct, radial and wedge-shaped central regions in phase contrast and cross polarized light. Roth (1973, p. 718) noted that the presence or absence of perforations seemed to depend on the state of preservation. He (Roth, 1973) included both perforate and imperforate forms in *Gartnerago obliquum* (=*G. segmentatum* herein). Since both types have been found in the same samples from Texas, they are regarded herein as separate and distinct species.

Known range.—Late Turonian through Maastrichtian.

Type locality.—Campanian chalk (*Actinocamax quadratus* beds) exposed along the north side of the Seine River at Quartiers-sur-Ville in northern France.

Occurrence.—This species has been recorded under a variety of names (see synonymy) from upper Turonian through middle Campanian cores, Leg 17, Deep Sea Drilling Project, central Pacific basin (Roth, 1973); the upper Turonian of Austria (Stradner, 1963); Turonian through Santonian of France (Manivit, 1968; Stover, 1966); Santonian strata of eastern Switzerland (Thierstein, 1971a); Campanian of France (Bukry, 1969; Noël, 1969a; 1970) middle Campanian of Germany (Bukry, 1969); reworked Paleocene sedimentary rocks of northern Germany (Locker, 1972); upper Maastrichtian strata of Austria (Priewalder, 1973); and from the Austin Group of Dallas and Travis Counties, and the Taylor Marl of Dallas and Ellis Counties, Texas (Gartner, 1968; Bukry, 1969; Smith, 1975a). During this study, *Gartnerago segmentatum* was observed throughout the upper Turonian, Coniacian and lower Santonian samples from each of the localities investigated.

Genus KAMPTNERIUS Deflandre 1959

Type species.—*Kamptnerius magnificus* Deflandre 1959.

Diagnosis.—Elliptical disk consisting of a broad perforate or imperforate central area traversed by a longitudinal suture alined with the major axis of the central area. The narrow rim is constructed of three or four cycles of numerous small elements bordered by an outer peripheral, asymmetrical rim flange constructed of elongate narrow elements continuous with the distal rim cycle.

Kamptnerius magnificus Deflandre 1959

Plate 8, figures 1–7, 8, 9–11

1959. *Kamptnerius magnificus* Deflandre, p. 135, pl. 1, figs. 1–4.

1963. *Kamptnerius magnificus* Deflandre 1959, Gorka, p. 16, (?)pl. 1, figs. 7–10; text–fig. 3 (nos. 1–3).

1963. *Kamptnerius magnificus* Deflandre 1959, Stradner, p. 179, pl. 2, figs. 2–2a.

1964. (?)*Kamptnerius magnificus* Deflandre 1959, Bramlette and Martini, p. 301–302, pl. 2, figs. 1–2, 3.

1964. *Kamptnerius magnificus* Deflandre 1959, Lezaud, p. 49, pl. 1, figs. 14, 15.

1964. *Kamptnerius magnificus* Deflandre 1959, Stradner, p. 138, text–fig. 51.

1966. *Kamptnerius magnificus* Deflandre 1959, Cohen, p. 21–22, pl. 17, fig. e.
1966. *Kamptnerius magnificus* Deflandre 1959, Edwards, p. 483, figs. 21, 24.
1966a. *Kamptnerius magnificus* Deflandre 1959, Reinhardt, p. 22–23, pl. 17, figs. 1, 2; pl. 18, figs. 1, 2a–b.
1966. *Kamptnerius magnificus* Deflandre 1959, Stover, p. 144, pl. 4, figs. 28, 29, 30a–b.
1967. *Kamptnerius magnificus* Deflandre 1959, Lyul'eva, p. 92, pl. 4, fig. 50.
1967. *Kamptnerius magnificus* Deflandre 1959, Moshkovitz, p. 150, pl. 5, fig. 5.
1967. *Kamptnerius magnificus* Deflandre 1959, Vangerow and Schloemer, p. 456, table 1, fig. 15.
1968. *Kamptnerius magnificus* Deflandre 1959, Black, pl. 152, figs. 4(?), 6; *not* fig. 7.
1968. (?)*Kamptnerius magnificus* Deflandre 1959, Forchheimer, p. 38, pl. 9, figs. 8a–8b; fig. 4, no. 4.
1968. *Kamptnerius magnificus* Deflandre 1959, Gartner, p. 39–40, pl. 2, figs. 1, 2; pl. 3, figs. 7a–c; pl. 6, figs. 10a–c; (?)pl. 10, figs. 11, 13; pl. 14, figs. 11, 12; pl. 15, figs. 15a–c; pl. 16, figs. 17, 18(?), 19; pl. 17, figs. 11a–c, 12a–c; pl. 21, figs. 12a–c; *not* pl. 10, fig. 12; *not* pl. 12, figs. 9a–c.
1968. *Kamptnerius magnificus* Deflandre 1959, Manivit, p. 280, pl. 2, fig. 7.
1968. *Kamptnerius magnificus* Deflandre 1959, Perch-Nielsen, p. 41–42, pl. 6, figs. 1–3, 5; text-fig. 16.
1969. *Kamptnerius magnificus magnificus* Deflandre 1959, Bukry, p. 25, pl. 5, figs. 7–9.
1969. *Kamptnerius magnificus sculptus* Bukry, p. 25, pl. 5, figs. 10–12.
1969. *Kamptnerius magnificus* Deflandre 1959, Čepek and Hay, p. 331, text-fig. 4, no. 15.
1969b. *Kamptnerius magnificus* Deflandre 1959, Noël, p. 482, pl. 2, figs. 4–6; text-fig. 5.
1970a. *Kamptnerius magnificus* Deflandre 1959, Hoffmann, p. 859, pl. 7, fig. 2.
1970a. *Kamptnerius granatus* Hoffmann, p. 859–860, pl. 4, fig. 3; text-fig. 4.
1970b. *Kamptnerius magnificus* Deflandre 1959, Reinhardt, p. 68–69, pl. 5, fig. 5; text-figs. 64, 65.
1971. *Kamptnerius magnificus* Deflandre 1959, Manivit, p. 107–108, pl. 14, figs. 10–11, 12–13, 14; pl. 20, fig. 11.
1971. *Kamptnerius magnificus* Deflandre 1959, Shafik and Stradner, p. 83, pl. 8, figs. 1, 2; pl. 9, figs. 1, 2; pl. 10, figs. 1, 2; pl. 11, fig. 1.
1971a. *Kamptnerius magnificus* Deflandre 1959, Thierstein, p. 38, pl. 2, figs. 35–36.
1972a. *Kamptnerius magnificus* Deflandre 1959, Hoffmann, p. 59–60, pl. 12, fig. 5; pl. 16, fig. 6; pl. 17, fig. 3; text-fig. 27.
1972. *Kamptnerius magnificus* Deflandre 1959, Locker, p. 770, pl. 7, figs. 19–20.
1972. *Kamptnerius magnificus* Deflandre 1959, Noël, p. 5, pl. 1, figs. 1, 2–3, 5; pl. 2, figs. 1a–c, 4; pl. 3, figs. 2, 4, 5.
1973. *Kamptnerius magnificus* Deflandre 1959, Risatti, p. 25, pl. 2, figs. 21–22.
1973. *Kamptnerius magnificus* Deflandre 1959, Roth, p. 718, pl. 23, figs. 1a–c, 2a–c.
1974. *Kamptnerius magnificus* Deflandre 1959, Thierstein, p. 640–641, pl. 8, (?)figs. 1, 2; pl. 9, figs. 4, 6, 7, 8–11; *not* pl. 8, figs. 3, 4, 5, 6–9; pl. 9, figs. 1–3, 5.
1976. *Kamptnerius magnificus* Deflandre 1959, Shumenko, p. 38, pl. 10, figs. 1, 2.
1976. *Kamptnerius magnificus* Deflandre 1959, Wind and Wise, p. 170, fig. 2c.
1978. *Kamptnerius magnificus* Deflandre 1959, Čepek, p. 677, pl. 1, fig. 3.
1978. *Kamptnerius magnificus* Deflandre 1959, Proto Decima, Medizza, and Todesco, p. 602, pl. 14, figs. 12a–c.
1978. *Kamptnerius magnificus* Deflandre 1959, Schmidt, p. 713, pl. 5, fig. 8.
1978. *Kamptnerius magnificus* Deflandre 1959, Shafik, p. 217, fig. 3, Va–Vb; p. 219, fig. 4, Oa–Ob, Q, R; *not* Na–Nb, Pa–Pb.

Diagnosis.—Broadly elliptical forms having an imperforate central area constructed of narrow elongate elements oriented nearly perpendicular to the margin of the inner rim cycle.

Description.—This species is broadly elliptical in outline and consists of a wide central area, three narrow rim cycles, and a broad outer peripheral, asymmetrical rim flange. In proximal view, the central area is distinctly concave and contains a medial suture alined with the longitudinal axis of the ellipse. Numerous narrow, elongate, and irregularly shaped elements extend in a transverse direction from both sides of the suture and merge with the inner rim cycle. The central area along the medial suture may be completely closed or rarely may possess a slitlike opening. The three rim cycles are constructed of 60 to 80 narrow, subrectangular elements. The broad asymmetrical outer rim flange is composed of about 70 narrow, very elongate, subparallel elements sinistrally inclined in proximal view and continuous with the distal rim cycle.

Plane transmitted and phase contrast light images of *Kamptnerius magnificus* show the diagnostic features characteristic of this species: (1) broad central area with its median suture and transversely alined central elements, (2) narrow, elliptical rim cycles, and (3) broad, asymmetrical, peripheral rim flange.

Remarks.—This species shows a large degree of variation in the nature of the peripheral flange. The structure seems rather delicate, for it is occasionally broken or entirely missing. When intact, it may extend laterally for only a short distance; or its length may be equal to or even greater than that of the long axis of the elliptical disk.

Kamptnerius magnificus sculptus Bukry 1969 is included in the present form as it differs only in possessing somewhat larger elements between the inner rim cycle and longitudinal axis of the central area. The forms illustrated by Perch-Nielsen (1968, see synonymy) as *K. magnificus* likewise appear to have somewhat larger elements filling the central area. The forms figured by Bramlette and Martini (1964, see synonymy) are questionably included herein although the images are indistinct and the structure of the critical central area cannot be resolved.

Kamptnerius magnificus Deflandre 1959 differs from *K. punctatus* Stradner 1963 in having an imperforate central area constructed of elongate, narrow transverse elements. Although Gartner (1968, p. 39) and Thierstein (1974, p. 640–641) described and figured both species as *K. magnificus,* the two forms should be regarded as distinct species with important biostratigraphic significance within the Late Cretaceous. (see "Remarks" herein for *K. punctatus*).

Known range.—Coniacian through late Maastrichtian.

Type locality.—Maastrichtian chalk from near Vanves, Seine, France.

Occurrence.—This species has a well-documented worldwide geographic occurrence throughout the Late Cretaceous. Gartner (1968) figured *Kamptnerius magnificus* from the Austin Group, Taylor Marl, and Corsicana Marl of north-central Texas, as well as from the Arkadelphia Marl of Arkansas. It has also been reported (Bukry, 1969) from the lower part of the Austin Group of Dallas County, Tex.; Eutaw Formation, Mooreville Chalk and Demopolis Chalk of Mississippi (Newell, 1968); Demopolis Chalk, Ripley Formation and Prairie Bluff Chalk of Mississippi (Risatti, 1973); and from the Ripley Formation and Prairie Bluff Chalk of Dallas and Wilcox Counties, Ala. (Black, 1968; Čepek and Hay, 1969). During this study, *K. magnificus* was observed throughout the Coniacian and lower Santonian part of the Austin Group, although it was not noted in upper Turonian samples from any of the localities that were investigated.

Kamptnerius punctatus Stradner 1963

Plate 8, figures 12, 13–18, 19–20

1963. *Kamptnerius punctatus* Stradner, p. 177, pl. 2, figs. 3–3a.
1967. *Kamptnerius punctatus* Stradner 1963, Sales, p. 305, pl. 3, figs. 5, (?) 6.
1968. *Kamptnerius magnificus* Deflandre 1959, Gartner, p. 39–40, pl. 10, figs. 12, 13(?); pl. 12, figs. 9a–c; pl. 16, fig. 18(?).
1969. *Kamptnerius punctatus* Stradner 1963, Bukry, p. 26, pl. 6, figs. 4–5.
1969. *Kamptnerius punctatus* Stradner 1963, Čepek and Hay, p. 329, text-fig. 4, no. 12.
1969. *Kamptnerius magnificus* Deflandre 1959, Pienaar, p. 103–104, pl. 3, fig. 9; pl. 9, fig. 1.
1970. *Kamptnerius punctatus* Stradner 1963, Čepek and Hay, p. 336, pl. 2, fig. 1.
1970b. *Kamptnerius punctatus* Stradner 1963, Reinhardt, p. 70, text-figs. 67, 68.
1971. *Kamptnerius punctatus* Stradner 1963, Manivit, p. 108, pl. 14, figs. 8–9.
1972. *Kamptnerius punctatus* Stradner 1963, Forchheimer, p. 30–31, pl. 4, figs. 1, 3; pl. 5, figs. 5, 6.
1972a. *Kamptnerius punctatus* Stradner 1963, Hoffmann, p. 60–61, pl. 16, fig. 5.
1972. *Kamptnerius punctatus* Stradner 1963, Noël, p. 5, pl. 2, fig. 5; pl. 3, figs. 1a–c.
1973. *Kamptnerius* sp. aff. *K. punctatus* Stradner 1963, Risatti, p. 25, pl. 2, fig. 23.
1974. *Kamptnerius magnificus* Deflandre 1959, Thierstein, p. 640–641, pl. 8, figs. (?)1, (?)2, 3, 4, 5, 6–9; pl. 9, figs. 1–3, 5; *not* pl. 9, figs. 4, 6, 7, 8–11.
1978. *Kamptnerius magnificus* Deflandre 1959, Shafik, p. 219, fig. 4, Na–Nb, Pa–Pb; *not* Oa–Ob, Q, R.

Diagnosis.—Elliptical coccoliths with a broad central area constructed of irregularly shaped elements and perforated by numerous small pores, either symmetrically or randomly arranged.

Remarks.—*Kamptnerius punctatus* differs from *K. magnificus* in having a perforate central area. The central plate is distinctly concave in proximal view and possesses a medial suture alined with the long axis of the ellipse, although the suture is not as distinct in this species as in *K. magnificus.*

Thierstein (1974, p. 640–641) presented a discussion accompanied by numerous scanning electron and transmitted light photomicrographs, which tend to indicate that *Kamptnerius magnificus* Deflandre 1959 is a heavily overgrown form of perforate *Kamptnerius punctatus* Stradner 1963. Thierstein noted that *K. punctatus* could be identified only from clayey well-preserved samples and that *K. magnificus* was invariably associated with chalky samples. Thus, his conclusion was that the two "morphotypes" should be regarded as conspecific and assigned to *K. magnificus.* Thierstein's documentation for his observations is convincing, and future study may prove his conclusion to be accurate. However, during the present investigation, well-preserved *K. punctatus* were found in many samples that contained typical *K. magnificus.* Since these species invariably occur together in chalk and chalky limestone of Coniacian and early Santonian Age throughout Texas, and since *K. punctatus* has its initial appearance in strata of late Turonian Age whereas *K. magnificus* has its initial appearance in strata of early Coniacian Age, both forms are regarded herein as morphologically distinct species with important biostratigraphic significance.

This species shows considerable variation in the size, number, and arrangement of pores within the central area. Stradner's original illustration (1963, pl. 2, fig. 3), although a diagrammatic line drawing, shows numerous perforations alined in concentric, transverse, and longitudinal rows that completely fill the central area. Forms from the Coniacian and lower Santonian part of the Austin Group, although somewhat poorly preserved, possess extremely small and irregularly arranged pores, which appear to be restricted to the central area of the plate. They have not been noted in the outer peripheral area of the central plate near its contact with the narrow rim cycles. In contrast, the individual illustrated by Čepek and Hay (1970, pl. 2, fig. 1). from the Mooreville Chalk of Mississippi shows numerous distinct, closely spaced, large perforations throughout the central plate.

Within the lower part of the Austin Group, perforations in *Kamptnerius punctatus* are so small that, in the majority of individuals, they cannot be observed with transmitted light optics. Under the light microscope, *K. punctatus* has been distinguished from *Kamptnerius magnificus* largely by having a somewhat uniform central area and poorly defined median suture, and by lacking the distinct, large, transverse elements characteristic of *K. magnificus*. Although Gartner (1968, p. 39–40) included no explanation for his assigning *K. punctatus* to *K. magnificus*, the indistinct nature of the two species in transmitted light optics was probably considered in his decision to combine these species.

Known range.—Late Turonian through (?) middle Maastrichtian.

Type locality.—Upper Turonian strata near Klafterbrunn, Austria.

Occurrence.—This species has been reported from Turonian through Santonian strata of Germany (Hoffmann, 1972a; Reinhardt, 1970b); subsurface Maastrichtian sedimentary rocks of western Africa (Sales, 1967); Coniacian and Santonian strata of France (Manivit, 1971); middle part of the Mooreville Chalk through the lower part of the Demopolis Chalk of Dallas and Wilcox Counties, Ala. (Čepek and Hay, 1969); Prairie Bluff Chalk of Wilcox County, Ala. (Black, 1968); Mooreville Chalk exposed at Plymouth Bluff along the Tombigbee River, Clay County, Miss. (Čepek and Hay, 1970); and lower part of the Austin Chalk of Dallas County, Tex. (Bukry, 1969). Gartner (1968, see synonymy) figured this species as *K. magnificus* from the Taylor Marl of Dallas County, Tex.

During this investigation, this species was observed in samples from the upper Turonian through lower Santonian part of the Eagle Ford and Austin Groups exposed at the Choctaw Creek locality. Repeated examination of upper Turonian, Coniacian, and lower Santonian samples from other sites, utilizing both the scanning electron microscope and transmitted light optics, failed in establishing its presence in samples from other localities.

Genus LITHASTRINUS Stradner 1962, emended

Synonyms.—*Eprolithus* Stover 1966; *Radiolithus* Stover 1966; *Polycyclolithus* Forchheimer 1968.

Type species.—*Lithastrinus grilli* Stradner 1962.

Emended description.—Forms with a short cylindrical body, circular to subcircular in plan view, flaring at both ends, with an open or closed internal plate at or near the midpoint of the longitudinal axis. The cylindrical body is constructed of a single cycle of 6 to 20 or more longitudinally elongate, flaring elements that, in plan view, result in a stellate peripheral outline. The body elements are slightly twisted so that the pointed tip of an element at one end is offset from the tip of the same element at the opposite end of the cylinder. An internal central plate, generally obscured, consists of radial projections extending from the inner margin of each body element into the central opening of the cylinder.

Remarks.—*Eprolithus* Stover 1966 was described (Stover, 1966, p. 149) as differing from *Lithastrinus* Stradner 1962 in having a conspicuous axial opening divided transversely by a central plate, and in lacking strongly attenuated segments. *Radiolithus* Stover 1966 was distinguished (Stover, 1966, p. 149, 158) from *Lithastrinus* by having radial segments thickened at the peripheral rim, and by having a U-shaped cross-sectional outline. *Polycyclolithus* Forchheimer was distinguished from *Lithastrinus* by having "more than two rim cycles composed of nine elements, concentrically covering each other" (Forchheimer, 1968). *Eprolithus, Radiolithus,* and *Polycyclolithus* have been observed to be the result not only of slight variation but of images produced by a progressive state in preservation, and are, therefore, regarded as junior synonyms of *Lithastrinus* Stradner.

Lithastrinus floralis Stradner 1962

Plate 8, figures 21, 22; plate 9, figures 1–5, 6–10

1962. *Lithastrinus floralis* Stradner, p. 370, 372, pl. 2, figs. 6–11.

1963. *Lithastrinus floralis* Stradner 1962, Stradner, p. 179, pl. 2, figs. 8–8a.

1964. *Lithastrinus floralis* Stradner 1962, Lezaud, p. 49, pl. 1, figs. 16, 17.

1964. *Lithastrinus floralis* Stradner 1962, Stradner, p. 138, text–figs. 49, 50.

1965. *Lithastrinus floralis* Stradner 1962, Manivit, p. 194, pl. 2, figs. 5a–c.

1966. *Eprolithus floralis* (Stradner 1962), Stover, p. 149, pl. 7, figs. 4, 5, 6a–b, 7, 9; pl. 9, fig. 21.
1966. *Eprolithus* sp., Stover, p. 149, pl. 7, fig. 8.
1966. *Radiolithus planus* Stover, p. 160, pl. 7, figs. 22a–c, 24a–b; pl. 9, fig. 23.
1967. Not *Lithastrinus floralis* Stradner 1962, Sales, p. 305, pl. 3, figs. 19a–b.
1967. *Lithastrinus moratus* Stover 1966, Sales, p. 305, pl. 3, fig. 20.
1968. *Lithastrinus* cf. *floralis* Stradner 1962, Forchheimer, pl. 9, figs. 2a–b, 3a–b, 4a–b; fig. 2, nos. 20, 24, 29.
1968. *Polycyclolithus brotzenii* Forchheimer, p. 41, pl. 6, figs. 6a–c, 7a–b; fig. 3, no. 17; text-figs. 15, 16.
1968. *Lithastrinus floralis* Stradner 1962, Gartner, p. 47, pl. 21, figs. 13a–d; pl. 22, fig. 28, 29; pl. 24, figs. 12a–d.
1968. *Cylindralithus gallicus* (Stradner 1963), Gartner, p. 46–47, pl. 1, fig. 20; pl. 6, figs. 11a–c.
1969. *Lithastrinus floralis* Stradner 1962, Bukry, p. 43, pl. 21, figs. 1, 2.
1969. *Eprolithus floralis* (Stradner 1962 , Čepek and Hay, p. 326, text–fig. 2, no. 10.
1970. *Eprolithus floralis* (Stradner 1962), Iaccarino and Follini, p. 595, pl. 40, figs. 20, 21.
1970b. *Lithastrinus floralis* Stradner 1962, Reinhardt, p. 71, text–figs. 69, 70.
1971. *Lithastrinus floralis* Stradner 1962, Manivit, p. 139, pl. 15, figs. 3, 7, 8, (?)9, 10, (?)11, 15, 16.
1971. *Lithastrinus grilli* Stradner 1962, Manivit, p. 140, pl. 15, figs. 4–5, 6, (?)12.
1971a. *Lithastrinus floralis* Stradner 1962, Thierstein, p. 36, pl. 2, figs. 25–26.
1971b. *Lithastrinus floralis* Stradner 1962, Thierstein, p. 481, pl. 7, figs. 1–5.
1972. *Polycylolithus brotzenii* Forchheimer 1968, Forchheimer, p. 56, pl. 27, fig. 3.
1972. *Polycyclolithus floralis* (Stradner 1962), Forchheimer, p. 57, pl. 27, fig. 4.
1972. *Polycyclolithus orbiculatus* Forchheimer, p. 57–58, pl. 27, figs. 5, 6.
1972b. *Lithastrinus floralis* Stradner 1962, Hoffmann, p. 54–55, pl. 4, figs. 1, 2.
1972. *Lithastrinus floralis* Stradner 1962, Lauer, p. 151, pl. 33, figs. 10a–b, 11a–b.
1972. *Lithastrinus floralis* Stradner 1962, Locker, p. 781, pl. 5, figs. 15, 16.
1973. *Eprolithus floralis* (Stradner 1962), Black, p. 99–100, text–fig. 50.
1974. *Lithastrinus floralis* Stradner 1962, Proto Decima, p. 591, pl. 3, figs. 33–35; pl. 7, figs. 2, 3.
1974. *Lithastrinus floralis* Stradner 1962, Totten, p. 83, pl. 1, figs. 12, 13–14.
1975. *Lithastrinus floralis* Stradner 1962, Burns, p. 474, figs. 22, 23, 24, 25, 26.
1975. *Polycyclolithus brotzenii* Forchheimer 1968, Monechi and Radrizzani, p. 34, pl. 6, (?)fig. 2.
1976. *Lithastrinus floralis* Stradner 1962, Hill, p. 143, pl. 7, figs. 21–22, 23, 24–29, 30–32, 33–35, 36–39, 40–41; pl. 8, figs. 1–5, 6–7; pl. 14, figs. 13, 14.
1976. *Lithastrinus floralis* Stradner 1962, Martini, p. 396, pl. 1, fig. 5.
1978. *Lithastrinus floralis* Stradner 1962, Čepek, p. 676, pl. 2, figs. 7, 8, 9.
1978. *Lithastrinus floralis* Stradner 1962, Proto Decima, Medizza, and Todesco, p. 602, pl. 16, figs. 7a–c, 9a–b.
1978. *Lithastrinus grillii* Stradner 1962, Proto Decima, Medizza, and Todesco, p. 602, pl. 16, figs. 1a–c.
1980. *Lithastrinus floralis* Stradner 1962, Barrier, p. 304, pl. 4, figs. 1, 2, 3, 4, 5, 6.
1980. *Lithastrinus floralis* Stradner 1962, Siesser, p. 826, pl. 2, figs. 18, 19; pl. 6, figs. 8–9, 10–11.

Diagnosis.—Short, double-flaring cylindrical forms having a wide circular opening along its longitudinal axis. The body of the cylinder is constructed of six to nine longitudinally elongate or twisted elements that become flaring at each end of the cylinder and terminate in short, bluntly pointed rays.

Remarks.—The short cylindrical body of this species is constructed of six to nine rather broad longitudinal elements that become pointed and flaring at both ends of the cylinder. The longitudinal elements are slightly twisted so that in plan view the stellate outline produced by the flaring pointed elements at one end of the cylinder are slightly rotated from those at the opposite end. Scanning electron micrographs of well-preserved individuals (Thierstein, 1971b, pl. 7, figs. 1, 5) show a central plate of nine toothlike rays or projections, presumably one ray for each of the body elements. Each ray extends from the inner part of the cylinder wall to the center of the opening near the midpoint of the short cylinder. Thierstein's illustrations (1971b) indicate that the rays do not merge, but become sharply pointed and terminate near the central axis of the cylindrical opening.

Transmitted light and phase contrast images of *Lithastrinus floralis* in plan view show a circular stellate cylinder. As the focal plane is adjusted from one end of the cylinder to the other, the pointed flaring tips of individual elements may be observed to rotate along the outer periphery of the cylinder. In cross-polarized light, the flaring tips of the body elements cannot be observed owing to the optical axes being perpendicular, or nearly perpendicular to, the transverse plane of the nicols. The cylindrical body produces a bright circular to subcircular image spanned by two dark, narrow, plus-shaped interference-extinction lines.

Radiolithus planus Stover 1966 was described from transmitted light photomicrographs as having eight or nine radial, wedge-shaped segments variously rounded, bilobed, or pointed at their outer peripheral margin. The outer one-third to one-fourth of the elements was described as being thickened to form a low peripheral rim. This species represents no more than well-preserved *Lithastrinus floralis* in that the outer lobed or pointed rim is generally more distinct and the wedge-shaped internal toothlike rays or plates are more clearly resolved. Thus, *Radiolithus* Stover 1966 (type species=*R. planus* Stover 1966) is herein regarded as a junior subjective synonym of *Lithastrinus* Stradner 1962.

Bukry (1969, p. 43) selected a lectotype (Stradner, 1962, pl. 2, fig. 8) for *Lithastrinus floralis,* and designated the remaining illustrations (Stradner, 1962, figs. 6, 7, 9, 10, 11) paralectotypes.

Known range.—Late Aptian through Campanian.

Type locality.—Senonian sedimentary rocks collected from a large landslide near Haidberg, along the road from Hohlweg toward Falkenstein, Austria.

Occurrence.—This species has been reported from Aptian strata of Austria (Lauer, 1972); Aptian and Albian strata of France (Manivit, 1965); upper Aptian through lower Cenomanian strata of southeastern France and from core samples, Leg 1, Deep Sea Drilling Project, sites 4, 4A, and 5A, Blake Bahama Basin area, western North Atlantic (Thierstein, 1971b); upper Aptian through Cenomanian cores from the eastern Indian Ocean (Proto Decima, 1974); Aptian through Cenomanian sedimentary rocks from the subsurface of southern Sweden (Forchheimer, 1968); upper Albian through Turonian strata of Germany (Hoffmann, 1972b); Cenomanian through upper Campanian of northwest Germany (Čepek, 1970) and from northern France and the Netherlands (Stover, 1966); Turonian and Campanian part of the Ladd Formation, Orange County, Calif. (Totten, 1974); Turonian through Santonian strata from the subsurface of western Africa (Sales, 1967); lower Coniacian through upper Santonian strata of northern France (Lezaud, 1964); Santonian of eastern Switzerland (Thierstein, 1971a); Graneros Shale, Greenhorn Limestone, and lower part of the Carlile Shale of Russell County, Kans. (Čepek and Hay, 1969); upper Aptian through Maastrichtian of Texas (Hill, 1976; Barrier, 1980); and from the Eagle Ford Group and Austin Group of Dallas County, Tex. (Gartner, 1968; Bukry, 1969).

Lithastrinus floralis was observed throughout the upper Turonian, Coniacian, and lower Santonian part of the Eagle Ford Group and Austin Group during this investigation.

Lithastrinus grillii Stradner 1962

Plate 9, figures 11–16

1962. *Lithastrinus grilli* Stradner, p. 369–370, pl. 2, figs. 1–5.
1963. *Lithastrinus grilli* Stradner 1962, Stradner, p. 179, pl. 2, figs. 9–9a.
1968. *Lithastrinus grilli* Stradner 1962, Gartner, p. 47, pl. 18, figs. 1, 2; pl. 20, fig. 17; pl. 21, figs. 1a–d, 11a–c; pl. 22, fig. 26; pl. 25, figs. 10, 11.
1969. *Lithastrinus grilli* Stradner 1962, Bukry, p. 43, pl. 21, figs. 3–6.
1969. *Lithastrinus grilli* Stradner 1962, Čepek and Hay, p. 326, 331, text-fig. 2, no. 11, text-fig. 4, no. 13.
1970b. *Lithastrinus grilli* Stradner 1962, Reinhardt, p. 71–72, text-figs. 71, 72.
1971. Not *Lithastrinus grilli* Stradner 1962, Manivit, p. 140, pl. 15, figs. 4–5, 6, (?)12.
1971a. *Lithastrinus grilli* Stradner 1962, Thierstein, p. 37, pl. 4, figs. 78–79.
1972. *Lithastrinus septenarius* Forchheimer, p. 53–54, pl. 24, figs. 1, 2, 3, 4; pl. 27, fig. 2.
1972b. *Lithastrinus grilli* Stradner 1962, Hoffmann, p. 53–54, pl. 5, figs. 1, 2, 3.
1972. *Lithastrinus grilli* Stradner 1962, Roth and Thierstein, pl. 16, figs. 12–17.
1974. *Lithastrinus grilli* Stradner 1962, Totten, p. 83, pl. 1, figs. 6, 7–8.
1978. Not *Lithastrinus grillii* Stradner 1962, Proto Decima, Medizza, and Todesco, p. 602, pl. 16, figs. 1a–c.

Diagnosis.—Short, double-flaring cylindrical or disk-shaped forms having a narrow circular opening along its longitudinal axis. The body of the cylinder is constructed of six or seven longitudinally elongate elements that spread outward at each end of the cylinder and terminate in rather long, sharply pointed conical rays.

Description.—Forms consisting of a short cylindrical or disk-shaped body constructed of six or seven longitudinal elements. At each end of the cylinder, the elements are reduced to broadly flaring and rather sharply pointed conical rays. The body elements are slightly twisted so that in plan view the conical rays at one end of the short cylinder are offset from the rays at the opposite end. In plan view, the cylindrical body has a central and narrow irregular opening at each end terminating in a plate positioned at or near the midpoint of the longitudinal axis of the cylindrical body. The central plate consists of six or seven radial wedge-shaped elements that are united along their margins and merge at a common point near the center of the small cylindrical opening.

In transmitted light optics, this species appears to have a more or less circular disk-shaped body. The conical raylike terminations of body elements are clearly visible, and give a ragged, stellate peripheral outline. In cross-polarized light, the bright circular body is bisected by two narrow, plus-shaped interference-extinction lines parallel to the vibration directions of each nicol. The wedge-shaped elements of the central plate appear to be continuous with the longitudinal body elements because, as the specimen is slowly rotated in cross-polarized light, each element becomes dark when it is alined parallel to either nicol. The stellate rays at each end of the short cylinder are generally not visible in cross-polarized light.

Remarks.—Although Bukry (1969, p. 43) noted that one end of the disk always has shorter rays, this could not be confirmed from the material examined herein.

Lithastrinus grillii differs from *L. floralis* in having (1) a more ragged, stellate peripheral margin, (2) a more narrow circular opening along the longitudinal axis of the cylinder, and (3) wedge-shaped elements that are dark when oriented parallel to either nicol in cross-polarized light.

Lithastrinus septenarius was described by Forchheimer (1972, p. 53–54) as differing from *Lithastrinus grillii* in having seven rather than six rays surrounding the openings of the cylindrical body. Bukry (1969, p. 43) observed that *L. grillii* from upper Turonian through Santonian strata of Texas and Nebraska consisted of either six or seven rays. Observations during this study have confirmed that forms having either six or seven rays invariably occur together in the same samples. Thus, *L. septenarius* is herein regarded as a junior synonym of *L. grillii* Stradner.

Known range.—Early Turonian through early Campanian.

Type locality.—Klementer Schichten collected from a graben northwest of Klafterbrunn, 1 km west of Bildstock, Austria.

Occurrence.—This species has been recorded from Coniacian through (?)lower Maastrichtian cores, Leg 14, Deep Sea Drilling Project, western Atlantic basin area (Roth and Thierstein, 1972); the upper Turonian and Coniacian of Austria (Stradner, 1963); lower Santonian strata of Germany (Hoffmann, 1972b); Santonian of eastern Switzerland (Thierstein, 1971a); middle or upper Turonian part of the Ladd Formation, Orange County, Calif. (Totten, 1974); Niobrara Chalk of Knox County, Nebr. (Bukry, 1969); uppermost lower Turonian part of the Greenhorn Limestone and middle Turonian part of the Carlile Shale of Russell County, Kans., as well as the Tombigbee Sand Member of the Eutaw Formation and lower part of the Mooreville Chalk of Dallas and Wilcox Counties, Ala. (Čepek and Hay, 1969); and from the Eagle Ford Group, Austin Group and Taylor Marl of Dallas and Ellis Counties, Tex. (Gartner, 1968; Bukry, 1969).

During this study, *Lithastrinus grillii* was observed to be geographically restricted to the Eagle Ford Group and Austin Group of central and north-central Texas. This species was not observed in samples from the Langtry Member of the Boquillas Formation (upper Turonian), nor from the Atco Formation of the Austin Group (Coniacian and lower Santonian) from the Sycamore and Pinto Creek localities, Kinney County, Tex.

Genus LITHRAPHIDITES Deflandre 1963

Type species.—*Lithraphidites carniolensis* Deflandre 1963.

Diagnosis.—Elongate calcareous rods, plus-shaped in cross section, consisting of four perpendicular keels.

Lithraphidites carniolensis Deflandre 1963

Plate 9, figures 17–22, 23–26, 27, 28–32, 33–36

1963. *Lithraphidites carniolensis* Deflandre, p. 3486, figs. 1–8.
1964. *Lithraphidites carniolensis* Deflandre 1963, Lezaud, p. 49, pl. 1, fig. 12.
1965. *Lithraphidites carniolensis* Deflandre 1963, Manivit, p. 194, pl. 2, fig. 19.
1967. *Lithraphidites carnilensis* Deflandre 1963, Moshkovitz, p. 155, pl. 5, figs. 7a–b.
1967. *Lithraphidites carniolensis* Deflandre 1963, Sales, p. 305, pl. 3, figs. 33a–b.
1968. *Lithraphidites carniolensis* Deflandre 1963, Gartner, p. 43, pl. 5, fig. 4; pl. 6, figs. 8a–b; pl. 10, figs. 16, 17; pl. 12, figs. 8a–c; pl. 22, figs. 24, 25; pl. 25, fig. 9.
1969. *Lithraphidites carniolensis* Deflandre 1963, Bukry, p. 66, pl. 39, fig. 12; pl. 40, figs. 1, 2.
1969. *Lithraphidites carniolensis* Deflandre 1963, Pienaar, p. 104, pl. 9, figs. 3, 6.
1971. *Lithraphidites carniolensis* Deflandre 1963, Hoffmann and Vetter, p. 1189, pl. 10, fig. 6.
1971. *Lithraphidites carniolensis* Deflandre 1963, Manivit, p. 130, pl. 16, figs. 13, 14, 15.
1972. *Lithraphidites carniolensis* Deflandre 1963, Wilcoxon, p. 432, pl. 5, figs. 5, 6; table 1.
1973. *Lithraphidites carniolensis* Deflandre 1963, Priewalder, p. 20, pl. 12, fig. 6.
1973. *Lithraphidites carniolensis* Deflandre 1963, Risatti, p. 28, pl. 7, figs. 11–12, 13, 14; *not* pl. 7, fig. 19.
1974. *Lithraphidites carniolensis* Deflandre 1963, Müller, p. 589, pl. 17, fig. 9.
1974. *Lithraphidites carniolensis* Deflandre 1963, Proto Decima, p. 591, pl. 6, figs. 10–11.
1975. *Lithraphidites carniolensis* Deflandre 1963, Čepek, p. 101, pl. 2, figs. 5a–b.
1976. *Lithraphidites carniolensis* Deflandre 1963, Shumenko, p. 65, pl. 24, figs. 8, 9.
1978. *Lithraphidites carniolensis* Deflandre 1963, Čepek, p. 676, pl. 3, fig. 8.
1978. *Lithraphidites carniolensis* Deflandre 1963, Roth, p. 743, pl. 3, fig. 6.
1978. *Lithraphidites carniolensis* Deflandre 1963, Shafik, p. 225, fig. 7, Aa–Ab.
1979. *Lithraphidites carniolensis* Deflandre 1963, Wind and Čepek, p. 223–224, pl. 2, figs. 14–15.
1980. *Lithraphidites carniolensis* Deflandre 1963, Siesser, p. 826, pl. 1, figs. 12, 13; pl. 5, figs. 3–4, 6–7.

Diagnosis.—Elongate, narrow, rodlike forms, plus-shaped in transverse section, consisting of four keels that meet at mutually perpendicular angles. Both ends of the rod taper gradually and terminate in blunt points.

Remarks.—*Lithraphidites carniolensis* is distinguished by its elongate, narrow, rodlike form that tapers gradually to form a blunt point at both ends. Four keel-like ridges, oriented at right angles to each other, extend throughout the length of the rod. Bukry (1969, p. 66) noted that each of the four keels consists of two closely spaced bladelike elements.

Under the light microscope, each of the four ridges appears to consist of a single unit of calcite with the optical axis oriented parallel to the long axis of the rod. In cross-polarized light, the rod is dark when its long axis is oriented parallel to the vibration direction of either nicol. However, when rotated about 45°, the blades of the rod are bright.

Known range.—Late Tithonian through late Maastrichtian.

Type locality.—Upper Aptian (Gargasian) sedimentary rocks in the vicinity of Carniol (Basses-Alpes), France.

Occurrence.—This species has been reported from upper Tithonian through lower Albian cores from Leg 11, Deep Sea Drilling Project, western North Atlantic Basin (Wilcoxon, 1972); Aptian and Albian strata of France (Manivit, 1965, 1971); type lower Albian marl at Dienville, France (Bukry, 1969); lower Turonian through upper Santonian strata of the Dieppe Region of northern France (Lezaud, 1964); Turonian sedimentary rocks from near Johannisberg, Germany (Hoffmann and Vetter, 1971); lower Coniacian through lower Maastrichtian of northwestern Germany (Čepek, 1970); Campanian and Maastrichtian strata from the subsurface of western Africa (Sales, 1967); Campanian strata of France and Germany (Bukry, 1969); Maastrichtian sedimentary rocks of Israel (Moshkovitz, 1967); Maastrichtian cores from the western Indian Ocean (Müller, 1974); upper Maastrichtian strata of Austria (Priewalder, 1973); upper part of the Niobrara Chalk of Knox County, Nebr. (Bukry, 1969); Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Mississippi (Risatti, 1973); and from the Eagle Ford Group, Austin Group, Taylor Marl, and Corsicana Marl of Texas and the Arkadelphia Marl of Arkansas (Gartner, 1968; Bukry, 1969).

Lithraphidites carniolensis was observed in samples throughout the Eagle Ford Group and Austin Group at all localities that were studied during this investigation.

Genus LUCIANORHABDUS Deflandre 1959

Type species.—*Lucianorhabdus cayeuxii* Deflandre 1959.

Diagnosis.—Elongate tapering calcareous rods, straight or curved, bluntly pointed at one end and cruciform or square-shaped at the opposite end. The rod is constructed of four longitudinal bladelike elements which may have a thickened flaring rim or possess a small rudimentary basal disk at its broad end.

Lucianorhabdus cayeuxii Deflandre 1959

Plate 9, figures 37–41, 42–44

1959. *Lucianorhabdus cayeuxi* Deflandre, p. 142–143, pl. 4, figs. 11–25.
1961. *Lucianorhabdus cayeuxi* Deflandre 1959, Martini, p. 19, pl. 4, fig. 39.
1961. *Lucianorhabdus cayeuxi* Deflandre 1959, Stradner, p. 82, text–figs. 45–48, 50.
1963. *Lucianorhabdus cayeuxi* Deflandre 1959, Gorka, p. 24, pl. 2, figs. 6–9; text–fig. 2 (nos. 6–9).
1963. *Lucianorhabdus cayeuxi* Deflandre 1959, Stradner, p. 181, pl. 6, figs. 6–6a.
1964. *Lucianorhabdus cayeuxi* Deflandre 1959, Bramlette and Martini, p. 312, 314, pl. 5, figs. 10–12.
1964. *Lucianorhabdus cayeuxi* Deflandre 1959, Lezaud, p. 49, pl. 1, fig. 20.
1966. ?*Lucianorhabdus cayeuxi* Deflandre 1959, Cohen, p. 35–36, pl. 5, figs. a–c, d, e.
1966. *Lucianorhabdus cayeuxi* Deflandre 1959, Stover, p. 152, pl. 7, figs. 13, 14.
1967. *Lucianorhabdus cayeuxi* Deflandre 1959, Vangerow and Schloemer, p. 456, table 1, fig. 39.
1968. *Lucianorhabdus cayeuxi* Deflandre 1959, Gartner, p. 45, pl. 10, figs. 18–20; pl. 12, figs. 7a–c; pl. 16, figs. 3, 4; pl. 18, figs. 3, 4; pl. 20, fig. 14.
1968. *Lucianorhabdus cayeuxi* Deflandre 1959, Manivit, pl. 2, fig. 5.
1968. *Lucianorhabdus cayeuxi* Deflandre 1959, Perch-Nielsen, p. 85, pl. 30, figs. 12–15.
1969. *Lucianorhabdus cayeuxi* Deflandre 1959, Bukry, p. 66–67, pl. 40, fig. 4.
1969. *Lucianorhabdus cayeuxi* Deflandre 1959, Čepek and Hay, p. 331, text–fig. 4, no. 27.
1969. *Lucianorhabdus cayeuxi* Deflandre 1959, Pienaar, p. 105, pl. 11, fig. 9.
1970. *Lucianorhabdus cayeuxi* Deflandre 1959, Iaccarino and Follini, p. 596, pl. 40, fig. 8.
1970. *Lucianorhabdus cayeuxi* Deflandre 1959, Noël, p. 101, pl. 38, figs. 3, 6.
1970b. *Lucianorhabdus cayeuxi* Deflandre 1959, Reinhardt, p. 74, text–fig. 78.
1971. *Lucianorhabdus cayeuxii* Deflandre 1959, Manivit, p. 138–139, pl. 15, figs. 1, 2; pl. 16, figs. 5, 6.
1971a. *Lucianorhabdus cayeuxii* Deflandre 1959, Thierstein, p. 36, pl. 3, figs. 58–59.
1972. *Lucianorhabdus cayeuxi* Deflandre 1959, Grün and others, p. 171, pl. 28, figs. 7a–b, 8a–b.
1972b. *Lucianorhabdus cayeuxii* Deflandre 1959, Hoffmann, p. 56–59, pl. 7, fig. 1.

1972. *Lucianorhabdus cayeuxii* Deflandre 1959, Lauer, p. 171, pl. 28, figs. 7a–b, (?)8a–b.
1972. *Lucianorhabdus cayeuxii* Deflandre 1959, Locker, p. 783, pl. 3, figs. 10–11.
1973. *Lucianorhabdus cayeuxii* Deflandre 1959, Risatti, p. 29, pl. 10, figs. 16–17.
1975. *Lucianorhabdus cayeuxii* Deflandre 1959, Wind, p. 351, figs. 1a, 1b, 2a, 2b; pl. 1, figs. 1, 6–7; pl. 2, fig. 5; pl. 3, figs. 1a–b, 8a–d.
1976. *Lucianorhabdus cayeuxi* Deflandre 1959, Shumenko, p. 78, pl. 30, fig. 3.
1977. *Lucianorhabdus cayeuxi* Deflandre 1959, Pavšič, p. 45, pl. 9, figs. 13, 14.
1978. *Lucianorhabdus cayeuxi* Deflandre 1959, Shafik, p. 217, fig. 3, Oa–Ob, Pa–Pb.
1978. *Lucianorhabdus cayeuxi* Deflandre 1959, Wind and Wise, p. 140, fig. 1, a, b, c, d; fig. 2, a, c.
1980. *Lucianorhabdus cayeuxi* Deflandre 1959, Barrier, p. 296, pl. 1, figs. 11, 12.

Diagnosis.—Tapering, calcareous rods having an irregular outer peripheral margin, constructed of four elongate, rectangular elements. The rod is usually bluntly pointed at one end, and may have a rudimentary basal disk at the broad, irregularly square opposite end of the tapering rod.

Remarks.—The images from the scanning electron microscope did not show this species during this investigation, although Gartner (1968), Bukry (1969), Noël (1970), and Wind (1975) adequately illustrated this form by transmission electron micrographs. It consists of an elongate tapering rod, either straight, irregularly curved, or sharply bent. The rod is constructed of four longitudinal bladelike or rectangular elements. It is usually bluntly pointed at one end, and varies from somewhat cruciform to irregularly square at the broad opposite end. Gartner (1968, p. 45) noted a rudimentary basal disk, or part of a basal disk, at the broad end of the tapering rod.

Transmitted light images show the highly variable and irregular, roughened outline that seems to characterize this species. Transmitted and phase contrast light images show a dark irregular line that longitudinally bisects the tapering rod. In cross-polarized light, the rod appears bright and has a distinct dark medial line when oriented with its long axis parallel to the vibration direction of either nicol. When rotated about 30° in either direction, half the rod (longitudinally) appears dark and the opposite half bright. On further rotation of an additional 30°, the dark and bright halves of the rod are reversed. On further rotation, 90° from its initial position, the form appears bright throughout its length.

Wind (1975) noted the affinity of several species of *Lucianorhabdus* Deflandre 1959 with ovate and elliptical species of *Tetralithus* Gardet 1955. Results of his studies indicate that the basal disk first observed by Gartner (1968, p. 45) on several specimens of *Lucianorhabdus* are, in fact, tetraliths previousy described as *Tetralithus obscurus* Deflandre 1959 and *Tetralithus ovalis* Stradner 1963 (see "Remarks" for *T. obscurus* herein). Although Wind concluded that two morphotypes of *L. cayeuxii* exist, each consistently associated with a *T. obscurus* or *T. ovalis* basal disk, he nevertheless retained the generic concepts of both *Lucianorhabdus* and *Tetralithus.* I agree with Wind in regarding the various species of *Lucianorhabdus* and disattached tetralith disks as distinct morphologic entities having important biostratigraphic significance within Upper Cretaceous strata.

Within Texas, *Lucianorhabdus cayeuxii* has its initial appearance in strata of early Coniacian Age, but *Tetralithus obscurus* has not been observed in strata older than the early Santonian. Because Wind (1975) restricted his studies to strata of Santonian through Maastrichtian Age, the early phylogenetic development of *Lucianorhabdus* and *Tetralithus* remains somewhat uncertain. On the basis of differences in their initial appearances, however, *Lucianorhabdus* probably lacked an ovate basal disk in its early history (during the Coniacian).

Known range.—Coniacian through middle Maastrichtian.

Type locality.—Maastrichtian chalk exposed near Vanves, Seine, France.

Occurrence.—*Lucianorhabdus cayeuxii* has been reported from the lower Coniacian through upper Santonian of northern France (Lezaud, 1964); Santonian of eastern Switzerland (Thierstein, 1971a); type middle Santonian chalk near Sens, France (Bukry, 1969); middle Campanian Aachen Marl near Aachen, Germany (Bukry, 1969); Campanian strata of Austria (Lauer, 1972); Campanian strata of France (Stover, 1966; Manivit, 1968; Noël, 1970); Campanian of Poland (Gorka, 1963); Senonian strata of France, England, Poland, and Australia (Deflandre, 1959); lower Maastrichtian chalk from Mons Klint, Denmark (Perch-Nielsen, 1968); upper Campanian through middle Maastrichtian strata of South Limburg, Netherlands (Vangerow and Schloemer, 1967); lower Maastrichtian of Israel (Moshkovitz, 1967); lower Maastrichtian strata of Holland, Denmark, Tunisia, and Alabama (Bramlette and Martini, 1964); reworked middle Oligocene sedimentary rocks of northern Germany (Locker, 1972); Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Lowndes County, Miss. (Newell, 1968); Demopolis Chalk and Ripley Formation of

Mississippi (Risatti, 1973; Wind and Wise, 1978); Tombigbee Sand Member of the Eutaw Formation, Mooreville Chalk, Demopolis Chalk, and the lower part of the Ripley Formation of central Alabama (Čepek and Hay, 1969) Coniacian through middle Maastrichtian strata of Texas (Barrier, 1980); and from the Austin Group and Taylor Marl of Texas (Gartner, 1968; Bukry, 1969).

During the present study, this species was observed, although somewhat rarely, throughout the Coniacian and lower Santonian part of the Austin Group. *Lucianorhabdus cayeuxii* was not noted in samples from upper Turonian strata of Texas, and is used herein as one of the criteria for distinguishing upper Turonian from lower Coniacian strata of Texas.

Genus MANIVITELLA Thierstein 1971

Type species.—*Cricolithus pemmatoideus* Deflandre ex Manivit 1965.

Diagnosis.—Coccoliths possessing two closely appressed and narrow elliptical shields that form an elliptical ring with a broad ovate central opening. Distal shield consisting of a single cycle of nonimbricate to slightly imbricate elements, the proximal shield consisting of an outer cycle of imbricate elements and a narrow cycle lining the central opening.

Remarks.—*Apertapetra* Hay, Mohler, and Wade 1966, was described as differing from *Reticulofenestra* Hay, Mohler, and Wade 1966, in that the narrow cycle lining the elliptical opening was visible both proximally and distally in *Apertapetra,* and exposed distally but not proximally in *Reticulofenestra.* According to Roth (1970, p. 852), the holotype of *Apertapetra* (*A. samodurovi* Hay, Mohler, and Wade, 1966, pl. 6, fig. 6) properly belongs in *Reticulofenestra* (but not a junior subjective synonym of *R. umbilica* as stated by Thierstein, 1971b, p. 480). Since *Apertapetra* is evidently an invalid name, the name *Manivitella* is used herein.

Manivitella pemmatoidea (Manivit 1965) Thierstein 1971

Plate 10, figures 1–6, 7–12

1964. *Cricolithus pemmatoideus* Deflandre in Bignot and Lezaud, p. 146 (naked name).
1964. *Cricolithus pemmatoideus* Deflandre in Bignot and Lezaud, 1964, Lezaud, p. 49, pl. 1, fig. 9 (naked name).
1965. *Cricolithus pemmatoideus* Deflandre in Manivit, p. 192, pl. 2, figs. 8a–b.
1966. *Cyclolithus gronosus* Stover, p. 140–141, pl. 1, figs. 1a–b, 2, 3; pl. 8, fig. 1.
1967. *Cricolithus pemmatoideus* Deflandre 1965, Sales, p. 305, pl. 3, figs. 7a–b.
1968. *Cricolithus* cf. *pemmatoidens* Deflandre in Manivit 1965, Forchheimer (error for *pemmatoideus*), p. 46–47, pl. 4, figs. 1a–b, 6a–b, 7a–b; fig. 2, no. 7.
1968. *Cyclolithus gronosus* Stover 1966, Gartner, p. 19, pl. 22, fig. 22.
1968. *Cricolithus pemmatoideus* Deflandre 1965, Manivit, p. 279, pl. 2, figs. 12a–b.
1969. *Apertapetra gronosa* (Stover 1966), Bukry, p. 26, pl. 6, figs. 6–9.
1969. *Apertapetra gronosa* (Stover 1966), Bukry and Bramlette, p. 375, pl. 1, fig. A.
1969. *Coccolithus* sp., Pant, p. 124, pl. 26, figs. 1, 5.
1970. Not *Cricolithus pemmatoideus* Deflandre 1965, Iaccarino and Follini, p. 598, pl. 40, fig. 33.
1971. *Cricolithus*? *pemmatoideus* Deflandre 1965, Manivit, p. 120–121, pl. 9, figs. 8–9; pl. 10, figs. 1, 2, 3, 4–5.
1971a. *Cricolithus pemmatoideus* Deflandre ex Manivit 1965, Thierstein, p. 40, pl. 3, figs. 41–42.
1971b. *Manivitella pemmatoidea* (Deflandre ex Manivit 1965), Thierstein, p. 480, pl. 5, figs. 1–3.
1972. *Apertapetra pemmatoides* (Deflandre in Manivit 1965), Grün and others, p. 153, pl. 23, figs. 9a–b, 10b.
1972. *Cricolithus*? *pemmatoideus* Deflandre 1965, Iaccarino and Rio, p. 658, pl. 71, figs. 10a–b.
1972. *Apertapetra pemmatoides* (Deflandre in Manivit 1965), Lauer, p. 153, pl. 23, figs. 9a–b, 10a–b.
1972. *Manivitella pemmatoides* (Deflandre ex Manivit 1965), Roth and Thierstein, pl. 11, figs. 6–13.
1972. Not *Apertapetra gronosa* (Stover 1966), Wilcoxon, p. 431, pl. 7, fig. 8.
1973. *Manivitella gronosa* (Stover 1966), Black, p. 79, pl. 23, figs. 4, 5.
1973. *Manivitella pemmatoidea* (Deflandre ex Manivit 1965), Black, p. 80, pl. 23, figs. 1, 2, 3.
1973. *Watznaueria gronosa* (Stover 1966), Risatti, p. 26, pl. 3, figs. 15–16.
1974. *Manivitella pemmatoidea* (Deflandre in Manivit 1965), Báldiné Beke, p. 450, pl. 3, figs. 11, 12.
1974. *Manivitella pemmatoides* (Deflandre ex Manivit 1965), Proto Decima, p. 591, pl. 5, figs. 5–7.
1975a. *Manivitella pemmatoidea* (Manivit 1965), Smith, p. 44, pl. 1, figs. 14–22.
1975. Not *Tubodiscus verenae* Thierstein 1973, Grün and Allemann, p. 197–198, pl. 10, figs. 1–12, text-figs. 32a–d.
1976. *Manivitella pemmatoidea* (Deflandre 1965), Hill, p. 144, pl. 8, figs. 15–17; pl. 14, figs. 18, 19.
1978. *Manivitella pemmatoidea* (Deflandre 1965), Proto Decima, Medizza, and Todesco, p. 602, pl. 14, figs. 7a–b.
1978. *Manivitella pemmatoidea* (Manivit 1965), Shafik, p. 223, fig. 6, Ea–Eb.
1980. *Manivitella pemmatoidea* (Deflandre 1965), Siesser, p. 826, pl. 3, figs. 13, 14; pl. 7, figs. 3–4.

Diagnosis.—Large, broadly ovate coccoliths consisting of a two-cycle rim tier and a large, open, elliptical central area lined with a narrow cycle of imbricate elements.

Description.—This species consists of two closely appressed and broadly elliptical rim cycles having a narrow cycle lining the broad oval central opening. The large distal cycle is constructed of 40 to 45 narrow elements with little or no imbrication. In distal view, the distal cycle elements are counterclockwise inclined near the inner margin and become clockwise inclined halfway to the outer peripheral margin of the shield. Generally, a small part of the cycle lining the oval opening is visible in distal view. In proximal view, the elements of the proximal cycle are dextrally imbricate and strongly inclined clockwise. A second narrow cycle lines the inner margin of the elliptical opening.

In plane transmitted light, the broadly ovate rim cycles appear distinctly grooved or segmented. Phase contrast images consist of a dark outer ring, distinctly scalloped or serrate along its inner margin where it is in contact with a bright inner ring. In cross-polarized light, the interference extinction lines are sinistrally curved in distal view and dextrally curved in proximal view.

Known range.—Berriasian through Maastrichtian.

Type locality.—Upper Campanian chalk in the vicinity of Vanves, France.

Occurrence.—This species has been recorded from the Berriasian through Albian of southeastern France, and Valanginian through Albian cores from Leg 1, Deep See Drilling Project, sites 4, 4A, and 5A, Blake Bahama Basin area (Thierstein, 1971b); Barremian through Albian, and Campanian strata of Austria (Lauer, 1972); Neocomian through Cenomanian strata of France (Manivit, 1971); upper Aptian through Cenomanian sedimentary rocks from the subsurface of southern Sweden (Forchheimer, 1968); type lower Albian from near Dienville, France, and upper Albian cores from Leg 1, Deep Sea Drilling Project, site 5A, Blake Bahama Basin area (Bukry, 1969; Bukry and Bramlette, 1969); upper Aptian through (?)lower Maastrichtian cores from Leg 14, Deep Sea Drilling Project, eastern and western Atlantic Basin (Roth and Thierstein, 1972); middle and upper Albian sedimentary rocks of England (Black, 1973); Albian through lower Maastrichtian sedimentary rocks from the surface of western Africa (Sales, 1967); lower Turonian and Campanian of France (Manivit, 1968); lower Turonian through upper Santonian strata of the Dieppe Region, northern France (Lezaud, 1964); upper Turonian part of the South Bosque Formation of Texas (Smith, 1975a); Campanian of France (Stover, 1966; Bukry, 1969); Santonian of eastern Switzerland (Thierstein, 1971a); and from the Eagle Ford Group, Austin Group, and Taylor Marl of Ellis and Dallas Counties, Tex. (Gartner, 1968; Bukry, 1969). Newell (1968) described this species as *Cyclolithella gronosa* from the Eutaw Formation, Mooreville Chalk, and Demopolis Chalk, but Risatti (1973) recorded it as *Watznaueria gronosa* from the Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Mississippi.

During this study, *Manivitella pemmatoidea* was observed throughout the upper Turonian, Coniacian, and lower Santonian part of the Eagle Ford Group and Austin Group of Texas.

Genus MARKALIUS Bramlette and Martini 1964

Type species.—*Coccosphaera leptoporus* Murray and Blackmann 1898 var. *inversus* Deflandre 1954.

Remarks.—Bramlette and Martini (1964, p. 302) originally defined *Markalius* as being constructed of two closely appressed circular plates connected by a large central "tube" described as "usually filled with radially oriented calcite." Perch-Nielsen (1968, p. 71) noted that their conclusions were drawn largely from light microscopic observations. She (Perch-Nielsen, 1968, p. 72–73) studied numerous individuals of *Markalius inversus*, the type species, and, using both transmitted light and the transmission electron microscope, she found no central connecting tube uniting the two plates. Her emended definition (Perch-Nielsen, 1968, p. 71–72), followed herein, includes forms with two closely appressed circular plates lacking a central connecting tube.

Markalius circumradiatus (Stover 1966) Perch-Nielsen 1968

Plate 10, figures 13, 14–17, 18–20, 21–22

1966. *Coccolithites circumradiatus* Stover, p. 138, pl. 5, figs. 2, 3a–c, 4a–b; pl. 9, fig. 10.
1967. *Coccolithus circumradiatus* (Stover 1966), Lyul'eva, p. 92, pl. 3, fig. 31.
1967. *Lithastrinus floralis* Stradner 1962, Sales, p. 305, pl. 3, figs. 19a–b.
1968. *Coccolithites* cf. *circumradiatus* Stover 1966, Forchheimer, p. 32, pl. 7, figs. 6a–6c; fig. 2, no. 19.
1968. *Markalius circumradiatus* (Stover 1966), Perch-Nielsen, p. 73–75, pl. 25, figs. 2–7; pl. 26, figs. 1–7; text-figs. 36, 37.
1968. *Maslovella africana* Pienaar, p. 365–366, pl. 69, fig. 8; pl. 70, fig. 6; pl. 71, fig. 3; *not* pl. 71, fig. 5.
1969. *Cyclagelosphaera*? *chronolitha* Bukry, p. 29, pl. 9, figs. 2, 3, 4.
1970. Not *Coccolithites* cf. *circumradiatus* Stover 1966, Iaccarino and Follini, p. 590–591, pl. 40, fig. 17.
1970. *Markalius circumradiatus* (Stover 1966), Noël, p. 93–94, pl. 36, figs. 1–7.
1971. *Markalius circumradiatus* (Stover 1966), Manivit, p. 116–117, pl. 26, figs. 1, 2–3, 4–5.
1971a. *Markalius circumradiatus* (Stover 1966), Thierstein, p. 39, pl. 1, figs. 1–2.
1971b. *Markalius circumradiatus* (Stover 1966), Thierstein, p. 479, pl. 4, figs. 1, 2–4, 5.
1972. *Markalius circumradiatus* (Stover 1966), Bystricka, p. 159–162, pl. 6, fig. 1.
1972. *Markalius circumradiatus* (Stover 1966), Forchheimer, p. 37, pl. 13, figs. 3, 5.

1972. *Markalius circumradiatus* (Stover 1966), Grün and others, p. 154, pl. 25, figs. 5a–b, 6a–b.
1972. *Markalius circumradiatus* (Stover 1966), Lauer, p. 154, pl. 25, figs. 5a–b, 6a–b.
1972. *Cyclococcolithus circumradiatus* (Stover 1966), Locker, p. 758, pl. 7, figs. 5, 6.
1973. *Markalius circumradiatus* (Stover 1966), Hekel, p. 227, pl. 1, figs. 7–8.
1973. *Markalius circumradiatus* (Stover 1966), Priewalder, p. 20, pl. 14, figs. 1, 2.
1973. *Markalius circumradiatus* (Stover 1966), Roth, p. 724, pl. 27, figs. 5a–b.
1974. *Markalius circumradiatus* (Stover 1966), Báldiné Beke, p. 450, (?)pl. 2, figs. 14, 15a–b, 16.
1974. *Markalius circumradiatus* (Stover 1966), Proto Decima, p. 591, pl. 6, figs. 7–9; *not* pl. 6, fig. 13.
1976. *Markalius circumradiatus* (Stover 1966), Hill, p. 145, pl. 8, figs. 20–23, 24–25, 26–27.

Diagnosis.—Large circular placoliths having a distal shield constructed of 35 to 50 or more narrow, elongate elements that are dextrally imbricate and slightly counterclockwise inclined in distal view.

Remarks.—*Markalius circumradiatus* may be confused with *M. inversus* (Deflandre, 1954). In electron micrographs, the first or outer cycle of elements of *M. circumradiatus* are counterclockwise inclined in distal view, whereas the same outer cycle of elements in *M. inversus* are inclined in a clockwise direction. In plane transmitted and phase contrast light, *M. circumradiatus* differs in having a more distinctly serrate peripheral margin and much more weakly birefringent central area. In cross-polarized light, *M. circumradiatus* has a distinct, plus-shaped interference figure extending across both shields, whereas the interference figure of *M. inversus* is restricted to the smaller proximal cycle.

Known range.—Early Valanginian through Maastrichtian.

Type locality.—Albian shale from a subsurface core sample at 1,970 feet in the Esso Delft Well No. 2, The Netherlands.

Occurrence.—This species has been reported from the lower Valanginian through upper Albian strata of southeastern France, and from cores recovered during Leg 1, Deep Sea Drilling Project, Blake Bahama Basin area in the western North Atlantic (Thierstein, 1971b); Valanginian and lower Hauterivian cores recovered during Leg 20, Deep Sea Drilling Project, in the northern part of the Philippine Sea (Hekel, 1973); Hauterivian through middle Campanian cores, Leg 14, Deep Sea Drilling Project, central Pacific basin (Roth, 1973); Barremian and Aptian strata of Austria (Lauer, 1972); late Aptian through Cenomanian subsurface sedimentary rocks from southern Sweden (Forchheimer, 1968, 1972); Albian through Turonian of France (Manivit, 1971); Albian through Turonian of Holland and France (Stover, 1966); Turonian strata of the Dnieper-Don Basin, Russia (Lyul'eva, 1967); Albian through Santonian strata from the subsurface of western Africa (Sales, 1967); Santonian of eastern Switzerland (Thierstein, 1971a); Campanian of France (Noël, 1970); lower Maastrichtian of Denmark (Perch-Nielsen, 1968); lower Maastrichtian of Austria (Priewalder, 1973); and from reworked middle Oligocene sedimentary rocks of Germany (Locker, 1968). Bukry (1969a) reported this species as *Cyclagelosphaera? chronolitha* from the Coniacian and lower Santonian part of the Austin Group of Dallas County, Tex.

Markalius circumradiatus is present, although somewhat rare, from the upper Turonian through lower Santonian samples that were studied. It was not observed in samples from the Maribel Shale Member of the Arcadia Park Formation of the Eagle Ford Group (upper Turonian) of Grayson County, nor was it noted in samples from the Austin Group (Coniacian) exposed along Sycamore Creek, Kinney County, Tex.

Genus MARTHASTERITES Deflandre 1959

Type species.—*Discoaster? furcatus* Deflandre 1954.

Diagnosis.—Calcareous asteroliths consisting of three bifurcating arms radiating from a common undifferentiated central area. These forms are apparently composed of a single calcite crystal whose *c*-crystallographic axis is oriented perpendicular to the plane of symmetry. The three arms are generally of equal length, and all lie in the same plane. Angles between adjacent arms are about 120°. The arms may terminate in bluntly rounded points or, more commonly, may terminate in bifurcating finger-like extensions.

Remarks.—Within the description of *Marthasterites*, Deflandre (1959, p. 138) noted the presence of two furcating lobes at the terminal ends of each arm. The left (sinistral) lobe lay above the plane of the radiating arms, and the right (dextral) lobe was directed below the plane of symmetry. Deflandre (1959) regarded this unique placement of the furcating lobes as the most important and diagnostic characteristic of the genus *Marthasterites*. Although this unusual orientation of lobes is readily observed in *Marthasterites furcatus*, it cannot be observed in the triangular form *M. inconspicuus* Deflandre 1959, or in other forms such as *M. crassus* Deflandre 1959 or *M. simplex* Bukry 1969. In these species, the arm terminates in rounded points, rather than in branching lobes.

Marthasterites is similar to the abundant and varied Tertiary species assigned to *Discoaster* Tan 1927, in that the *c*-crystallographic axes are parallel to the axes of symmetry (perpendicular to the plane of symmetry). In slides prepared for light microscopic investigation, members of both genera normally lie flat against the coverglass and, consequently, remain dark in cross-polarized light. In *Marthasterites,* however, the entire frame is constructed of a single unit of calcite, whereas in *Discoaster* each arm or ray is crystallographically distinct and is often attached to, or originates from, a differentiated central structure.

Marthasterites sp. aff. M. furcatus crassus Deflandre 1959

Plate 10, figures 23–25; plate 11, figures 1–3

1959. *Marthasterites furcatus crassus* Deflandre, p. 139, pl. 2, fig. 17; pl. 3, figs. 3, 4.
1968. *Marthasterites furcatus crassus* Deflandre 1959, Gartner, p. 42, pl. 21, fig. 16.
1969a. *Marthasterites furcatus crassus* Deflandre 1959, Bukry, p. 65–66, pl. 39, fig. 5.
1971a. *Marthasterites furcatus* (Deflandre 1954), Thierstein, p. 40, pl. 3, fig. 51.

Remarks.—The forms figured herein differ from typical *Marthasterites furcatus crassus* in having somewhat longer and more narrow arms and a more narrow central body.

Roth (1973, p. 728) noted that most of the specimens assigned to *Marthasterites* from the central Pacific were strongly overgrown and resembled *M. furcatus crassus*. He, thus, considered *M. furcatus crassus* as an overgrowth stage of the typical form *M. furcatus*.

Known range.—Coniacian through middle Campanian.

Type locality.—Senonian chalk exposed near Saint-Denis-de-Moronval, France.

Occurrence.—*Marthasterites furcatus crassus* has been reported from Santonian strata of eastern Switzerland (Thierstein, 1971a); Tombigbee Sand Member of the Eutaw Formation and the lower half of the Mooreville Chalk of Mississippi (Newell, 1968); Bonham Marl near Detroit, Red River County, Tex. (Deflandre, 1959); and from the Austin Chalk and Taylor Marl of Dallas County, Tex. (Gartner, 1968; Bukry, 1969).

This form was observed from the Coniacian and lower Santonian part of the Austin Group of Kinney, Dallas, and Grayson Counties, Tex. It was not observed in strata exposed along Sycamore Creek, Kinney County, nor at the Oak Haven Waterfall locality, Travis County, Tex.

Marthasterites furcatus (Deflandre 1954) Deflandre 1959

Plate 11, figures 4–6, 7, 8–10, 11, 12–14, 15

1954. *Discoaster? furcatus* Deflandre in Deflandre and Fert, p. 168, pl. 13, fig. 14.
1959. *Marthasterites furcatus* (Deflandre 1954), Deflandre, p. 139, pl. 2, figs. 3–12; pl. 3, figs. 1, 5.
1961. *Marthasterites furcatus* (Deflandre 1954), Martini, p. 15, pl. 3, fig. 31.
1961. *Marthasterites furcatus* (Deflandre 1954), Stradner, p. 83, text–figs. 62–63.
1964. *Marthasterites furcatus* (Deflandre 1954), Stradner, p. 138, text–fig. 46.
1966. *Marthasterites furcatus* (Deflandre 1954), Pant, p. 41, pl. 1, fig. 4.
1967. *Marthasterites furcatus* (Deflandre 1954), Sales, p. 305, pl. 3, fig. 22.
1968. *Marthasterites furcatus* (Deflandre 1954), Gartner, p. 42, pl. 18, figs. 5, (?)6; pl. 20, fig. 18; pl. 21, fig. 3; pl. 23, fig. 2.
1968. *Marthasterites furcatus* (Deflandre 1954), Manivit, pl. 1, fig. 10.
1969. *Marthasterites furcatus furcatus* Deflandre 1959, Bukry, p. 65, pl. 39, figs. 2, 3, 4.
1969. *Marthasterites furcatus* (Deflandre 1954), Čepek and Hay, p. 327, text–fig. 4, no. 18.
1970. *Marthasterites furcatus* (Deflandre 1954), Čepek, p. 245–246, pl. 23, figs. 11, 12a–b.
1970. *Marthasterites furcatus* (Deflandre 1954), Čepek and Hay, p. 335–336, pl. 20, fig. 5.
1970b. *Marthasterites furcatus* (Deflandre 1954), Reinhardt, p. 77, text–fig. 84.
1971. *Marthasterites furcatus* (Deflandre 1954), Manivit, p. 140–141, pl. 16, figs. 7, 8.
1976. *Marthasterites furcatus* (Deflandre 1954), Shumenko, pl. 28, fig. 3.
1976b. *Marthasterites furcatus* (Deflandre 1954), Verbeek, p. 133, 136–137, pl. 1, fig. 7.
1977. *Marthasterites furcatus* (Deflandre 1954), Perch-Nielsen, p. 726, 738, pl. 48, figs. 14, 15.
1978. *Marthasterites furcatus* (Deflandre 1954), Čepek, p. 677, pl. 1, fig. 8.
1978. *Marthasterites furcatus* (Deflandre 1954), Shafik, p. 217, fig. 3, U; p. 219, fig. 4, G.
1980. *Marthasterites furcatus* (Deflandre 1954), Barrier, p. 304–305, pl. 1, figs. 6, 7, 8, 9; pl. 3, figs. 5, 6.

Diagnosis.—Triradiate forms having rather narrow arms that terminate in bifurcating finger-like extensions. The sinistral lobe or extension of each arm is directed above the plane of the radiating arms, and the dextral lobe is extended below the plane of symmetry.

Remarks.—Electron micrographs reveal little structural detail that cannot be observed by using the transmitted light microscope. This species is characterized by having rather narrow arms (in proportion to their length) that terminate in narrow, finger-like bifurcations. Each arm may possess only two of these extensions, or, more commonly, each of the bifurcating extensions may be branched into smaller terminations.

This species is variable in width and length, and in the nature of the terminal extensions of each arm. Deflandre (1959, p. 138) noted that of the two major bifurcations at the end of each arm, the sinistral extension invariably extended above the plane of the arms, but the dextral extension was below this plane. This peculiar feature is readily observed in forms assigned to this species and has been noted on all individuals of *Marthasterites furcatus* examined in either electron or light optics.

Known range.—Late Turonian through Campanian.

Type locality.—Campanian strata near Salies-de-Bearn, (Basses Pyrenees), France.

Occurrence.—This species has been recorded from Turonian through Santonian strata from the subsurface of western Africa (Sales, 1967); Coniacian through Campanian strata of France (Manivit, 1968, 1971); upper Coniacian and Companian of northwestern Germany (Čepek, 1970); Campanian strata of southern France (Deflandre, 1954, 1959); Danian (reworked?) strata of Germany (Stradner, 1961); upper part of the Niobrara Chalk of Nebraska (Bukry, 1969); Tombigbee Sand Member of the Eutaw Formation of Clay County, Miss. (Čepek and Hay, 1970); Tombigbee Sand Member of the Eutaw Formation and the lower half of the Mooreville Chalk of Lowndes County, Miss. (Newell, 1968); Mooreville Chalk of Dallas and Wilcox Counties, Ala. (Čepek and Hay, 1969); Bonham Marl near Detroit, Red River County, Tex. (Deflandre, 1959); and from the Austin Group and Taylor Marl of Dallas and Ellis Counties, Tex. (Gartner, 1968; Bukry, 1969). During this investigation, *M. furcatus* was observed throughout the upper Turonian through lower Santonian strata of Texas.

Marthasterites simplex Bukry 1969

Plate 11, figures 16–18, 19–21

1969. *Marthasterites furcatus simplex* Bukry, p. 66, pl. 39, figs. 6, 7.

Diagnosis.—Simple triradiate nannofossils in which each arm terminates in a concave depression.

Remarks.—The forms figured herein agree well with the description and illustrations of *Marthasterites furcatus simplex* Bukry. It is distinguished by the slight flaring and convex, cup-like terminations of each of the three rays.

Known range.—Late Turonian through Santonian.

Type locality.—Upper part of the Niobrara Chalk from its type locality in Knox County, Nebr.

Occurrence.—Bukry (1969, p. 66) noted this species in only a single sample representing the lower part of the Austin Group, about 37 feet above its contact with the underlying Eagle Ford Group, Dallas County, Tex. During this study *Marthasterites simplex* was observed, although rarely, in samples from the upper Turonian through lower Santonian part of the Eagle Ford Group and Austin Group of Texas.

Marthasterites sp.

Plate 11, figures 22–24

1963. *Marthasterites inconspicuus* Deflandre 1959, Stradner, p. 178, pl. 2, fig. 12; *not* pl. 2, figs. 12a, 12b.

1964. *Marthasterites inconspicuus* Deflandre 1959, Bramlette and Martini, p. 314, pl. 6, fig. 6.

1967. *Marthasterites inconspicuus* Deflandre 1959, Sales, p. 305, pl. 3, fig. 21.

1968. *Marthasterites inconspicuus* Deflandre 1959, Gartner, p. 42, pl. 2, fig. 9; pl. 10, fig. 10.

Remarks.—Forms similar to that figured herein have been previously referred to *Marthasterites inconspicuus* Deflandre 1959 (see synonymy), although they differ in being distinctly branched and triradiate, rather than triangular, as defined by Deflandre. Gartner (1968, p. 42) noted that Stradner (1963) and Bramlette and Martini (1964) placed these forms in *M. inconspicuus* on the basis of the occurrence of both forms in the same sample material.

A review of the literature indicates that *M. inconspicuus* s. str. is restricted to Campanian and Maastrichtian strata. As typical *M. inconspicuus* was not noted by Gartner (1968) or Bukry (1969) from Turonian through Santonian strata of Texas, nor was it observed herein, these triradiate forms will be restricted to a separate, as yet undescribed, species.

Known range.—Late Turonian through middle Maastrichtian.

Occurrence.—This form has been figured from Turonian through Santonian sedimentary rocks from the subsurface of western Africa (Sales, 1967); the Prairie Bluff Chalk of Wilcox County, Ala. (Bramlette and Martini, 1964); and from the Arkadelphia Marl of Clarke County, Ark., and the Taylor Marl of Kaufman County, Tex. (Gartner, 1968). It was observed, although rarely, in samples from the upper Turonian through lower Santonian strata of Texas. It was not noted in Austin Group samples from the Arcadia Park or Choctaw Creek localities.

Genus MICRORHABDULUS Deflandre 1959

Type species.—*Microrhabdulus decoratus* Deflandre 1959.

Diagnosis.—Straight or somewhat curved calcareous rods either pointed or bluntly terminated at each end, circular in transverse section, and constructed of alined or complexly oriented calcite prisms.

Microrhabdulus belgicus Hay and Towe 1963

Plate 11, figures 25–31; plate 12, figures 1–9

1963. *Microrhabdulus belgicus* Hay and Towe, p. 95, pl. 1.
1963. *Microrhabdulus margaritatus* Deflandre, p. 3486, figs. 12–18.
1963. *Microrhabdulus nodosus* Stradner, p. 177, pl. 4, fig. 13.
1965. *Microhabdulus belgicus* Hay and Towe 1963, Black, p. 135, fig. 16.
1966a. *Microrhabdulus belgicus* Hay and Towe 1963, Reinhardt, p. 42, pl. 16, fig. 3.
1968. *Microrhabdulus belgicus* Hay and Towe 1963, Gartner, p. 44, pl. 6, figs. 13a–c; pl. 10, figs. 21, 22, 23; pl. 12, figs. 13a–c; pl. 22, fig. 27.
1969. *Microrhabdulus belgicus* Hay and Towe 1963, Bukry, p. 66, pl. 39, figs. 9, 10, 11.
1969. *Microrhabdulus belgicus* Hay and Towe 1963, Čepek and Hay, p. 326, text-fig. 2, no. 15.
1969. *Microrhabdulus belgicus* Hay and Towe 1963, Pienaar, p. 107–108, pl. 2, fig. 10.
1970. *Microrhabdulus belgicus* Hay and Towe 1963, Čepek, p. 246, pl. 25, figs. 11, 12a–c.
1970. *Microrhabdulus belgicus* Hay and Towe 1963, Noël, p. 97–98, pl. 38, figs. 8–10.
1971. *Microrhabdulus belgicus* Hay and Towe 1963, Shafik and Stradner, p. 84, text-fig. 3.
1972. *Microrhabdulus belgicus* Hay and Towe 1963, Roth and Thierstein, pl. 3, figs. 10, 11, 15, 16.
1973. *Microrhabdulus belgicus* Hay and Towe 1963, Risatti, p. 28, pl. 3, fig. 25.
1974. *Microrhabdulus belgicus* Hay and Towe 1963, Müller, p. 589, pl. 17, fig. 8.
1976. *Microrhabdulus stradneri* Bramlette and Martini 1964, El-Dawoody and Zidan, p. 425–426, pl. 7, figs. 4a–b.

Diagnosis.—Elongate, cylindrical, doubly tapering calcareous rods that terminate in blunt points at each end. Numerous cycles or rings of small subrhombohedral nodes are evenly spaced along the longitudinal axis of the rod.

Known range.—Turonian through middle Maastrichtian.

Type locality.—Lower Campanian chalk at Fox-les-Caves, Belgium.

Occurrence.—This species has been reported from Coniacian through Santonian cores from Leg 14, Deep Sea Drilling Projects, site 144 in the western North Atlantic Basin (Roth and Thierstein, 1972); Upper Cretaceous chalk of England (Black, 1965); Turonian strata of Austria (Stradner, 1963); Coniacian through Campanian of northwestern Germany (Čepek, 1970); Senonian strata near Gingen, Austria (Deflandre, 1963); type middle Santonian and middle(?) Campanian strata of France (Bukry, 1969); Campanian deposits of Fox-les-Caves in Belgium (Hay and Towe, 1963; Campanian and Maastrichtian of France (Noël, 1970); lower Maastrichtian of Germany (Reinhardt, 1966a); Maastrichtian cores from the western Indian Ocean (Müller, 1974); and Maastrichtian strata of Egypt (Shafik and Stradner, 1971). Bukry (1969) reported this species from the Niobrara Chalk of Knox County, Nebr., and Risatti (1973) reported it from the Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Miss. Bukry (1969) and Gartner (1968) reported this species from the Austin Group and Taylor Marl of Texas, and the Arkadelphia Marl of Arkansas.

During this study, *Microrhabdulus belgicus* was rare in occurrence in samples from upper Turonian, Coniacian, and lower Santonian strata. It was not noted in samples from the Sycamore Creek or Oak Haven Waterfall sites.

Microrhabdulus decoratus Deflandre 1959

Plate 12, figures 10–18, 19–21

1959. *Microrhabdulus decoratus* Deflandre, p. 140–141, pl. 4, figs. 1–5.
1961. *Microrhabdulus decoratus* Deflandre 1959, Martini, p. 20, pl. 4, fig. 40.
1961. *Microrhabdulus decoratus* Deflandre 1959, Stradner, p. 83, text-fig. 70.
1963. *Microrhabdulus decoratus* Deflandre 1959, Deflandre, p. 3486, fig. 19.
1963. *Microrhabdulus decoratus* Deflandre 1959, Gorka, p. 23–24, text-pl. 3, figs. 4a–b; pl. 1, figs. 11a–b.
1963. *Microrhabdulus decoratus* Deflandre 1959, Stradner, p. 180, pl. 4, fig. 14.
1964. *Microrhabdulus decoratus* Deflandre 1959, Bramlette and Martini, p. 314, pl. 6, figs. 1a–b.
1964. *Microrhabdulus decoratus* Deflandre 1959, Lezaud, p. 49, pl. 1, fig. 13.
1966. *Microrhabdulus decoratus* Deflandre 1959, Stover, p. 152, pl. 7, figs. 15a–c, 16a–c.
1967. *Microrhabdulus decoratus* Deflandre 1959, Moshkovitz, p. 157, pl. 5, fig. 6a.
1967. *Microrhabdulus decoratus* Deflandre 1959, Sales, p. 305, pl. 3, fig. 32.
1967. *Microrhabdulus decoratus* Deflandre 1959, Vangerow and Schloemer, p. 456, table 1, fig. 29.
1968. *Microrhabdulus decoratus* Deflandre 1959, Gartner, p. 44, pl. 2, fig. 4; pl. 5, fig. 3; pl. 6, figs. 12a–c; pl. 28, fig. 1.
1968. *Microrhabdulus decoratus* Deflandre 1959, Perch-Nielsen, p. 83, pl. 30, figs. 10, 11.
1969. *Microrhabdulus decoratus* Deflandre 1959, Čepek and Hay, p. 326, 331, text-fig. 2, no. 17, text-fig. 4, no. 26.
1969b. *Microrhabdulus decoratus* Deflandre 1959, Noël, p. 483, pl. 1, figs. 5, 6; text-fig. 3.

1969. *Microrhabdulus decoratus* Deflandre 1959, Pienaar, p. 108, pl. 8, fig. 2.
1970. *Microrhabdulus decoratus* Deflandre 1959, Noël, p. 96–97, pl. 38, figs. 7, 12, 13.
1970. *Microrhabdulus decoratus* Deflandre 1959, Shumenko, p. 161–162, pl. 1, fig. 7.
1971. *Microrhabdulus decoratus* Deflandre 1959, Manivit, p. 128–129, pl. 18, figs. 1–2, 3, 4, 5.
1971a. *Microrhabdulus decoratus* Deflandre 1959, Thierstein, p. 36, pl. 4, figs. 66–68.
1972. *Microrhabdulus decoratus* Deflandre 1959, Locker, p. 783, pl. 3, figs. 5, 6, 7.
1973. *Microrhabdulus decoratus* Deflandre 1959, Risatti, p. 28, pl. 10, figs. 14–15.
1974. *Microrhabdulus decoratus* Deflandre 1959, Báldiné Beke and Báldi, p. 77, pl. 6, fig. 10.
1975. *Microrhabdulus decoratus* Deflandre 1959, Jafar, pl. 13, figs. 20–21.
1975. *Microrhabdulus decoratus* Deflandre 1959, Proto Decima, Roth, and Todesco, p. 50, pl. 5, figs. 6a–b.
1976. *Microhabdulus decoratus* Deflandre 1959, El-Dawoody and Zidan, p. 425, pl. 7, figs. 3a–b.
1977. *Microrhabdulus decoratus* Deflandre 1959, Pavšič, p. 44, pl. 9, figs. 15, 16.
1978. *Microrhabdulus decoratus* Deflandre 1959, Proto Decima, Medizza, and Todesco, p. 603, pl. 13, figs. 1a–c.
1978. *Microrhabdulus decoratus* Deflandre 1959, Shafik, p. 221, fig. 5, Sa–Sd; *not* p. 223, fig. 6, Pa–Pb.

Diagnosis.—Long rod-shaped forms, circular in transverse section, constructed of elongate rectangular elements arranged in circular rings about the longitudinal axis of the rod. Conspicuous and distinctive in cross-polarized light in that the rod appears to be constructed of numerous pairs of opposing rectilinear plates, which are alternately light and dark.

Description.—Electron micrographs of this species show that the elongate cylindrical rod is constructed of longitudinally arranged laths of elongate calcite prisms. The prisms are arranged in circular rings about the long axis of the rod, although individual prisms between adjoining rings are often slightly offset.

Microrhabdulus decoratus is distinctive and readily recognized in cross-polarized light. When oriented with the long axis parallel to either nicol, the rod appears to be broken into opposing pairs of small rectilinear plates. In this orientation, opposite plates throughout the length of the rod are bright. When rotated clockwise about 30° from the vibration direction of neither nicol, alternate plates become bright and dark in a transverse and longitudinal direction, with respect to the long axis of the rod. This distinctive "stadia-rod" pattern is readily recognized in cross-polarized light.

Remarks.—Shumenko (1970) described three new species of *Microrhabdulus, M. orbitosus, M. reticulatus,* and *M. serratus,* on the basis of the nature of surface sculpturing as observed in transmission electron micrographs. Although each of these new species appears distinct in electron images, none were illustrated in transmitted light photomicrographs. Since no images of these species were produced by the scanning electron microscope during this investigation, the stratigraphic value of these species is uncertain where the transmitted light microscope is used to detect these species.

Known range.—Middle Turonian through Maastrichtian.

Type locality.—Maastrichtian chalk from near Vanves, Seine, France.

Occurrence.—This species is well documented in upper Turonian through Maastrichtian strata of Australia, western Africa, Tunisia, Poland, Russia, Switzerland, France, Germany, Denmark, and Holland (see synonymy). Gartner (1968) reported *Microhabdulus decoratus* from the Taylor Marl and Corsicana Marl of Texas, and from the Arkadelphia Marl of Arkansas. Risatti (1973) recorded this species from the Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Mississippi. Čepek and Hay (1969) reported this species from the Pfeifer Shale Member of the Greenhorn Limestone and from the Fairport Chalk Member of the Carlile Shale, and recorded it from the Tombigbee Sand Member of the Eutaw Formation through the Prairie Bluff Chalk of Dallas and Wilcox Counties, Ala. During this investigation, *M. decoratus* was observed throughout the upper Turonian through lower Santonian part of the Eagle Ford Group and Austin Group of Texas. Although generally rare in occurrence, it was not noted in samples from the Langtry Member of the Boquillas Formations (upper Turonian), exposed along Sycamore Creek, Kinney County, Tex.

Genus PARHABDOLITHUS Deflandre 1952

Type species.—*Parhabdolithus liasicus* Deflandre 1952.

Diagnosis.—Elliptical forms consisting of a rim composed of imbricate elements that are flaring and extend distally into a narrow, raised distal rim. Central area constructed of irregularly shaped polygonal elements having a relatively large, thin-walled, hollow stem.

Remarks.—*Parhabdolithus* Deflandre differs from *Rhagodiscus* Reinhardt 1971 in having a more strongly flaring and distally extended rim and a wider central stem.

Parhabdolithus angustus (Stradner 1963) Stradner, Adamiker, and Maresch 1968

Plate 12, figures 22–26

1963. *Rhabdolithus angustus* Stradner, p. 178, pl. 5, figs. 6–6a.
1965. *Ahmuellerella angusta* (Stradner 1963) Reinhardt, p. 31.
1966. *Parhabdolithus elongatus* Stover, p. 144, pl. 6, figs. 16, 17a–b, 18a–b, 19a–b; pl. 9, fig. 18.
1966a. *Ahmuellerella angusta* (Stradner 1963), Reinhardt, p. 25, pl. 22, figs. 9–12.
1967. *Rhabdolithina angusta* (Stradner 1963) Reinhardt, p. 168, fig. 7, no. 4–5.
1967. *Parhabdolithus elongatus* Stover 1966, Sales, p. 305, pl. 3, figs. 10a–b.
1968. *Parhabdolithus angustus* (Stradner 1963), Stradner, Adamiker, and Maresch, p. 32, pl. 20, figs. 1–5.
1969. *Parhabdolithus angustus* (Stradner 1963), Bukry, p. 53, pl. 29, figs. 8–11.
1971. *Parhabdolithus angustus* (Stradner 1963), Manivit, p. 86–87, pl. 19, figs. 1, 2, 3.
1971. *Rhagodiscus angustus* (Stradner 1963), Reinhardt, p. 23, pl. 2, figs. 1, 2; text–fig. 10.
1972. *Parhabdolithus angustus* (Stradner 1963), Grün and others, p. 168, pl. 30, figs. 7a–b.
1972a. *Rhabdolithina angusta* (Stradner 1963), Hoffmann, p. 46–47, pl. 9, figs. 3, 4.
1972. *Parhabdolithus angustus* (Stradner 1963), Lauer, p. 168, pl. 30, figs. 7a–b.
1972. *Parhabdolithus angustus* (Stradner 1963), Roth and Thierstein, pl. 6, figs. 14–18; pl. 7, fig. 1.
1973. *Parhabdolithus angustus* (Stradner 1963), Priewalder, p. 22, pl. 16, figs. 1, 2.
1973. *Parhabodithus angustus* (Stradner 1963), Risatti, p. 20, pl. 2, figs. 8–9.
1973. *Parhabdolithus angustus* (Stradner 1963), Roth, p. 725, pl. 24, figs. 4a–d.
1974. *Parhabdolithus angustus* (Stradner 1963), Proto Decima, p. 591, pl. 3, figs. 29–30.
1975. *Parhabdolithus angustus* (Stradner 1963), Krancer, p. 15, pl. 3, fig. 3.
1976. *Eiffellithus eximius* (Stover 1966), El-Dawoody and Zidan, p. 420, pl. 4, figs. 5a–b.
1976. *Parhabdolithus angustus* (Stradner 1963), Hill, p. 146, pl. 9, figs. 16–17, 18–20, 21–23; pl. 14, figs. 27, 28, 29.
1976b. *Parhabdolithus angustus* (Stradner 1963), Verbeek, p. 133, pl. 3, fig. 8.
1977. *Rhagodiscus angustus* (Stradner 1963), Manivit and others, p. 171–172, pl. 1, fig. 1.
1978. *Parhabdolithus angustus* (Stradner 1963), Čepek, p. 676, pl. 3, figs. 4, 5, 6.
1978. *Parhabdolithus angustus* (Stradner 1963), Shafik, p. 219, fig. 4, Ea–Eb.
1980. *Parhabdolithus angustus* (Stradner 1963), Siesser, p. 826, pl. 1, fig. 4; pl. 5, figs. 1–2.

Diagnosis.—Elongate coccoliths having long, parallel sides and a central area constructed of relatively few irregular, poygonal-shaped elements. The central area is greatly restricted by the presence of a large, thin-walled, hollow stem.

Remarks.—Bukry's description (1969, p. 53) of this species, based on electron micrographs, is followed herein. Transmitted light images of *Parhabdolithus angustus* reveal little detail beyond its broadly ovate peripheral outline. Its elongate elliptical form that has two rather long parallel sides distinguishes this species from other forms assigned to this genus. Phase contrast images reveal the narrow rim cycle and rather large, narrow-walled, hollow stem. In cross-polarized light and the longitudinal axis parallel to the vibration direction of either nicol, the long parallel sides are bright with two indistinct interference-extinction lines bisecting the bright rim at each end of the elongate form.

Known range.—Late Aptian through late Maastrichtian.

Type locality.—Upper Albian strata from the Netherlands.

Occurrence.—This species has been reported from lower Albian through (?) lower Maastrichtian cores, Leg 14, Deep Sea Drilling Project, eastern and western North Atlantic basin (Roth and Thierstein, 1972); Aptian or lower Albian through Santonian cores, Leg 17, central Pacific basin (Roth, 1973); upper Aptian through Cenomanian cores from the eastern Indian Ocean (Proto Decima, 1974); Albian strata of Austria (Lauer, 1972); Albian through lower Santonian strata of northern Germany (Hoffmann, 1972a; Reinhardt, 1966a, 1967, 1971); Albian marl from Les Drillions Quarry, northeast of St. Florentin, north-central France (Stover, 1966); Coniacian through Maastrichtian strata from the subsurface of western Africa (Sales, 1967); upper Maastrichtian strata of Austria (Priewalder, 1973); Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Mississippi (Risatti, 1973); and from type Campanian strata near Barbezieux, France; middle Campanian Aachen Marl of Germany; Niobrara Chalk of Knox County, Nebr.; middle Albian through lower Cenomanian strata of Texas (Hill, 1976); Austin Group of Dallas and Travis Counties, and the Taylor Marl of Ellis County, Tex. (Bukry, 1969.)

Parhabdolithus angustus ranges throughout the upper Turonian and lower Santonian strata of Texas, although it was not observed in samples from the Langtry Member of the Boquillas Formation (upper Turonian) at Pinto Creek, Kinney County, Tex.

Parhabdolithus embergeri (Noel 1958) Stradner 1963

Plate 12, figures 27–32; plate 13, figures 1–3, 4–6

1958. *Discolithus embergeri* Noël, p. 164–165, pl. 1, figs. 5, 6a–e, 7a–b, 8.
1961. *Discolithus embergeri* Noël 1958, Stradner, p. 80–81, figs. 20, 21, 22, 23, 24.

1963. *Parhabdolithus embergeri* (Noël 1958), Stradner, p. 174, 179, pl. 4, figs. 1, 1a–b.
1964. *Discolithus embergeri* Noël 1958, Báldiné Beke, p. 135, pl. 1, fig. 3, *not* pl. 1, figs. 2, 4, 5, 6.
1966. *Discolithus embergeri* Noël 1958, Stover, p. 142, pl. 2, figs. 13, 14.
1966. *Parhabdolithus embergeri* (Noël 1958), Pant, p. 41, pl. 1, fig. 7.
1967. *Parhabdolithus embergeri* (Noël 1958), Lyul'eva, p. 93, pl. 2, figs. 17–17b.
1967. *Parhabdolithus embergeri* (Noël 1958), Moshkovitz, p. 149–150, pl. 1, figs. (?) 15, 16.
1968. *Zygodiscus crassicaulis* Gartner, p. 32, pl. 21, figs. 14a–d, pl. 23, fig. 3.
1968. *Zygodiscus lacunatus* Gartner, p. 33, pl. 17, figs. 6a–d; pl. 18, figs. 15, 16; pl. 19, figs. 5a–d; pl. 23, figs. 15, 16; pl. 24, figs. 3a–d.
1969. *Parhabdolithus embergeri* (Noël 1958), Bilgütay, Jafar, Stradner, and Szöts, p. 173, pl. 1, figs. 3–4.
1969. *Parhabdolithus embergeri* (Noël 1958), Bukry and Bramlette, p. 373, 375, pl. 3, fig. F.
1969. *Zygodiscus lacunatus* Gartner 1968, Bukry, p. 60, pl. 34, figs. 11, 12.
1970. *Discolithus embergeri* Noël 1958, Iaccarino and Follini, p. 589, pl. 39, fig. 4.
1971. *Parhabdolithus embergeri* (Noël 1958), Manivit, p. 88, pl. 20, figs. 1–2, 3–4, 5–6.
1971. *Parhabdolithus embergeri* (Noël 1958), Thierstein, Franz, and Roth, p. 502, text–figs. 2a–c.
1972. *Parhabdolithus embergeri* (Noël 1959), Grün, et. al., p. 168, pl. 30, figs. 10a–b, 11a–b, 12a–b.
1972. *Parhabdolithus embergeri* (Noël 1958), Lauer, p. 168, pl. 30, figs. 10a–b, 11a–b, 12a–b.
1972. *Parhabdolithus embergeri* (Noël 1958), Roth and Thierstein, p. 429, pl. 9, figs. 1–5, 6.
1972. *Parhabdolithus embergeri* (Noël 1958), Stradner, p. 1199, pl. 48, figs. 6–7, 8; (?) pl. 49, figs. 5, 6; (?) pl. 50, figs. 5, 6.
1973. *Parhabdolithus embergeri* (Noël 1958), Thierstein, p. 37.
1974. *Parhabdolithus embergeri* (Noël 1958), Báldiné Beke and Báldi, p. 77, (?) pl. 5, fig. 13.
1974. *Parhabdolithus embergeri* (Noël 1958), Barnard and Hay, p. 577–578, pl. 3, fig. 13; pl. 6, fig. 12.
1974. *Parhabdolithus embergeri* (Noël 1958), Proto Decima, p. 591, pl. 5, figs. 19, 20, 24; pl. 7, fig. 14.
1975. *Parhabdolithus embergeri* (Noël 1958), Grün and Allemann, p. 191–192, pl. 7, figs. 7, 8, 9, 10, 11.
1975. *Parhabdolithus embergeri* (Noël 1958), Jafar, pl. 13, figs. 10–11.
1976. *Parhabdolithus embergeri* (Noël 1959), Hill, p. 147–148, pl. 9, figs. 30–31; pl. 10, figs. 1–5.
1978. *Parhabdolithus embergeri* (Noël 1959), Čepek, p. 676, pl. 3, figs. 1, 2.
1978. *Parhabdolithus embergeri* (Noël 1959), Proto Decima, Medizza, and Todesco, p. 603, pl. 16, figs. 10a–c.
1980. *Parhabdolithus embergeri* (Noël 1959), Siesser, p. 826, pl. 6, figs. 1–2, 3, 4–5.

Diagnosis.—Large, elongate elliptical forms that have the distal rim cycle elements sharply bent and extended distally to form a high, narrow, slightly flaring rim. The elliptical central area is dominated by a transverse crossbar that supports a large, irregularly circular stem.

Description.—Although this species was not observed by means of the scanning electron microscope, transmitted light images of topotype material agree well with the figures presented by Noël (1958; see synonymy). This rather large form consists of an elongate elliptical disk constructed of imbricate elements that are strongly extended distally to form a very high and narrow rim. In cross-polarized light, the narrow rim and broad central area are separated by a thin, distinct, elliptical interference-extinction line. The large, irregularly circular stem and broad crossbars may completely fill the central opening or reduce it to two small openings at the inner margin of the rim. Two distinct interference-extinction lines are present along either side of the longitudinal axis of the disk. The extinction lines curve dextrally as observed in distal view.

Remarks.—Examination of topotype material of *Zygodiscus crassicaulis* Gartner 1968 and *Zygodiscus lacunatus* Gartner 1968 from the lower part of the Austin Group of Dallas County, Tex., indicates that these species should be assigned to *Parhabdolithus embergeri* (Noël 1958). This species exhibits variation in size, in degree of closure of the central area by the relatively broad crossbars, and in the size and shape of the distal stem.

Known range.—Early Tithonian through Maastrichtian.

Type locality.—Not designated by Noël (1958), although two localities were mentioned: Kef Talrempt, Ampère and Rivin bleu Batna, Algérie.

Occurrence.—This species has been reported from lower Tithonian through Albian sedimentary rocks from several localities in southwestern France, Switzerland, Great Britain, the central and western Atlantic, Indian Ocean, Venezuela, and Trinidad (Manivit, 1971; Thierstein, 1973; Proto Decima, 1974); Tithonian through Hauterivian cores from Leg 1, Deep Sea Drilling Project, Blake Bahama Basin area (Bukry and Bramlette, 1969); Valangian sedimentary rocks of northern Africa (Stradner, 1961); Valanginian through Tithonian strata of northern Africa and southern Europe (Noël, 1958); Upper Jurassic through Maastrichtian of France (Manivit, 1971); Barremian and Aptian strata of Austria (Lauer, 1972); lower Aptian through lower Maastrichtian cores, Leg 14, Deep Sea Drilling Project, from the eastern and western parts of the southern Atlantic (Roth and Thierstein, 1972); Albian through Turonian sedimentary rocks of northern France and the Netherlands (Stover, 1966); Albian strata of Hungary (Báldiné Beke, 1964); and from middle Albian through upper Coniacian cores, Leg 26, Deep Sea Drilling Project, southern Indian Ocean (Thierstein, 1974).

Within North America, *Parhabdolithus embergeri* has been figured as *Zygodiscus crassicaulis* and *Z. lacunatus* from the Austin Group and Taylor Marl of Dallas and Ellis Counties, Tex. (Gartner, 1968; Bukry, 1969); middle Albian through lower Cenomanian strata of Texas (Hill, 1976); and from the Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi (Newell, 1968). During this investigation, *P. embergeri* was observed only from upper Turonian through Coniacian strata of Texas. Its apparent absence within Texas from strata of early Santonian Age is puzzling, for this species is well known in Santonian strata from other localities. Its absence, therefore, cannot be reliably used as an indicator of pre-Santonian Age strata within Texas.

Genus PREDISCOSPHAERA Vekshina 1959

Synonyms.—*Deflandrius* Bramlette and Martini 1964.

Type species.—*Prediscosphaera decorata* Vekshina 1959.

Diagnosis.—Elliptical or circular rhabdolithis consisting of a disk constructed of two cycles of elements, the proximal cycle smaller, with an open central area spanned by two crossbars surmounted by a complexly constructed stem.

Prediscosphaera cretacea (Arkhangelsky 1912) Gartner 1968

Plate 13, figure 7

1912. *Coccolithophora cretacea* Arkhangelsky, p. 410, pl. 6, figs. 12, (?)13.
1952b. *Coccolithus cretaceus* (Arkhangelsky 1912), Deflandre, p. 463, fig. 360D.
1954. *Rhabdolithus intercisus* Deflandre in Deflandre and Fert, p. 159, pl. 13, figs. 12–13; text-figs. 91–92.
1957. *Discolithus cretaceus* (Arkhangelsky 1912), Gorka, p. 251, pl. 2, fig. 11.
1957. *Tremalithus cretaceus* (Arkhangelsky 1912), Noël, p. 324, pl. 3, figs. 24, 25.
1959. *Discolithus cretaceus* (Arkhangelsky 1912), Black and Barnes, p. 326–327, pl. 11, figs. 1, 2.
1959. *Zygrhablithus intercisus* (Deflandre 1954), Deflandre, p. 136, pl. 1, figs. 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, * * * 20.
1959. *Prediscosphaera decorata* Vekshina, p. 73, pl. 1, figs. 8, 9; pl. 2, fig. 13.
1963. *Zygrhablithus intercisus* (Deflandre 1954), Gorka, p. 11–12, pl. 1, figs. 2–4; text-fig. 2 (nos. 1–3).
1963. *Zygrhablithus intercisus* (Deflandre 1954), Stradner, p. 180, pl. 5, fig. 3.
1964. *Discolithus cretaceus* (Arkhangelsky 1912), Báldiné Beke, p. 135–136, pl. 1, fig. 9.
1964. *Zygrhablithus cretaceus* (Arkhangelsky 1912), Black and others, p. 504, pl. 43, fig. a.
1964. *Deflandrius cretaceous* (Arkhangelsky 1912), Bramlette and Martini, p. 301, pl. 2, figs. 11–12.
1964. *Deflandrius intercisus* (Deflandre 1954), Bramlette and Martini, p. 301, pl. 2, figs. 13–14, 15–16.
1964. *Deflandrius intercisus* (Deflandre 1954), Lezaud, p. 49, pl. 1, figs. 10, 11.
1964. *Zygrhablithus intercisus* (Deflandre 1954), Stradner, p. 139, text-figs. 36, 37.
1965. *Deflandrius intercisus* (Deflandre 1954), Manivit, p. 193, pl. 1, figs. 7a–d.
1965. *Eiffellithus cretaceus cretaceus* (Arkhangelsky 1912), Reinhardt, p. 35, pl. 2, fig. 4; *not* text-fig. 3.
1965. *Eiffellithus cretaceus intercisus* (Deflandre 1954), Reinhardt, p. 36.
1966. *Deflandrius intercisus* (Deflandre 1954), Cohen, p. 28, pl. 4, figs. c–d, e.
1966. Not *Deflandrius cretaceus* (Arkhangelsky 1912), Edwards, p. 483, figs. 16, 19.
1966a. *Deflandrius cretaceus cretaceus* (Arkhangelsky 1912), Reinhardt, p. 35, pl. 15, fig. 4; *not* pl. 10, figs. 1a–b, 2a–b; text-figs. 14a–b.
1966a. *Deflandrius cretaceus intercisus* (Deflandre 1954), Reinhardt, p. 35, pl. 19, fig. 3; pl. 22, fig. 2; *not* text-figs. 20a–b.
1966. *Deflandrius columnatus* Stover, p. 141–142, pl. 6, figs. 6a–b, 7, 8a–b, 9, 10; pl. 9, fig. 16.
1966. *Deflandrius intercisus* (Deflandre 1954), Stover, p. 142, pl. 6, figs. 1a–c, 2, 3, 4, 5a–b.
1967. *Deflandrius cantabrigensis* Black, p. 140, text-fig. 1.
1967. *Deflandrius intercisus* (Deflandre 1954), Lyul'eva, p. 96, pl. 3, figs. 23–23a.
1967. *Deflandrius intercisus* (Deflandre 1954), Moshkovitz, p. 149, pl. 1, fig. 18.
1967. *Zygolithus cretaceus* (Arkhangelsky 1912), Trexler, p. 1357, text-fig. 2, no. 27.
1967. *Deflandrius cretaceus* (Arkhangelsky 1912), Vangerow and Schloemer, p. 456, table 1, fig. 12.
1968. *Deflandrius cretaceus* (Arkhangelsky 1912), Black, p. 807, pl. 151, figs. 4, 5.
1968. *Prediscosphaera cretacea* (Arkhangelsky 1912), Gartner, p. 19–20, pl. 2, figs. 10–14; pl. 3, figs. 8a–c; pl. 4, figs. 19–24; pl. 6, figs. 14a–c, 15a–c; pl. 9, figs. 1–4; pl. 12, figs. 1a–c; pl. 14, figs. 20–22; pl. 18, fig. 8; pl. 22, figs. 1–3; pl. 23, figs. 4–6; pl. 25, figs. 12–14; pl. 26, figs. 2a–c.
1968. *Deflandrius intercisus* (Deflandre 1954), Manivit, pl. 2, figs. 6a–d.
1968. *Deflandrius cretaceus* (Arkhangelsky 1912), Perch-Nielsen, p. 62–65, pl. 13, figs. 1, 2, 3–4, 5–6; pl. 14, figs. 1, 2; pl. 15, fig. 1; pl. 16, figs. 1–4, 5.
1969. *Deflandrius* aff. *intercisus* (Deflandre 1954), Barbieri and Medioli, p. 739, pl. 49, figs. 2a, 2b, 2c, 2d, 2e, 2f, 2g.
1969. *Prediscosphaera cretacea cretacea* (Arkhangelsky 1912), Bukry, p. 38, pl. 16, fig. 12; pl. 17, figs. 1–6.
1969. *Prediscosphaera cretacea* (Arkhangelsky 1912), Bukry and Kennedy, pl. 2, fig. 16.
1969b. *Deflandrius intercisus* (Deflandre 1954), Noël, p. 483, pl. 3, figs. 1–6; text-figs. 6a–c.
1969. *Deflandrius cretaceus* (Arkhangelsky 1912), Pienaar, p. 96–97, pl. 7, fig. 5; pl. 8, fig. 9.

1970. *Deflandrius intercisus* (Deflandre 1954), Čepek, p. 239–240, pl. 22, figs. 3, 4a–b; pl. 26, figs. 2–3.
1970. *Deflandrius cantabrigensis* Black 1967, Forchheimer, p. 37, figs. 34, 35, 36, 37, 38a–b, 39, 40.
1970a. *Prediscosphaera cretacea* (Arkhangelsky 1912), Hoffmann, p. 854, pl. 6, fig. 3.
1970. *Deflandrius intercisus* (Deflandre 1954), Iaccarino and Follini, p. 588, pl. 39, figs. 5, 6; pl. 40, figs. 16, (?)40, (?)41.
1970. *Prediscosphaera cretacea* (Arkhangelsky 1912), Noël, p. 64–66, pl. 15, figs. 3, 4, 5, 6, 9, 11; pl. 16, figs. 2, 3, 7, 8; text–fig. 16.
1970b. *Prediscosphaera cretacea* (Arkhangelsky 1912) Reinhardt, p. 91–92, text–fig. 118.
1971a. *Deflandrius cretaceus* (Arkhangelsky 1912), Black, p. 617, pl. 45.3, figs. 26, 27.
1971. *Prediscosphaera cretacea* (Arkhangelsky 1912), Manivit, p. 99–100, pl. 22, figs. 1, 2–3, 4–5, 6–8, 9, 10, 11–12, 13–14.
1971a. *Prediscosphaera cretacea* (Arkhangelsky 1912), Thierstein, p. 38, pl. 4, figs. 76–77.
1971b. *Prediscosphaera cretacea* (Arkhangelsky 1912), Thierstein, p. 479, pl. 7, fig. 7.
1972. *Deflandrius cantabrigensis* Black 1967, Forchheimer, p. 42–44, pl. 7, figs. 1, 2, 3, 4, 5, 6, 7.
1972. *Deflandrius columnatus* Strover 1966, Grün and others, p. 160, pl. 30, figs. 1a–b.
1972. *Deflandrius cretaceus* (Arkhangelsky 1912), Grün and others, p. 159, pl. 30, figs. 4a–b, 5a–b, 6a–b.
1972a. *Prediscosphaera cretacea* (Arkhangelsky 1912), Hoffmann, p. 51–53, pl. 4, fig. 4; pl. 13, figs. 1, 2, 3, 4; pl. 14, figs. 1, 2, 3.
1972. *Prediscosphaera cretacea* (Arkhangelsky 1912), Iaccarino and Rio, p. 655, pl. 71, fig. 14; pl. 72, fig. 1.
1972. *Deflandrius columnatus* Stover 1966, Lauer, p. 160, pl. 30, figs. 1a–b.
1972. *Deflandrius cretaceus* (Arkhangelsky 1912), Lauer, p. 159, pl. 30, figs. 4a–b, 5a–b, 6a–b.
1972. *Deflandrius cretaceus* (Arkhangelsky 1912), Locker, p. 766, pl. 10, figs. 19–20.
1972. *Prediscosphaera cretacea* (Arkhangelsky 1912), Perch-Nielsen, p. 1011, pl. 22, figs. 1, 3.
1973. *Deflandrius columnatus* Stover 1966, El-Dawoody and Barakat, p. 107–108, pl. 10, figs. 5a–b, 6a–b.
1973. *Deflandrius intercisus* (Deflandre 1954), El-Dawoody and Barakat, p. 107–108, pl. 10, figs. 7a–b, 8a–b.
1973. *Prediscosphaera cretacea* (Arkhangelsky 1912), Perch-Nielsen, p. 330, pl. 7, figs. 3, 5.
1973. *Prediscosphaera cretacea cretacea* (Arkhangelsky 1912), Priewalder, p. 23, pl. 17, figs. 1, 2, 3, 4.
1973. *Prediscosphaera cretacea* (Arkhangelsky 1912), Risatti, p. 25, pl. 2, figs. 10–11.
1973. *Prediscosphaera cretacea* (Arkhangelsky 1912), Roth, p. 725, pl. 21, figs. 4, 5.
1974. *Prediscosphaera cretacea* (Arkhangelsky 1912), Báldiné Beke and Báldi, p. 76–77, pl. 5, figs. 9a–b, 10a–b.
1974. *Prediscosphaera cretacea* (Arkhangelsky 1912), Müller, p. 589, pl. 18, figs. 2, 3.
1974. *Prediscosphaera cretacea* (Arkhangelsky 1912), Proto Decima, p. 591, pl. 3, figs. 26–28; pl. 7, figs. 5, 6.
1974. *Corollithion signum* Stradner 1963, Totten, p. 83, pl. 1, figs. 18–19.
1975. *Prediscosphaera cretacea* (Arkhangelsky 1912), Čepek, p. 95–96, pl. 1, figs. 2a–c.
1975. *Prediscosphaera cretacea* (Arkhangelsky 1912), Hill, p. 231, pl. 2, fig. 4.
1975. *Deflandrius columnatus* Stover 1966, Krancer, p. 8, pl. 1, figs. 5, 6.
1975. *Predicosphaera cretacea* (Arkhangelsky 1912), Monechi and Radrizzani (error for *Prediscosphaera*), p. 35–36, pl. 5, fig. 2; pl. 6, figs. 4, (?)5.
1975. *Prediscosphaera cretacea* (Arkhangelsky 1912), Proto Decima, Roth, and Todesco, p. 50, pl. 5, figs. 5a–b.
1975. *Deflandrius cretaceus* (Arkhangelsky 1912), Stapleton, p. 55, pl. 4, figs. 13a–b, 14a–b.
1975. *Deflandrius intercisus* (Deflandre 1954), Stapleton, p. 55, pl. 4, figs. 15a–b, 16a–b.
1976. *Prediscosphaera cretacea cretacea* (Arkhangelsky 1912), Burns, p. 293, pl. 4, fig. 5.
1976. *Deflandrius cretaceus* (Arkhangelsky 1912), El-Dawoody and Zidan, p. 415, pl. 3, figs. 5a–b.
1976. *Deflandrius columnatus* Stover 1966, El-Dawoody and Zidan, p. 415, pl. 3, figs. 7a–b; *not* pl. 3, figs. 8a–b.
1976. *Prediscosphaera cretacea cretacea* Gartner 1968, Hill, p. 150–151.
1976. *Prediscosphaera cretacea columnata* Hill, p. 151–152, pl. 11, figs. 5, 6, 7–10, 11.
1976. *Predicosphaera cretacea* (Arkhangelsky 1912), Martini (error for *Prediscosphaera*), p. 396, pl. 1, fig. 9.
1977. *Prediscosphaera cretacea* (Arkhangelsky 1912), Gašparíková, p. 162, pl. 75, figs. 5, 6.
1977. *Prediscosphaera columnata* (Stover 1966), Manivit and others, p. 172, pl. 1, figs. 2, 3.
1977. *Prediscosphaera cretacea* (Arkhangelsky 1912), Monechi, p. 770–771, pl. 40, figs. 1, 2; pl. 43, figs. 7, 8, 9; pl. 45, figs. 8, 10.
1978. *Prediscosphaera cretacea* (Arkhangelsky 1912), Proto Decima, Medizza, and Todesco, p. 603, pl. 15, figs. 5, 9a–b.
1978. *Prediscosphaera cretacea* (Arkhangelsky 1912), Shafik, p. 219, fig. 4, La–Lb; p. 223, fig. 6, Ma–Mb.
1979. *Prediscosphaera cretacea* (Arkhangelsky 1912), Pierce and Hart, p. 45, pl. 14, figs. 14, 15.
1980. *Prediscosphaera cretacea* (Arkhangelsky 1912), Siesser, p. 826, pl. 2, figs. 6, 7; (?)pl. 5, figs. 16–17.

Diagnosis.—Circular or slightly elliptical rhabdoliths consisting of a distal rim cycle constructed of 16 elements, each element having an arrowhead-shaped tab at its sinistral margin that penetrates the dextral margin of the adjacent element. The open central area is spanned by four plus-shaped crossbars, which form support struts for the short distal stem.

Description.—Circular to elliptical in outline consisting of a two-cycle rim tier and circular to ovate central area spanned by four crossbars. In distal view, the broad outer distal cycle is constructed of about 16 trapezoidal elements. As noted by Bukry (1969, p. 38), each of the elements has an arrowhead-shaped tab along its sinistral margin that penetrates or overlaps the dextral margin of the adjacent element. A narrow inner cycle of about 16 elements lines the relatively large open central area. Four narrow X-shaped crossbars symmetrically divide the central area and form support struts for a short distal stem. Although the crossbars originate at the inner margin of the distal cycle, they appear to be attached to the distal set, arise from the inner distal surface of the proximal cycle, and merge immediately below (proximally) the upper distal set. In proximal view, the proximal cycle is slightly more narrow than the distal cycle and is constructed of about 16 elements interlocked together by narrow notches and tabs in adjoining elements. The species is strongly concave proximally and convex distally.

Phase contrast light images consist of a circular to slightly ovate, dark, rather broad rim and large central area spanned by four narrow perpendicular, or nearly perpendicular, crossbars. In cross-polarized light, the broad outer rim appears dark and is lined internally by a narrow bright rim. The contact between the two cycles may be smooth or somewhat crenulate, although it is invariably marked by a thin and distinct dark line. The crossbars are bright in cross-polarized light, and, when oriented parallel to either nicol, are bordered by a thin dark line.

Remarks.—The confused taxonomic history of this species has been summarized by Gartner (1968, p. 20) and will not be duplicated herein. Bukry (1969, p. 38–39) regarded the form described herein as a subspecies, and proposed two new subspecies of *Prediscosphaera cretacea* on the basis of variation observed in transmission electron images. Although Bukry noted only one of the two new subspecies in the lower part of the Austin Group, namely *P. cretacea ponticula* Bukry, it was not observed during this investigation.

Prediscosphaera cretacea is one of the most common calcareous nannoplankton in worldwide Upper Cretaceous sedimentary rocks. Although the central crossbars are often found broken and the coccolith reduced to an open ring, transmitted light images of the ring structure are so distinct that proper taxonomic assignment can be made with little or no uncertainty.

Known range.—Albian through Maastrichtian.

Type locality.—Upper Cretaceous strata of eastern Russia.

Occurrence.—This species has a well-documented worldwide geographic distribution throughout the Upper Cretaceous (see synonymy). It is one of the dominant species of the nannoplankton floras throughout the upper Turonian through lower Santonian strata of Texas.

Prediscosphaera spinosa (Bramlette and Martini 1964) Gartner 1968

Plate 13, figures 8, 9, 10–15

1964. *Deflandrius spinosus* Bramlette and Martini, p. 301, pl. 2, figs. 17–18, 19–20.
1965. *Eiffellithus cretaceus cretaceus* (Arkhangelsky 1912), Reinhardt, p. 35, text-fig. 3; *not* pl. 2, fig. 4.
1966. *Deflandrius cretaceus* (Arkhangelsky 1912)?, Edwards, p. 487, figs. 16, 19.
1966a. *Deflandrius cretaceus cretaceus* (Arkhangelsky 1912), Reinhardt, p. 35, pl. 10, figs. 1a–b, 2a–b; text-figs. 14a–b; *not* pl. 15, fig. 4.
1966a. *Deflandrius cretaceus intercisus* (Deflandre 1954), Reinhardt, p. 35, text-figs. 20a–b; *not* pl. 19, fig. 3; pl. 22, fig. 2.
1966. *Discolithus incohatus* Stover, p. 143, pl. 2, figs. 23a–c, 24a–b; pl. 8, fig. 17.
1967. *Deflandrius spinosus* Bramlette and Martini 1964, Lyul'eva, p. 96, pl. 3, figs. 24–24a.
1967. *Deflandrius quadripunctatus* (Gorka 1957), Reinhardt and Gorka, p. 252, pl. 31, figs. 21, 25; pl. 32, fig. 3.
1967. Not *Deflandrius spinosus* Bramlette and Martini 1964, Vangerow and Schloemer, p. 456, table 1, fig. 13.
1968. *Deflandrius spinosus* Bramlette and Martini, Black, p. 807, pl. 151, figs. 2, 3.
1968. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Gartner, p. 20–21; pl. 2, figs. 15–16; pl. 3, figs. 9a–b, 10a–b; pl. 5, figs. 7–9; pl. 6, (?) figs. 16a–d; pl. 11, figs. 17a–c.
1968. *Deflandrius spinosus* Bramlette and Martini 1964, Perch-Nielsen, p. 65–66, pl. 14, figs. 3–8; pl. 16, figs. 8–10; text-fig. 28b.
1969. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Bukry, p. 40, pl. 18, figs. 7–9.
1969. *Deflandrius spinosus* Bramlette and Martini 1964, Pienaar, p. 97–98, pl. 5, fig. 5; pl. 8, figs. 10, 11.
1970. (?)*Deflandrius spinosus* Bramlette and Martini 1964, Black, p. 40, pl. 3, fig. 6.
1970. *Discolithus incohatus* Stover 1966, Čepek, p. 241, pl. 22, figs. 5, 6a–c.
1970a. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Hoffmann, p. 854–855, pl. 5, fig. 4.
1971a. *Deflandrius spinosus* Bramlette and Martini 1964, Black, p. 617, pl. 45.3, fig. 28.
1971. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Manivit, p. 101, pl. 21, figs. 4–5, 6–7, 8.
1971. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Shafik and Stradner, p. 88, pl. 20, figs. 1–4.
1971a. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Thierstein, p. 39, pl. 4, figs. 64–65.
1972. *Deflandrius spinosus* Bramlette and Martini 1964, Forchheimer, p. 44–45, pl. 6, figs. 1, 2, 4, 6, 7.
1972. *Deflandrius spinosus* Bramlette and Martini 1964, Grün, et. al., p. 159–160, pl. 30, figs. 2a–b, 3a–b.
1972a. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Hoffmann, p. 53, pl. 13, figs. 5, 6; pl. 14, figs. 4, 5.
1972. *Deflandrius spinosus* Bramlette and Martini 1964, Lauer, p. 159–160, pl. 30, figs. 2a–b, 3a–b.
1973. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Perch-Nielsen, p. 330, pl. 7, fig. 2.
1973. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Priewalder, p. 24, pl. 18, figs. 3, 4.

1973. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Risatti, p. 25–26, pl. 2, figs. 12–13.
1974. *Staurolithites crux* (Deflandre and Fert 1952), Totten, p. 84, pl. 1, fig. 9.
1975. *Deflandrius spinosus* Bramlette and Martini, Stapleton, p. 55, pl. 5, figs. 1a–b, 2a–b.
1976. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Hill, p. 152, pl. 11, figs. 12–15, 16–17.
1977. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Monechi, p. 771, pl. 40, fig. 3.
1978. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Shafik, p. 219, fig. 4, Ma–Mb; p. 223, fig. 6, Ka–Kb(?), La–Lb(?).
1979. *Prediscosphaera spinosa* (Bramlette and Martini 1964), Pierce and Hart, p. 45, pl. 14, fig. 16.

Diagnosis.—Elliptical rhabdoliths consisting of a 16-element distal rim cycle, and a more narrow 16-element proximal rim cycle lining the ovate central region. The open and elongate central area is spanned by four plus-shaped crossbars alined, or in near alinement, with the longitudinal and transverse axes of the rhabdolith. The two transverse crossbars are distinctly shorter than the two longitudinal bars.

Description.—This species was not observed by means of the scanning electron microscope. In transmitted light optics, *Prediscosphaera spinosa* is elliptical in peripheral outline and consists of a dark outer and bright inner rim cycle. The large ovate central area is spanned by four crossbars which, in transmitted light, appear to be alined with the major and minor axes of the central area. Gartner (1968, p. 20) noted that the crossbars are offset about 5° counterclockwise when viewed distally. In cross-polarized images, the boundary between the dark outer and bright inner rims is marked by a distinct dark line. This contact may be smooth or somewhat crenulate and scalloped. The crossbars are distinct and bright in cross-polarized light.

Remarks.—In transmitted light photomicrographs, this species is similar to *Prediscosphaera cretacea* in having a dark outer and bright inner rim cycle, and in having a somewhat crenulate margin separating the two cycles. *Prediscosphaera spinosa* is distinguished from *Prediscosphaera cretacea* in (1) being more elliptical in outer peripheral outline, (2) having the two cycles of the rim almost equal in width, (3) having crossbars alined, or in near alinement, with the major and minor axes of the central area, and (4) having crossbars which are unequal in length.

Gorka (1957, p. 250–251, pl. 2, fig. 13) described and illustrated, by a rather indistinct line drawing, a new species from the upper Maastrichtian of Poland. This species, *Discolithus propinquus*, was regarded by Reinhardt (1970b, p. 93) to be a senior synonym of *Prediscosphaera spinosa*. Reinhardt (1970b, text-fig. 120) presented a single line drawing of *P. propinqua* nearly identical to Gorka's earlier illustration, which added little in revealing the taxonomic identity of the two species. Until electron and light optical images of the type material of *Discolithus propinquus* Gorka 1957 are published, its status cannot be satisfactorily resolved.

Known range.—Middle Albian through late Maastrichtian.

Type locality.—Arkadelphia Marl 4 miles north of Hope, Hempstead County, Ark.

Occurrence.—This species has been well documented from Cretaceous strata of northern Africa and throughout Europe. Within North America, *Prediscosphaera spinosa* has been recorded from the middle to upper Turonian part of the Ladd Formation, Orange County, Calif. (Totten, 1974); the Niobrara Chalk of Knox County, Nebr. (Bukry, 1969); Ripley Formation and Prairie Bluff Chalk of Alabama (Black, 1968; Bramlette and Martini, 1964); Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Mississippi (Risatti, 1973); middle Albian through lower Cenomanian strata of Texas (Hill, 1976); and from the Austin Group, Taylor Marl, and Corsicana Marl of central and north-central Texas (Gartner, 1968; Bukry, 1969). Newell (1968) recorded this species as *Deflandrius spinosus* from the Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi.

During the present investigation, this species was observed to range throughout the upper Turonian through lower Santonian strata of Texas. It was not seen in samples from the Coniacian part of the Austin Group as exposed along Sycamore Creek, Kinney County, nor in samples representing the same biostratigraphic interval exposed at the Oak Haven Waterfall site, Travis County, Tex.

Genus STEPHANOLITHION Deflandre 1939

Type species.—*Stephanolithion bigoti* Deflandre 1939.

Diagnosis.—Circular, elliptical, or elongate polygonal disks or short tapering cylinders consisting of a narrow rim constructed of one or two cycles of elements and radial spines or processes projecting radially from the outer peripheral margin. The large, open, central area is spanned by crossbars that intersect at the center of the opening. The crossbars may or may not support a short stem.

Remarks.—*Stephanolithion* Deflandre differs from *Corollithion* Stradner 1961 in possessing radial, outer peripheral spines or projections, although they appear to be absent or reduced to small peripheral nodes in *S. laffittei* Noel.

Stephanolithion laffittei Noel 1957

Plate 13, figures 16–19, 20–23, 24, 25

1957. *Stephanolithion laffittei* Noël, p. 318–319, pl. 2, fig. 5; *not* pl. 2, fig. 6.
1958. *Stephanolithion laffittei* Noël 1957, Noël, p. 161–162, pl. 1, figs. 1, 2.
1963. *Stephanolithion laffittei* Noël 1957, Stradner, p. 178, pl. 1, figs. 14a–b.
1964. *Stephanolithion* cf. *S. laffittei* Noël 1957, Bramlette and Martini, p. 320, pl. 6, figs. 12–13, 14, 15.
1964. *Stephanolithion laffittei* Noël 1957, Lezaud, p. 49, pl. 1, fig. 8.
1964. *Stephanolithion laffitei* Noël 1957, Stradner (error for *laffittei*), p. 138, text-figs. 47, 48.
1965. *Stephanolithion* Black, p. 132, fig. 11.
1965. *Stephanolithion laffittei* Noël 1957, Manivit, p. 191, pl. 2, fig. 21.
1965. *Stephanolithion laffittei* Noël 1957, Noël, p. 4–5, text-figs. 15, 16.
1966. *Stephanolithion laffitei* Noël 1957, Maresch (error for *laffittei*), p. 383, pl. 3, fig. 5.
1966a. *Stephanolithion laffittei* Noël 1957, Reinhardt, p. 41, pl. 21, fig. 19; pl. 23, fig. 23.
1966. *Stephanolithion crenulatum* Stover, p. 160, pl. 7, figs. 25, 26a–c, 27a–b.
1967. *Stephanolithion crenulatum* Stover 1966, Lyul'eva, p. 96, pl. 4, fig. 46.
1967. *Stephanolithion crenulatum* Stover 1966, Sales, p. 305, pl. 3, figs. 23a–b.
1967. *Stephanolithion laffittei* Noël 1957, Vangerow and Schloemer, p. 456, table 1, fig. 35.
1968. *Stephanolithion laffittei* Noël 1957, Black, p. 807–808, pl. 152, figs. 2, 3.
1968. *Corollithion octoradiatum* Gartner, p. 35–36, pl. 6, figs. 5a–c; pl. 10, figs. 14, 15; pl. 11, figs. 7a–c; pl. 22, fig. 19.
1968. Not *Stephanolithion* sp. aff. *S. laffitei* Noël 1957, Gartner (error for *laffittei*), p. 35, pl. 5, fig. 14; pl. 22, fig. 18.
1969. *Stephanolithion laffittei* Noël 1957, Bukry, p. 43–44, pl. 21, figs. 7–11.
1969. *Stephanolithion laffittei* Noël 1957, Čepek and Hay, p. 326, text-fig. 2, no. 12.
1969. *Stephanolithion* sp. Feldmann and Holland, p. 106, pl. 1, fig. 17.
1969. *Stephanolithion* aff. *laffittei* Noël 1957, Pienaar, p. 111–112, pl. 5, fig. 7.
1970. *Stephanolithion laffitei* Noël 1957, Čepek (error for *laffittei*), p. 246, pl. 23, figs. 9, 10.
1970. *Stephanolithion laffittei* Noël 1957, Noël, p. 85–86, pl. 29, figs. 1–11; pl. 31, fig. 4.
1971. *Stephanolithion laffittei* Noël 1957, Manivit, p. 108–109, pl. 23, figs. 14, 15–17, 18.
1971. *Stephanolithion laffitei* Noël 1957, Shafik and Stradner (error for *laffittei*), p. 89, pl. 47, fig. 2.
1972. *Stephanolithion laffittei* Noël 1957, Grün and others, p. 169, pl. 24, figs. 12a–b.
1972b. *Stephanolithion laffittei* Noël 1957, Hoffmann, p. 48–49, pl. 3, figs. 3, 4, 5, 6; pl. 4, figs. 3, 4.
1972. *Stephanolithion laffittei* Noël 1957, Iaccarino and Rio, p. 656, pl. 71, fig. 6.
1972. *Stephanolithion laffittei* Noël 1957, Lauer, p. 169, pl. 24, figs. 12a–b.
1972. *Cribrosphaerella ehrenbergi* (Arkhangelsky 1912), Lauer, p. 158–159, pl. 25, figs. 9a–b; *not* pl. 25, figs. 7a–b, 8a–b.
1972. *Stephanolithion laffittei* Noël 1957, Rood and Barnard, p. 330–331, pl. 1, figs. 6, 12.
1972. *Stephanolithion laffittei* Noël 1957, Roth and Thierstein, pl. 16, figs. 6–11.
1972. *Stephanolithion laffittei* Noël 1957, Wilcoxon, p. 432, pl. 4, figs. 5, 7, 8; table 1.
1973. *Cylindralithus laffittei* (Noël 1957), Black, p. 95–96, pl. 29, figs. 1, 2, 3, 4, 5, 6; text-fig. 4–6.
1973. *Stephanolithion laffittei* Noël 1957, Hekel, p. 227, pl. 1, fig. 3.
1973. *Stephanolithion laffitei* Noël 1957, Priewalder (error for *laffittei*), p. 25, pl. 6, fig. 2.
1973. *Stephanolithion laffittei* Noël 1957, Risatti, p. 23, pl. 1, figs. 7–8.
1974. *Stephanolithion laffittei* Noël 1957, Müller, p. 589, pl. 17, figs. 3, 4.
1974. *Stephanolithion laffittei* Noël 1957, Proto Decima, p. 591, pl. 4, fig. 15.
1975. *Stephanolithion laffittei* Noël 1957, Grün and Allemann, p. 187–188, pl. 7, fig. 4; text-fig. 26.
1975. *Corollithion octoradiatum* Gartner 1968, Krancer, p. 13, pl. 2, fig. 9.
1976. *Stephanolithion laffittei* Noël 1957, Hill, p. 155, pl. 11, figs. 30–32; pl. 15, figs. 11, 12.
1976. *Stephanolithion laffittei* Noël 1957, Shumenko, p. 67, pl. 25, figs. 7, 8, 9.
1977. *Cylindralithus laffittei* (Noël 1957), Gašparikvá, p. 164–165, pl. 78, fig. 2.
1978. *Stephanolithion laffittei* Noël 1957, Roth, p. 743, pl. 1, figs. 10a–b.
1978. *Stephanolithion laffittei* Noël 1957, Shafik, p. 221, fig. 5, Fa–Fb, Ga–Gb.
1979. *Stephanolithion laffittei* Noël 1957, Wind and Čepek, p. 223–224, pl. 3, figs. 1, 2.
1980. *Stephanolithion laffittei* Noël 1957, Siesser, p. 826, 828, pl. 3, figs. 8, 9.

Diagnosis.—Short tapering cylindrical forms with a narrow rim and large, open circular central area. The smaller proximal end of the cylinder is spanned by eight radial bars that intersect at the center of the opening.

Description.—As noted by Bukry (1969, p. 43–44), *Stephanolithion laffittei* consists of a short tapering cylinder with usually eight radial spokes extending from the rim to the center of the smaller circular base at the proximal end. The proximal end of the cylinder consists of two concentric cycles of elements. The outer cycle is composed of irregularly polygonal elements that are the terminal ends of longitudinal and rod-shaped elements of the cylinder wall. The inner cycle of elements forms a rim for attachment of the radial spokes, and is restricted to the proximal end of the cylinder. In distal view, only the polygonal elements of the outer or cylinder wall cycle are visible.

In phase contrast light, this species appears as a narrow and irregularly circular ring, which may or may not have short spines or protuberances along its outer periphery. The spokes are visible in either proximal or distal views, although they are invariably indistinct. In cross-polarized light, both the outer cylinder wall cycle and the inner spoke-rim cycle are distinct. The outer cycle appears as a dark ring owing to the near vertical orientation of the optic axis of the elements. The inner cycle appears bright and bisected by four indistinct interference-extinction lines.

Remarks.—*Stephanolithion laffittei* differs from *Corollithion exiguum* Stradner in (1) being cylindrical rather than disk-shaped, (2) being circular to subcircular rather than regular polygonal in outline, (3) having two concentric ring cycles as observed in cross-polarized light, and (4) being more strongly birefringent in phase contrast as well as in cross-polarized light.

Known range.—Early Tithonian through Maastrichtian.

Type locality.—Upper Tithonian strata exposed near Kef Talrempt, northeastern Algeria.

Occurrence.—This species has been reported throughout its known geological range in northern Africa, Asia, and Europe. In North America, it has been reported from the Niobrara Chalk of Nebraska (Bukry, 1969) and North Dakota (Feldmann and Holland, 1969); Graneros Shale, Greenhorn Limestone, and Carlile Shale of Kansas; Ripley Formation and Prairie Bluff Chalk of Alabama, and the Arkadelphia Marl of Arkansas (Bramlette and Martini, 1964); Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Mississippi (Risatti, 1973); middle Albian through lower Cenomanian strata of Texas (Hill, 1976); and from the Eagle Ford Group, Austin Group, Taylor Marl, and Corsicana Marl of Texas, and Arkadelphia Marl of Arkansas (Gartner, 1968; Bukry, 1969). Newell (1968) figured this species as *Corollithion octoradiatus* from the Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi. During the present study, *Stephanolithion laffittei* was observed to be rare throughout the upper Turonian, Coniacian, and lower Santonian part of the Eagle Ford Group and Austin Group of Texas.

Genus TETRALITHUS Gardet 1955

Type species.—*Tetralithus pyramidus* Gardet 1955.

Diagnosis.—Variously square, circular, or elliptical calcareous bodies consisting of from three to eight parts. Each part is a discrete unit of calcite with the *c*-crystallographic axis radially or subradially oriented.

Tetralithus obscurus Deflandre 1959

Plate 13, figures 26–34

1959. *Tetralithus obscurus* Deflandre, p. 138, pl. 3, figs. 26–29.
1961. *Tetralithus obscurus* Deflandre 1959, Martini, p. 3, pl. 1, fig. 2.
1963. *Tetralithus obscurus* Deflandre 1959, Gorka, p. 22–23, pl. 2, figs. 4a–b, 5; text–fig. 4 (no. 5).
1964. *Tetralithus obscurus* Deflandre 1959, Bramlette and Martini, p. 320, pl. 4, figs. 26–28.
1964. *Tetralithus obscurus* Deflandre 1959, Lezaud, p. 49, pl. 1, fig. 18.
1966. *Tetralithus obscurus* Deflandre 1959, Stover, p. 162, pl. 7, fig. 10.
1967. *Tetralithus obscurus* Deflandre 1959, Vangerow and Schloemer, p. 456, table 1, fig. 36.
1968. *Tetralithus obscurus* Deflandre 1959, Perch-Nielsen, p. 87–88, pl. 31, figs. 6, 7, 8, 10–11; (?) text–fig. 44.
1969. *Tetralithus obscurus* Deflandre 1959, Bukry, p. 63–64, pl. 37, figs. 11, 12.
1969. *Tetralithus obscurus* Deflandre 1959, Čepek and Hay, p. 330, text–fig. 4, no. 23.
1970. *Tetralithus obscurus* Deflandre 1959, Čepek, p. 247, pl. 25, figs. 15, 16a–c; pl. 26, fig. 10.
1972. *Tetralithus obscurus* Deflandre 1959, Iaccarino and Follini, p. 593, pl. 40, fig. 14.
1971. *Tetralithus obscurus* Deflandre 1959, Manivit, p. 144–145, pl. 25, figs. 3, 4, 5.
1972. *Tetralithus obscurus* Deflandre 1959, Grün and others, p. 171–172, pl. 29, figs. 7a–b.
1972. *Tetralithus obscurus* Deflandre 1959, Iaccarino and Rio, p. 662, pl. 71, fig. 13.
1972. *Tetralithus obscurus* Deflandre 1959, Lauer, p. 171–172, pl. 29, figs. 7a–b.
1975. *Tetralithus obscurus* Deflandre 1959, Jafar, pl. 13, figs. 6–7.
1975. *Tetralithus obscurus* Deflandre 1959, Wind, p. 351–353, figs. 1d(?), 1e; pl. 2, figs. 4, 6; pl. 3, figs. 11a–b, 15a–c.
1978. *Tetralithus obscurus* Deflandre 1959, Shafik, p. 217, fig. 3, A, B, C, D, Ea–Eb.
1978. *Phanulithus obscurus* (Deflandre 1959), Wind and Wise, p. 141, fig. 2, a, d.
1980. *Tetralithus obscurus* Deflandre 1959, Barrier, p. 296, pl. 1, fig. 3.

Diagnosis.—Elliptical calcareous forms constructed of four trapezoidal to triangular elements. Sutures between adjacent elements are somewhat H-shaped along the transverse axis of the ellipse. In cross-polarized light, with the long axis of the nannofossil oriented at 45° to either nicol, the four elements of calcite are bright and the interelement sutures sharply defined.

Description.—*Tetralithus obscurus* was not observed by means of the scanning electron microscope during this investigation. Under the light microscope, this form is elongate elliptical in outline and is constructed of four somewhat trapezoidal- to triangular-shaped pieces of calcite. This species has very low birefringence in plane transmitted light, and small specimens may be easily overlooked. When the analyzer is inserted into the light path and the long axis of the elliptical form is parallel to the vibration direction of the nicol, the two pieces of calcite at opposite ends of the long axis show strong birefringence (pl. 13, fig. 26). When rotated 90° and the short axis is parallel to the vibration direction, the two pieces of calcite at opposite sides of the short axis are strongly birefrigent (pl. 13, fig. 28). Cross-polarized images are indistinct when either axis of the elliptical form is parallel to either nicol (pl. 13, figs. 32, 34). However, when the long axis is rotated to 45°, the four pieces of calcite are bright, and the interelement sutures sharply defined (pl. 13, fig. 33).

Remarks.—*Tetralithus obscurus* differs from *T. ovalis* Stradner 1963 in having a more strongly elliptical outline and in possessing sutures oriented diagonally, rather than parallel to the long and short axes of the ellipse.

Wind (1975) studied the morphologic relationships between several species of *Lucianorhabdus* Deflandre 1959 and ovate to elliptical species of *Tetralithus* Gardet 1955. Results of his studies indicate that the "vestigial basal disk" noted by Gartner (1968, p. 45) on several specimens of *Lucianorhabdus cayeuxii* Deflandre were, in fact, tetraliths previously described at *T. obscurus* Deflandre 1959 and *T. ovalis* Stradner 1963. Although Wind noted two distinct forms of *Lucianorhabdus cayeuxii*, each form consistently associated with either a *T. obscurus* or *T. ovalis* basal disk, he proposed no taxonomic revisions of the *Tetralithus* or *Lucianorhabdus* species groups. Since most species of *Lucianorhabdus* have their long axis perpendicular to the axis of observation, the ovate basal disk cannot be adequately observed in permanent mounts for transmitted light microscopy. Furthermore, since the various morphologic species of disattached tetraliths are readily identifiable in electron as well as transmitted light micrographs, it seems best, at present, to retain the generic concepts of both *Lucianorhabdus* Deflandre 1959 and *Tetralithus* Gardet 1955.

Known range.—Early Santonian through middle Maastrichtian.

Type locality.—Upper Turonian(?) strata exposed near Klafterbrunn, Austria.

Occurrence.—This species has been reported from Santonian strata of western Australia (Shafik, 1978); Santonian and Coniacian(?) strata of northwestern Germany (Čepek, 1970); upper Coniacian(?) through upper Santonian strata of northern France (Lezaud, 1964); middle(?) Campanian chalk near Meudon, France (Bukry, 1969); Santonian through Maastrichtian sedimentary rocks of France (Manivit, 1971); Campanian chalk of north-central France (Stover, 1966); Campanian and Maastrichtian strata of Poland (Gorka, 1963); Campanian strata of Austria (Lauer, 1972); Senonian and Maastrichtian chalks from several localities in France (Deflandre, 1959); upper Campanian through middle Maastrichtian strata of South Linburg, Netherlands (Vangerow and Scholoemer, 1967); from the Maastrichtian of Denmark (Perch-Nielsen, 1968); lower and middle Campanian part of the Ladd Formation of California (Totten, 1974); upper part of the Mooreville Chalk, throughout the Demopolis Chalk and into the lower part of the Ripley Formation of Wilcox County, Ala. (Čepek and Hay, 1969); Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Lowndes County, Miss. (Newell, 1968); and from the Demopolis Chalk and Ripley Formation of Mississippi (Risatti, 1973).

During this investigation, *Tetralithus obscurus* was noted throughout the lower Santonian part of the Austin Group. It was not observed from upper Turonian or Coniacian strata at any of the sampled localities. This species have proven, therefore, to be an important nannofossil in distinguishing Coniacian from lower Santonian strata of Texas.

Tetralithus pyramidus Gardet 1955

Plate 13, figures 35–38, 39–46, 47–50

1955. *Tetralithus pyramidus* Gardet, p. 521, pl. 7, fig. 66.
1959. *Tetralithus gothicus* Deflandre, p. 138, pl. 3, fig. 25.
1961. *Tetralithus pyramidus* Gardet 1955, Martini, p. 3, pl. 1, fig. 1.
1961. *Tetralithus gothicus* Deflandre 1959, Martini, p. 4, pl. 1, fig. 4.
1963. *Tetralithus pyramidus* Gardet 1955, Stradner, p. 181, pl. 6, fig. 3; *not* pl. 6, fig. 4.
1967. *Tetralithus pyramidus* Gardet 1955, Lyul'eva, p. 96, pl. 4, fig. 45.
1968. *Tetralithus pyramidus* Gardet 1955, Forchheimer, p. 57, pl. 6, figs. 5a–b; fig. 3, no. 3.
1968. *Tetralithus gothicus* Deflandre 1959, Gartner, p. 42, pl. 24, figs. 4a–d.
1969. *Tetralithus pyramidus* Gardet 1955, Bukry, p. 64, pl. 38, fig. 1.
1969. *Tetralithus pyramidus* Gardet 1955, Čepek and Hay, p. 327, text-fig. 2, no. 18, text-fig. 4, no. 22.
1970. *Tetralithus pyramidus* Gardet 1955, Čepek and Hay, p. 335, pl. 20, fig. 4.
1970. *Tetralithus gothicus* Deflandre 1959, Iaccarino and Follini, p. 599–600, pl. 41, figs. 24, 25.

1970. *Tetralithus murus* Martini 1961, Iaccarino and Follini, p. 598, pl. 40, fig. 1.
1971. *Tetralithus gothicus* Deflandre 1959, Grigorovich, p. 96, pl. 3, figs. 1–2.
1971. *Tetralithus gothicus* Deflandre 1959, Manivit, p. 143–144, pl. 25, figs. 18, 19, 20–21.
1971. *Tetralithus pyramidus* Gardet 1955, Manivit, p. 145, pl. 25, figs. 1–2, 6–7, 8.
1971a. *Tetralithus pyramidus* Gardet 1955, Thierstein, p. 40, pl. 2, figs. 37–38.
1972. Not *Tetralithus pyramidus* Gardet 1955, Grün and others, p. 171, pl. 29, figs. 6a–b.
1972. *Tetralithus gothicus* Deflandre 1959, Iaccarino and Rio, p. 662, pl. 71, figs. 20a–b.
1972. Not *Tetralithus pyramidus* Gardet 1955, Lauer, p. 171, pl. 29, figs. 6a–b.
1972. Not *Tetralithus gothicus* Deflandre 1959, Locker, p. 775, pl. 13, fig. 18.
1973. Not *Tetralithus pyramidus* Gardet 1955, Risatti, p. 32, pl. 4, figs. 6, 7.
1973. *Tetralithus descriptus* Martini 1961, Risatti, p. 31, pl. 4, figs. 16–17.
1973. *Tetralithus* sp. aff. *T. gothicus* Deflandre 1959, Risatti, p. 32, pl. 4, figs. 8–9.
1974. *Micula staurophora* (Gardet 1955), Thierstein, p. 641, pl. 12, figs. (?)3, 4–8; *not* pl. 12, figs. 1–2, (?)3, 9, 10, 11.
1974. *Tetralithus pyramidus* Gardet 1955, Totten, p. 83, pl. 1, fig. 23.
1975. *Tetralithus* sp., Proti Decima, Roth, and Todesco, p. 52, pl. 6, figs. 33a–c.
1976. *Tetralithus gothicus* Deflandre 1959, Martini, p. 396, pl. 12, figs. 3–4.

Diagnosis.—Cube-shaped calcareous bodies constructed of eight smaller cube-shaped blocks of calcite. Sutures between adjacent blocks are normal to the side of the nannofossil and meet at a common point in the center of each face of the block. The corners of the cube may be normal, or somewhat rounded, to elongate and bluntly pointed.

Description.—Electron images of *Tetralithus pyramidus* reveals little that cannot be observed in transmitted light. This species is constructed of eight rectilinear pieces of calcite molded together to form a cube-shaped block. The block may be symmetrical, or more commonly, one tier of four pieces may be rotated parallel to the plane of the opposite four pieces. This rotation results in the corners of one tier being offset from the corners of the opposite tier. The sides of the cube may be straight and their corners perpendicular. Where the sides are convex and the corners somewhat elongate and pointed, the cube appears to be constructed of elongate and ovate pieces of calcite.

In transmitted light, this species appears to be constructed of four square pieces of calcite arranged to form a larger square. The contact margins between each of the four smaller blocks is distinct. In cross-polarized light, the block appears bright when either side is parallel to either nicol. When rotated 45°, the block appears dark owing to the radial orientation of the *c*-crystallographic axis of each of the four smaller blocks.

Remarks.—Thierstein (1974, p. 641) regarded *Tetralithus pyramidus* Gardet 1955 as a heavily calcified and overgrown morphotype of *Micula staurophora* (Gardet 1955) Stradner 1963. Evidently, Thierstein was not aware that *T. pyramidus* is the type species of *Tetralithus* (=*Micula* of Thierstein 1974), for in his distribution and range charts he continued to use the name *Tetralithus* for species other than *T. pyramidus*. I do not agree with Thierstein's taxonomic treatment of these forms. Even though *T. pyramidus* may prove to be a heavily calcified *M. staurophora,* I have observed both types in the same sample material, indicating that excess calcification, if present, must have been selective on only certain specimens. Furthermore, I have observed *T. pyramidus* in excellently preserved nannoplankton assemblages. At present, it seems best to retain the genus *Tetralithus* since its type species, *T. pyramidus* Gardet 1955, is distinct in both electron and transmitted light optics and should not be confused with other species.

Tetralithus gothicus Deflandre 1959 is herein regarded as a junior subjective synonym because it differs only in having convex sides and elongate corners. These two forms are completely gradational and both invariably occur together in the same samples.

Known range.—Cenomanian through (?)early Maastrichtian.

Type locality.—Miocene (reworked) sedimentary rocks of northwestern Algeria.

Occurrence.—Gardet (1955, p. 521) originally described *Tetralithus pyramidus* from upper Miocene strata of Algeria. No specific type locality was given for the single illustrated specimen, although she listed three localities from which the new species was observed: Marceau, Tliouanet, and Djebel Bou Ziri. Its presence in Miocene strata at these sites is undoubtedly due to reworking, or an unrecognized mode of contamination. All available records indicate that *T. pyramidus* is restricted to the Upper Cretaceous.

Tetralithus pyramidus has been reported from subsurface Cenomanian strata of Sweden (Forchheimer, 1968); Turonian strata of the Dnieper-Don Basins, U.S.S.R. (Lyul'eva, 1967); Santonian of eastern Switzerland (Thierstein, 1971a); Santonian and Campanian of France (Manivit, 1971); Campanian and Maastrichtian strata along the northern slope of the Ukrainian Carpathians, U.S.S.R. (Grigorovich, 1971); middle(?) Campanian chalk near Meudon, France (Bukry, 1969); Campanian part of the Ladd Formation, Orange County, Calif. (Totten, 1974); Jetmore Chalk and Pfeifer Shale Members of the Greenhorn Limestone and lower part of the Carlile Shale of Russell County, Kans., and from the upper part of the Tombigbee Sand Member of the Eutaw Formation, and lower part of the Mooreville Chalk of Dallas and Wilcox Counties, Ala. (Čepek and Hay, 1969; 1970); Demopolis Chalk of Lowndes County, Miss. (Newell, 1968); and from the Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Mississippi (Risatti, 1973).

This species was observed throughout the upper Turonian and Coniacian samples that were studied during the present investigation. Its initial appearance in Turonian strata of Texas was not observed. Although *Tetralithus pyramidus* was not noted in samples from lower Santonian strata of Texas, it cannot be regarded as a reliable indicator of the Turonian and Coniacian Stages because it is known to occur in upper Santonian, Campanian, and (?)lower Maastrichtian sedimentary rocks of Alabama and Mississippi (Čepek and Hay, 1969; 1970; Newell, 1968; Risatti 1973).

Genus VAGALAPILLA Bukry 1969

Type species.—Vekshinella imbricata Gartner 1968.

Diagnosis.—Elliptical forms, in distal view, consisting of a single and rather broad distal rim cycle constructed of dextrally imbricate elements strongly clockwise inclined along the inner margin of the distal cycle. In proximal view, a narrow proximal cycle of radial or nearly radial, arranged elements surrounds the central area. The broad, open, elliptical central area is spanned by single or double crossbars alined with the major and minor axes of the opening. Distally, the crossbars may or may not support a central stem.

Remarks.—The morphological relationships between the genera *Ephippium* Vekshina 1959, *Staurolithites* Caratini 1963, *Vekshinella* Loeblich and Tappan 1963 emend. Gartner 1968, and *Vagalapilla* Bukry 1969 have been previously discussed by Bukry (1969, p. 55) and Thierstein (1973, p. 37). Since the ultrastructure of the type species of *Staurolithites*, *S. laffittei* Caratini 1963, is not known, the restricted definition of *Vagalapilla* Bukry is used herein. As noted by Thierstein (1973, p. 37), future electron microscopy may prove *Vagalapilla* Bukry to be a junior synonyn of *Vekshinella* as emended by Gartner (1968) or *Staurolithites* Caratini 1963, or both.

Vagalapilla matalosa (Stover 1966) Thierstein 1973

Plate 14, figures 1–11, 12, 13.

1966. *Coccolithus matalosus* Stover, p. 139, pl. 2, figs. 1a–c, 2a–b; pl. 8, fig. 10.
1968. *Coccolithus matalosus* Stover 1966, Gartner, p. 18, pl. 24, figs. 5a–c.
1969. *Vagalapilla imbricata elongata* Bukry, p. 58, pl. 33, figs. 3–4.
1969. *Staurolithites matalosus* (Stover 1966), Čepek and Hay, p. 326, 331, text–fig. 2, no. 4, text–fig. 4, no. 5.
1969. *Staurolithites matalosus* (Stover 1966), Gartner in Cita and Gartner, pl. 7, fig. 3; text–fig. 6 (no pagination).
1971a. *Coccolithus matalosus* Stover 1966, Thierstein, p. 37, pl. 1, figs. 9–10.
1971. *Staurolithites matalosus* (Stover 1966), Manivit, p. 84, pl. 24, figs. 6–8, 9–10.
1972. *Deflandrius* cf. *D. stoveri* Perch-Nielsen 1968, Forchheimer, p. 46, pl. 6, figs. 10, 11.
1973. (?)*Staurolithites siggitus* Risatti, p. 20–21, pl. 6, figs. 14–15.
1973. *Vagalapilla matalosa* (Stover 1966), Thierstein, p. 37–38, pl. 3, figs. 15–17, 18.
1974. *Vagalapilla matalosa* (Stover 1966), Proto Decima, p. 591, pl. 3, figs. 23–25; pl. 7, (?)fig. 20; pl. 8, (?)fig. 1.
1976. *Vagalapilla matalosa* (Stover 1966), Hill, p. 159, pl. 12, figs. 7–9, 10–12, 13–15.
1978. *Vagalapilla matalosa* (Stover 1966), Proto Decima, Medizza, and Todesco, p. 603, pl. 15, fig. 7a–b.

Diagnosis.—Elliptical coccoliths with a distal rim cycle constructed of about 35 dextrally imbricate elements, which are slightly counterclockwise inclined toward the outer peripheral margin and become strongly clockwise inclined along the inner margin of the cycle. The open central area is spanned by four crossbars alined with the axes of the coccolith. Each crossbar consists of two parallel series of rectilinear elements joined along a distinct medial furrow.

Description.—Elliptical in outline consisting of a relatively broad distal cycle and somewhat narrower proximal cycle and a broad central area bisected by longitudinal and transverse crossbars. In distal view, the rim is constructed of about 35 dextrally imbricate elements that are slightly counterclockwise inclined, becoming sharply inclined clockwise along the inner margin of the rim cycle. The crossbars are alined with the major and minor axes of the elliptical central area. Each crossbar is relatively broad and consists of two parallel series of elements bisected by a longitudinal and medial furrow. The crossbars normally support a short and solid stem. The proximal cycle consists of 35 to 40 radially inclined, sinistrally imbricate, rectangular elements. The proximal surface of distal cycle elements is strongly counterclockwise inclined.

Transmitted light images show that this form consists of a rather broad and smooth rim cycle and open central area spanned by two crossbars alined with the axes of the ellipse. The crossbars become somewhat expanded where they appear to overlap onto the distal rim cycle. In cross-polarized light images, the rim cycle remains bright and is bisected by four interference-extinction lines, two at either end of the rim. The extinction lines curve dextrally in distal view and sinistrally in proximal view. When oriented with the long axis parallel to the vibration direction of either nicol, the double crossbars remain bright and are bisected by a dark, medial interference-extinction line.

Remarks.—Both Stover (1966) and Gartner (1968) figured this species from transmitted light micrographs. Studies conducted herein, based on the examination of the same specimen both by the scanning electron microscope and in transmitted light optics, indicate that *Vagalapilla imbricata elongata* Bukry properly belongs to *Vagalapilla matalosa*. *Vekshinella imbricata* Gartner 1968 differs from *V. matalosa* in having a more narrow rim cycle and much more narrow, single(s) crossbars. The two species are distinct and should not be confused in either electron or transmitted light micrographs.

Known range.—Albian through early Maastrichtian.

Type locality.—Lower Cenomanian light-gray marl near the base of Mt. Avrolet, north-central France.

Occurrence.—This species has been reported from Albian sedimentary rocks near St. Florentin, France (Stover, 1966); middle and upper Albian strata of northwestern Europe, the Atlantic, and Caribbean (Thierstein, 1973); middle and upper Albian cores from the eastern Indian Ocean (Proto Decima, 1974); upper Albian through lower Turonian strata of France (Manivit, 1971); Santonian strata of eastern Switzerland (Thierstein, 1971a); upper Campanian through lower Maastrichtian cores from Leg 2, Deep Sea Drilling Project, Site 10, along the western flank of the Mid-Atlantic Ridge, Cita and Gartner, 1971); upper part of the Niobrara Chalk, Knox County, Nebr. (Bukry, 1969); Graneros Shale, Greenhorn Limestone, and Carlile Shale of Russell County, Kans., and from the Tombigbee Sand Member of the Eutaw Formation, Mooreville Chalk, and lower part of the Demopolis Chalk of Dallas and Wilcox Counties, Ala. (Čepek and Hay, 1969); middle Albian through lower Cenomanian strata of Texas (Hill, 1976); and from the Eagle Ford Group and Austin Group of Dallas County, Tex. (Gartner, 1968; Bukry, 1969). During this study, *Vagalapilla matalosa* was observed in samples from the upper Turonian through Santonian strata at all localities that were investigated in Texas.

Genus WATZNAUERIA Reinhardt 1964

Synonyms.—*Colvillea* Black 1964, *Maslovella* Loeblich and Tappan 1966, *Ellipsagelosphaera* Noël 1965, *Actinosphaera* Noël 1965, *Calolithus* Noël 1965.

Type species.—*Tremalithus barnesae* Black 1959.

Diagnosis.—Placoliths generally elliptical in outer peripheral outline and consisting of two closely appressed shields. The distal shield is composed of two cycles of nonradial elements. The smaller proximal shield consists of a single cycle of radial-, or nearly radial-, arranged elements. The small central area may be open, or partially or completely closed by regularly or irregularly shaped elements.

Watznaueria barnesae (Black 1959) Perch-Nielsen 1968

Plate 14, figures 14, 15, 16–24, 25, 26, 27–35

1959. *Tremalithus barnesae* Black in Black and Barnes, p. 325, pl. 9, figs. 1, 2.
1964. *Colvillea barnesae* (Black 1959), Black, p. 311.
1964. *Colvillea barnesae* (Black 1959), Black in Black, Hill, Laughton, and Matthews, p. 504, pl. 43, fig. f.
1964. *Coccolithus* cf. *C. barnesae* (Black 1959), Bramlette and Martini, p. 298, pl. 1, figs. 13–14.
1964. Not *Tergestiella barnesae* (Black 1959), Reinhardt, p. 753.
1964. *Watznaueria angustoralis* Reinhardt, p. 753, pl. 2, fig. 2; text–figs. 4a–b.
1965. *Colvillea barnesae* (Black 1959), Black, p. 132, fig. 2.
1965. *Ellipsagelosphaera frequens* Noël, p. 8, pl. 11, figs. 7–10; pl. 12, figs. 1–10; text–figs. 3, 8.
1966. (?)*Coccolithus* aff. *sarsiae* Black 1962, Cohen, p. 12, pl. 13, figs. c, d.
1966a. *Tergestiella barnesae* (Black 1959), Reinhardt, p. 15–16, pl. 2, fig. 1; pl. 12, fig. 2; pl. 23, fig. 6; *not* pl. 1, figs. 1, 2; *not* text–figs. 2a–c.
1966a. *Watznaueria angustoralis* Reinhardt 1964, Reinhardt, p. 16–17, pl. 2, fig. 2; pl. 3, figs. 1–3; pl. 23, fig. 4; text–figs. 5a–b.
1966b. *Watznaueria angustoralis* Reinhardt 1964, Reinhardt, p. 522–523, pl. 1, figs. 9, 12; text–figs. 3, 8.
1966. *Coccolithus paenepelagicus* Stover, p. 139–140, pl. 1, figs. 10a–b, 11; pl. 3, fig. 22b(B); pl. 8, fig. 5.
1966. *Maslovella barnesae* (Black 1959), Tappan and Loeblich, p. 43.
1967. *Ellipsagelosphaera frequens* Noël 1965, Lezaud, p. 16, pl. 1, fig. 12.
1967. *Coccolithus* cf. *barnesae* (Black 1959), Vangerow and Schloemer, p. 456, table 1, fig. 3.
1968. *Ellipsagelosphaera* sp. Black, p. 797, pl. 143, figs. 5, 6.

1968. *Watznaueria* cf. *angustoralis* Reinhardt 1964, Forchheimer, p. 30, pl. 2, figs. 7a–7b; fig. 3, no. 6; text-fig. 10.

1968. *Colvillea* cf. *barnesae* (Black 1959), Forchheimer, p. 34, fig. 3, no. 14, (?)15; text-figs. 12, 13; *not* pl. 7, figs. 4a–b.

1968. *Coccolithus barnesae* (Black 1959), Gartner, p. 17, pl. 1, fig. 12; pl. 4, figs. 6, 7; pl. 8, figs. 18, 19, 20, 21, 22; pl. 11, figs. 11a–c; pl. 14, figs. 4, 5; pl. 15, figs. 8a–d; pl. 16, figs. 15, 16; pl. 19, figs. 12a–d; pl. 20, figs. 12, 13; pl. 22, figs. 16, 17; pl. 24, figs. 8a–d; pl. 25, figs. 1, 2.

1968. *Watznaueria angustoralis* Reinhardt 1964, Locker, p. 225, pl. 2, fig. 17.

1968. *Watznaueria barnesae* (Black 1959), Perch-Nielsen, p. 69–70, pl. 22, figs. 1, 2, 3, 4, 5–7; pl. 23, figs. 1, 4, 5, 16; text-figs. 32, 33a–b.

1968. *Coccolithus barnesae* (Black 1959), Stradner in Stradner, Adamiker, and Maresch, p. 24–25, pl. 1; pl. 2, figs. 1, 2, 3, 4, 5; text-fig. 2.

1969. *Watznaueria barnesae* (Black 1959), Bukry, p. 31–32, pl. 10, figs. 1–7.

1970. *Coccolithus* cf. *barnesae* (Black 1959), Forchheimer, p. 17–22, figs. 3, 4, 14–22, 42, 43.

1970a. *Watznaueria barnesae* (Black 1959), Hoffmann, p.861, pl. 5, fig. 5; pl. 6, fig. 1.

1970. *Watznaueria* aff. *W. barnesae* (Black 1959), Noël, p. 92–93, pl. 34, figs. 2a–b; pl. 35, figs. 1–11.

1971a. *Ellipsagelosphaera frequens* Noël 1965, Black, p. 616, pl. 45.1, figs. 8, 9.

1971. *Watznaueria barnesae* (Black 1959), Hoffmann and Vetter, p. 1179–1180, pl. 5, figs. 1–6; pl. 6, figs. 1–4; text-figs. 2, 3.

1971. *Watznaueria barnesae* (Black 1959), Manivit, p. 113–114, pl. 28, figs. 1–2, 3–4, 8, 9, 12, 13.

1971. *Watznaueria barnesae* (Black 1959), Shafik and Stradner, p. 90, pl. 1, figs. 1–5.

1971a. *Watznaueria barnesae* (Black 1959), Thierstein, p. 39, pl. 2, figs. 21–22.

1972. *Watznaueria barnesae* (Black 1959), Grün and others, p. 154, pl. 26, figs. 1a–b, 2a–b, 3a–b, 4a–b, 5a–b.

1972a. *Watznaueria barnesae* (Black 1959), Hoffmann, p. 64–66, pl. 11, fig. 6; pl. 18, figs. 1, 2, 3; text-figs. 28, 29.

1972. *Watznaueria barnesae* (Black 1959), Iaccarino and Rio, p. 657, pl. 71, figs. 18a–b; pl. 72, (?)fig. 5, (?)fig. 6.

1972. *Watznaueria barnesae* (Black 1959), Lauer, p. 154, pl. 26, figs. 1a–b, 2a–b, 3a–b, 4a–b, 5a–b.

1972. *Watznaueria paenepelagica* (Stover 1966), Lauer, p. 155, pl. 26, figs. 8a–b.

1972. *Watznaueria barnesae* (Black 1959), Locker, p. 763–764, pl. 6, figs. 1, 2.

1972. *Watznaueria barnesae* (Black 1959), Stradner, p. 1199, pl. 48, fig. 9; pl. 49, figs 1, 2; pl. 50, figs. 1, (?)2, (?)3.

1972. *Watznaueria barnesae* (Black 1959), Wilcoxon, p. 432, pl. 1, figs. 6, 7; table 1.

1973. *Watznaueria barnesae* (Black 1959), Black, p. 82, pl. 24, fig. 7; text-figs. 40, 41.

1973. *Coccolithus barnesae* (Black 1959), El-Dawoody and Barakat, p. 107–108, pl. 10, figs. 2a–b.

1973. *Watznaueria barnese* (Black 1959), Priewalder (error for *barnesae*), p. 27, pl. 14, figs. 3, 4, 5, (?)6.

1973. *Watznaueria barnesae* (Black 1959), Risatti, p. 26, pl. 3, figs. 6, 7, 8, 9.

1973. *Watznaueria barnesae* (Black 1959), Roth, p. 718, 723, pl. 19, fig. 2; pl. 20, fig. 3; pl. 26, figs. 4a–c.

1974. *Watznaueria barnesae* (Black 1959), Proto Decima, p. 591, pl. 4, fig. 27; pl. 7, fig. 1.

1975. *Watznaueria barnesae* (Black 1959), Čepek, p. 93–94, pl. 2, figs. 4a–b.

1975. *Watznaueria barnesae* (Black 1959), Grün and Allemann, p. 162–164, pl. 2, fig. 10; text-figs. 8a–c.

1975. *Watznaueria barnesae* (Black 1959), Hill, p. 232, pl. 2, figs. 1, 7.

1975. *Watznaueria barnesae* (Black 1959), Jafar, pl. 13, fig. 1.

1976. *Watznaueria barnesae* (Black 1959), Burns, p. 298, pl. 5, figs. 4, 5, 6, 7, 8, *not* pl. 5, fig. 3.

1976. *Coccolithus barnesae* (Black 1959), El-Dawoody and Zidan, p. 411, pl. 2, figs. 5a–b, 6a–b.

1976. *Watznaueria barnesae* (Black 1959), Hill, p. 159–160, pl. 12, figs. 16, 17–18; pl. 15, figs. 21, 22, 23, 24.

1976. *Watznaueria barnesae* (Black 1959), Keupp, p. 373, fig. 1.

1976. *Watznaueria barnesae* (Black 1959), Martini, p. 396, pl. 1, figs. 6, 7.

1976. *Watznaueria barnesae* (Black 1959), Shumenko, p. 24–25, pl. 1, figs. 1, 2, 3, 4, 5, 6; pl. 2, figs. 1, 2.

1977. *Watznaueria barnesae* (Black 1959), Gašpariková, p. 165–166, pl. 78, fig. 6; pl. 79, figs. 1, 2, 3, 4.

1977. *Watznaueria barnesae* (Black 1959), Pravšič, p. 40, pl. 3, figs. 10, 11, 12, 13, 14, 15, 16.

1978. *Watznaueria barnesae* (Black 1959), Proto Decima, Medizza, and Todesco, p. 603, pl. 16, figs. 8a–b.

1978. *Watznaueria barnesae* (Black 1959), Shafik, p. 223, fig. 6, Aa–Aȧ.

1980. *Watznaueria barnesae* (Black 1959), Siesser, p. 826, pl. 1, fig. 7, 8; pl. 5, fig. 5.

Diagnosis.—Circular to elliptical placoliths that have an outer distal rim cycle composed of numerous elements that are dextrally imbricate and counterclockwise inclined. The inner distal rim cycle is constructed of dextrally imbricate elements which are very slightly clockwise inclined. This inner cycle may be raised, depressed, or at the same level as the outer distal cycle. The central area may be closed or possess a small, circular, to elliptical opening. Elements of the large proximal shield terminate in triangular points, resulting in a distinctive serrate outer peripheral margin.

Description.—Scanning electron micrographs show that in distal view the first, or outermost, cycle of elements is dextrally imbricate and counterclockwise inclined. The second cycle is also dextrally imbricate, but the sutures are nearly radial to slightly inclined clockwise. Distally, the central area may be completely closed, or may possess a small circular to subcircular or broadly elliptical opening. In proximal view, the large proximal shield is only slightly smaller than the diameter of the distal shield. The proximal shield is broadly and distinctly concave, and is composed of a single cycle of elements with radial or slightly counterclockwise inclination. The outer ends of elements in the proximal shield are bluntly pointed, being somewhat recessed at the interelement sutures, resulting in a distinctly serrate outer peripheral margin. Interelement sutures of the distal shield, although almost entirely concealed by the proximal shield, appear to be radially to slightly counterclockwise inclined. In proximal view, the central opening, although generally obscured, appears to be completely closed or reduced to a small circular to irregularly shaped opening.

Watznaueria barnesae has moderate to strong birefringence in plane transmitted and phase contrast light, although it is most easily recognized because of its distinctive appearance in cross-polarized light. The orientation of the optical axis of calcite is parallel to the long axis of elements in both the distal and proximal cycles. The dark lines of the interference-extinction figures are sharp, narrow, and straight in the central area because of the nearly radial arrangement of inner cycle elements. Extinction lines in the outer cycle become progressively wider and more uneven toward the outer periphery owing to the wider and more strongly inclined outer distal cycle elements. The curvature of extinction lines is sinistral in distal view and dextral in proximal view.

Remarks.—Bukry (1969) described eight new species of *Watznaueria* on the basis of differences observed in transmission electron micrographs. Although each of the new species appears distinct in electron images, none were illustrated by transmitted light photomicrographs. As no images of Bukry's new species were produced by the scanning electron microscope during this investigation, the stratigraphic value of the various species is uncertain where transmitted light microscope is used to detect these species.

Known range.—Oxfordian or Kimmeridgian through Maastrichtian.

Type locality.—Turonian chalk from near Weston Colville, Cambridgeshire, England .

Occurrence.—*Watznaueria barnesae* has a well-documented worldwide occurrence throughout the Upper Cretaceous. Bukry (1969) recorded its presence in the type lower Albian near Dienville, France, and Wilcoxon (1972, table 1) recently extended its initial appearance into the Upper Jurassic. It dominated the nannoplankton floras of all samples studied during this investigation.

Genus ZYGODISCUS Bramlette and Sullivan 1961, emended

Type species.—*Zygodiscus adamas* Bramlette and Sullivan 1961.

Emended description.—Elliptical forms with one or more rim cycles and a central area transversely bisected by either a single or a double crossbar, or partially or completely filled by large polygonal elements, with or without a central stem.

Remarks.—The emended definition of *Zygodiscus* is admittedly broad and is intended to include forms previously assigned to *Zygolithus* Kamptner ex. Matthes 1956, *Zygodiscus* Bramlette and Sullivan 1961, *Glaukolithus* Reinhardt 1964, *Zeugrahabdotus* Reinhardt 1965, *Tranolithus* Stover 1966, *Placozygus* Hoffmann 1970, and *Zygostephanos* Hoffmann 1970.

This study does not include the exhaustive reexamination of these genera. To do so would require the complete abandonment of certain genera, or a redefinition or emendation adding little other than an additional contribution to an existing chaotic taxonomy. The emphasis here is placed on gross morphology, which can be observed in both electron and light optical images.

Zygodiscus acanthus (Reinhardt 1965) Reinhardt 1966

Plate 14, figures 36–38, 39–44; plate 15, figures 1, 2–7

1965. *Zeugrahabdotus acanthus* Reinhardt, p. 37, pl. 3, fig. 1.
1966a. *Zygodiscus acanthus* (Reinhardt 1965), Reinhardt, p. 40, pl. 15, figs. 5; pl. 23, fig. 8.
1968. *Zygodiscus acanthus* (Reinhardt 1965), Perch-Nielsen, p. 88–89, pl. 29, figs. 3–6.
1969. *Zygodiscus acanthus* (Reinhardt 1965), Bukry, p. 58, pl. 33, figs. 8, 9.
1971. *Zygodiscus acanthus* (Reinhardt 1965), Shafik and Stradner, p. 90, pl. 36, figs. 1–4.
1972. *Zygodiscus compactus* Bukry 1969, Forchheimer, p. 66–67, pl. 26, (?) fig. 2; *not* pl. 26, figs. 1, 3, 4.
1972. *Zygodiscus inclinatus* Forchheimer, p. 68–69, pl. 3, fig. 6, 7.

Diagnosis.—Elliptical coccoliths consisting of a narrow rim, a narrow double crossbar, and two large circular openings dominating the central area. In distal view, the outer rim cycle consists of 30 to 40 dextrally imbricate and radially arranged elements, and the inner cycle consists of an equal number of dextrally imbricate elements that are very strongly clockwise inclined.

Description.—This form consists of a narrow rim and large central area bisected by a relatively narrow double crossbar. In distal view, the rim consists of an outer rim cycle constructed of 30 to 40 dextrally imbricate and radial elements and an inner rim cycle composed of 30 to 40 dextrally imbricate elements with strong clockwise inclination. The narrow arched crossbar consists of two complexly constructed parts, which may support a narrow solid stem. The central area is dominated by two large subcircular openings along either side of the crossbar. In proximal view, the outer rim cycle elements, continuous with the outer distal cycle, are very strongly curved counterclockwise. An inner rim cycle, continuous with the inner distal cycle, is constructed of 30 to 40 somewhat wedge-shaped, dextrally imbricate and radial elements.

Transmitted light and phase contrast images have a narrow dark outer rim and bright inner rim. The crossbar is distinct, although it appears to be constructed of a single series of elements. In cross-polarized light, the rim is bright in all orientations and has a thin, distinct, dark interference-extinction line marking the contact between the two cycles of elements. When oriented with the longitudinal axis parallel to either nicol, two indistinct interference lines radially bisect the rim at either end of the ellipse. They appear to be offset sinistrally when viewed distally.

Known range.—Albian through Maastrichtian.

Type locality.—Lower Maastrichtian strata near Sassnitz, Germany.

Occurrence.—*Zygodiscus acanthus* has been reported from Albian, Turonian, and Maastrichtian strata of Germany (Reinhardt, 1966a); middle(?) Campanian chalk near Meudon, France, middle Campanian Aachen Marl near Aachen, Germany, and from the Maastrichtian Kjolby Gaard Marl of Denmark (Bukry, 1969); lower Maastrichtian of Mons Klint, Denmark (Perch-Nielsen, 1968); Maastrichtian from the subsurface of the Dnjepr-Donetz Region, U.S.S.R. (Shafik and Stradner, 1971); and from the lower part of the Austin Group of Dallas County, Tex. (Bukry, 1969). This species was observed, although somewhat rarely, from throughout the upper Turonian through lower Santonian part of the Eagle Ford Group and Austin Group of Texas.

Zygodiscus sp. cf. Z. biclavatus Bukry 1969

Plate 15, figures 8–14

1968. *Zygodiscus biperforatus* Gartner (part), p. 31–32, pl. 18, fig. 20.
1969. *Zygodiscus biclavatus* Bukry, p. 58, pl. 33, figs. 10, 11.

Remarks.—*Zygodiscus biclavatus* was not previously figured by transmitted light micrographs. A single individual questionably assigned to this species was observed under the scanning electron microscope. Although the rim structure appears similar to *Z. biclavatus*, the "L-shaped" bars within the central area are only poorly defined, and the specimen apparently lacks the central stem noted to be present in this species. Transmitted and cross-polarized light images of the same specimen observed in the scanning electron microscope could be easily confused with either *Z. elegans* Gartner or *Z. orionatus* (Reinhardt). The nature and distinctive characteristics of light optical images, if any, of *Z. biclavatus* must await future electron and light optical examinations of this species.

Known range.—Late Turonian (?) through middle Santonian.

Type locality.—Dessau Formation of the Austin Group exposed in a stream cut along Walnut Creek just north of the bridge of U.S. Highway 290, Austin, Travis County, Tex.

Occurrence.—Bukry (1969a) reported this species only from strata within its type locality. It was figured by Gartner (1068) as *Z. biperforatus* from the upper part of the Austin Group of Dallas County, Tex. During this study, the form questionably assigned herein was observed in only a single sample from the Langtry Member of the Boquillas Formation, upper Turonian, exposed along Pinto Creek, Kinney County, Tex.

Zygodiscus compactus Bukry 1969

Plate 15, figures 15–21, 22–34

1969. *Zygodiscus compactus* Bukry, p. 59, pl. 34, figs. 1, 2.
1970. *Zygolithus compactus* (Bukry 1969), Noël, p. 26–28, pl. 2, figs. 2–8; pl. 3, figs. 1–3; text–figs. 2, 3.
1971a. *Glaukolithus diplogrammus* (Deflandre 1954), Thierstein, p. 35, pl. 2, figs. 23–24.
1972. *Zygodiscus compactus* Bukry 1969, Forchheimer, p. 66–67, pl. 26, figs. 1, (?)2, 3, 4.
1975a. *Zygodiscus compactus* Bukry 1969, Smith, p. 44, pl. 1, figs. 23–35.

Diagnosis.—Elliptical coccoliths that have a rather broad rim constructed of a single cycle of 20 to 35 dextrally imbricate elements. Distally, the interelement sutures are counterclockwise inclined, becoming very strongly clockwise inclined near the inner peripheral margin of the cycle. The elongate elliptical central area is largely filled by a very broad biserial crossbar.

Description.—The description of this species that is based on electron micrographs by Bukry (1969) is followed herein. Transmitted light and phase contrast images of *Zygodiscus compactus* show the characteristic broad rim cycle, smooth to somewhat serrate in outer peripheral outline. The rather narrow central area is bisected by a transverse crossbar constructed of two broad elements, which may entirely fill the central area, or reduce the central area to two small openings flanking the crossbar. Transmitted light images indicate that the crossbar partially overlaps and extends onto the distal surface of the rim cycle. Cross-polarized light images show somewhat spiraled or strongly curved interference-extinction lines within the rim, a result of the strong counterclockwise inclination of rim cycle elements as observed in proximal views of specimens photographed with the electron microscope. The two broad crossbar elements are bright when the longitudinal axis is oriented parallel to the vibration direction of either nicol.

Known range.—Late Turonian through middle Campanian.

Type locality.—Craie de Meudon (?), middle Campanian chalk exposed near Meudon, France.

Occurrence.—This species has been reported from the Santonian strata of eastern Switzerland (Thierstein, 1971a); Campanian strata of France (Noël, 1970); and from the middle Campanian Aachen Marl near Aachen, Germany (Bukry, 1969). Bukry (1969) reported this species from the Niobrara Chalk, Knox County, Nebr., Austin Group of Dallas and Ellis Counties, Tex., and from the Taylor Marl of Ellis County, Tex. Smith (1975a) recorded this species from the Coniacian part of the Atco Formation, Austin Group of Travis County, Tex. During this investigation, *Zygodiscus compactus* was observed in samples from the upper Turonian, Coniacian, and lower Santonian strata of all sampled localities.

Zygodiscus diplogrammus (Deflandre 1954) Gartner 1968

Plate 15, figures 35–41, 42–48, 49, 50–53

1954. *Zygolithus diplogrammus* Deflandre in Deflandre and Fert, p. 148, pl. 10, fig. 7; text–fig. 57.
1963. *Zygolithus diplogrammus* Deflandre 1954, Deflandre, p. 179, pl. 4, figs. 3–3a.
1964. *Zygolithus diplogrammus* Deflandre 1954, Bramlette and Martini, p. 304, pl. 4, figs. 11–12.
1964. *Zygolithus diplogrammus* Deflandre 1954, Stradner, p. 138, text–fig. 44.
1966a. *Glaukolithus* cf. *diplogrammus* (Deflandre 1954), Reinhardt, p. 41, pl. 15, figs. 6; pl. 23, figs. 25–28; text–fig. 15.
1966. *Tranolithus exiguus* Stover, p. 146, pl. 4, figs. 19, 20, 21a–c; pl. 9, figs. 3, 4.
1967. *Chiastozygus diplogrammus* (Deflandre 1954), Honjo and Minoura, pl. 50, figs. 3, 4.
1967. *Zygolithus diplogrammus* Deflandre 1954, Moshkovitz, p. 152, pl. 1, figs. 11, 12, 13.
1967. *Zygolithus diplogrammus* Deflandre 1954, Sales, p. 305, pl. 3, figs. 13a–b, 14a–b.
1967. *Zygolithus diplogrammus* Vangerow and Schloemer, p. 456, table 1, fig. 22.
1968. *Zygolithus diplogrammus* Deflandre 1954, Black, pl. 148, fig. 8.
1968. *Glaukolithus diplogrammus* (Deflandre 1954), Forchheimer, p. 50, pl. 5, figs. 1a–b; fig. 2, no. 14.
1968. *Zygodiscus diplogrammus* (Deflandre 1954), Gartner p. 32, pl. 14, fig. 18; pl. 17, figs. 4a–d; pl. 19, figs. 3a–d; pl. 21, figs. 2a–d; pl. 22, fig. 7; pl. 23, figs. 12, 13, 14; pl. 24, figs. 6a–d; pl. 25, figs. 17, (?) 18.
1969. *Zygodiscus deflandrei* Bukry, p. 59, pl. 34, figs. 3, 4, 5.
1969. *Glaukolithus diplogrammus* (Deflandre 1954), Čepek and Hay, p. 326, text–fig. 2, no. 9.
1970. *Zygolithus diplogrammus* Deflandre 1954, Čepek, p. 243, pl. 25, figs. 13, 14a–b.
1971. *Zygostephanos diplogrammus* (Deflandre 1954), Hoffmann and Vetter, p. 1174–1175, pl. 1, fig. 6; pl. 2, fig. 6; *not* pl. 1, fig. 5.
1971. *Glaukolithus diplogrammus* (Deflandre 1954), Manivit, p. 81, pl. 13, figs. 2–3, 4, 5–6, 7, 12–13, 14.
1971. *Tranolithus exiguus* Stover 1966, Manivit, p. 85, pl. 26, figs. 10, 11–12, 18.
1971. *Zygolithus* cf. *diplogrammus* Deflandre 1954, Shafik and Stradner, p. 92, pl. 35, fig. 4.
1972. *Tranolithus exiguus* Stover 1966, Forchheimer, p. 60–61, pl. 9, fig. 6; pl. 16, figs. 2, 4; pl. 17, figs. 1, 2, 3, 4.
1972. *Tranolithus skoglundii* Forchheimer, p. 61–62, pl. 17, figs. 5, 6.
1972a. *Zygostephanos diplogrammus* (Deflandre 1954), Hoffmann, p. 24–26, pl. 1, figs. 4, 5; text–figs. 11, 12.
1972. *Tranolithus exiquus* (sic!) Stover 1966, Lauer, p. 163–164, pl. 27, figs. 5a–b, 6a–b.
1972. *Tranolithus manifestus* Stover 1966, Lauer, p. 164, pl. 31, figs. 7a–b.
1972. *Zygodiscus deflandrei* Bukry 1969, Lauer, p. 162–163, pl. 28, figs. 4a–b, 5a–b.
1972. *Glaukolithus diplogrammus* (Deflandre 1954), Wilcoxon, p. 428, pl. 2, figs. 1, 2; table 1.
1973. *Glaukolithus diplogrammus* (Deflandre 1954), Risatti, p. 20, pl. 1, figs. 9–10; (?) pl. 9, figs. 14–15.
1973. *Zygodiscus diplogrammus* (Deflandre 1954), Thierstein, p. 36, pl. 3 fig. 19.
1974. *Zygodiscus deflandrei* Bukry 1969, Bukry, p. 356, fig. 5K.
1974. *Zygodiscus diplogrammus* (Deflandre 1954), Proto Decima, p. 591, pl. 4, figs. 6–7; pl. 7, fig. 15.
1974. *Tranolithus exiguus* Stover 1966, Totten, p. 83, pl. 1, fig. 21.
1975. *Zygodiscus diplogrammus* (Deflandre 1954), Krancer, p. 16, pl. 3, figs. 5, 6.
1975. *Zygodiscus deflandrei* Bukry 1969, Krancer, p. 16, pl. 3, fig. 4.
1976. *Glaukolithus diplogrammus* (Deflandre 1954), Burns, p. 289, pl. 3, fig. 9.
1976. *Zygodiscus diplogrammus* (Deflandre 1954), Hill, p. 161, pl. 12, figs. 25–27.
1978. *Zygodiscus diplogrammus* (Deflandre 1954), Shafik, p. 219, figs. 4, Ka–Kb.

Diagnosis.—Elliptical coccoliths consisting distally of a single cycle of dextrally imbricate elements that are counterclockwise inclined along the outer peripheral margin, becoming strongly clockwise inclined toward the inner margin of the cycle. The central area is spanned by a double crossbar that supports a rather large hollow stem. Two small perforations are present along the median line of the crossbar near its contact with the rim.

Remarks.—This species is characterized by its broadly elliptical form, narrow rim cycle, large central area, and relatively broad double crossbar surmounted by a hollow stem. Bukry (1969, p. 59) noted two small perforations on either side of the stem. These lateral pores lie along the median line of the double crossbar near its contact with the inner portion of the rim margin. The crossbar is constructed of four somewhat triangular elements, which are wide at the rim margin and taper to blunt points along either side of the central stem. The rest of the central area is occupied by large openings at either end of the elliptical central area. Bukry (1969, p. 59) noted that, in broken specimens, the central stem is removed, leaving a long transverse opening between two apparent crossbars. *Tranolithus exiguus* Stover appears to have been based on broken specimens, the central area being dominated by the four triangular projections of the crossbar. The individual figured by Shafik and Stradner (1971, pl. 35, fig. 4) also represents a broken specimen.

In transmitted light images, *Zygodiscus diplogrammus* differs from *Z. acanthus* (Reinhardt 1965) in lacking a distinct two-cycle rim and in possessing a double crossbar. It differs from *Z. theta* (Black 1959) in having a smooth peripheral outline, smaller openings in the central area, and a wide, distinctly double crossbar.

Known range.—Kimmeridgian through Maastrichtian.

Type locality.—Miocene (reworked) strata of Algeria.

Occurrence.—This species is well documented throughout Upper Cretaceous strata of Africa and Europe. Within Texas, it has been reported from the middle Albian through lower Cenomanian strata of Texas (Hill, 1976); Eagle Ford Group, Austin Group, and the Taylor Marl of Dallas and Ellis Counties (Gartner, 1968; Bukry, 1969). During this study, *Zygodiscus diplogrammus* was observed from the upper Turonian through lower Santonian part of the Eagle Ford Group and Austin Group throughout the area of investigation.

Zygodiscus elegans Gartner 1968

Plate 16, figures 7–13, 14, 15

1968. *Zygodiscus elegans* Gartner, p. 32, pl. 10, figs. 3, 4, 5, 6; pl. 12, figs. 3a–c, 4a–c; pl. 27, figs. 1a–b.

1968. *Zygodiscus sisyphus* Gartner, p. 34, pl. 14, fig. 19; pl. 18, figs. 17, 18, 19; pl. 21, figs. 6a–d; pl. 22, figs. 5, 6; pl. 23, figs. 17, 18; pl. 25, figs. 19, 20, 21, 22; pl. 26, figs. 6a–d.

1968. *Cretarhabdus* sp., Forchheimer, p. 28, pl. 3, figs. 3a–b; fig. 3, no. 10.

1969. *Zygodiscus elegans* Gartner 1968, Bukry, p. 59, pl. 34, figs. 6, 7, 8.

1969. *Zygodiscus sisyphus* Gartner 1968, Bukry, p. 61, pl. 36, figs. 3, 4.

1971. *Zygodiscus sisyphus* Gartner 1968, Shafik and Stradner, p. 90, pl. 34, figs. 1–4.

1972. *Zygodiscus sisyphus* Gartner 1968, Lauer, p. 161, pl. 28, figs. 1a–b, 2a–b.

1972. *Glaukolithus elegans* (Gartner 1968), Roth and Thierstein, pl. 10, figs. 16–20.

1974. *Zygodiscus elegans* Gartner 1968, Proto Decima, p. 591, pl. 4, (?)figs. 8–9; pl. 7, fig. 13.

1975. *Zygodiscus elegans* Gartner 1968, Hill, p. 232, pl. 2, fig. 9.

1978. *Zygodiscus elegans* Gartner 1968, Taylor, p. 199–200, pl. 6, figs. 13, 14.

Diagnosis.—Elliptical nannofossils having a rather broad rim distally constructed of a single cycle of dextrally imbricate elements. Interelement sutures are radial or slightly counterclockwise inclined, becoming sharply clockwise inclined toward the inner margin of the cycle. The outer peripheral margin of the rim may be either smooth or serrate. The elongate and open central area is spanned by a rather broad double crossbar, which distally may support a hollow or solid stem.

Remarks.—The descriptions given by Gartner (1968) and Bukry (1969) are followed herein. On the basis of the examination of numerous individuals by both scanning electron and transmitted light optics, *Zygodiscus sisyphus* Gartner is herein included in *Z. elegans* Gartner. Bukry (1969, p. 59, 61) noted that in the two forms "The general size and proportions of their crossbars stems, and rims overlap." Bukry (1969, p. 59, 61), however, emended the definition of *Z. elegans* to include only forms with a smooth peripheral outline and solid stem. *Zygodiscus sisyphus* was emended to include only forms with a serrate peripheral outline and a hollow stem. The emended definition of *Z. sisyphus* as outlined by Bukry is invalid because it excludes the holotype of the species (Gartner, 1968, pl. 25, fig. 22), a form with a smooth outline and a solid stem. Since a complete gradation exists between strongly serrate forms and those forms with a smooth peripheral outline, and the presence of a hollow or solid stem is at best of doubtful taxonomic significance, both forms are herein considered equal. On the basis of page priority of coequal species, *Zygodiscus sisyphus* is herein included in *Z. elegans* Gartner.

Zygodiscus elegans differs from *Z. compactus* Bukry in (1) having a more narrow rim, (2) lacking the distinctive "blocky" double crossbar characteristic of *Z. compactus,* and (3) having a narrow stem.

Known range.—Late Barremian through Maastrichtian.

Type locality.—Eagle Ford Shale exposed in a meander scar along the West Fork of the Trinity River, about 500 feet east of the intersection of Belt Line Road and the Dallas-Fort Worth Toll Road, Dallas County, Tex.

Occurrence.—This species has been reported from the upper Barremian through lower Aptian cores recovered during Leg 11, Deep Sea Drilling Project, site 105, western North Atlantic basin (Wilcoxon, 1972); upper Barremian and Aptian strata of Austria (Lauer, 1972); Cenomanian subsurface sedimentary rocks from southern Sweden (Forchheimer, 1968); type lower Albian and middle (?) Campanian chalk of France, and middle Campanian Aachen Marl of Aachen, Germany, (Bukry, 1969); and Maastrichtian sedimentary rocks from the subsurface of the Dnjepr-Donetz Region, U.S.S.R. (Shafik and Stradner, 1971).

Within North America, *Zygodiscus elegans* has been reported from the Niobrara Chalk, Knox County, Nebr. (Bukry, 1969); and from the Eagle Ford Group, Austin Group, and Taylor Marl of Dallas, Ellis, and Travis Counties, Tex. During the present investigation, this species was observed in samples from the upper Turonian through lower Santonian part of the Eagle Ford Group and Austin Group of Texas.

Zygodiscus fibuliformis (Reinhardt 1964) Bukry 1969

Plate 16, figures 16–24

1964. *Glaukolithus* (?) *fibuliformis* Reinhardt, p. 758, pl. 1, fig. 4.
1964. *Zygodiscus spiralis* Bramlette and Martini, p. 303, pl. 4, figs. 6–8.
1966a. *Glaukolithus fibuliformis* Reinhardt 1964, Reinhardt, p. 41, pl. 9, figs. 1–3; pl. 22, fig. 22.
1966. *Zygolithus stenopous* Stover, pl. 148, pl. 4, figs. 6a–b, 7a–b, 8, 9; pl. 8, fig. 25.
1966. *Zygolithus xenotus* Stover, p. 149, pl. 4, figs. 16a–b, 17a–c; pl. 9, fig. 2.
1968. *Glaukolithus fibuliformis* Reinhardt 1964, Forchheimer, p. 51, text-fig. 19.
1968. *Zygodiscus nanus* Gartner, p. 33, pl. 14, (?)fig. 17; pl. 18, figs. 12, 13, (?)14.
1968. *Zygodiscus spiralis* Bramlette and Martini 1964, Gartner, p. 35, pl. 5, figs. 21, 22; pl. 7, figs. 3a–c.
1968. *Zygodiscus spiralis* Bramlette and Martini 1964, Perch-Nielsen, p. 89, pl. 29, figs. 7–13.
1969. *Zygodiscus fibuliformis* (Reinhardt 1964), Bukry, p. 59–60, pl. 34, figs. 9, 10.
1970a. *Placozygus fibuliformis* (Reinhardt 1964), Hoffmann, p. 848, pl. 1, figs. 1, 2.
1971. *Placozygus fibuliformis* (Reinhardt 1964), Hoffmann and Vetter, p. 1175–1176, pl. 2, figs. 2, 3; pl. 3, figs. 1, 2.
1971. *Zygodiscus spiralis* Bramlette and Martini 1964, Manivit, p. 80–81, pl. 29, figs. 13–14.
1971. *Zygodiscus spiralis* Bramlette and Martini 1964, Shafik and Stradner, p. 90, pl. 33, figs. 1–4.
1972a. *Placozygus fibuliformis* (Reinhardt 1964), Hoffmann, p. 34, pl. 3, fig. 6; pl. 4, figs. 1, 2, 3.
1972. *Zygodiscus spiralis* Bramlette and Martini 1964, Lauer, p. 160, pl. 27, figs. 10a–b, 11a–b, 12a–b.
1973. *Zygodiscus spiralis* Bramlette and Martini 1964, Priewalder, p. 27, figs. (?)3, (?)4, 5, 6.
1973. *Zygodiscus nanus* Gartner 1968, Risatti, p. 21, pl. 9, fig. 20.
1973. *Zygodiscus xenotus* (Stover 1966), Risatti, p. 22, pl. 7, figs. 1–2.
1974. *Zygodiscus fibuliformis* Bramlette and Martini 1964, Müller, p. 589, pl. 18, fig. 5.
1978. *Zygodiscus spiralis* Bramlette and Martini 1964, Shafik, p. 219, fig. 4, Ia–Ib, Ja–Jb

Diagnosis.—Elliptical forms that distally have a single cycle of dextrally imbricate elements and radial sutures. The central area is transversely spanned by a broad double crossbar, reducing the area to two rather small, semicircular openings along either side of the bar. In proximal view, a second cycle of dextrally imbricate elements and radial sutures lines the central area.

Description.—Broadly elliptical in peripheral outline. The distal rim cycle is constructed of about 25 somewhat wedge-shaped, radially arranged, dextrally imbricate elements. The complex, slightly arched crossbar is constructed of elongate rods or rectangular blocks of calcite, and may support a short solid stem. In proximal view, a second cycle of elements is present. This proximal ring is attached to the distal cycle and is constructed of about 35 radially arranged and dextrally imbricate elements. In proximal view, a medial groove bisects the transverse crossbar.

Transmitted light images show the rather broad rim, transverse crossbar, and two small semicircular openings within the central area at either side of the crossbar. In cross-polarized light, three or four narrow, strongly curved, interference-extinction lines are spirally arranged within the bright rim cycle. The curvature of extinction lines is dextral when viewed distally.

Remarks.—*Zygodiscus fibuliformis* differs from *Z. compactus* Bukry in having (1) an inner cycle of elements in proximal view, (2) radial than strongly inclined sutures proximally, (3) crossbars that do not overlap onto the distal rim cycle, (4) strongly curved and somewhat spirally arranged rim-cycle interference-extinction lines, and (5) a less distinct double crossbar as observed in phase contrast or cross-polarized light.

Known range.—Albian through late Maastrichtian.

Type locality.—Lower Maastrichtian strata near Sassnitz, Germany.

Occurrence.—This species has been reported from Albian through Maastrichtian strata of France (Bramlette and Martini, 1964; Stover, 1966; Bukry, 1969); Albian strata of Austria (Lauer, 1972); Cenomanian strata from the subsurface of southern Sweden (Forchheimer, 1968); Turonian through Maastrichtian strata of Germany (Reinhardt, 1966a; Bukry, 1969; Hoffmann, 1970a, 1972; Hoffmann and Vetter, 1971); Maastrichtian cores from the western Indian Ocean (Müller, 1974); Maastrichtian chalks of Denmark and Holland (Perch-Nielsen, 1968; Bramlette and Martini, 1964); Maastrichtian strata of Egypt and the U.S.S.R. (Shafik and Stradner, 1971); Maastrichtian sedimentary rocks of France (Manivit, 1971); Maastrichtian strata of Tunisia (Bramlette and Martini, 1964); and lower Maastrichtian strata of Austria (Priewalder, 1973).

Within North America, *Zygodiscus fibuliformis* has been noted from the upper part of the Niobrara Chalk of Knox County, Nebr. (Bukry, 1969); Ripley Formation and Prairie Bluff Chalk of Alabama, and the Arkadelphia Marl of Arkansas (Bramlette and Martini, 1964); Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk of Mississippi (Risatti, 1973); and from the Austin Group, Taylor Marl, and Corsicana Marl of Texas (Gartner, 1968; Bukry, 1969). This species was reported as *Zygodiscus* aff. *Z. spiralis* from the Eutaw Formation, Mooreville Chalk, and Demopolis Chalk of Mississippi (Newell, 1968). During this study, *Z. fibuliformis* was observed, although rarely, throughout upper Turonian, Coniacian, and lower Santonian strata of Texas.

Zygodiscus orionatus (Reinhardt 1966), new combination

Plate 16, figures 25, 26, 27–33, 34–40

1966a. *Discolithus orionatus* Reinhardt, p. 42, pl. 23, figs. 22, 31–33.
1966. *Tranolithus phacelosus* Stover, p. 146–147, pl. 4, figs. 23a–b, 24, 25a–b; pl. 9, fig. 6.
1967. *Tranolithus phacelosus* Stover 1966, Sales, p. 305, pl. 3, figs. 16a–b.
1968. (?)*Discolithus* sp., Forchheimer, p. 44, pl. 9, figs. 6a–b; fig. 2, (?)no. 3.
1968. *Zygolithus phacelosus* (Stover 1966), Manivit, p. 280, pl. 1, figs. 12a–b; *not* pl. 1, figs. 13a–b. (Note that in explanation of plate 1, figs. 11 and 12 are reversed).
1968. *Tranolithus orionatus* (Reinhardt 1966), Perch-Nielsen, p. 35–36, pl. 4, figs. 15–19; text-fig. 9.
1969. *Zygodiscus phacelosus* (Stover 1966), Bukry, p. 61, pl. 35, fig. 12.
1970. *Tranolithus phacelosus* Stover 1966, Čepek, p. 243, pl. 23, figs. 7, 8a–c; pl. 26, fig. 8.
1970. *Tranolithus orionatus* (Reinhardt 1966), Noël, p. 44–45, pl. 9, figs. 4a–c, 6; pl. 10, figs. 5a–b; text-fig. 7.
1971. (?)*Zygostephanos diplogrammus* (Deflandre 1954), Hoffmann and Vetter, p. 1174–1175, pl. 1, fig. 5; *not* pl. 1, fig. 6; *not* pl. 2, fig. 6.
1971. *Tranolithus orionatus* (Reinhardt 1966), Manivit, p. 85–86, pl. 26, figs. 13, 14–15, 16–17.
1971a. *Tranolithus orionatus* (Reinhardt 1966), Thierstein, p. 35, pl. 4, figs. 69–70.
1972. *Zygodiscus phacellosus* (Stover 1966), Lauer (error for *phacelosus*), p. 162, pl. 27, figs. 7a–b.
1972. *Tranolithus orionatus* (Reinhardt 1966), Locker, p. 754, pl. 4, fig. 7.
1972. *Tranolithus orionatus* (Reinhardt 1966), Roth and Thierstein, pl. 10, figs. 11–15.
1973. *Tranolithus orionatus* (Reinhardt 1966), Thierstein, p. 38, pl. 4, figs. 12–15.
1974. *Tranolithus orionatus* (Reinhardt 1966), Totten, p. 23, pl. 1, figs. 10–11.
1975. *Tranolithus orionatus* (Reinhardt 1966), Hill, p. 232, pl. 2, fig. 3.
1976. *Tranolithus phacelosus* Stover 1966, Burns, p. 298, pl. 5, figs. 2, 3.
1976. *Tranolithus gabalus* Stover 1966, Hill, p. 156, pl. 11, figs. 36–39, 40–41; pl. 15, fig. 13.
1976. *Tranolithus orionatus* (Reinhardt 1966), Hill, p. 156–157, pl. 12, figs. 1–2; pl. 15, figs. 14, 15.
1977. *Tranolithus orionatus* (Reinhardt 1966), Pašvič, p. 37, pl. 1, figs. 10, 11.
1978. *Tranolithus orionatus* (Reinhardt 1966), Proto Decima, Medizza, and Todesco, p. 603, pl. 15, fig. 6.
1978. *Tranolithus exiguus* Stover 1966, Shafik, p. 225, fig. 7, Ba–Bb.
1978. *Tranolithus* sp., Shafik, p. 225, fig. 7, Ca–Cb.

Diagnosis.—Elliptical coccoliths distally consisting of a narrow rim constructed of 40 to 50 dextrally imbricate elements whose sutures are slightly counterclockwise inclined, becoming very strongly clockwise inclined near the inner peripheral margin of the cycle. The central area is occupied by four large rectangular blocks, which partially or completely fill the central opening.

Description.—This species is elliptical in peripheral outline and consists of a narrow rim cycle and large central area predominately filled by four large and irregularly shaped rectangular or square blocky elements. In distal view, the rim is constructed of a single cycle of 40 to 50 dextrally imbricate elements, which show slight counterclockwise inclination. Along the inner margin of the rim, the sutures are strongly clockwise inclined. The central area contains four large elements, one occupying each quadrant, which share a common boundary along the longitudinal axis of the central area. Two diagonally opposed elements are either smaller or larger than the remaining diagonal pair, which results in a transverse suture offset along the median line of the longitudinal axis. The large elements may completely fill the central area, or they may reduce the area to two small openings at either end along the inner margin of the rim. In proximal view, the rim consists of two distinct cycles. The outer cycle of elements, somewhat serrate in peripheral outline, are strongly inclined counterclockwise and represent the proximal continuation of the distal cycle elements. The narrow inner or proximal cycle elements lie on the proximal margin of the distal cycle and line the elliptical central opening. It consists of about 35 somewhat square-shaped elements with little or no imbrication and slight clockwise inclination.

In both transmitted light and phase contrast images, this species consists of a narrow rim cycle and broad central area filled with four irregularly shaped and blocky elements. The rim may be either distinct, or in plane transmitted light appear to be in complete optical continuity with the large central-area elements. The longitudinal sutures bisecting the central-area elements can normally be seen in plane transmitted light images. In cross-polarized light, the narrow rim cycle is somewhat indistinct owing to the presence of strongly curved and dark interference-extinction lines. The large blocky elements of the central area appear bright when the longitudinal axis of the elliptical form is oriented parallel to the plane of either nicol. When in this orientation, the contact margins between the four central-area elements appear as indistinct longitudinal and transverse extinction lines.

Remarks.—This species cannot be assigned to *Tranolithus* Stover 1966 because (1) the rim consists of two cycles rather than a single cycle of elements, and (2) the large central-area elements are in neither crystallographic nor optical continuity, as observed in cross-polarized light, with elements of the rim cycles. This species is distinct, however, in having large elements which may completely fill the central area.

Known range.—Middle Albian through late Maastrichtian.

Type locality.—Middle Albian sedimentary rocks from a bore hole near Parchim, Germany.

Occurrence.—*Zygodiscus orionatus* has been reported from middle and upper Albian strata of northwestern Europe, the Atlantic and Caribbean (Thierstein, 1973); upper Albian through upper Maastrichtian sedimentary rocks of France (Manivit, 1971); lower Cenomanian through lower Maastrichtian strata of northwestern Germany (Čepek, 1970); Albian through Turonian strata from the subsurface of western Africa (Sales, 1967); Albian strata of Austria (Lauer, 1972); Turonian near Pasewalk, Germany (Hoffmann and Vetter, 1971); Turonian through lower Campanian strata of France (Manivit, 1968); lower Santonian of eastern Switzerland (Thierstein, 1971a); Campanian of France (Noël, 1970); and lower Maastrichtian of Mons Klint, Denmark (Perch-Nielsen, 1968).

Bukry (1969) reported this species from the lower and middle part of the Austin Group of Travis and Dallas Counties, Tex. During the present investigation, this species was observed throughout the upper Turonian through lower Santonian part of the Eagle Ford Group and Austin Group of Texas.

Zygodiscus theta (Black 1959) Bukry 1969

Plate 16, figures 41–45

1959. *Discolithus theta* Black in Black and Barnes, p. 327, pl. 12, fig. 1.
1969. *Zygodiscus theta* (Black 1959), Bukry, p. 62, pl. 36, figs. 7, 8.
1971. *Zygodiscus theta* (Black 1959), Shafik and Stradner, p. 92, pl. 35, figs. 1, 2.
1972. *Zygodiscus theta* (Black 1959), Grün and others, p. 161, pl. 28, figs. 11a–b.
1972. *Zygodiscus erectus* (Deflandre 1954), Forchheimer, p. 67–68, pl. 26, figs. 5, 6.
1972. *Zygodiscus theta* (Black 1959), Lauer, p. 161, pl. 28, figs. 11a–b.
1974. *Zygodiscus theta* (Black 1959), Totten, p. 83, pl. 1, figs. 27–28.
1976a. *Zygodiscus theta* (Black 1959), Verbeek, p. 76–77, pl. 1, figs. 7a–b.
1978. *Zygodiscus* sp. cf. *Z. pseudoanthophorus Bramlette* and Martini 1964, Shafik, p. 225, fig. 7, Ea–Eb.
1978. Not *Zygodiscus theta* (Black 1959), Shafik, p. 225, fig. 7, Da–Db.

Diagnosis.—Large, elongate elliptical forms with a narrow rim distally constructed of a single cycle of dextrally imbricate elements with radially arranged sutures. The large, open, central area is spanned by a very narrow crossbar resulting in two large semicircular openings along either side of the crossbar.

Description.—This relatively large, elliptical species consists of a narrow rim and a large, elongate, central area bisected by a narrow crossbar. In distal view, the rim consists of a single cycle of dextrally imbricate elements. Sutures between adjacent elements are nearly radial or slightly inclined counterclockwise along the outer part of the cycle and are strongly inclined clockwise along the inner portion of the distal rim. The narrow distally arched crossbar appears to be constructed of a single group of elongate elements and may support a thin solid stem. In proximal view, the outer cycle of elements is strongly inclined counterclockwise. A second inner cycle of proximal elements, closely attached to the distal cycle, shows slight counterclockwise inclination with little or no imbrication.

In transmitted and phase contrast light, the rim appears to be constructed of a single cycle of elements. The narrow crossbar distinctly overlaps onto the inner margin of the rim cycle. In cross-polarized light, the rim appears bright with a narrow, strongly curved, interference-extinction line at either end of the rim.

Remarks.—*Zygodiscus theta* is distinguished by having a narrow rim and large central area bisected by a single crossbar. It differs from *Z. acanthus* (Reinhardt 1965) in having a single cycle distal rim and larger, more elongate central opening.

Known range.—Albian through Maastrichtian.

Type locality.—Burwell Rock from near Burwell, Cambridgeshire, England.

Occurrence.—This species has been reported from Albian strata of Austria (Lauer, 1972); Maastrichtian sedimentary rocks from the subsurface of the Dnjepr-Donetz Region, U.S.S.R. (Shafik and Stradner, 1971); lower and middle Campanian part of the Ladd Formation of Orange County, Calif. (Totten, 1974); and from the Austin Group of Dallas County, and Taylor Marl of Ellis County, Tex. (Bukry, 1969). It is present throughout the upper Turonian, Coniacian, and lower Santonian strata investigated during this study.

ALPHABETICAL INDEX TO NANNOFOSSIL GENERA AND SPECIES CONSIDERED IN SYSTEMATIC DESCRIPTIONS

(Rejected names in parenthesis)

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PLATES

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PLATE 1

[Length of bar=4 μm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–9. *Ahmuellerella octoradiata* (Gorka 1957) Reinhardt 1966
South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30797, USNM 218682). Views of proximal surface: 1–3, transmitted light; 4–6, phase contrast; and 7–9, cross-polarized light.

10–15. *Ahmuellerella octoradiata* (Gorka 1957) Reinhardt 1966
South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30797, USNM 218683). Views of proximal surface: 10–11, transmitted light; 12–13, phase contrast; and 14–15, cross-polarized light.

16–24. *Arkhangelskiella cymbiformis* Vekshina 1959
Atco Formation, Austin Group, early Santonian, Kinney County, Texas (USGS 30834, USNM 218684). Views of distal surface: 16–18, transmitted light; 19–21, phase contrast; and 22–24, cross-polarized light.

25–31. *Arkhangelskiella cymbiformis* Vekshina 1959
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218685). 25, scanning electron micrograph of proximal surface. Figures 26–31 are views of proximal surface of specimen shown in figure 25: 26, transmitted light; 27–29, phase contrast; and 30–31, cross-polarized light.

32–34. *Arkhangelskiella cymbiformis* Vekshina 1959
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218686). Views of distal surface: 32, transmitted light; 33, phase contrast; and 34, cross-polarized light.

35–40. *Biscutum blackii* Gartner 1968
South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30797, USNM 218687). Views of distal surface: 35–36, transmitted light; 37–38, phase contrast; and 39–40, cross-polarized light.

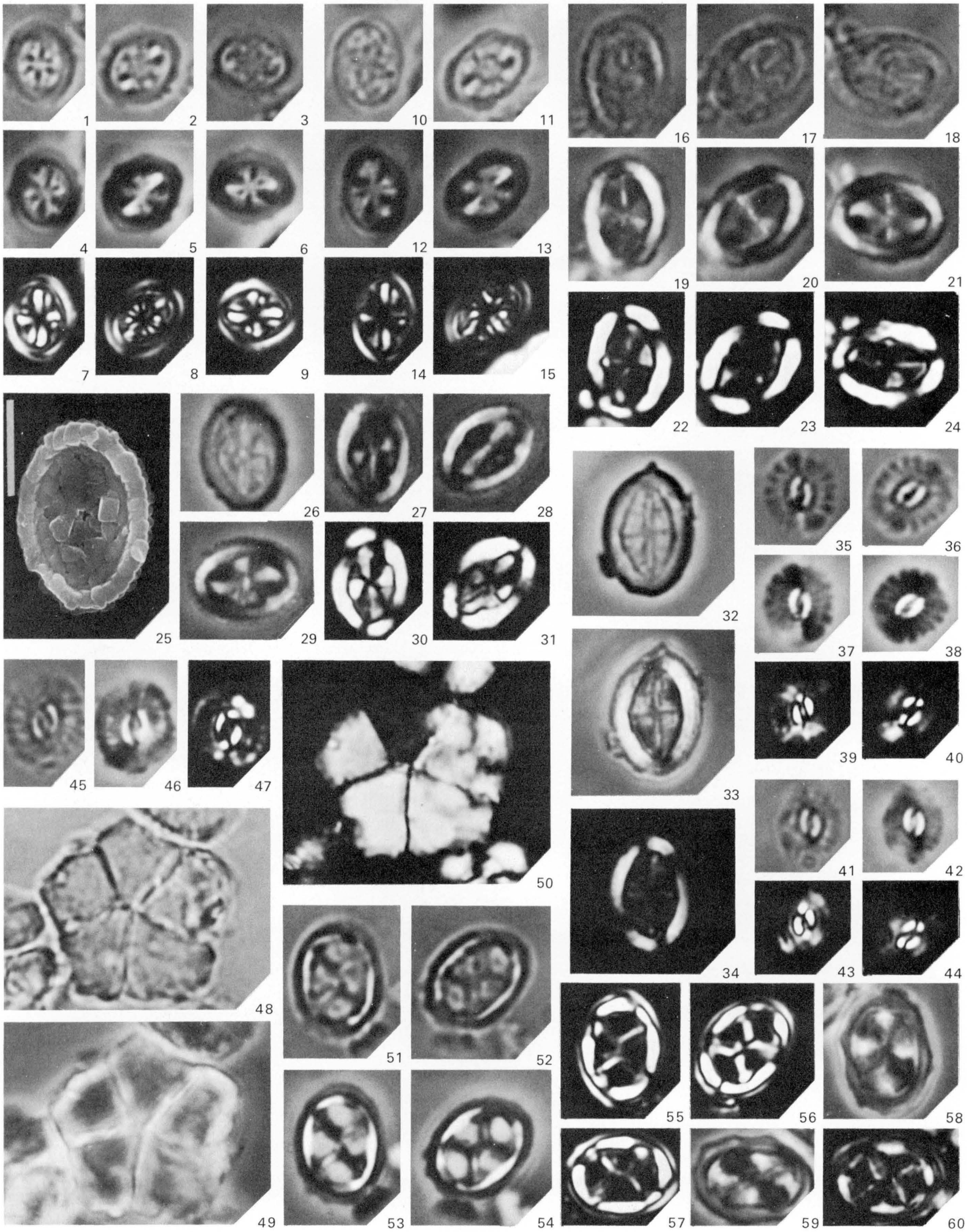
41–44. *Biscutum blackii* Gartner 1968
South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30796, USNM 218688). Views of distal surface: 41, transmitted light; 42, phase contrast; and 43–44, cross-polarized light.

45–47. *Biscutum blackii* Gartner 1968
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30778, USNM 218689). Views of proximal surface: 45, transmitted light; 46, phase contrast; and 47, cross-polarized light.

48–50. *Braarudosphaera bigelowii* (Gran and Braarud 1935) Deflandre 1947
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30778, USNM 218690). Views of distal surface of specimen: 48, transmitted light; 49, phase contrast; and 50, cross-polarized light.

51–57. *Chiastozygus cuneatus* (Lyul'eva 1967) Čepek and Hay 1969
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30782, USNM 218691). Views of proximal surface of specimen: 51–52, transmitted light; 53–54, phase contrast; and 55–57, cross-polarized light.

58–60. *Chiastozygus cuneatus* (Lyul'eva 1967) Čepek and Hay 1969
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30787, USNM 218692). Views of proximal surface of specimen: 58–59, phase contrast; and 60, cross-polarized light.



Ahmuellerella, *Arkhangelskiella*, *Biscutum*, *Braarudosphaera*, and *Chiastozygus*

PLATE 2

[Length of bar = 4 μm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–9. *Chiastozygus plicatus* Gartner 1968

South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30797, USNM 218693). 1, scanning electron micrograph of distal surface. Figures 2–9 are views of distal surface of specimen shown in figure 1: 2–4, transmitted light; 5–7, phase contrast; and 8–9, cross-polarized light.

10–12. *Chiastozygus plicatus* Gartner 1968

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30780, USNM 218694). Views of distal surface: 10, transmitted light; 11, phase contrast; and 12, cross-polarized light.

13–18. *Corollithion exiguum* Stradner 1961

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218695). 13, scanning electron micrograph of distal surface. Figures 14–18 are views of distal surface of specimen shown in figure 13: 14–15, transmitted light; 16–17, phase contrast; and 18, cross-polarized light.

19–21. *Corollithion exiguum* Stradner 1961

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30778, USNM 218696). Views of proximal surface of specimen: 19, transmitted light; 20, phase contrast; and 21, cross-polarized light.

22–24. *Corollithion signum* Stradner 1963

Atco Formation Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218697). Views of distal surface: 22, transmitted light; 23, phase contrast; and 24, cross-polarized light.

25–31. *Corollithion signum* Stradner 1963

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30783, USNM 218698). 25, scanning electron micrograph of distal surface. Figures 26–31 are views of distal surface of specimen shown in figure 25: 26–27, transmitted light; 28–29, phase contrast; and 30–31, cross-polarized light.

32–36. *Corollithion signum* Stradner 1963

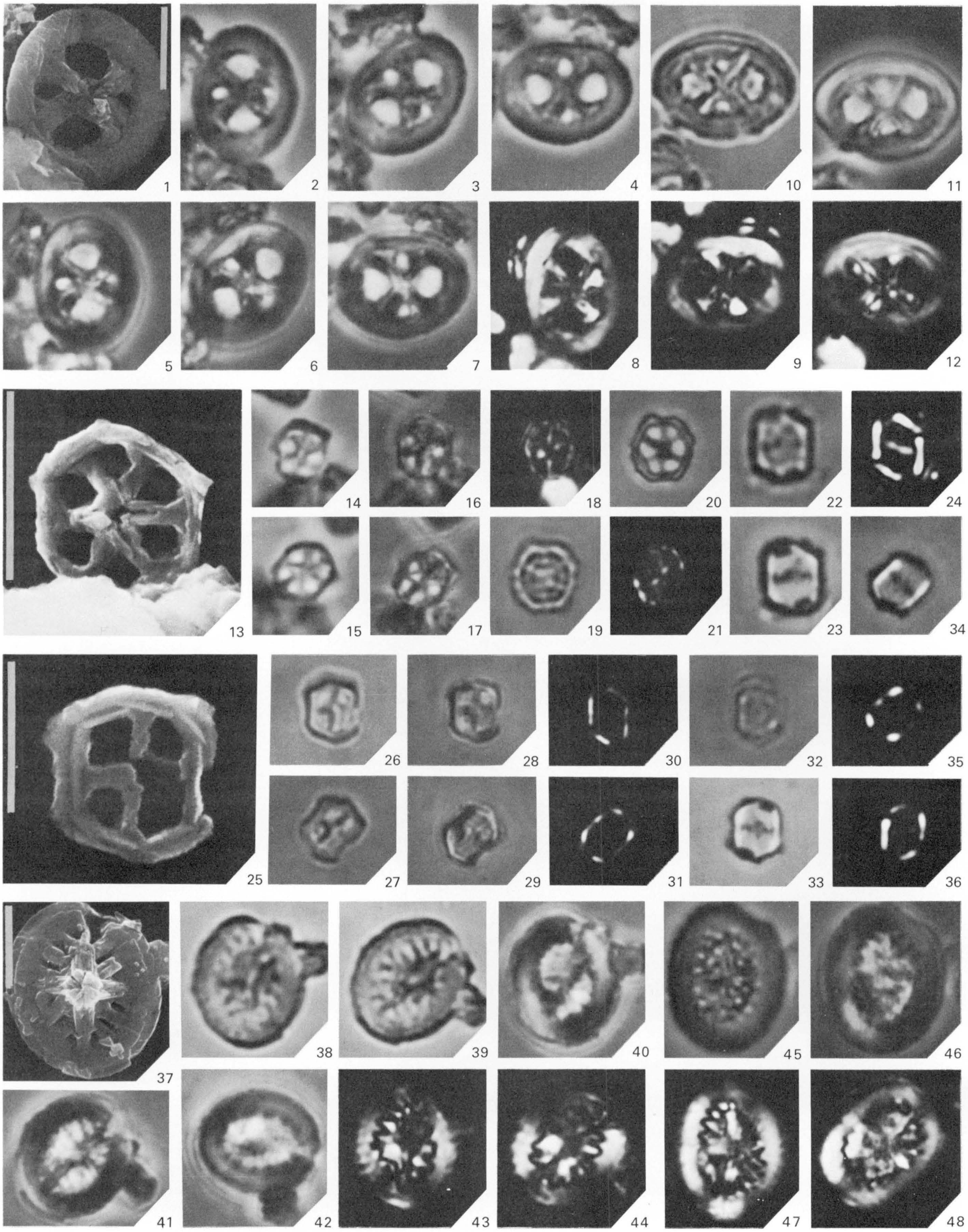
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30784, USNM 218699). Views of proximal surface: 32, transmitted light: 33–34, phase contrast; and 35–36, cross-polarized light.

37–44. *Cretarhabdus conicus* Bramlette and Martini 1964

Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30773, USNM 218700). 37, scanning electron micrograph of distal surface. Figures 38–44 are views of distal surface of specimen shown in figure 37: 38–39, transmitted light; 40–42, phase contrast; and 43–44, cross-polarized light.

45–48. *Cretarhabdus conicus* Bramlette and Martini 1964

Ector Chalk, Austin Group, early Santonian, Grayson County, Tex. (USGS 30775, USNM 218701). Views of proximal surface: 45, transmitted light; 46, phase contrast; and 47–48, cross-polarized light.



Chiastozygus, *Corollithion*, and *Cretarhabdus*

PLATE 3

[Length of bar=4 μm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–9. *Cretarhabdus conicus* Bramlette and Martini 1964

Langtry Member, Boquillas Formation, late Turonian, Kinney County, Tex. (USGS 30812, USNM 218702). 1, scanning electron micrograph of distal surface. Figures 2–9 are views of distal surface of specimen shown in figure 1: 2–3, transmitted light; 4–6, phase contrast; and 7–9, cross-polarized light. Note the narrow rim cycle and relatively large elliptical central area as compared with *C. crenulatus* (figs. 20–28).

10–15. *Cretarhabdus conicus* Bramlette and Martini 1964

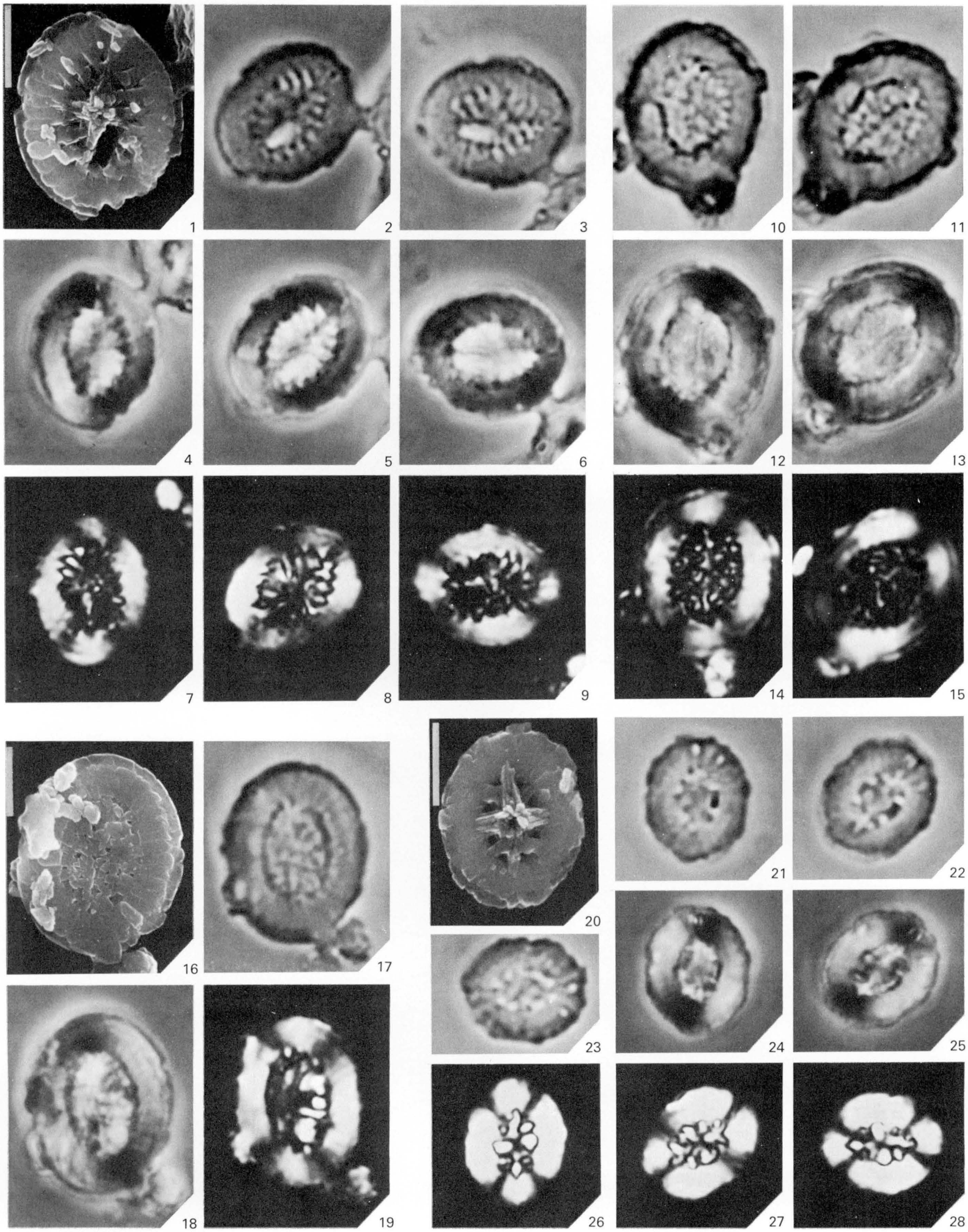
Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30773, USNM 218703). Views of proximal surface: 10–11, transmitted light; 12–13, phase contrast; and 14–15, cross-polarized light.

16–19. *Cretarhabdus conicus* Bramlette and Martini 1964

Atco Formation, Austin Group, Coniacian, Travis County, Tex. (USGS 30799, USNM 218704). 16, scanning electron micrograph of proximal surface. Figures 17–19 are views of proximal surface of specimen shown in figure 16: 17, transmitted light; 18, phase contrast; and 19, cross-polarized light. Note radial elements of the proximal cycle and randomly oriented elements of the central area.

20–28. *Cretarhabdus crenulatus* Bramlette and Martini 1964

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30782, USNM 218705). 20 scanning electron micrograph of distal surface. Figures 21–28 are views of proximal surface of specimen shown in figure 20: 21–23, transmitted light; 24–25, phase contrast; and 26–28, cross-polarized light. Note the relatively broad rim cycle and narrow elliptical central area as compared with *C. conicus.*



Cretarhabdus

PLATE 4

[Length of bar=4 μm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–9. *Cretarhabdus crenulatus* Bramlette and Martini 1964
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218706). 1, scanning electron micrograph of distal surface. Figures 2–9 are views of distal surface of specimen shown in figure 1: 2–4, phase contrast; 5–6, transmitted light; and 7–9, cross-polarized light.

10. *Cretarhabdus crenulatus* Bramlette and Martini 1964
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30825, USNM 218707). Scanning electron micrograph of proximal surface.

11–17. *Cretarhabdus crenulatus* Bramlette and Martini 1964
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218708). 11, scanning electron micrograph of proximal surface. Figures 12–17, views of proximal surface of specimen shown in figure 11: 12, transmitted light; 13–14, phase contrast; and 15–17, cross-polarized light.

18–27. *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912) Deflandre 1952
Atco Formation, Austin Group, early Santonian, Dallas County, Tex. (USGS 30783, USNM 218709). 18, scanning electron micrograph of distal surface. Figures 19–27 are views of distal surface of specimen shown in figure 18: 19–21, transmitted light; 22–24, phase contrast; and 25–27, cross-polarized light.

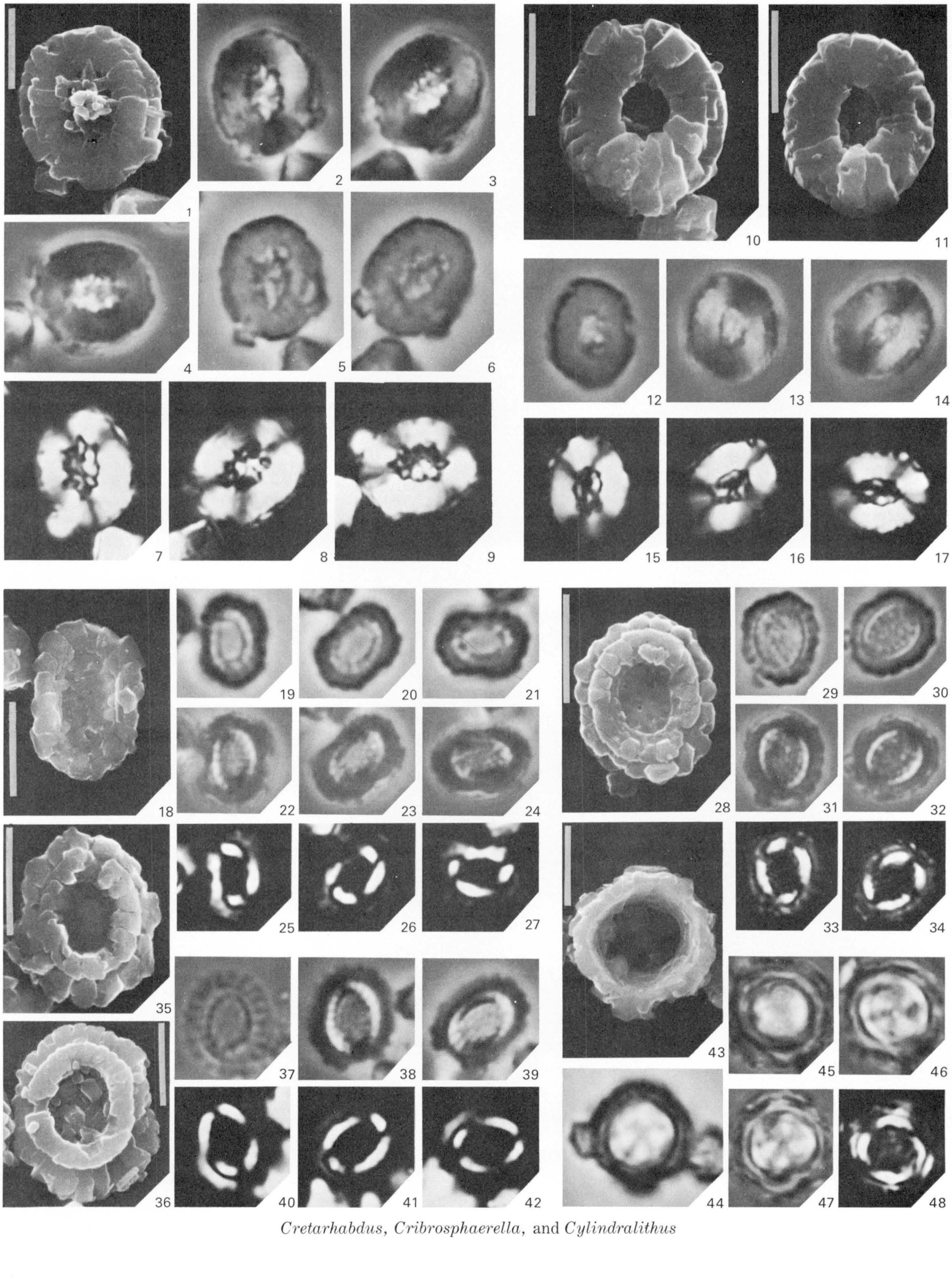
28–34. *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912) Deflandre 1952
Ector Chalk, Austin Group, early Santonian, Grayson County, Tex. (USGS 30775, USNM 218710). 28, scanning electron micrograph of proximal surface. Figures 29–34 are views of proximal surface of specimen shown in figure 28: 29–30, transmitted light; 31–32, phase contrast; and 33–34, cross-polarized light.

35. *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912) Deflandre 1952
Ector Chalk, Austin Group, early Santonian, Grayson County, Tex. (USGS 30775, USNM 218711). Scanning electron micrograph of proximal surface.

36. *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912) Deflandre 1952
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218712). Scanning electron micrograph of proximal surface.

37–42. *Cribrosphaerella ehrenbergii* (Arkhangelsky 1912) Deflandre 1952
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30818, USNM 218713); views of distal surface. 37, transmitted light; 38–39, phase contrast; and 40–42, cross-polarized light.

43–48. *Cylindralithus asymmetricus* Bukry 1969
Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30772, USNM 218714). 43, scanning electron micrograph of distal surface. Figures 44–48 are views of distal surface of specimen shown in figure 43: 44, transmitted light; 45–47, phase contrast; and 48, cross-polarized light. Note the X-shaped crossbars at the proximal end of the flaring cylinder. Note that the focal plane is at the distal end of the cylinder in figure 45, and at the proximal end in figures 46–47. Figures 45, 46, and 48 are rotated 45° clockwise with respect to the orientation in figures 43, 44, and 47.



Cretarhabdus, *Cribrosphaerella*, and *Cylindralithus*

PLATE 5

[Length of bar = 4 μm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–7. *Cylindralithus asymmetricus* Bukry 1969

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218715). 1, scanning electron micrograph of distal surface. Figures 2–7 are views of distal surface of specimen shown in figure 1: 2–3, transmitted light; 4–5, phase contrast; and 6–7, cross-polarized light. Note figures 3, 5, and 7 rotated 45° clockwise with respect to the orientation in figures 1, 2, 4, and 6.

8. *Cylindralithus asymmetricus* Bukry 1969

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218716). Scanning electron micrograph of distal surface.

9–17. *Cylindralithus asymmetricus* Bukry 1969

Langtry Member, Boquillas Formation, late Turonian, Kinney County, Tex. (USGS 30812, USNM 218717). 9, scanning electron micrograph of proximal surface. Figures 10–17 are views of proximal surface of specimen shown in figure 9: 10–11, transmitted light; 12–15, phase contrast; and 16–17, cross-polarized light. Note the plus-shaped crossbars spanning the proximal end of the flaring cylinder. Note the focal plane at the distal end of the cylinder in figure 12, and at the proximal end in figure 13. Fgures 11, 14, and 16 are rotated 45° clockwise, and figures 15 and 17 are rotated 90° clockwise with respect to the orientation shown in figures 9, 10, 12, and 13.

18–24. *Eiffellithus eximius* (Stover 1966) Perch-Nielsen 1968

Atco Formation, Austin Group, early Santonian, Dallas County, Tex. (USGS 30793, USNM 219718). 18, scanning electron micrograph of distal surface. Figures 19–24 are views of distal surface of specimen shown in figure 18: 19–21, phase contrast; 22, transmitted light; and 23–24, cross-polarized light.

25. *Eiffellithus eximius* (Stover 1966) Perch-Nielsen 1968

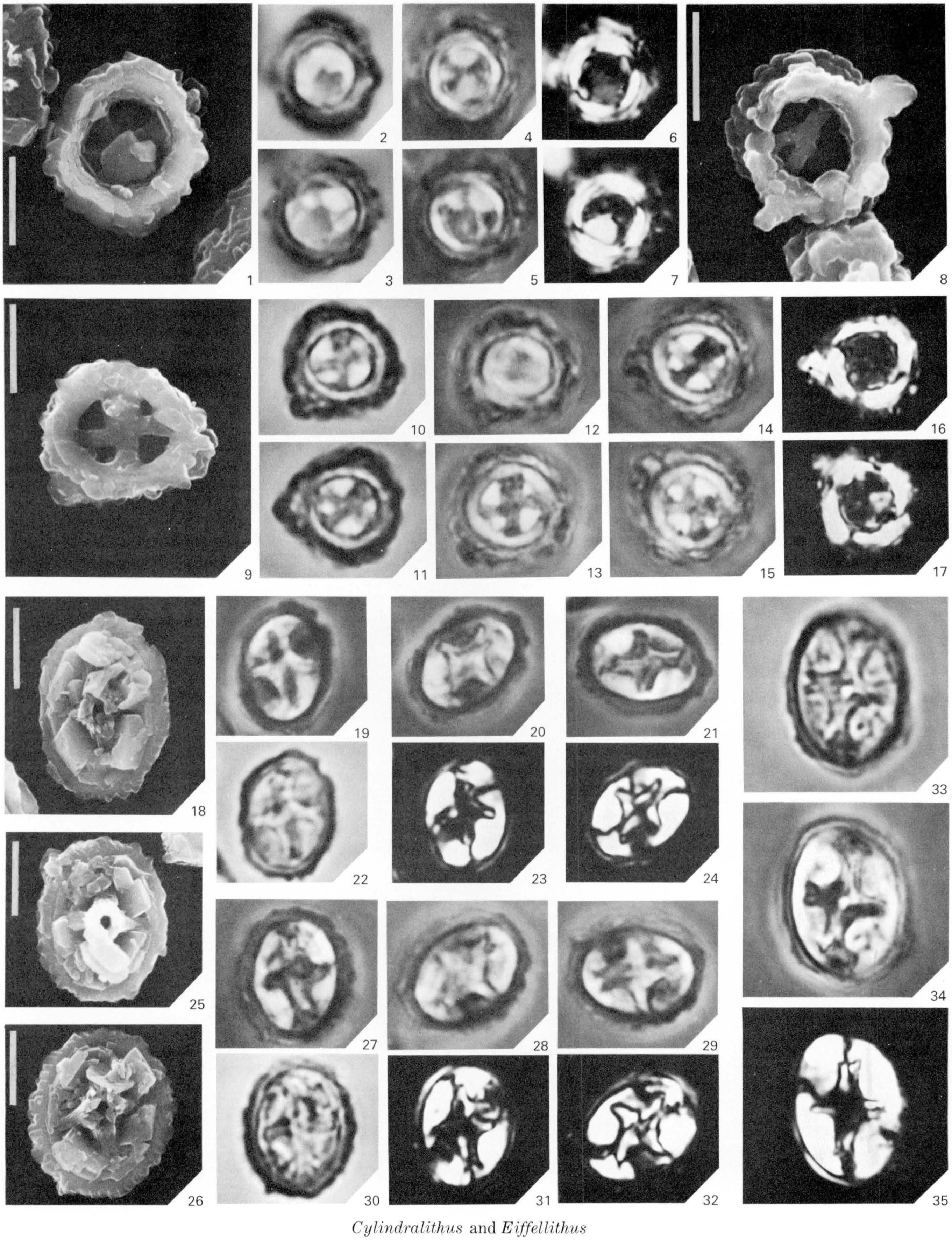
Atco Formation, Austin Group, early Santonian, Dallas County, Tex. (USGS 30793, USNM 218719). Scanning electron micrograph of distal surface.

26–32. *Eiffellithus eximius* (Stover 1966) Perch-Nielsen 1968

Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30772, USNM 218720). 26, scanning electron micrograph of distal surface. Figures 27–32 are views of distal surface of specimen shown in figure 26: 27–29, phase contrast; 30, transmitted light; and 31–32, cross-polarized light.

33–35. *Eiffellithus eximius* (Stover 1966) Perch-Nielsen 1968

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30782, USNM 218721); views of proximal surface. 33, transmitted light; 34, phase contrast; and 35, cross-polarized light.



Cylindralithus and *Eiffellithus*

PLATE 6

[Length of bar = 4 μm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–7. *Eiffellithus trabeculatus* (Gorka 1957) Reinhardt and Gorka 1967

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30823, USNM 218722). 1, scanning electron micrograph of distal surface. Figures 2–7 are views of distal surface of specimen shown in figure 1: 2–3, transmitted light; 4–5, phase contrast; and 6–7, cross-polarized light.

8–13. *Eiffellithus trabeculatus* (Gorka 1957) Reinhardt and Gorka 1967

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30818, USNM 218723); views of distal surface of specimen. 8–9, transmitted light; 10–11, phase contrast; and 12–13, cross-polarized light.

14–17. *Eiffellithus trabeculatus* (Gorka 1957) Reinhardt and Gorka 1967

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218724); views of distal surface of specimen. 14, transmitted light; 15, phase contrast; and 16–17, cross-polarized light.

18–24. *Eiffellithus turriseiffeli* (Deflandre 1954) Reinhardt 1965

Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30772, USNM 218725). 18, scanning electron micrograph of distal surface. Figures 19–24 are views of distal surface of specimen shown in figure 18: 19–20, transmitted light; 21–22, phase contrast; and 23–24, cross-polarized light.

25–33. *Eiffellithus turriseiffeli* (Deflandre 1954) Reinhardt 1965

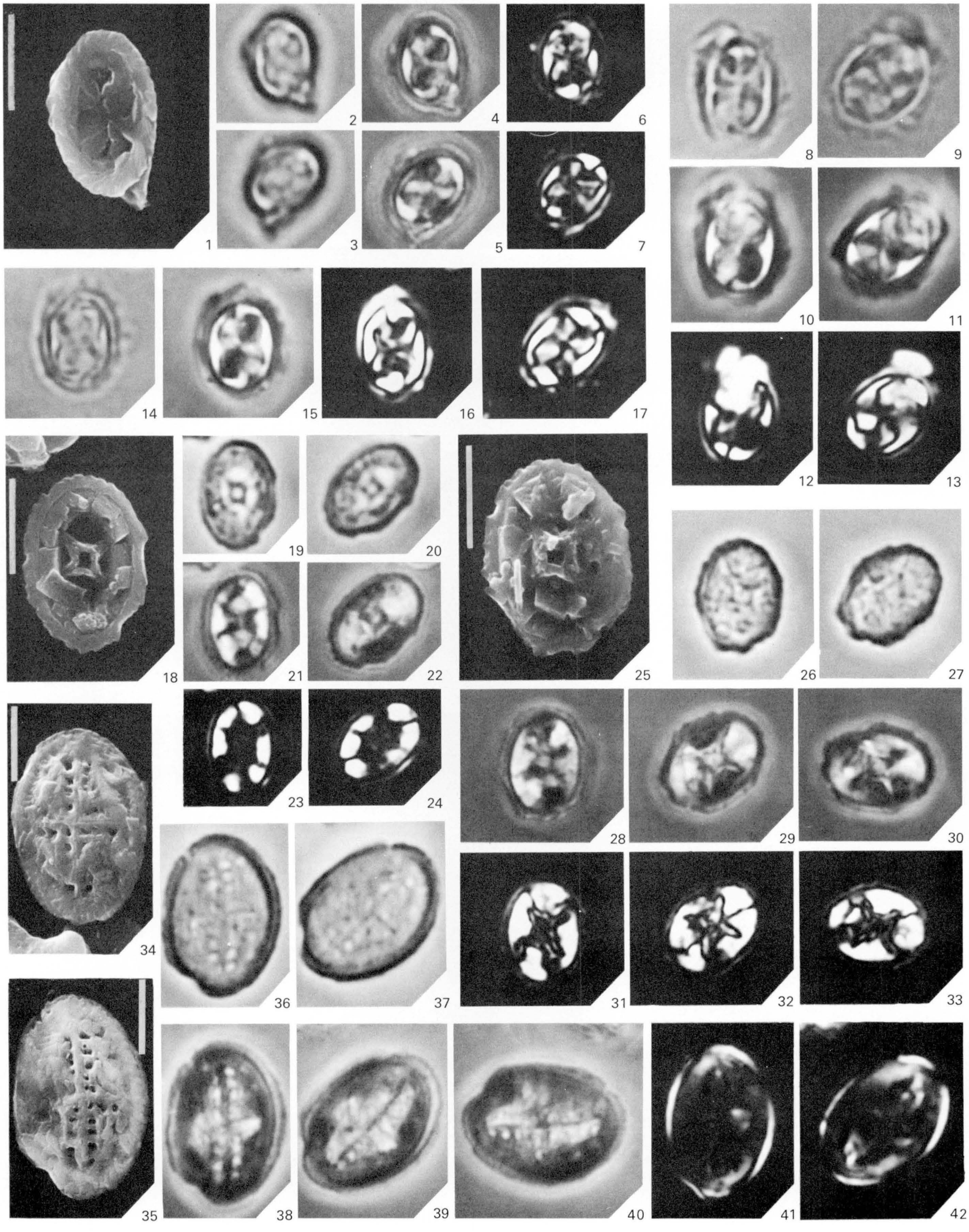
Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30771, USNM 218726). 25, scanning electron micrograph of distal surface. Figures 26–33 are views of distal surface of specimen shown in figure 25: 26–27, transmitted light; 28–30, phase contrast; and 31–33, cross-polarized light.

34. *Gartnerago costatum* (Gartner 1968) Bukry 1969

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218727). Scanning electron micrograph of distal surface.

35–42. *Gartnerago costatum* (Gartner 1968) Bukry 1969

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218728). 35, scanning electron micrograph of distal surface. Figures 36–42 are views of distal surface of specimen shown in figure 35: 36–37, transmitted light; 38–40, phase contrast; and 41–42, cross-polarized light.



Eiffellithus and *Gartnerago*

PLATE 7

[Length of bar=4 μm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–9. *Gartnerago costatum* (Gartner 1968) Bukry 1969
Ector Chalk, Austin Group, early Santonian, Grayson County, Tex. (USGS 30775, USNM 218729); views of proximal surface. 1–3, transmitted light; 4–6, phase contrast; and 7–9, cross-polarized light.

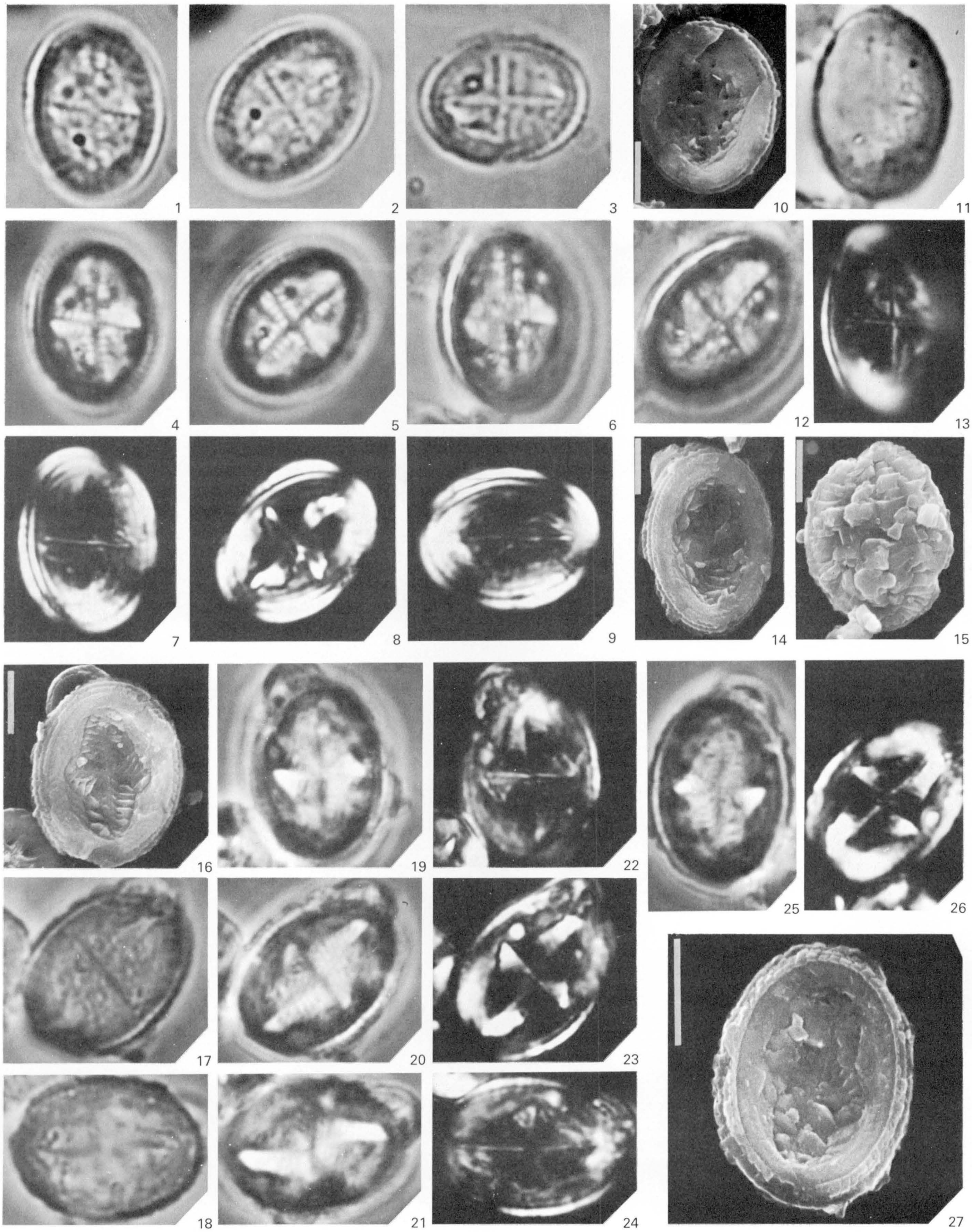
10–13. *Gartnerago costatum* (Gartner 1968) Bukry 1969
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218730). 10, scanning electron micrograph of proximal surface. Figures 11–13 are views of proximal surface of specimen shown in figure 10: 11, transmitted light; 12, phase contrast; and 13, cross-polarized light.

14. *Gartnerago costatum* (Gartner 1968) Bukry 1969
Ector Chalk, Austin Group, early Santonian, Grayson County, Tex. (USGS 30775, USNM 218731). Scanning electron micrograph of proximal surface.

15. *Gartnerago segmentatum* (Stover 1966) Thierstein 1974
Atco Formation, Austin Group, Coniacian, Travis County, Tex. (USGS 30799, USNM 218732). Scanning electron micrograph of distal surface.

16–26. *Gartnerago segmentatum* (Stover 1966) Thierstein 1974
South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30797, USNM 218733). 16, scanning electron micrograph of proximal surface. Figures 17–24 are views of proximal surface of specimen shown in figure 16: 17–18, transmitted light; 19–21, phase contrast; and 22–24, cross-polarized light. Figures 25 and 26 are views of distal surface of specimen shown in figure 16. 25, phase contrast; and 26, cross-polarized light.

27. *Gartnerago segmentatum* (Stover 1966) Thierstein 1974
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30783, USNM 218734). Scanning electron micrograph of proximal surface.



Gartnerago

PLATE 8

[Length of bar=4 μm unless noted otherwise. All light micrographs $\times$ 1760]

FIGURES 1–7. *Kamptnerius magnificus* Deflandre 1959
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30787, USNM 218735); views of proximal surface of specimen. 1–2, transmitted light; 3–5, phase contrast; and 6–7, cross-polarized light.

8. *Kamptnerius magnificus* Deflandre 1959
Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30772, USNM 218736). Scanning electron micrograph of proximal surface.

9–11. *Kamptnerius magnificus* Deflandre 1959
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30787, USNM 218737); views of proximal surface of specimen. 9, transmitted light; 10, phase contrast; and 11, cross-polarized light.

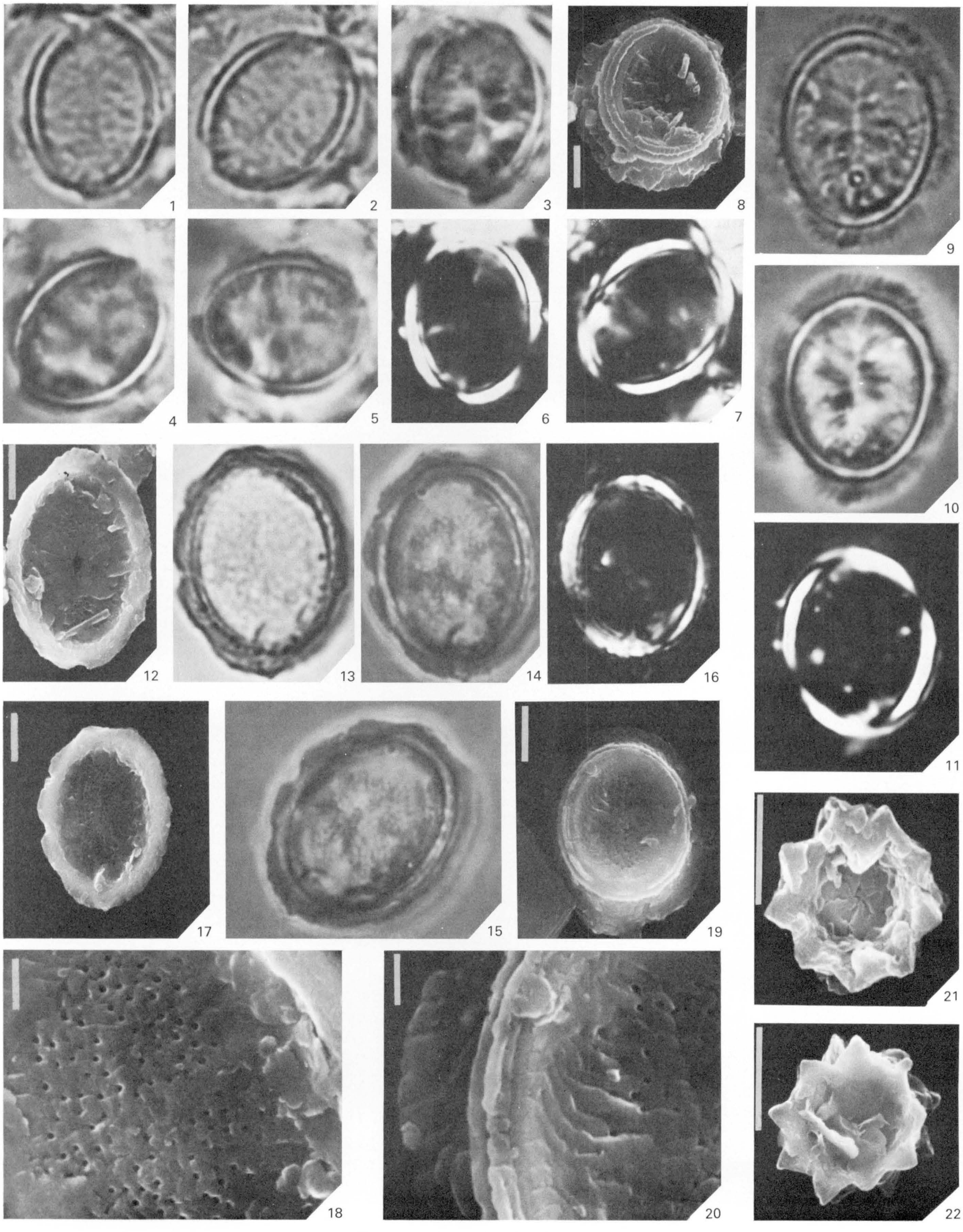
12. *Kamptnerius punctatus* Stradner 1963
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218738). Scanning electron micrograph of distal surface.

13–18. *Kamptnerius punctatus* Stradner 1963
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218739). 17, scanning electron micrograph of distal surface; 18, enlargement of a portion of the central area showing random arrangement and size of pores (Note: bar scale=1 μm). Figures 13-16 are views of distal surface of specimen shown in figure 17: 13, transmitted light; 14–15, phase contrast; and 16, cross-polarized light.

19–20. *Kamptnerius punctatus* Stradner 1963
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218740). 19, scanning electron micrograph of proximal surface; 20, enlargement of a portion of the central area showing outer peripheral flange, rim cycle construction, and central area medial suture and pores (Note: bar scale=1 μm).

21. *Lithastrinus floralis* Stradner 1962
South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30797, USNM 218741). Scanning electron micrograph.

22. *Lithastrinus floralis* Stradner 1962
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218742). Scanning electron micrograph.



Kamptnerius and *Lithastrinus*

PLATE 9

[Length of bar = 4 μm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–5. *Lithastrinus floralis* Stradner 1962

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218743). 1, scanning electron micrograph. Figures 2–5 are views of same side of specimen shown in figure 1: 2–3, transmitted light; 4, phase contrast; and 5, cross-polarized light. Note that figure 3 is rotated 90° clockwise with respect to the orientation in figure 1.

6–10. *Lithastrinus floralis* Stradner 1962

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218744). 6, scanning electron micrograph. Figures 7–10 are views of same side of specimen shown in figure 6: 7–8, transmitted light; 9, phase contrast; and 10, cross-polarized light. Note focal plane at base in figure 7 and at the top of the specimen in figure 8.

11–16. *Lithastrinus grillii* Stradner 1962

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218745). 11, scanning electron micrograph. Figures 12–16 are views of same side of specimen shown in figure 11: 12–13, transmitted light; 14–15, phase contrast; and 16, cross-polarized light. Note focal plane at base in figures 12 and 14 and at the top of the specimen in figures 13, 15, and 16.

17–22. *Lithraphidites carniolensis* Deflandre 1963

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30778, USNM 218746). 17, scanning electron micrograph. Figures 18–22 are views of same side of specimen shown in figure 17: 18, transmitted light; 19–20, phase contrast; and 21–22, cross-polarized light.

23–26. *Lithraphidites carniolensis* Deflandre 1963

Atco Formation, Austin Group, Coniacian, Travis County, Tex. (USGS 30799, USNM 218747). 23, scanning electron micrograph. Figures 24–26 are views of same side of specimen shown in figure 23: 24, transmitted light; 25, phase contrast; and 26, cross-polarized light.

27. *Lithraphidites carniolensis* Deflandre 1963

South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30797, USNM 218748). Scanning electron micrograph.

28–32. *Lithraphidites carniolensis* Deflandre 1963

Atco Formation, Austin Group, early Santonian, Kinney County, Tex. (USGS 30835, USNM 218749). Views of same side of specimen: 28, transmitted light; 29–30, phase contrast; and 31–32, cross-polarized light.

33–36. *Lithraphidites carniolensis* Deflandre 1963

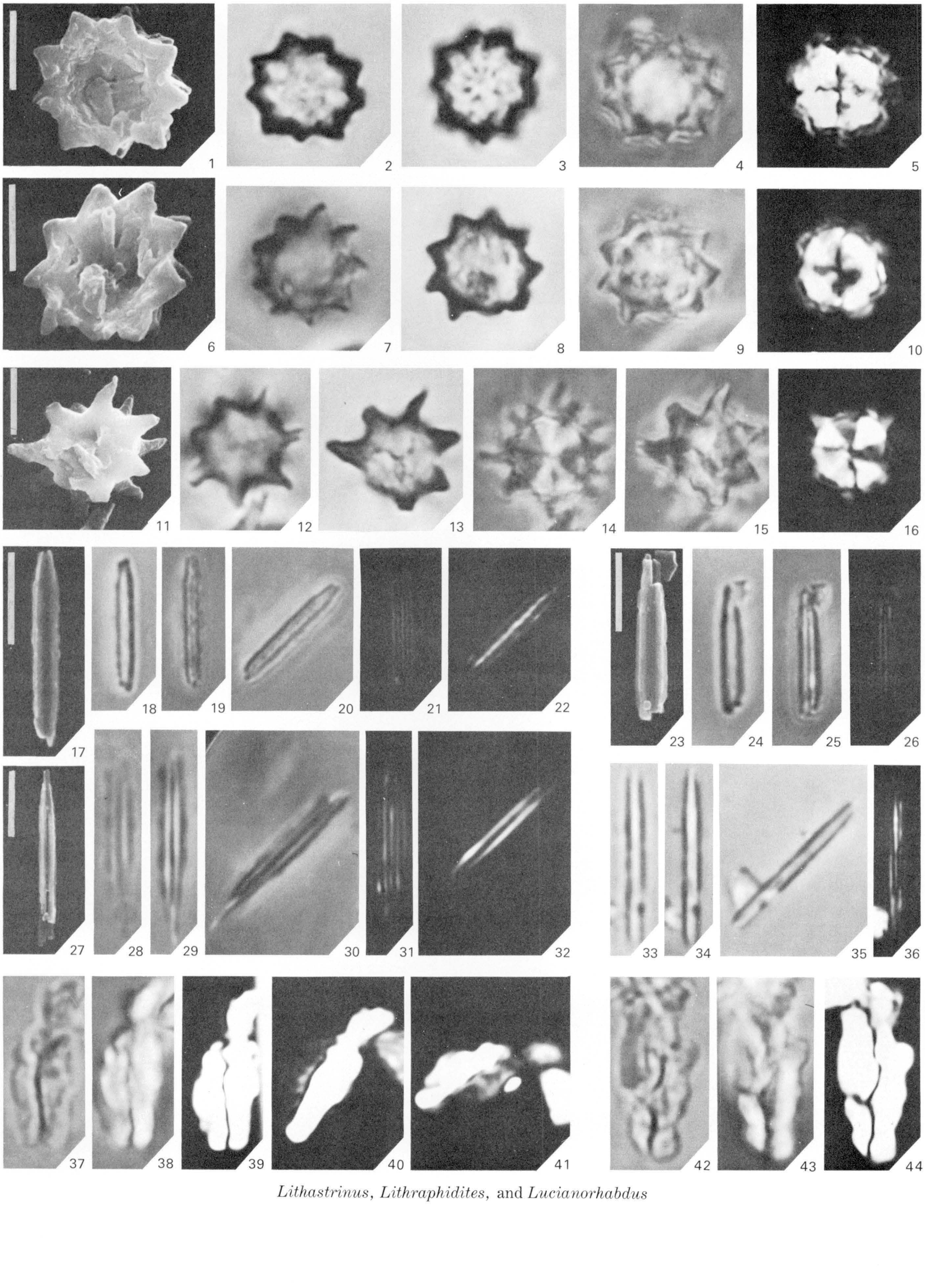
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218750). Views of same side of specimen: 33, transmitted light; 34–35, phase contrast; and 36, cross-polarized light.

37–41. *Lucianorhabdus cayeuxii* Deflandre 1959

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30818, USNM 218751). Views of same side of specimen: 37, transmitted light: 38, phase contrast; and 39–41, cross-polarized light. Note figure 40 rotated 30° clockwise and figure 41 rotated 60° clockwise with respect to orientation of figures 37–39.

42–44. *Lucianorhabdus cayeuxii* Deflandre 1959

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30816, USNM 218752). Views of same side of specimen: 42, transmitted light; 43, phase contrast; and 44, cross-polarized light.



Lithastrinus, *Lithraphidites*, and *Lucianorhabdus*

PLATE 10

[Length of bar=4 μm unless noted otherwise. All light micrographs $\times$ 1760]

FIGURES 1–6. *Manivitella pemmatoidea* (Manivit 1965) Thierstein 1971

South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30797, USNM 218753). 1, scanning, electron micrograph of distal surface. Figures 2–6 are views of distal surface of specimen shown in figure 1: 2, transmitted light; 3–4, phase contrast; and 5–6, cross-polarized light.

7–12. *Manivitella pemmatoidea* (Manivit 1965) Thierstein 1971

Langtry Member, Boquillas Formation, late Turonian, Kinney County, Tex. (USGS 30810, USNM 218754). 7, scanning electron micrograph of distal surface. Figures 8–12 are views of distal surface of specimen shown in figure 7: 8, transmitted light; 9–10, phase contrast; and 11–12, cross-polarized light.

13. *Markalius circumradiatus* (Stover 1966) Perch-Nielsen 1968

Ector Chalk, Austin Group, early Santonian, Grayson County, Tex. (USGS 30775, USNM 218755). Scanning electron micrograph of distal surface.

14–17. *Markalius circumradiatus* (Stover 1966) Perch-Nielsen 1968

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30818, USNM 218756). 14, scanning electron micrograph of distal surface. Figures 15–17 are views of distal surface of specimen shown in figure 14: 15, transmitted light; 16, phase contrast; and 17, cross-polarized light.

18–20. *Markalius circumradiatus* (Stover 1966) Perch-Nielsen 1968

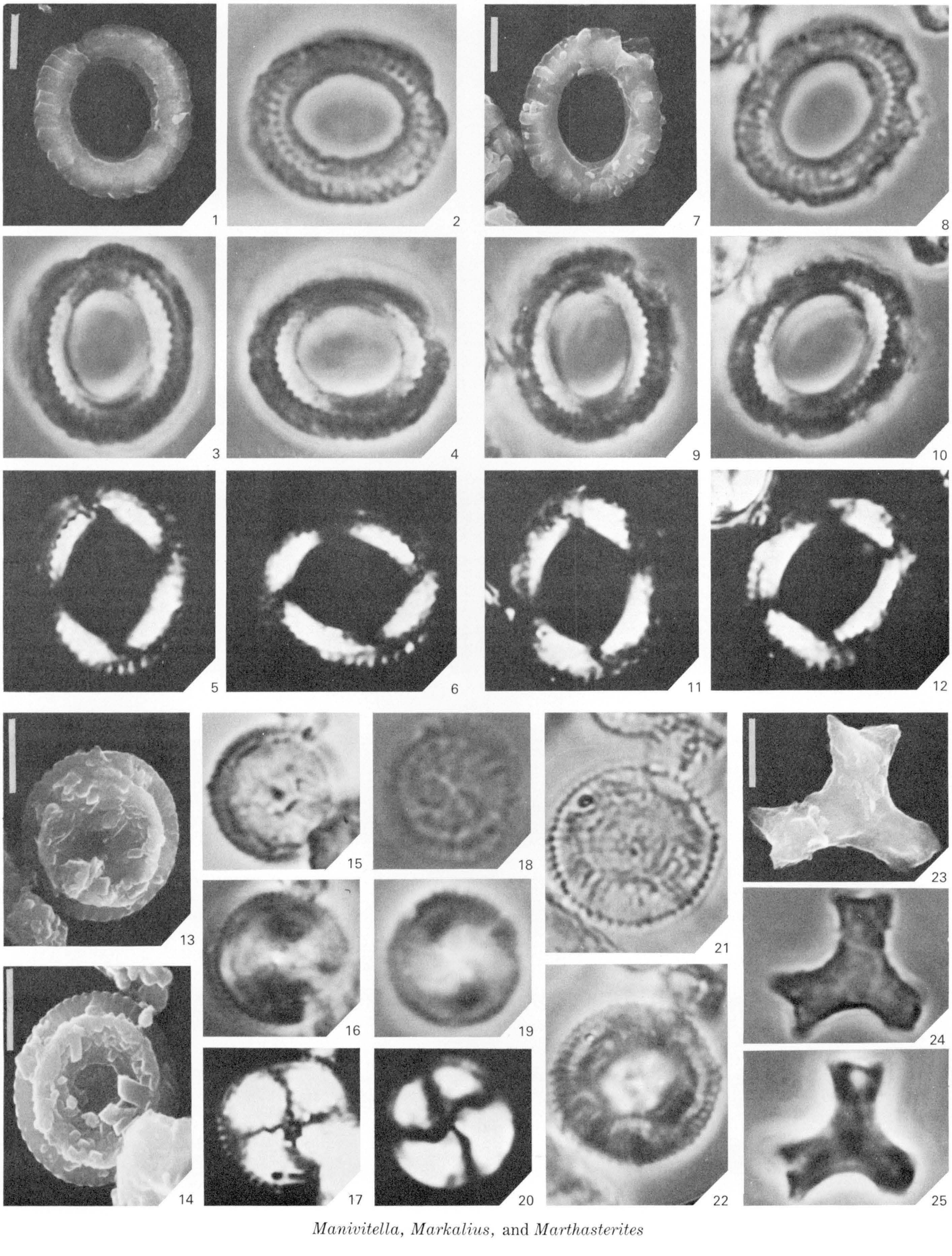
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30828, USNM 218757). Views of distal surface: 18, transmitted light; 19, phase contrast; and 20, cross-polarized light.

21, 22. *Markalius circumradiatus* (Stover 1966) Perch-Nielsen 1968

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30780, USNM 218758). Views of distal surface: 21, transmitted light; and 22, phase contrast.

23–25. *Marthasterites* sp. aff. *M. furcatus crassus* Deflandre 1959

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30783, USNM 218759). 23, scanning electron micrograph. Figures 24 and 25 are views of same side of specimen shown in figure 23: 24, transmitted light; and 25, phase contrast.



Manivitella, *Markalius*, and *Marthasterites*

PLATE 11

[Length of bar=4 µm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–3. *Marthasterites* sp. aff. *M. furcatus crassus* Deflandre 1959

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30784, USNM 218760). 1, scanning electron micrograph. Figures 2 and 3 are views of same side of specimen shown in figure 1: 2, transmitted light; and 3, phase contrast.

4–6. *Marthasterites furcatus* (Deflandre 1954) Deflandre 1959

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218761). 4, scanning electron micrograph. Figures 5 and 6 are views of same side of specimen shown in figure 4: 5, transmitted light; and 6, phase contrast.

7. *Marthasterites furcatus* (Deflandre 1954) Deflandre 1959

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218762). Scanning electron micrograph.

8–10. *Marthasterites furcatus* (Deflandre 1954) Deflandre 1959

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218763). 8, scanning electron micrograph. Figures 9 and 10 are views of same side of specimen shown in figure 8: 9, transmitted light; and 10, phase contrast.

11. *Marthasterites furcatus* (Deflandre 1954) Deflandre 1959

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30779, USNM 218764). Scanning electron micrograph.

12–14. *Marthasterites furcatus* (Deflandre 1954) Deflandre 1959

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218765). 12, scanning electron micrograph. Figures 13 and 14 are views of same side of specimen shown in figure 12: 13, transmitted light; and 14, phase contrast.

15. *Marthasterites furcatus* (Deflandre 1954) Deflandre 1959

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218766). Scanning electron micrograph.

16–18. *Marthasterites simplex* Bukry 1969

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218767). 16, scanning electron micrograph. Figures 17 and 18 are views of same side of specimen shown in figure 16: 17, transmitted light; and 18, phase contrast.

19–21. *Marthasterites simplex* Bukry 1969

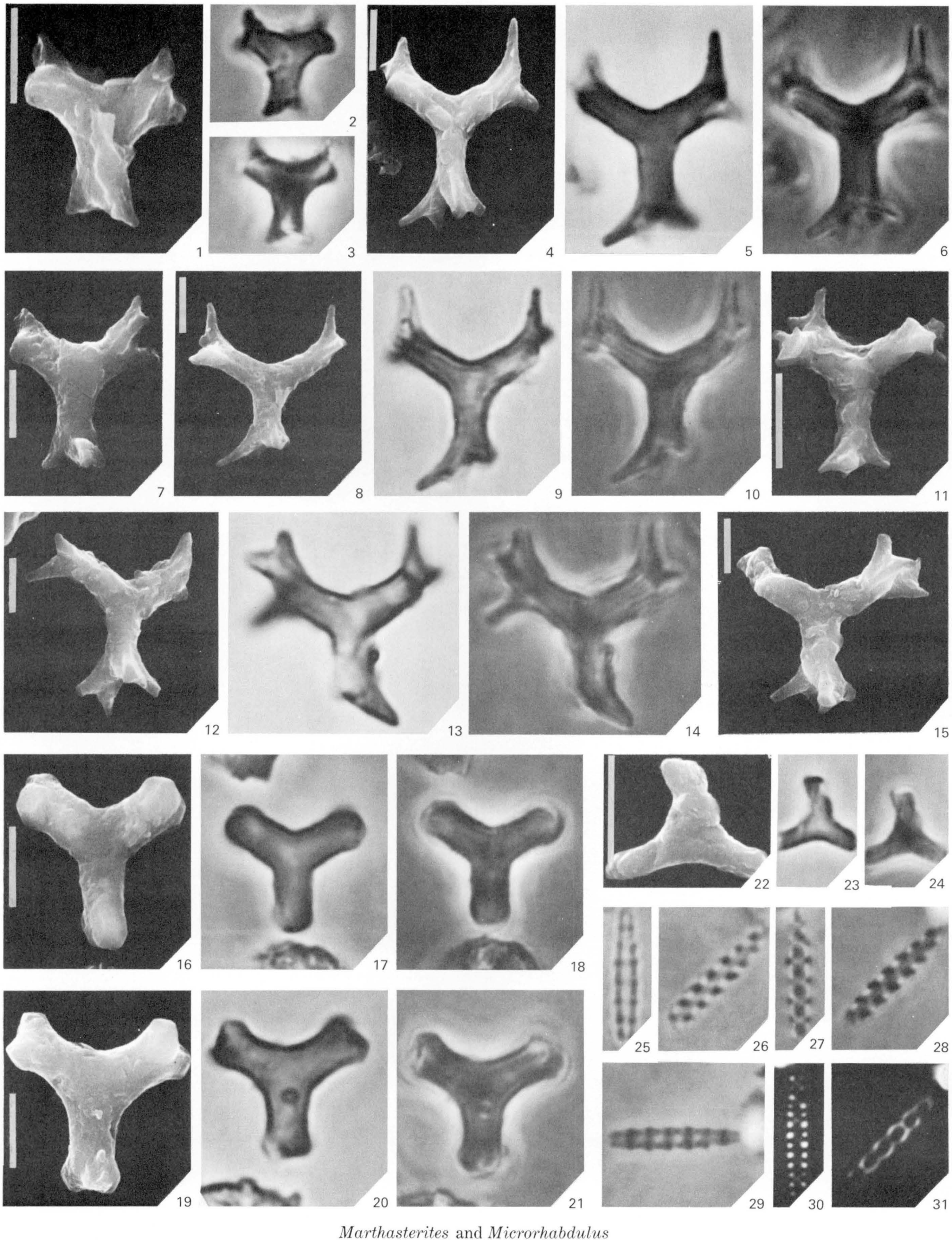
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218768). 19, scanning electron micrograph. Figures 20 and 21 are views of same side of specimen shown in figure 19: 20, transmitted light; and 21, phase contrast.

22–24. *Marthasterites* sp.

Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218769). 22, scanning electron micrograph. Figures 22 and 23 are views of same side of specimen shown in figure 22: 23, transmitted light; and 24, phase contrast.

25–31. *Microrhabdulus belgicus* Hay and Towe 1963

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30779, USNM 218770). Views of same side of specimen: 25–26, transmitted light; 27–29, phase contrast; and 30–31, cross-polarized light.



Marthasterites and *Microrhabdulus*

PLATE 12

[Length of bar=4 μm unless noted otherwise. All light micrographs $\times$ 1760]

FIGURES 1–9. *Microrhabdulus belgicus* Hay and Towe 1963

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30779, USNM 218771). Views of same side of specimen: 1–3, transmitted light; 4–6, phase contrast; and 7–9, cross-polarized light views.

10–18. *Microrhabdulus decoratus* Deflandre 1959

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30831, USNM 218772). Views of same side of specimen: 10–12, transmitted light; 13–15, phase contrast; and 16–18, cross-polarized light.

19–21. *Microrhabdulus decoratus* Deflandre 1959

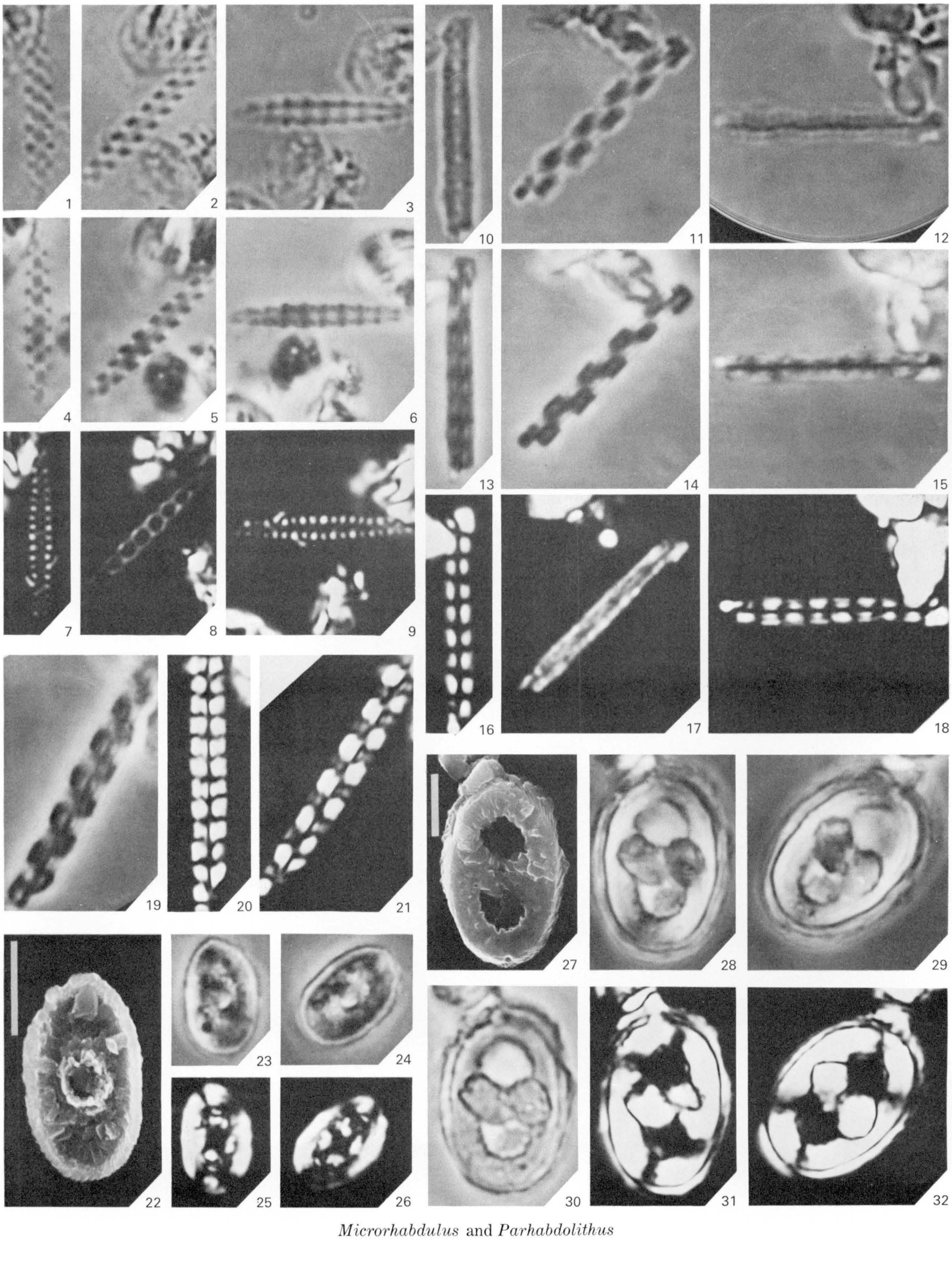
Langtry Member, Boquillas Formation, late Turonian, Kinney County, Tex. (USGS 30807, USNM 218773). Views of same side of specimen: 19, phase contrast; and 20–21, cross-polarized light. Note figures 19 and 21 rotated 30° clockwise with respect to orientation in figure 20.

22–26. *Parhabdolithus angustus* (Stradner 1963) Stradner, Adamiker, and Maresch 1968

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30782, USNM 218774). 22, scanning electron micrograph of distal surface. Figures 23–26 are views of proximal surface of specimen shown in figure 22: 23–24, phase contrast; and 25–26, cross-polarized light.

27–32. *Parhabdolithus embergeri* (Noël 1958) Stradner 1963

Langtry Member, Boquillas Formation, late Turonian, Kinney County, Tex. (USGS 30812, USNM 218775). 27, scanning electron micrograph of proximal surface. Figures 28–32 are views of proximal surface of specimen shown in figure 27: 30, transmitted light; 28–29, phase contrast; and 31–32, cross-polarized light.



Microrhabdulus and *Parhabdolithus*

PLATE 13

[Length of bar = 4 μm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–3. *Parhabdolithus embergeri* (Noël 1958) Stradner 1963
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30779, USNM 218776). Views of proximal surface: 1, transmitted light; 2, phase contrast; and 3, cross-polarized light.

4–6. *Parhabdolithus embergeri* (Noël 1958) Stradner 1963
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30784, USNM 218777). Views of proximal surface: 4, transmitted light; 5, phase contrast; and 6, cross-polarized light.

7. *Prediscosphaera cretacea* (Arkhangelsky 1912) Gartner 1968
Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30772, USNM 218778). Scanning electron micrograph of distal surface.

8, 9. *Prediscosphaera spinosa* (Bramlette and Martini 1964) Gartner 1968
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218779). Views of proximal surface: 8, phase contrast; and 9, cross-polarized light.

10–15. *Prediscosphaera spinosa* (Bramlette and Martini 1964) Gartner 1968
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30787, USNM 218780). Views of proximal surface: 10–11, transmitted light; 12–13 phase contrast; and 14–15, cross-polarized light.

16–19. *Stephanolithion laffittei* Noël 1957
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30786, USNM 218781). Views of same side of specimen: 16, transmitted light; 17, phase contrast; and 18–19, cross-polarized light. Note figure 19 rotated 45° clockwise with respect to orientation in figures 16–18.

20–23. *Stephanolithion laffittei* Noël 1957
Atco Formation, Austin Group, early Santonian, Dallas County, Tex. (USGS 30793, USNM 218782). 20, scanning electron micrograph of distal surface. Figures 21–23 are views of distal surface of specimen shown in figure 20: 21, transmitted light; 22, phase contrast; and 23, cross-polarized light.

24. *Stephanolithion laffittei* Noël 1957
Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30772, USNM 218783). Scanning electron micrograph of proximal surface.

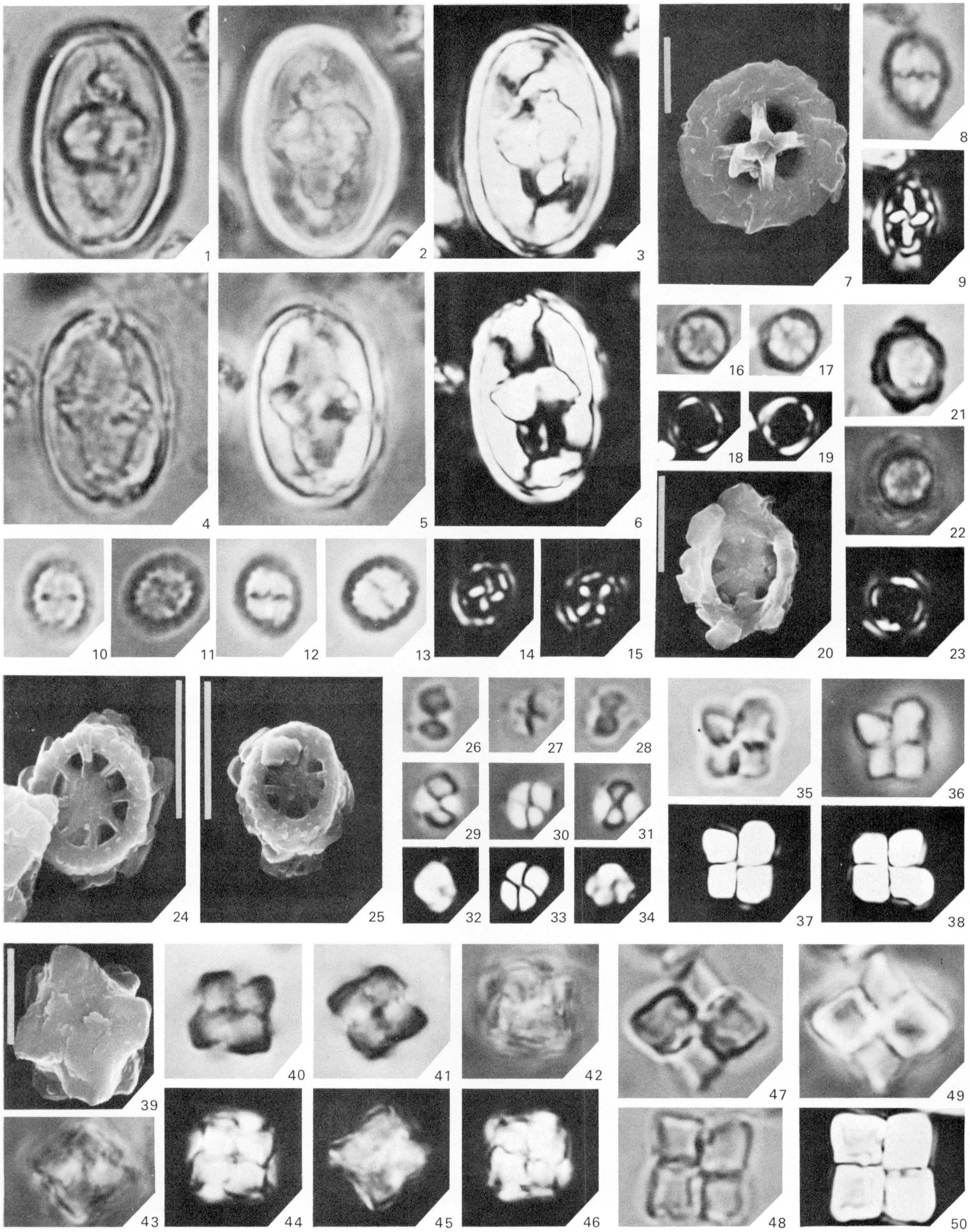
25. *Stephanolithion laffittei* Noël 1957
Atco Formation, Austin Group, early Santonian, Dallas County, Tex. (USGS 30793, USNM 218784). Scanning electron micrograph of proximal surface.

26–34. *Tetralithus obscurus* Deflandre 1959
Atco Formation, Austin Group, early Santonian, Kinney County, Tex. (USGS 30834, USNM 218785). Views of same side of specimen: 26–28, transmitted light; 29–31, phase contrast; and 32–34, cross-polarized light.

35–38. *Tetralithus pyramidus* Gardet 1955
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30818, USNM 218786). Views of same side of specimen: 35, transmitted light; 36, phase contrast; and 37–38, cross-polarized light. Note figure 38 rotated 90° clockwise with respect to orientation in figures 35–37.

39–46. *Tetralithus pyramidus* Gardet 1955
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218787). 39, scanning electron micrograph. Figures 40–46 are views of same side of specimen shown in figure 39: 40–41, transmitted light; 42–43, phase contrast; and 44–46, cross-polarized light.

47–50. *Tetralithus pyramidus* Gardet 1955
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30818, USNM 218788). Views of same side of specimen: 47–48, transmitted light; 49, phase contrast; and 50, cross-polarized light.



Parhabdolithus, *Prediscosphaera*, *Stephanolithion*, and *Tetralithus*

PLATE 14

[Length of bar = 4 µm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–11. *Vagalapilla matalosa* (Stover 1966) Thierstein 1973
South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30797, USNM 218789). 1, scanning electron micrograph of proximal surface. Figures 2, 4, 6, 8, and 10 are views of proximal surface, and figures 3, 5, 7, 9, and 11 are views of distal surface of specimen shown in figure 1: 2–3, transmitted light; 4–7, phase contrast; and 8–11, cross-polarized light.

12. *Vagalapilla matalosa* (Stover 1966) Thierstein 1973
Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30772, USNM 218790). Scanning electron micrograph of proximal surface.

13. *Vagalapilla matalosa* (Stover 1966) Thierstein 1973
Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30772, USNM 218791). Scanning electron micrograph of distal surface.

14. *Watznaueria barnesae* (Black 1959) Perch-Nielsen 1968
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30817, USNM 218792). Scanning electron micrograph of distal surface.

15. *Watznaueria barnesae* (Black 1959) Perch-Nielsen 1968
Atco Formation, Austin Group, early Santonian, Kinney County, Tex. (USGS 30839, USNM 218793). Scanning electron micrograph of distal surface.

16–24. *Watznaueria barnesae* (Black 1959) Perch-Nielsen 1968
South Bosque Formation, Eagle Ford Group, late Turonian, Travis County, Tex. (USGS 30797, USNM 218794). 16, scanning electron micrograph of distal surface. Figures 17, 19, 21, and 23 are views of distal surface, and figures 18, 20, 22, and 24 are views of proximal surface of specimen shown in figure 16: 17–18, transmitted light; 19–20, phase contrast; and 21–24, cross-polarized light.

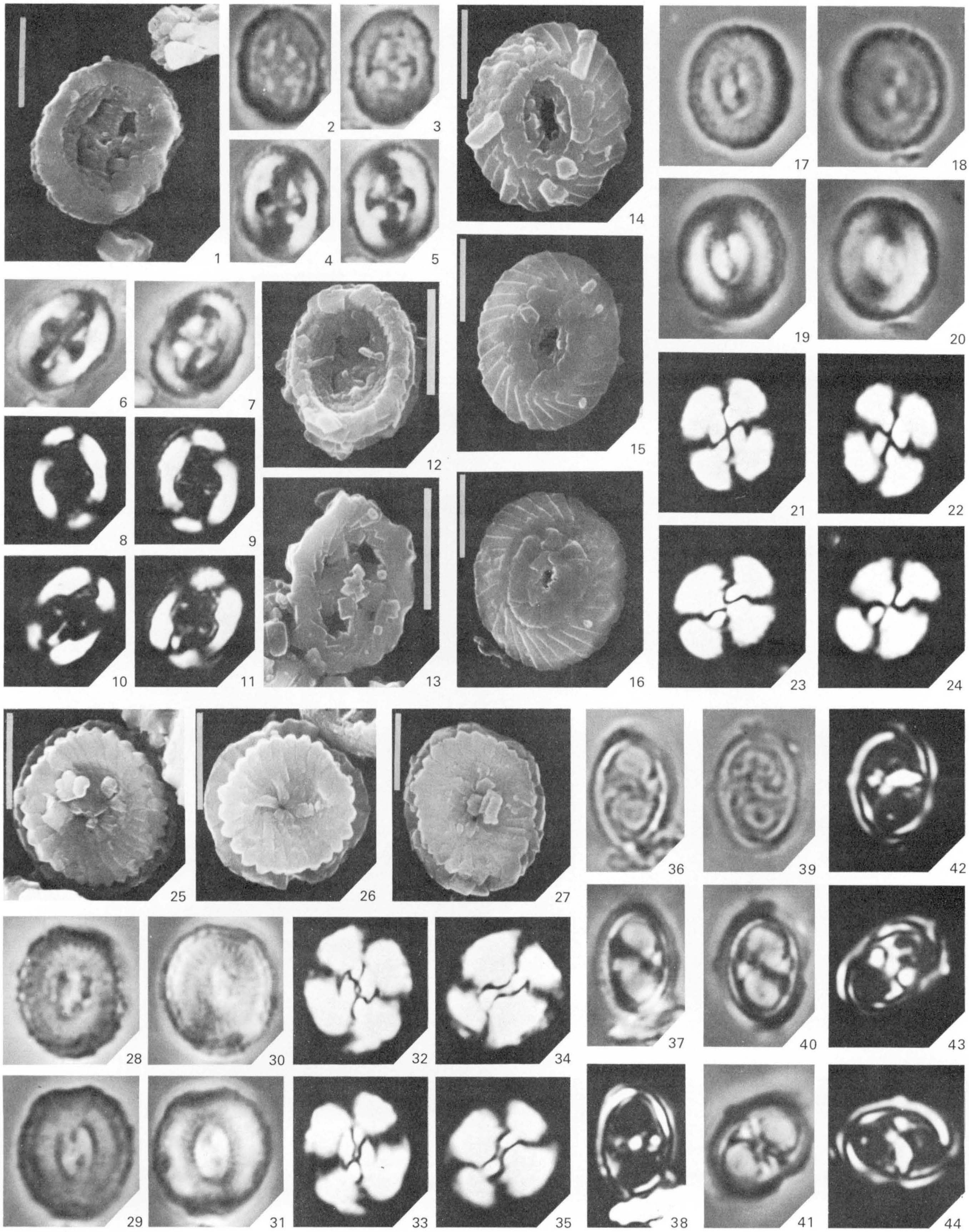
25. *Watznaueria barnesae* (Black 1959) Perch-Nielsen 1968
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30818, USNM 218795). Scanning electron micrograph of proximal surface.

26. *Watznaueria barnesae* (Black 1959) Perch-Nielsen 1968
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30782, USNM 218796). Scanning electron micrograph of proximal surface.

27–35. *Watznaueria barnesae* (Black 1959) Perch-Nielsen 1968
Atco Formation, Austin Group, Coniacian, Travis County, Tex. (USGS 30799, USNM 218797). 27, scanning electron micrograph of proximal surface. Figures 28, 30, 32, and 34 are views of proximal surface, and figures 29, 31, 33, and 35 are views of distal surface of specimen shown in figure 27: 28–29, transmitted light; 30–31, phase contrast; and 32–35, cross-polarized light.

36–38. *Zygodiscus acanthus* (Reinhardt 1965) Reinhardt 1966
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30784, USNM 218798). Views of proximal side of specimen: 36, transmitted light; 37, phase contrast; and 38, cross-polarized light.

39–44. *Zygodiscus acanthus* (Reinhardt 1965) Reinhardt 1966
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30785, USNM 218799). Views of proximal side of specimen: 39, transmitted light; 40–41, phase contrast; and 42–44, cross-polarized light.



Vagalapilla, *Watznaueria*, and *Zygodiscus*

PLATE 15

[Length of bar=4 µm unless noted otherwise. All light micrographs × 1760]

FIGURE 1. *Zygodiscus acanthus* (Reinhardt 1965) Reinhardt 1966
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30783, USNM 218800). Scanning electron micrograph of distal surface.

2–7. *Zygodiscus acanthus* (Reinhardt 1965) Reinhardt 1966
Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30787, USNM 218801). Views of proximal surface of specimen: 2, transmitted light; 3–4, phase contrast; and 5–7, cross-polarized light.

8–14. *Zygodiscus* sp. cf. *Z. biclavatus* Bukry 1969
Langtry Member, Boquillas Formation, late Turonian, Kinney County, Tex. (USGS 30812, USNM 218802). 8, scanning electron micrograph of distal surface. Figures 9–14 are views of distal surface of specimen shown in figure 8: 9–10, transmitted light; 11–12, phase contrast; and 13–14, cross-polarized light.

15–21. *Zygodiscus compactus* Bukry 1969
Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30816, USNM 218803). 15, scanning electron micrograph of distal surface. Figures 16–21 are views of distal surface of specimen shown in figure 15: 16, transmitted light; 17–18, phase contrast; and 19–21, cross-polarized light.

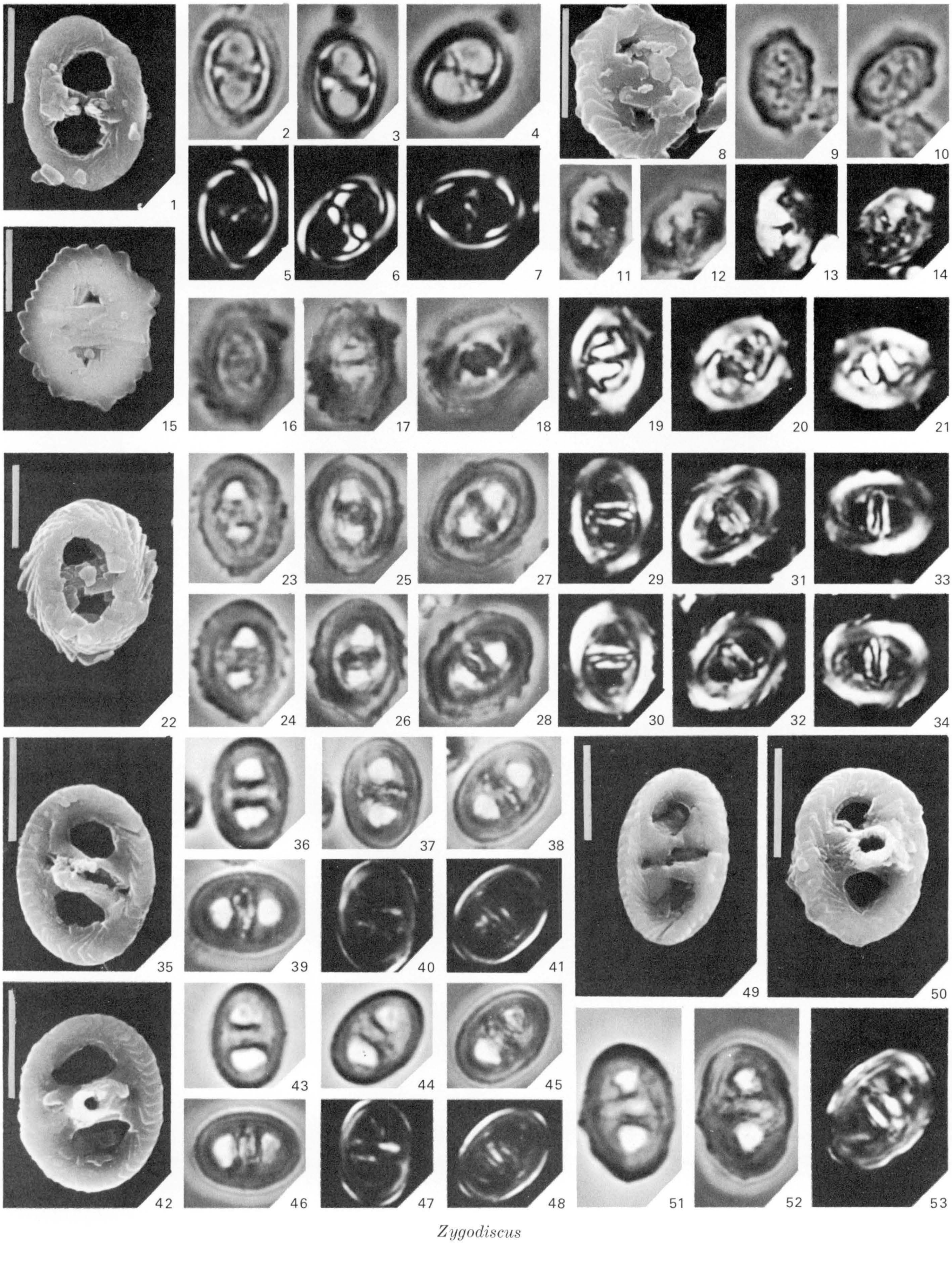
22–34. *Zygodiscus compactus* Bukry 1969
Atco Formation, Austin Group, Coniacian, Travis County, Tex. (USGS 30799, USNM 218804). 22, scanning electron micrograph of proximal surface. Figures 23, 25, 27, 29, 31, and 33 are views of proximal surface, and figures 24, 26, 28, 30, 32, and 34 are views of distal surface of specimen shown in figure 22: 23–24, transmitted light; 25–28, phase contrast; and 29–34, cross-polarized light.

35–41. *Zygodiscus diplogrammus* (Deflandre 1954) Gartner 1968
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218805). 35, scanning electron micrograph of distal surface. Figures 36–41 are views of distal surface of specimen shown in figure 35: 36, transmitted light; 37–39, phase contrast; and 40–41, cross-polarized light.

42–48. *Zygodiscus diplogrammus* (Deflandre 1954) Gartner 1968
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218806). 42, scanning electron micrograph of distal surface. Figures 43–48 are views of distal surface of specimen shown in figure 42: 43–44, transmitted light; 45–46, phase contrast; and 47–48, cross-polarized light.

49. *Zygodiscus diplogrammus* (Deflandre 1954) Gartner 1968
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218807). Scanning electron micrograph of distal surface.

50–53. *Zygodiscus diplogrammus* (Deflandre 1954) Gartner 1968
Maribel Shale Member, Arcadia Park Formation, Eagle Ford Group, late Turonian, Grayson County, Tex. (USGS 30767, USNM 218808). 50, scanning electron micrograph of distal surface. Figures 51–53 are views of distal surface of specimen shown in figure 50: 51, transmitted light; 52, phase contrast; and 53, cross-polarized light.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Zygodiscus

PLATE 16

[Length of bar=4 μm unless noted otherwise. All light micrographs × 1760]

FIGURES 1–6. *Zygodiscus elegans* Gartner 1968

Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30773, USNM 218809). 1, scanning electron micrograph of distal surface. Figures 2–6 are views of distal surface of specimen shown in figure 1: 2, transmitted light; 3–4, phase contrast; and 5–6, cross-polarized light.

7–13. *Zygodiscus elegans* Gartner 1968

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30818, USNM 218810). 7, scanning electron micrograph of proximal surface. Figures 8–13 are views of proximal surface of specimen shown in figure 7: 8, transmitted light; 9–11, phase contrast; and 12–13, cross-polarized light.

14. *Zygodiscus elegans* Gartner 1968

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30782, USNM 218811). Scanning electron micrograph of distal surface.

15. *Zygodiscus elegans* Gartner 1968

Atco Formation, Austin Group, Coniacian, Dallas County, Tex. (USGS 30777, USNM 218812). Scanning electron micrograph of distal surface.

16–24. *Zygodiscus fibuliformis* (Reinhardt 1964) Bukry 1969

Ector Chalk, Austin Group, early Santonian, Grayson County, Tex. (USGS 30776, USNM 218813). 16, scanning electron micrograph of proximal surface. Figures 17–24 are views of proximal surface of specimen shown in figure 16: 17–18, transmitted light; 19–21, phase contrast; and 22–24, cross-polarized light.

25. *Zygodiscus orionatus* (Reinhardt 1966) n. comb.

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30819, USNM 218814). Scanning electron micrograph of proximal surface.

26. *Zygodiscus orionatus* (Reinhardt 1966) n. comb.

Ector Chalk, Austin Group, Coniacian, Grayson County, Tex. (USGS 30772, USNM 218815). Scanning electron micrograph of proximal surface.

27–33. *Zygodiscus orionatus* (Reinhardt 1966) n. comb.

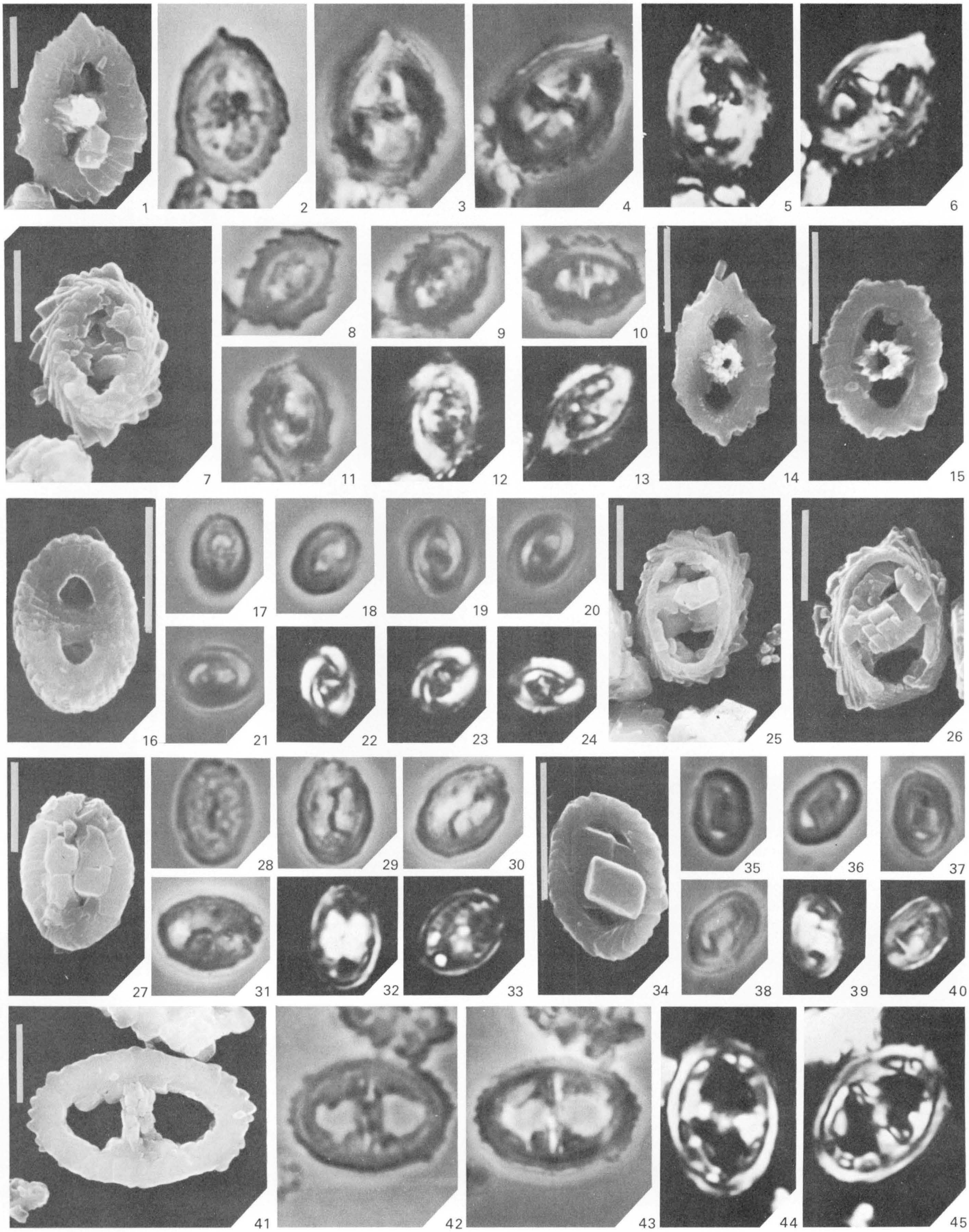
Langtry Member, Boquillas Formation, late Turonian, Kinney County, Tex. (USGS 30810, USNM 218816). 27, scanning electron micrograph of distal surface. Figures 28–33 are views of distal surface of specimen shown in figure 27: 28, transmitted light; 29–31, phase contrast; and 32–33, cross-polarized light.

34–40. *Zygodiscus orionatus* (Reinhardt 1966) n. comb.

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30818, USNM 218817). 34, scanning electron micrograph of distal surface. Figures 35–40 are views of distal surface of specimen shown in figure 34: 35–36, transmitted light; 37–38, phase contrast; and 39–40, cross-polarized light.

41–45. *Zygodiscus theta* (Black 1959) Bukry 1969

Atco Formation, Austin Group, Coniacian, Kinney County, Tex. (USGS 30816, USNM 218818). 41, scanning electron micrograph of distal surface. Figures 42–45 are views of distal surface of specimen shown in figure 41: 42, transmitted light; 43, phase contrast; and 44–45, cross-polarized light.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Zygodiscus