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COCCOLITHS AND RELATED CALCAREOUS NANNOFOSSILS FROM UPPER CRETACEOUS DEPOSITS OF TEXAS AND ARKANSAS

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ABSTRACT

Coccoliths have been studied for about a hundred years, and they have been recognized in calcareous deposits from many parts of the world. Upper Cretaceous chalks and calcareous shales of the northwestern Gulf Coast contain abundant coccoliths and related calcareous nannofossils. Because of the small size of these microfossils, it is desirable to study nannofossils with an electron microscope. In order to make them useful for routine biostratigraphic work, however, light microscopic study is equally important. For study with an electron microscope, coccoliths must be specially prepared by making a thin-film carbon replica and then examining the replica instead of the specimen. For study with a light microscope it is desirable to mount coccoliths in a nondrying viscous fluid so that specimens can be examined from all sides. Often it is difficult, however, to characterize species adequately and to identify them with the literature. Furthermore, the methods of study—carbon replicas and mobile (nonfixed) mounts—make it impossible to designate a type specimen in the way usually done with larger fossils.

In the past, both botanical and zoological nomenclature have been applied to calcareous nannofossils. Because strong affinities to the plant kingdom have been demonstrated for most modern coccolithophorids, the botanical code should be given preference. The 92 species encountered in this study, of which 37 are new, are assigned to 30 genera, of which 5 are new. All but 3 genera are assigned readily to family groups.

The eight samples studied range in age from Eaglefordian to Navarroan, and the assemblages from each sample contain distinctive elements. Although a detailed zonation of the Upper Cretaceous cannot be derived from this limited study, a zonation based on nannofossils clearly is possible.

INTRODUCTION

GENERAL

The discovery of coccoliths can be credited to C. G. Ehrenberg who in 1836 described some peculiar minute bodies that he called "agaric minerals" in inorganically precipitated calcium carbonate. In 1840 Ehrenberg published descriptions and illustrations of several widely distributed chalk samples that he had studied in great detail and again noted minute calcareous bodies, calling them "elliptical granular platelets." Again in 1854 in his *Mikrogeologie* he illustrated minute calcareous objects which he called "chalk morpholiths." Ehrenberg always worked with samples of soft rock and as late as 1872 considered these ubiquitous little objects to be entirely inorganic.

In 1858 T. H. Huxley discovered minute calcareous bodies in deep-sea sediment samples gathered by H.M.S. *Cyclops* in the summer of 1857 while making soundings of the ocean floor of the North Atlantic. In describing these minute bodies, he called them simply coccoliths (see Huxley, 1868, p. 203). Two years later Wallich examined sediments from the floor of the North Atlantic obtained by H.M.S. *Bulldog,* and, in addition to the coccoliths noted by Huxley, he also found spherical bodies seemingly formed of a number of coccoliths. He named these spheres "coccospheres" and suggested that all coccoliths originated from the disintegration of such spheres. In the following year Wallich (1861) first entertained the idea that these coccoliths from deep-sea sediments might be identical with minute bodies observed by H. C. Sorby in chalk samples. In the same year Sorby (1861) stated that the so-called "crystalloids" found by him in chalk and described earlier by Ehrenberg, were identical with the coccoliths of Huxley. Sorby also suggested that coccoliths were not inorganically precipitated but had an organic origin, and that the coccospheres may be "an independent kind of organism."

Huxley restudied the *Cyclops* samples which were preserved in alcohol, and in a paper (1868) he divided the coccoliths into two groups: *Discolithus* and *Cyatholithus.* "The *Discolithi,*" as he also called them, "are oval discoidal bodies, with a thick, strongly refracting rim, and a thinner central portion, the greater part of which is occupied by a slightly opaque, as it were, cloudlike patch." . . . "In general, the discoliths are slightly convex on one side, slightly concave on the other, and the rim is raised into a prominent ridge on the more convex side . . ."

About the *Cyatholithi* he said: "when full grown [it] has an oval contour, convex upon one face, and flat or concave upon the other." HUXLEY went on to describe cyatholiths as follows: "Supposing it to rest upon its convex surface, it consists of a lower plate, shaped like a deep saucer or watch glass; of an upper plate, which is sometimes flat, sometimes more or less watch-glass shaped; of the oval, thick-walled, flattened corpuscle, which connects the centers of the two plates; and an intermediate substance, which is closely connected with the under surface of the upper plate, or more or less fills up the interval between the two plates, and often has a coarsely granular margin."

HUXLEY found that with dilute acid the calcium carbonate could be dissolved out of the cyatholith, leaving behind a delicate "membranous network of the same size and shape as the cyatholith." He also observed that the coccoliths commonly were embedded in a granular gelatinous matrix which he assumed to be protoplasm, and he thought that the cloudlike patch in the central portion of the *Discolithi* and the granular substance between the plates of *Cyatholithi* was also protoplasm. He therefore concluded that coccoliths were the skeletal elements or spicules of a primitive organism, a Moner, and he named this organism *Bathybius Haeckelli.*

Regarding the coccosphere, HUXLEY did not agree with WALLICH that coccoliths resulted from the disintegration of coccospheres but believed rather that coccospheres may be the result of the coalescence of cyatholiths or that they may be entirely independent from cyatholiths and possibly serve as a reproductive process in *Bathybius.*

The matter of *Bathybius* and coccoliths was taken up two years later by HAECKEL (1870), who pictured the vast expanses of the ocean floor as the cradle of life, covered by the free protoplasm of *Bathybius,* the coccoliths being its spicular skeletal material. In 1870 SCHMIDT reported the occurrence of *Bathybius* slime from the floor of the Adriatic and noted that in addition to coccoliths there were also large numbers of rods, some of uniform thickness, others club-shaped and tapered, many equipped with a disc or other type of structure at one end. To these he gave the name *Rhabdolithes.*

Thus three of the major groups of the calcareous nannofossils had been discovered: coccoliths, discoliths, and rhabdoliths. *Bathybius* later was shown to be a gelatinous calcium sulphate precipitated by the alcohol in which the samples were stored. The true nature of coccoiths, discoliths, and rhabdoliths as skeletal parts of minute calcareous algae eventually was determined by Sir JOHN MURRAY (MURRAY & RENARD, 1891) and later confirmed by MURRAY & BLACKMAN (1898). Today these coccolith- and rhabdolith-bearing organisms are known from all oceans except the frigid arctic and antarctic waters. They are single-celled, flagella-bearing organisms related to the group of golden-brown algae known as the Chrysophyceae and make up a major portion of the phytoplankton of the open ocean from the surface down to the limit of light penetration. They have characteristics of both the animal and plant kingdoms. They are related to the animals in that they are motile and equipped with flagellae and have been observed to ingest food particles. Their claim to placement in the plant kingdom is that they possess chromatophores and are capable of photosynthetic activity.

The average size for these organisms is generally less than 50 μ in maximum diameter, and the coccoliths and other skeletal structures range from less than 1 μ to more than 20 μ in maximum dimension. Most of these skeletal parts are constructed by a complex arrangement of calcite crystallites, usually in a more or less radial pattern.

As has been pointed out already, fossil coccoliths played an important role in the early phases of the study of these minute calcite bodies during the second half of the nineteenth century. Among those who took an active interest in fossil forms were EHRENBERG (1836, 1840, 1854, 1873), GÜMBEL (1870, 1873), SORBY (1861), WALLICH (1860, 1861, 1877), and others, but no serious efforts were made during these years to undertake a systematic and detailed study of these fossils, beyond noting their occurrence and speculating on their origin and relationship to modern forms.

In North America coccoliths and rhabdoliths were first recorded by DAWSON (1875) from Cretaceous rocks of Manitoba where he found them "to constitute a considerable proportion of the rock." He illustrated several representative specimens, and pointed out that it was the first record of fossil rhabdoliths, only three years after their discovery by SCHMIDT.

In 1882 coccoliths and rhabdoliths were also discovered in the chalk of Kansas by W. S. BUNN (see WILLISTON, 1890b), although their true nature was recognized only by WILLISTON (1890a). In 1898 MCCLUNG illustrated some representative specimens from the Kansas chalk, noting that they "constitute a large portion of the real chalk."

In 1894 CUNNINGHAM in studying the chalk of Alabama identified what were probably coccoliths with the "crystalloids" of EHRENBERG, and in 1895 WOODWARD & THOMAS described and illustrated coccoliths and rhabdoliths from the chalk of Minnesota.

The study of fossil coccoliths and rhabdoliths was more or less dormant during the early part of the present century with a single notable exception—the work of ARKHANGELSKY in 1912 on Upper Cretaceous deposits of the European part of USSR. In his investigation some of the fossil coccoliths and rhabdoliths were named and described for the first time rather than just being noted as curiosities. Recent coccoliths received considerably more attention for a time, but interest in these also declined.

After a decade of being virtually ignored, coccoliths and related objects again caught the attention of investigators, and knowledge about them increased at a slow but steady rate, owing chiefly to the efforts of ERWIN KAMPTNER in Austria and GEORGES DEFLANDRE in France.

At about the middle of this century coccoliths again started to be studied intensively. Partly this was due to the introduction of better optical equipment and the application of electron microscopy, which has shown an endless variety and complexity among these minute objects; partly this interest also was due to the application of fossil coccoliths and rhabdoliths in biostratigraphy. The great abundance, endless variety, and world-wide distribution of calcareous nannofossils make them excellent stratigraphic markers by means of which strata containing them can be zoned readily and correlated with deposits in widely separated areas. The recognition of the value of coccoliths and related nannofossils as stratigraphic markers is due largely to the efforts of M. N. BRAMLETTE and his co-workers, but important contributions have been made by many others.

Because of the small size of coccoliths, study with the light microscope is not always satisfactory. The very best light optics are capable only of resolution to 0.25 μ, so that, for example, two points separated by a distance of less than 0.25 μ cannot be distinguished as two points. As a result, much of the structural detail of calcareous nannofossils is beyond the limit of resolution of light optics.

Early studies with polarized light suggested considerable complexity in the structure of coccoliths. Forms which show no structural details at all in transmitted light may show a swastika-like pseudointerference figure in polarized light. Much of the structural complexity, however, only was inferred from such evidence as the image in polarized light until 1952 when electron-microscopic examination of coccoliths was begun in two places at approximately the same time. In Oslo, Norway, BRAARUD, GAARDER, MARKALI, and NORDLI (BRAARUD *et al.*, 1952) initiated electron-microscopic examination of the calcareous skeletal elements of Recent coccolithophorids from the Norwegian sea. They used mainly transmission micrographs of coccoliths. Such micrographs reveal much of the outline and shape of coccoliths, but because of the opaqueness of calcite to the electron beam, structural details cannot be seen.

In order to get some idea of the internal structures of coccoliths BRAARUD and his associates employed a technique that was first used by HUXLEY. They dissolved the calcium carbonate of the coccoliths by treating them with a mild acid. The remaining organic network is semitransparent to the electron beam and shows much of the internal structure of the coccoliths. This technique, however, cannot be used on fossil forms in which the organic network has been altered or destroyed.

In France, DEFLANDRE & FERT, (1952, 1954) made transmission micrographs of fossil coccoliths at about the same time. In 1957 DEFLANDRE and LOUIS DURRIEU made the first carbon replicas of coccoliths for examination of structural details with the electron microscope. This same basic technique was used by BLACK & BARNES (1959) in England and by HAY and TOWE in 1962 at the University of Illinois.

PURPOSE OF INVESTIGATION

The different approaches used in light microscopy and in electron microscopy often make it difficult to relate the results of the several investigators who employ the two different techniques. Also each of the approaches has certain shortcomings that can be more or less supplemented by the other. Thus, for example, it is sometimes difficult to get an accurate idea of depth in electron micrographs even when using stereoscopic pairs or shadowed specimens. In light microscopy this can be remedied easily by using mobile mounts. On the other hand, details of structure of the coccoliths and rhabdoliths that are necessary to discriminate species accurately are not even visible generally with the light microscope. In many cases, however, subtle differences in the light-optical picture, such as generally escape even the eye of a trained observer, may be recognized easily after they have been observed in electron micrographs.

This investigation, using both light microscopy and electron microscopy, involved a detailed and systematic study of the calcareous nannofossils (coccoliths, rhabdoliths, and associated forms) in the Upper Cretaceous of the northwestern Gulf Coast area and this report describes and illustrates all of the forms encountered. It is hoped that the research will serve as a framework for further detailed biostratigraphic study, make possible a more nearly natural classification, and ultimately lead to wider application of nannofossils in stratigraphic problems.

The Upper Cretaceous deposits of the northwestern Gulf Coast were chosen because of the abundant occurrence of nannofossils and also because the general stratigraphic relationship of these deposits is fairly well known, owing primarily to the large amount of work that has been done in the area by geologists in the petroleum industry. The nearly complete nature of the stratigraphic record also makes it well suited as a standard of reference for further local and regional work with nannofossils. Samples representing all stages of the Upper Cretaceous of the Gulf Coast were examined, and the most promising were studied intensively. The Woodbine sand (Woodbinian Stage) is the only major unit not represented; it has an unfavorable lithology. Rocks of all other stages yielded excellent assemblages from almost every sample examined, and the limiting factor in the investigation was the number of samples that could be studied adequately in the time available. For this reason samples were selected carefully to yield the optimum amount of information.

METHODS OF INVESTIGATION

Most samples were examined as they were collected, using a Cooke-McArthur field microscope to determine the presence of nannofossils. It became clear very quickly that in the Upper Cretaceous deposits of the Gulf Coast a dearth of nannofossils would not be a problem, inasmuch as they were found to be a major constituent of many of the calcareous shales and in some make up almost one-fourth of the bulk. In chalk they are even more abundant, although at times difficult to extract from the more indurated layers. Shaly layers between massive beds of chalk, however, yield equally good specimens, and these samples are much easier to process.

Almost everyone who studies nannofossils prefers his own special preparation techniques, so only a brief account of sample preparation and processing is given here. A detailed discussion of preparation techniques and methods of study for calcareous nannofossils is given in a forthcoming publication by Hay, Gartner & Mohler.

A few grams of a sample are pulverized with mortar and pestle, and a suspension is prepared with distilled water. The size fraction containing the nannofossils is concentrated by allowing the suspension to settle in a 2-cm. column of water for two minutes, then decanting the supernatant in a second beaker, and after another 12 to 15 minutes of settling, decanting into a third beaker. The residue remaining in the second beaker is a concentrate of the size fraction containing the nannofossils. The process can be repeated several times and the settling times varied to suit a particular sample. In this way it is possible to obtain a high concentration of nannofossils from samples that contain only modest numbers of specimens.

From this concentrate, permanently mounted slides are prepared for light microscopy by spreading a few drops of the suspension on a cover glass, allowing it to dry, and then mounting it with Caedax, Canada balsam, or any one of a number of suitable mounting materials.

The platy nature of nannofossils causes them to settle on the cover glass in a preferred orientation, so that a side view is obtainable only accidentally and rarely. Even if such a side view is obtained, it generally is impossible to relate this view to the plan views of the same object. It is, therefore, very important for a complete understanding of the structure of a particular specimen that it be examined from all sides. For this reason a mobile mount is prepared by drying a few drops of suspension on a glass slide and then loosening the residue with the edge of a cover glass or a razor blade. The loose material then is thoroughly mixed with two drops of a nondrying, viscous (30,000 centistoke) silicone oil and covered by a cover glass. Gentle pressure applied to the cover glass causes the silicone oil to spread out and form a thin film. The nannofossils in this mount can be turned by merely moving the cover glass slightly and may be viewed from any angle with the light microscope.

The light-microscopic work was done with a Zeiss photomicroscope equipped with polarizing attachments, phase optics, and a 12-V, 60-W light source. The specimens were photographed on 35-mm. Plus-X pan film in phase contrast and in transmitted light and cross-polarized light. In noncircular specimens the vibration direction of the polarizing elements was aligned with the long and short axes of the specimen unless otherwise indicated.

For electron-microscopic study special preparation of the specimens is necessary. As has been pointed out, calcite is opaque to the electron beam; specimens, therefore, do not lend themselves to direct examination with the conventional electron microscope. The best technique for circumventing this problem was first used by Deflandre & Durrieu (1957), and this same basic process was used here. The technique involves making a thin-film surface replica of the nannofossils, much like the acetate peels that are made by paleontologists of polished and etched surfaces of larger fossils. It has been found that the most suitable substance for making such a thin-film replica of nannofossils is carbon evaporated in a vacuum. The procedure is as follows:

A few drops of coccolith suspension are placed on a fresh cleavage surface of a piece of mica trimmed to about the size of a standard glass slide. Mica is preferable to a glass slide because the thin film of carbon can be stripped off the mica more easily than from glass. The slide then is dried with the aid of a heat lamp or hot-air blower. When the slide is completely dry, it is placed in the bell jar of a vacuum evaporator about 10 cm. below the carbon rods and 15° to 20° from the vertical. Placing the slide at a slight angle from the vertical causes all raised objects to cast a "shadow" of nondeposition which is proportional to the height of the object. The bell jar then is evacuated to about 0.1 μ or less pressure, and carbon is evaporated onto the surface of the slide by passing a high current through the carbon rods. The thickness of the carbon film depends on the amount of carbon evaporated, and it is important that the film be of the proper thickness. If the film is too thick, it will not be sufficiently transparent to the electron beam, and if too thin, it may break apart during subsequent handling. The thickness of the film can be measured accurately with devices made for this purpose, but a qualitative, and with some practice, fairly accurate determination of the thickness of the film being deposited can be made quickly by placing a white paper beside the mica slide and noting the change in color as carbon is deposited on it. When the paper has turned to grayish brown, the film is of about the right thickness. With some practice an operator can become quite proficient at making qualitative thickness determinations by this technique.

When a sufficiently thick film has been evaporated onto the slide, it is removed from the bell jar, and the film is scored with a razor blade or other suitable instrument into small squares about 2 mm. on a side. The film then is "stripped" off of the mica slide by slowly immersing the slide into water while holding it at about 30° from the horizontal. The small squares of carbon film float free of the slide with most of the nannofossils and associated clay particles adhering to the film. In order to remove the clay particles the film is treated with hydrochloric and hydrofluoric acids, and when the film is clean it is picked up on standard copper electron-microscope grids.

The electron micrographs were made with Hitachi HS-6, RCA EM-2, RCA EMU-3, and Phillips 75 electron microscopes. All specimens except those of samples ARK and no. 13 were photographed on 2x2-inch glass plates; samples ARK and no. 13 were photographed on 35-mm. film. The photographs were printed at a magnification ×10,000 for further study.

SPECIAL PROBLEMS

In addition to preparation techniques some consideration should be given to the mode by which nannofossils commonly are illustrated. Of the two types—drawings and photographs—the former presents problems only insofar as the accuracy of reproduction by the artist is concerned. Photographic illustrations present a more complex situation. In using the light microscope, problems in illustrations are related to the image techniques of the microscope, which in turn are intimately related to the construction of each particular type of microscope. In most modern microscopes, prisms are used to modify the path of the light beam variously and to direct it toward the eye of the observer or toward a photographic recording device. When the beam is reflected in one of the prisms of the microscope, the image is left-right reversed just as is the image in a mirror. If the beam passes through two prisms, this reversal is corrected. Thus, in the Zeiss photomicroscope used in this study, for example, the beam passes through three prisms during normal observation; as the number of prisms (=reversals) is odd (three), the final image seen by the observer is reversed. When the microscope is adjusted for photography, a "beam splitter" is inserted into the path of the beam so that the portion of the beam directed towards the observer's eye now passes through eight prisms; because the number of prisms is even (eight), the final image is in correct orientation. The portion of the beam directed to the film, however, passes through five prisms and the image recorded by the film is reversed.

In order to give the correct orientation to the image it would be necesary to reverse the film when making a print from the negative. The last step was not followed in this study, that is, all of the photographs made with the light microscope are left-right reversed. This arrangement can be justified because the image seen by the observer in the microscope also is reversed (unless another type of microscope is used, in which case the investigator must first determine whether his image is reversed), so that a photographic print in which the image is reversed offers a better means of comparison.

In using the electron microscope, image reversal does not occur within the microscope. Where such a reversal is seen in electron micrographs, it is due either to the replica-preparation technique used for that sample or to a reversal of the photographic negative when the print was made. With regard to reversals caused during replica preparation, it can be avoided on single-stage replicas by mounting the replica with the imprint side on the support grid. On multistage replicas it must be taken into account that generally every stage in the replicating process also causes a reversal of the image.

Photographic reversal of electron micrographs frequently, though not invariably, occurs when negative prints are made. This process generally involves making a second negative by printing the original negative on photographic film instead of photographic paper and then using the second negative to make the final print. Positive and negative prints, respectively, of the same specimen are shown on Plate 27, figure 2. Obviously the negative print is more striking; the dark background appears more natural as also do the dark shadows. As is pointed out above, making a negative print requires an additional photographic step with the added possibility of making errors. The chief objection to negative prints, however, is that the image in the electron microscope does not appear that way, and comparing a negative print with an electron-microscope image is somewhat like comparing a photographic negative of a fossil with a fossil.

Photographing objects at high magnification also presents problems insofar as showing depth in objects is concerned. In the light microscope this problem is overcome by mounting nannofossils in a viscous fluid so that they can be photographed from any desired direcion. This procedure cannot be used with the electron microscope. Instead stereoscopic pairs have been used occasionally to give "depth" to electron micrographs (Pl. 27, fig. 1). Such stereoscopic pairs of photographs are not particularly difficult to make, but for technical reasons may have limited usefulness. A recent article by HELMCKE, KLEINN & BURKHARDT (1965) presents a quantitative discussion of electron stereomicrography.

PREVIOUS WORK

The first systematic work on Cretaceous nannofossils was done in 1912 by ARKHANGELSKY as part of his study of the Upper Cretaceous deposits of east European Russia. He described and illustrated several typical Upper Cretaceous species. There followed a period of relatively little work on Cretaceous nannofossils, but eventually interest was reawakened, and in the 1950's several papers by DEFLANDRE (1952a, b; 1953; 1959) and DEFLANDRE & FERT (1952, 1954) brought up to date knowledge of nannofossils, including Cretaceous nannofossils, and made several new and important contributions. One such contribution is the study by DEFLANDRE (1959) in which several of the most characteristic Cretaceous species are described and illustrated in great detail.

In 1957 GORKA studied coccolithophorids of the upper Maastrichtian of Poland and described many new forms; unfortunately the illustrations in this study are highly diagrammatic and difficult to interpret. In 1959 VEKSHINA studied coccolithophorids from the Maastrichtian of the west Siberian lowlands, describing and illustrating several new forms. During the past few years a number of important studies have appeared, notably those by MARTINI (1961) and STRADNER (1961, 1962, 1963) and by DEFLANDRE mentioned earlier. The study by BRAMLETTE & MARTINI in 1964 is particularly interesting because many of the previously described species are illustrated photographically for the first time and the great change in nannofossils that occurs at the Maastrichtian-Danian boundary is extensively documented.

ACKNOWLEDGMENTS

The investigations on which this report is based were submitted as a Ph.D. dissertation at the University of Illinois in May 1965. The study was made under the supervision of Professor W. W. HAY who introduced me to nannofossils and to electron microscopy and gave generously of his time and knowledge throughout the study. He supplied samples COR and CKL-127 and, with Dr. HANSPETER MOHLER of Basel, Switzerland, helped collect about 40 samples, of which 5 were used in this study. The electron micrographs were made by me at the Central Electron Microscope Laboratory of the University of Illinois and at the Esso Production Research Company in Houston, Texas. The latter organization also contributed sample ARK. Dr. L. A. SMITH, now with Esso Libya, Inc., provided several light-microscope pictures. Dr. R. M. JEFFORDS, Esso Production Research Company, made helpful suggestions during the preparation of the final manuscript.

STRATIGRAPHY

Upper Cretaceous deposits of the western Gulf Coast area crop out in an arc from the Rio Grande eastward to San Antonio, from there north to the Texas-Oklahoma border, and then east into Arkansas. They are up to 6,000 feet thick and consist of five readily recognizable lithostratigraphic units, the Woodbine, Eagle Ford, Austin, Taylor, and Navarro groups. These five groups correspond to the five provincial stages that have been grouped together into the Gulfian Series. The correlation of the Upper Cretaceous deposits of the northwestern Gulf Coast area with the European Upper Cretaceous stages usually referred to as a standard is shown in Figure 1. The Gulfian Series is most complete in northeastern Texas where it has a total thickness of 3,000 to 4,000 feet.

The lowermost unit, the Woodbine Sandstone, is thin in outcrop but thickens to more than 1,000 feet in the Tyler basin and consists primarily of sand with some shale. It was not examined for nannofossils as its lithology generally is unfavorable.

Above the Woodbine Sandstone is the Eagle Ford Shale. In northeastern Texas it attains its maximum thickness of about 500 feet and consists mainly of calcareous black shale that weathers brown or gray in outcrop. The following species were found in sample no. 2 from the Eagle Ford Shale but were not found above this unit: *Coccolithus coronatus* GARTNER, n. sp., *Prediscosphaera orbiculofenestra* GARTNER, n. sp., *Pontilithus obliquicancellatus* GARTNER, n. sp., and *Cretarhabdus loriei* GARTNER, n. sp., and *Chiastozygus laterculus* GARTNER, n. sp., are abundant in the Eagle Ford Shale but very rare in the lower part of the Austin Chalk.

Overlying the Eagle Ford Shale is the Austin Chalk, which in northeastern Texas consists of a lower chalk about 200 feet thick, a middle marl about 220 feet thick, and an upper chalk about 180 feet thick. Three samples were studied from the Austin Chalk, from the lower, middle, and upper parts of the unit. Many of the Austin Chalk species are forms also present in the Eagle Ford Shale. Still others continue from the Austin on into the

	EUROPEAN STAGES	SERIES	GULF COAST STAGES	GROUPS	STRATIGRAPHIC UNITS		SAMPLES
LATE CRETACEOUS	MAASTRICHTIAN	GULFIAN	NAVARROAN	NAVARRO		Kemp Clay / Arkadelphia Marl	ARK
						Corsicana Marl	COR
						Nacatoch Sandstone	
	CAMPANIAN		TAYLORAN	TAYLOR		Naylandville Marl	
						Taylor Marl (upper)	CKL-127
						Pecan Gap Chalk	
						Wolf City Sandstone	
						Taylor Marl (lower)	13
			AUSTINIAN	AUSTIN	Austin Chalk	upper Austin Chalk	12
	SANTONIAN					Bonham Marl	9
	CONIACIAN					Ector tongue	5
	TURONIAN		EAGLEFORDIAN	EAGLE FORD		South Bosque Sh.	
	CENOMANIAN				LAKE WACO	Bouldin Mbr.	2
						Cloice Mbr.	
						Bluebonnet Mbr.	
			WOODBINIAN	WOODBINE		Woodbine Sandstone	

FIG. 1. Correlation of Upper Cretaceous deposits of northwestern Gulf Coast and the European Late Cretaceous stages usually referred to as standard (N. K. BROWN, personal communication, 1966).

lower part of the Taylor Marl. One such species is *Marthasterites furcatus* (DEFLANDRE), which was found throughout the Austin Chalk and rarely at the base of the Taylor Marl. Two subspecies of the species, *M. furcatus* (DEFLANDRE) *bramlettei* DEFLANDRE and *M. furcatus* (DEFLANDRE) *crassus* DEFLANDRE were found only in the sample from the lower Austin Chalk.

The genus *Lithastrinus* does not appear to range above the Austin Chalk but is found also in the Eagle Ford Shale below.

Above the Austin Chalk are beds of the Taylor Marl. Although the latter unit consists mostly of marl, it also contains sandy and chalky beds. In northeastern Texas this unit attains a thickness of 1,000 feet or more.

Two samples were studied from the Taylor Marl; one from about 1 foot above the Austin-Taylor contact and one from near the top of the Taylor Marl. As would be expected, the assemblage from the base of the Taylor Marl resembles much more closely those from the Austin Chalk than that from near the top of the Taylor Marl. Two species of *Arkhangelskiella, A. concava* GARTNER, n. sp., and *A. scapha* GARTNER, n. sp., range from the Austin into the base of the Taylor. Near the top of the Taylor Marl these two species appear to be replaced by *A. costata* GARTNER, n. sp., *A. parca* STRADNER, and *A. specillata* VEKSHINA. *Chiastozygus plicatus* GARTNER, n. sp., *Zygodiscus biperforatus* GARTNER, n. sp., *Z. diplogrammus* (DEFLANDRE), *Z. lacunatus* GARTNER, n. sp., and *Z. sisyphus* GARTNER, n. sp., are all found in the Austin Chalk and near the base of the Taylor Marl but not in the upper part of the Taylor Marl. On the other hand, many rhabdolith-like forms occur in the upper Taylor and above but do not occur near the base of the Taylor.

Above the Taylor Marl is the Navarro Group, consisting of the Neylandville Marl, Nacatoch Sandstone, Corsicana Marl, and Kemp Clay. The last is partly equivalent to the marly Arkadelphia Formation of Arkansas. In the northwestern Gulf Coast region, the Navarro Group has a total thickness of about 1,000 feet.

Two Navarroan samples were studied, one from near the top of the Corsicana Marl and one from the lower part of the Arkadelphia Formation.

Among the assemblages from the samples, two species appear to be very significant, *Arkhangelskiella cymbiformis* VEKSHINA and *Lithraphidites quadratus* BRAMLETTE & MARTINI. Both are easily recognized and appear to be restricted to the Navarroan.

Occurrences and abundances of all species are shown in Figure 2.

TAXONOMIC AND SYSTEMATIC PROBLEMS

IDENTIFICATION

The problems of systematic study of coccoliths and related nannofossils are many and will not be resolved easily. As methods of study are related intimately to problems in taxonomy, these also will be touched on here. BRAMLETTE & MARTINI (1964) discuss most of these problems in their study of Maastrichtian and Danian nannofossils.

In electron-microscopic studies the structure of nannofossils is interpreted from the surface details that are reproduced by the carbon film. In light-microscopic studies such structure as cannot be seen has to be interpreted largely from what happens to a beam of polarized light when it passes through the object. When the results of the two techniques are taken together, a fairly accurate impression of the structure of the object is obtained. As it is as yet largely impractical to study the same specimen in both the light microscope and the electron microscope, matching electron micrographs and light micrographs of the same species can be a problem, particularly when several similar species are present in the sample. Relative abundance has been suggested as a useful way to match species, but BRAMLETTE & MARTINI raised the objection that abundance of a species also is dependent on the method by which the sample is prepared; that is, large specimens or small specimens may be favored by the settling technique used to isolate and concentrate the coccoliths. This objection can be overcome easily by using the same preparation for electron microscopy and light microscopy. A more serious objection to this method is that it would be a monumental photographing task because it is quite impractical to make a count in a darkened room such as is required for electron microscopy and at least this part of a study would have to be done from photographs.

It is important in describing a new genus or species that emphasis be put on overall morphology, rather than detail visible only with the electron microscope or between the crossed nicols of a light microscope. For example, rhabdolith-like species having two cycles of elements in the basal disc probably are not related closely to rhabdolith-like species which have only a single cycle of elements in the basal disc. Species in which the crossbars are at about 45° to the major and minor axes of the elliptical basal disc readily are distinguished from species in which the crossbars are aligned with the major and minor axes. Such readily recognizable features are most useful when defining taxa.

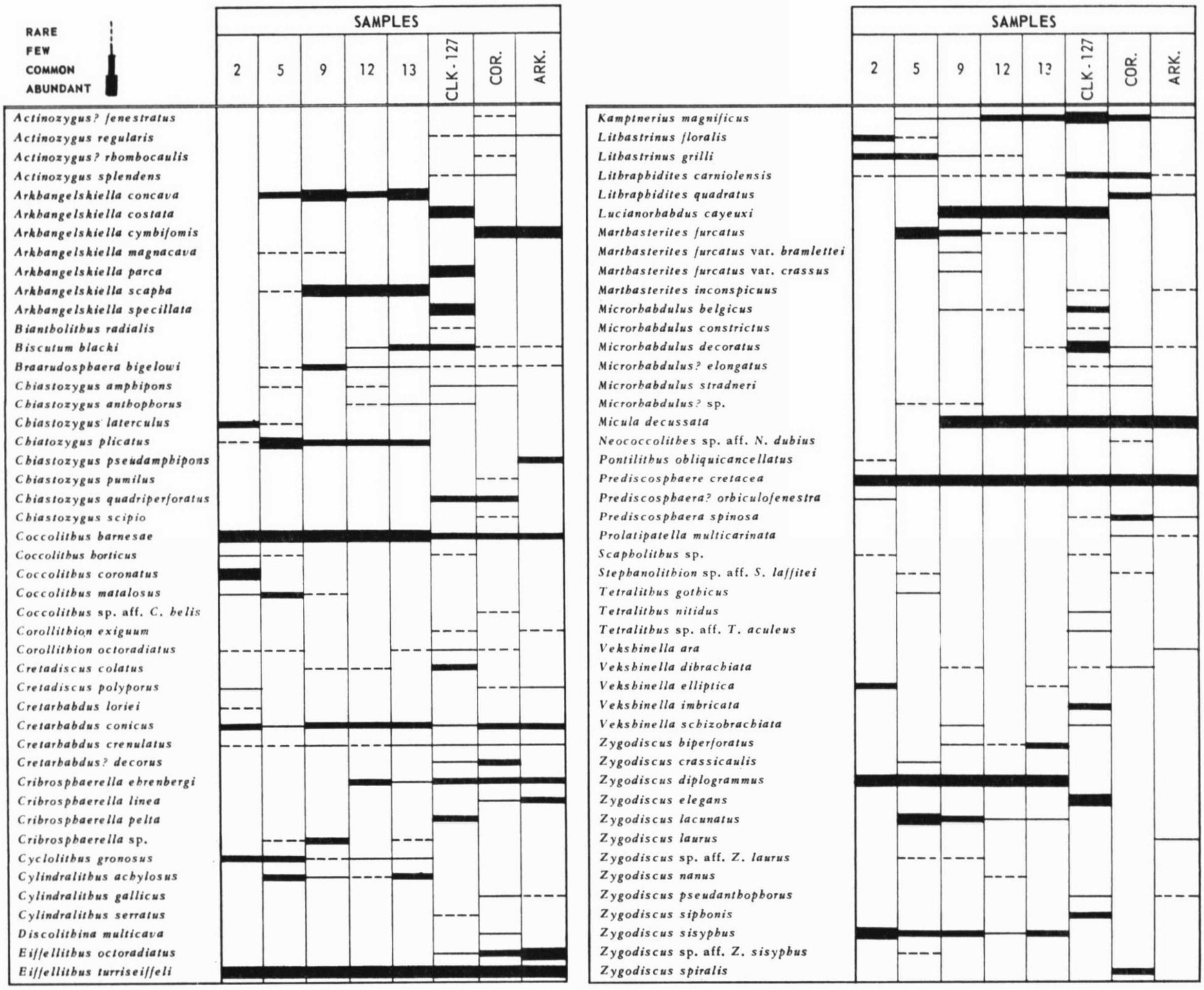


FIG. 2. Distribution of calcareous nannofossils in Upper Cretaceous of northwestern Gulf Coast.

NOMENCLATURE

It is generally accepted today that the coccolithophorids belong to the Protophyta so there is little question as to which nomenclatural code must be applied to living forms. Not so with fossil forms; in recent years botanical nomenclature and zoological nomenclature have been used with almost equal frequency by paleontologists working on nannofossils. Some authors do not make clear which code is used, and this is not determinable from their text. Since a large area of agreement is found in comparing the two codes, this problem is not necessarily very serious, but in order to insure nomenclatural stability it certainly is desirable to maintain uniformity, and hence, to follow a single nomenclatural code. The fact that the true affinity of many forms is still in doubt does not justify the application of zoological nomenclature to all calcareous nannofossils, especially those in which affinity to the plant kingdom has been established firmly.

Also available in botanical nomenclature are the concepts of organ genus and form genus, provided expressly for the naming and classification of fossil parts, as for example an isolated leaf or fructification, lacking known relationship to a specific plant. Although these concepts do not have the unanimous support of all paleobotanists concerned with taxonomy, they still are useful, even if modified, for the classification of fossil material such as nannofossils, for which little is known of the parent organism.

Objective nomenclatural problems of the calcareous nannoplankton have been resolved in the "Annotated index and bibliography of the calcareous nannoplankton" compiled by LOEBLICH & TAPPAN (1966). This work has been followed here. Subjective determinations, however, are entirely my responsibility.

TYPIFICATION

A serious problem encountered by everyone studying nannofossils with an electron microscope—and to a lesser degree, with the light microscope—is the matter of designating a type specimen. In preparing a carbon replica, it is necessary to dissolve the specimen after it has been replicated, and consequently, the would-be type is destroyed. The nearest thing to the specimen available for type designation is the replica of the specimen. This is not desirable for a type designation because the replica of a particular specimen often is extremely difficult to relocate, especially in the case of replicas mounted on unmarked grids rather than the marked variety available now. Another objection is that the delicate carbon film does not stand up well to repeated handling. Finally, the quality of the replica deteriorates with exposure to the electron beam, owing mainly to the deposition of contaminants. Therefore, the first photograph made from a replica is, under normal circumstances, better than any subsequent photographs of the same replica. The only choice that remains for the designation of a type is the first negative. It can be argued further that a negative also is ephemeral and all too easily damaged, as are all the prints made from it. This aspect of the problem is still unsolved.

In light microscopy the problem is equally perplexing. In order to be able to view a specimen from various angles the specimen must be in a mobile mount. To relocate such a specimen is impossible, and it would be a mockery to designate such a specimen as the type. In a permanent mount the position of a specimen is more or less fixed, but it has been found that for some types of permanent mounts it is impossible commonly to relocate a specimen after a period of time. What is more important, moreover, is that a specimen in a permanent mount can be viewed only from one angle, and this is unsatisfactory for an adequate determination.

The most acceptable procedure under the circumstances appears to be to designate a negative as the type (electron micrograph or light micrograph) and to conserve, along with the negative, the slides used in light microscopic work—permanent mounts and mobile mounts—as well as the replicas. Seemingly the botanical rules should be modified as soon as possible to resolve this difficulty and fix what may constitute a type.

SUPRAGENERIC CLASSIFICATION

The rapid advances being made in all areas of study of living coccolithophores and of nannofossils have virtually made every attempt at a suprageneric classification obsolete in a very short time. Several such attempts at classification have been made in the past two decades notably those of DEFLANDRE (1952a, b) and KAMPTNER (1958). Because of the limited scope of the present work, these classifications will not be reviewed here nor will any of them be given preference. Instead, the genera studied here are arranged in natural groups within established families and subfamilies and where necessary new families and subfamilies are proposed. The suprageneric assignment of the genera recognized in this present study follows.

Outline of Classification Here Adopted

Family Coccolithaceae KAMPTNER, 1928
  Subfamily Coccolithoideae KAMPTNER, 1928
    Genus *Coccolithus* SCHWARZ, 1894
      Biscutum BLACK, 1959
      Cyclolithus DEFLANDRE, 1952
Family Rhabdosphaeraceae LEMMERMANN, 1903
  Subfamily Prediscosphaeroideae GARTNER, new subfamily
    Genus *Prediscosphaera* VEKSHINA, 1959
      Cretarhabdus BRAMLETTE & MARTINI, 1964
  Subfamily Parhabdolithoideae GARTNER, new subfamily
    Genus *Actinozygus* GARTNER, new genus
      Eiffellithus REINHARDT, 1965
      Chiatozygus GARTNER, new genus
      Neococcolithes SUJKOWSKI, 1931
      Pontilithus GARTNER, new genus
      Vekshinella LOEBLICH & TAPPAN, 1963
      Zygodiscus BRAMLETTE & SULLIVAN, 1961
  Subfamily Stephanolithoideae VEKSHINA, 1959
    Genus *Stephanolithion* DEFLANDRE, 1939
      Corollithion STRADNER, 1961
Family Syracosphaeraceae LEMMERMANN, 1903
  Subfamily Syracosphaeroideae KAMPTNER, 1928
    Genus *Cretadiscus* GARTNER, new genus
      Discolithina LOEBLICH & TAPPAN, 1963
  Subfamily Arkhangelskielloideae GARTNER, new subfamily
    Genus *Arkhangelskiella* VEKSHINA, 1959
      Kamptnerius DEFLANDRE, 1959
      Cribrosphaerella DEFLANDRE, 1952
      Prolatipatella GARTNER, new genus
Family Discoasteraceae VEKSHINA, 1959
    Genus *Marthasterites* DEFLANDRE, 1959
      Tetralithus GARDET, 1956
Family Microrhabdulaceae GARTNER, new family
    Genus *Microrhabdulus* DEFLANDRE, 1959
      Lithraphidites DEFLANDRE, 1963
      Lucianorhabdus DEFLANDRE, 1959
Family Braarudosphaeraceae DEFLANDRE, 1947
    Genus *Braarudosphaera* DEFLANDRE, 1947
      Biantholithus BRAMLETTE & MARTINI, 1964
Family Calciosoleniaceae KAMPTNER, 1937
    Genus *Scapholithus* DEFLANDRE, 1954
Genera Incertae Sedis
    Genus *Cylindralithus* BRAMLETTE & MARTINI, 1964
      Lithastrinus STRADNER, 1962
      Micula VEKSHINA, 1959

SYSTEMATIC PALEONTOLOGY

Family COCCOLITHACEAE Kamptner, 1928

Subfamily COCCOLITHOIDEAE Kamptner, 1928

Genus COCCOLITHUS Schwarz, 1894

Type Species.—Coccolithus oceanicus SCHWARZ, 1894 (=*Coccosphaera pelagica* WALLICH, 1877) (see BRAARUD *et al.*, 1964).

Elliptical placoliths consisting of smaller proximal and larger distal shield, shields constructed of imbricate elements that meet along sutures inclined to radius; shields connected at their center by elliptical tube or collar that is continuous with proximal shield; central tube may be open or closed.

COCCOLITHUS BARNESAE (Black)

Tremalithus barnesae BLACK in BLACK & BARNES, 1959, p. 325, pl. 9, fig. 1-2.

Colvillea barnesae (Black), BLACK, 1964, p. 311.

Watznaueria angustoralis REINHARDT, 1964, p. 753, fig. 4a,b; pl. 2, fig. 2.

Coccolithus paenepelagicus STOVER, 1966, p. 139, pl. 1, fig. 10-11; pl. 3, fig. 22b.

Discussion.—The description given for this species by BLACK seems overly restrictive. The number of elements in either of the shields can vary from 23 to 37 and this number does not appear to be dependent on the size of the specimen. The central area may be closed at both ends as in the specimens figured by BLACK & BARNES, or it may be partially or completely open. Distally the central opening generally flares out and forms a conical depression surrounded by the collar or central tube. Proximally the opening is not so regular and commonly covered completely or obscured. The coccosphere of this species (Pl. 16, fig. 16) is made up of about 10 elliptical placoliths which overlap and imbricate to form a durable structure that is commonly preserved in Upper Cretaceous sediments. Some confusion has arisen as to the nomenclature of this species, probably because of its variability, abundance, and widespread occurrence. The species originally was described as *Tremalithus barnesae* by BLACK (1959). In 1964 BLACK proposed the generic name *Colvillea* for this species, and stated that *Colvillea* differs from *Coccolithus* primarily in having the shields in contact and in lacking a central pore. Close examination of the species in viscount mount demonstrated that the two shields are separated, and indeed, even specimens with a perforated center are encountered (Pl. 1, fig. 12).

The genus *Watznaueria* proposed by REINHARDT in 1964 also for this species is distinguished from *Coccolithus* by the *"zentrale Micell-Kraenze,"* a feature that may or may not be developed in this species and consequently cannot be made the basis for a generic distinction.

Maximum diameter.—4.5-8.5 μ.

Occurrence.—This species was found in all samples and is very common throughout the Eagle Ford Shale, Austin Chalk, Taylor Marl, and Navarro Group.

Illustrations.—Plate 1, figure 12. Specimen from Arkadelphia Formation in Arkansas (sample ARK); distal view, electron micrograph, ×5,000.——Plate 4, figures 6-7. Specimens from Corsicana Marl of Texas (sample COR); proximal views, electron micrographs, ×5,000.——Plate 8, figures 18-22; Plate 11, figure 11; Plate 14, figures 4-5; Plate 15, figure 8. Specimens from Taylor Marl of Texas. Pl. 8, fig. 18-20, distal views, fig. 21-22, proximal views (sample CKL-127 from upper beds), electron micrographs, ×5,000. Pl. 11, fig. 11, distal views (sample CKL-127 from upper beds), light micrographs, phase contrast (11a), transmitted light (11b), cross-polarized light (11c), ×2,500. Pl. 14, fig. 4-5, distal views (sample 13), electron micrographs, ×5,000. Pl. 15, fig. 8, distal (8a-c) and side (8d) views (sample 13), light micrographs, phase contrast (8a), transmitted light (8b), cross-polarized light, transmitted light (8d), ×2,500.——Plate 16, figures 15-16; Plate 19, figure 12; Plate 20, figures 12-13; Plate 22, figures 16-17. Specimens from Austin Chalk of Texas. Pl. 16, fig. 15-16, proximal view and coccosphere (sample 12), electron micrographs, ×5,000. Pl. 19, fig. 12, proximal (12a-c) and side (12d) views (sample no. 9), light micrographs, phase contrast (12a), transmitted light (12b,d), cross-polarized light (12c), ×2,500. Pl. 20, fig. 12-13, proximal and distal views (sample 9), electron micrographs, ×5,000. Pl. 22, fig. 16-17, distal and proximal views (sample no. 5), electron micrographs, ×5,000.——Plate 24, figure 8; Plate 25, figures 1-2. Specimens from Eagle Ford Shale (sample 2) of Texas. Pl. 24, fig. 8, proximal (8a-c) and oblique (8d) views, light micrographs, phase contrast (8a), transmitted light (8b,d), cross-polarized light, ×2,500. Pl. 25, fig. 1-2, proximal and distal views, electron micrographs, ×5,000.

COCCOLITHUS CORONATUS Gartner, new species

Elliptical placolith with small notch developed in each element of proximal shield.

Description.—Both shields of the placolith are constructed of 27 to 33 elements, those of the distal shield imbricating dextrally, and when viewed proximally, the sutures are seen to incline clockwise. The elements of the proximal shield also imbricate dextrally but the sutures incline counterclockwise. The elements of the distal shield are squarely truncated and form a smooth periphery; elements of the proximal shield are terminated squarely or rounded but do not come to a point as in *Coccolithus barnesae* (BLACK). A central area is defined by notches in the elements of the proximal shield. The notches are developed where the elements bend sharply to form the collar or central tube. The central area may be open or closed.

Discussion.—This species differs from *Coccolithus barnesae* (BLACK) in the notch developed in the elements of the proximal shield.

Maximum diameter.—6.4-7.3 μ.

Type specimen.—UI-H-2539 (Pl. 23, fig. 27), from the Eagle Ford Shale.

Occurrence.—Sample 2 from the Eagle Ford Shale.

Illustrations.—Plate 23, figures 26-28, probably proximal view of isolated distal shield (26); proximal views of type and another specimen (27-28), electron micrographs, ×5,000.

COCCOLITHUS HORTICUS Stradner, Adamiker & Maresch

Coccolithus horticus STRADNER, ADAMIKER & MARESCH, in STRADNER & ADAMIKER, 1966, p. 337, pl. 2, fig. 4; text-fig. 1, 2.

Discussion.—The three subparallel longitudinal bars in the large central area of this species appear to be more strongly converging in the type specimen than in any specimen figured here. This convergence away from the transverse bar that is aligned with the short axis of the ellipse may be due in part to the curvature of the coccolith; however, this is difficult to judge. The type specimen of the species also appears to be more elongate than any of the specimens illustrated here.

Maximum diameter.—5.0-6.4 μ.

Occurrence.—Sample 2 from the Eagle Ford Shale, sample 5 from the lower Austin Chalk, and sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 10, figure 2. Proximal view of specimen from upper Taylor Marl (sample CKL-127) of Texas, electron micrograph, ×5,000.——Plate 25, figures 6-8; Plate 26, figure 1. Specimens from Eagle Ford Shale (sample 2) of Texas. Pl. 25, fig. 6-8, several interlocked specimens of *C. horticus* with one of *Chiastozygus laterculus* GARTNER, n. sp. (6), two interlocked specimens with central area broken out (7), isolated specimen (8), electron micrographs, ×5,000. Pl. 26, fig. 1, distal (1a-c) and side (1d) views of specimens, phase contrast (1a), transmitted light (1b,d), cross-polarized light, light micrographs, ×2,500.

COCCOLITHUS MATALOSUS Stover

Coccolithus matalosus STOVER, 1966, p. 139, pl. 2, fig. 1-2, pl. 8, fig. 10.

Discussion.—In 1963 STRADNER (in GOHRBAND, PAPP & STRADNER) described *Coccolithus helis* from the Danian of Austria. The two specimens that he illustrated are very similar to *Coccolithus matalosus* STOVER. Also BRAMLETTE & MARTINI (1963) illustrated two specimens of *C. helis* from the Clayton Formation (Danian) of Alabama. Electron micrographs of these specimens show uniquely constructed crossbars and auxiliary structure. The diagnostic features of the crossbars, however, are too small to be resolved with a light microscope; consequently some doubt remains about the validity of the distinction. Nevertheless, it appears that two distinct species are involved; *C. helis* is known only from the Danian, whereas *C. matalosus* has not been found higher than the Austin Chalk.

Maximum diameter.—6.2 μ.

Occurrence.—Sample 2 from the Eagle Ford Shale, and samples 5 and 9 from the Austin Chalk.

Illustrations.—Plate 24, figure 5. Proximal (5a-c) and side (5d) views of specimens from Austin Chalk (sample 5) of Texas, phase contrast (5a), transmitted light (5b,d), cross-polarized light (5c), light micrographs, ×2,500.

COCCOLITHUS SP. aff. COCCOLITHUS HELIS Stradner

Discussion.—This elliptical placolith is smaller than *Coccolithus helis* STRADNER and has only about half as many elements in each shield. It has a smaller central opening and a somewhat different structure across the opening. It is also similar to *Prediscosphaera spinosa* (BRAMLETTE & MARTINI) but appears to be more closely allied to the *C. helis* type. Because of these similarities the single electron micrograph is not sufficient to differentiate a new species.

Maximum diameter.—4.4 μ.

Occurrence.—Sample COR, Corsicana Marl, Navarroan.

Illustrations.—Plate 4, figure 8. Proximal view of specimen from Corsicana Marl (sample COR) of Texas, electron micrograph, ×5,000.

Genus BISCUTUM Black, 1959

Type species.—*Biscutum testudinarium* BLACK, 1959.

Elliptical placolith with closely appressed shields; shields constructed of large elements that meet along straight, nearly radial sutures; center generally not perforated.

BISCUTUM BLACKI Gartner, new species

Broadly elliptical species of *Biscutum* with wedge-shaped elements and straight, radial sutures.

Description.—This placolith is constructed of 2 closely appressed shields, the proximal shield being the smaller one. The shields are made of 16 to 22 elements which show only slight dextral imbrication. The sutures are straight and very nearly radial, and the elements are terminated squarely or slightly rounded along the periphery. The collar or central tube connecting the two shields is closed.

Discussion.—*Biscutum blacki* is similar to *B. testudinarium* BLACK but differs in that the latter species has a peculiar granular structure in the center which is built of calcite rhombs arranged in a rosette in the center of the proximal shield.

Maximum diameter.—4.9-6.8 μ.

Type specimen.—UI-H-2249 (Pl. 8, fig. 9) from the Taylor Marl.

Occurrence.—Sample 12 from the Austin Chalk; samples 13 and CKL-127 from the Taylor Marl; samples COR from the Corsicana Marl, and ARK from the Arkadelphia Formation, both of Navarroan age.

Illustrations.—Plate 1, figure 7. Proximal view of specimen from Arkadelphia Formation (sample ARK) of Arkansas, electron micrograph, ×5,000.——Plate 6, figure 2. Distal view of specimen from Corsicana Marl (sample COR) of Texas, light micrographs, phase contrast (2a), transmitted light (2b), cross-polarized light (2c),

×2,500.——Plate 8, figures 8-10; Plate 11, figure 8; Plate 15, figure 2. Specimens from Taylor Marl of Texas; Pl. 8, fig. 8-10 (from sample CKL-127), distal view (8), proximal views of type (9) and another specimen (10), electron micrographs, ×5,000; Pl. 11, fig. 8 (from sample CKL-127), proximal view, light micrographs, phase contrast (8a), transmitted light (8b), cross-polarized light (8c), ×2,500; Pl. 15, fig. 2 (from sample 13), distal view, light micrographs, phase contrast (2a), transmitted light (2b), cross-polarized light (2c), ×2,500.——Plate 16, figure 8. Proximal view of specimen from Austin Chalk (sample 12) of Texas, electron micrograph, ×5,000.

Genus CYCLOLITHUS Deflandre, 1952

Type species.—Cyclolithus inflexus DEFLANDRE, 1952.

Elliptical ring with large open center and consisting of two closely appressed cycles of which proximal cycle is smaller.

CYCLOLITHUS GRONOSUS Stover, 1966

Cyclolithus gronosus STOVER, 1966, p. 140, pl. 1, fig. 1-3, pl. 8, fig. 1.

Discussion.—This species is unusual in several respects. It looks like a large species of *Coccolithus* that has a very large open center. It is also very similar to the basal disc of large specimens of *Cretarhabdus conicus* from which the stem supporting structure has broken out. There is, however, no indication that the latter is the case. Each cycle of the species is constructed of about 35 dextrally imbricate elements that incline clockwise when viewed proximally. The two cycles are closely appressed but a definite groove lies between them.

Maximum diameter.—10.0 μ.

Occurrence.—STOVER recorded the species from Albian to Cenomanian. In the present study it was recorded in sample 2 from the Eagle Ford Shale, in samples 5, 9 and 12 from the Austin Chalk, and in sample 13 from the base of the Taylor Marl.

Illustration.—Plate 22, figure 22. Proximal view of specimen from Austin Chalk (sample 5) of Texas, electron micrograph, ×5,000.

Family RHABDOSPHAERACEAE Lemmermann, 1903

Subfamily PREDISCOSPHAEROIDEAE Gartner, new subfamily

Rhabdoliths in which basal disc is constructed of two distinct cycles of elements.

Genus PREDISCOSPHAERA Vekshina, 1959

Type species.—Prediscosphaera decorata VEKSHINA, 1959.

Rhabdoliths in which basal disc is constructed of two distinct cycles of elements, cycles being separated by groove with proximal cycle smaller; open central area spanned by two crossbars that intersect at center and are surmounted by stem (Figure 3).

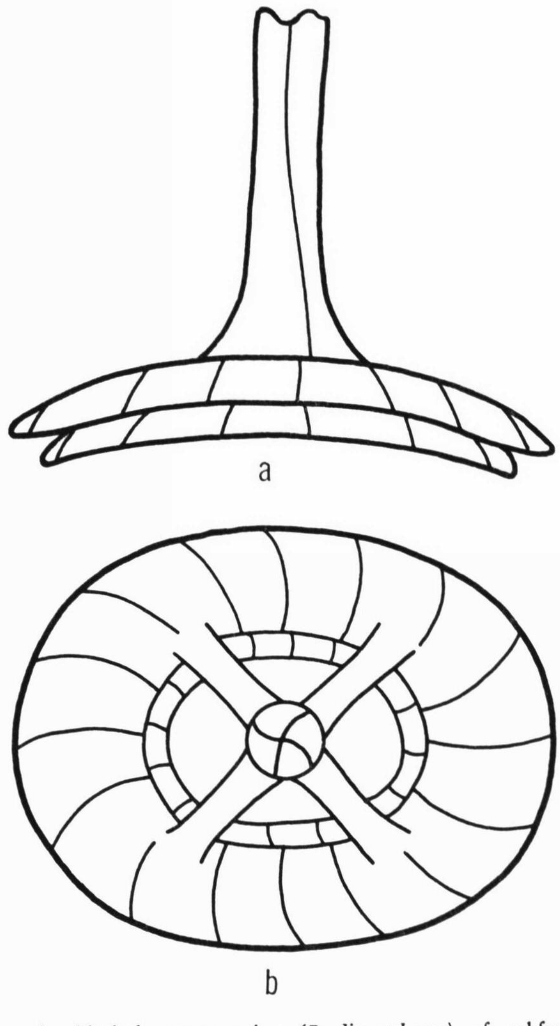


FIG. 3. Typical representative *(Prediscosphaera)* of subfamily Prediscosphaeroideae showing two-cycle construction of basal disc and groove that separates the two cycles. *a*—Side view; *b*—distal view.

PREDISCOSPHAERA CRETACEA (Arkhangelsky)

Coccolithophora cretacea ARKHANGELSKY, 1912, p. 410, pl. 6, fig. 12-?13.

non Coccolithus cretaceus Arkhangelsky, DEFLANDRE 1952a, p. 463, fig. 300D.

Rhabdolithus intercisus DEFLANDRE in DEFLANDRE & FERT, 1954, p. 159, pl. 13, fig. 12-13, text-fig. 91-92.

Discolithus cretaceus (Arkhangelsky), GORKA, 1957, p. 251, pl. 2, fig. 11.—BLACK & BARNES, 1959, p. 326, pl. 11, fig. 1-2.

Prediscosphaera decorata VEKSHINA, 1959, p. 73, pl. 1, fig. 8-9, pl. 2, fig. 13a.

Zygrhablithus intercisus (DEFLANDRE) 1959, p. 136, pl. 1, fig. 5-20.

Deflandrius cretaceus (Arkhangelsky), BRAMLETTE & MARTINI, 1964, p. 301, pl. 2, fig. 11-12.

Deflandrius intercisus (Deflandre), BRAMLETTE & MARTINI, 1964, p. 301, pl. 2, fig. 13-16.

Discussion.—The basal disc of this species consists of 2 cycles of about 16 keystone-shaped elements arranged in a broad ellipse. The cycles, the proximal being the smaller, are closely appressed and in some instances appear to be fused together into one massive disc with a peripheral groove. The x-shaped crossbars that extend across the central area may have a square or rounded opening at their intersection. The crossbars, when seen in well-preserved specimens, are almost invariably double, consisting of a distal and proximal set. Viewed proximally the nearest set is rotated 5° to 10° clockwise from the distal set.

From the center of the crossbars a stem may extend distally. At the distal tip of the stem 4 or more triangular plates extend laterally. The stem consists of 2 distinct segments joined near the middle by 4 teeth on one part of the stem fitting into 4 grooves or sockets on the other part. The stem frequently separates at this point, each part appearing to be made of a bundle of 4 calcite rods, a feature that is very distinct in polarized light.

The nomenclature of this species is somewhat confused. The species was first described by ARKHANGELSKY in 1912, but his illustrations are ambiguous. In 1954 DEFLANDRE described *Rhabdolithus intercisus,* but illustrations of this species also are not very clear. In 1959, VEKSHINA named and described *Prediscosphaera decorata,* citing *Coccolithophora cretacea* ARKHANGELSKY in her synonymy. She also pointed out the similarity of her specimens to ARKHANGELSKY's. The specific name *"decorata"* is an objective junior synonym of the specific name *"cretacea,"* and, therefore, is invalid. The transmission electron micrographs of VEKSHINA (1959, pl. 1, figs. 8, 9) are more accurate than her drawings, which appear to be largely interpretations. In 1959 DEFLANDRE redescribed *R. intercisus,* reillustrated the type specimen, and transferred the species to the new genus *Zygrhablithus.* DEFLANDRE's 1959 characterization and illustration of *Z. intercisus* are excellent, and he indicated that he did not believe *C. cretacea* ARKHANGELSKY to be the same species.

BRAMLETTE & MARTINI in 1964 illustrated the 2 species and indicated that they are very similar and, in fact, may prove to be identical. They proposed the genus *Deflandrius,* and designated *Rhabdolithus intercisus* DEFLANDRE as the type. DEFLANDRE (1959) and BRAMLETTE & MARTINI (1964) indicated that *Zygrhablithus intercisus* (DEFLANDRE) was similar to *Coccolithophora cretacea* ARKHANGELSKY, but it is disappointing that they did not point out the differences between the 2 species. Numerous electron micrographs and a considerable amount of light microscopic observations have failed to yield any sensible grouping and lead to the conclusion that only a single species is involved.

Maximum height.—4.0-16.4 μ.

Occurrences.—This species was found in all samples examined and appears to be abundant throughout the Upper Cretaceous.

Illustrations.—Plate 2, figures 10-14; Plate 3, figure 8. Specimens from Arkadelphia Formation (sample ARK) of Arkansas; Pl. 2, fig. 10-14, distal (10), proximal (11-12), and side (13-14) views, electron micrographs, ×5,000; Pl. 3, fig. 8, side view, light micrographs, phase contrast (8a), transmitted light (8b), cross-polarized light, (8c), ×2,500.——Plate 4, figures 19-24; Plate 6, figures 14-15. Specimens from Corsicana Marl (sample COR) of Texas; Pl. 4, fig. 19-24, distal (19), proximal (20), side (21-23), and oblique (24) views, electron micrographs, ×5,000; Pl. 6, fig. 14-15, side (14) and distal (15) views, light micrographs, phase contrast (14a, 15a), transmitted light (14b, 15b), cross-polarized light (14c, 15c), ×2,500.——Plate 9, figures 1-4; Plate 12, figure 1; Plate 14, figures 20-22. Specimens from Taylor Marl of Texas; Pl. 9, fig. 1-4 (from sample CKL-127), side (1-2) and distal (3-4) views, electron micrographs, ×5,000; Pl. 12, fig. 1 (from sample CKL-127), side view, light micrographs, phase contrast (1a), transmitted light (1b), cross-polarized light (1c), ×2,500; Pl. 14, fig. 20-22 (from sample 13), side (20-21) and distal (22) views, electron micrographs, ×5,000.——Plate 18, figure 8; Plate 22, figures 1-3; Plate 23, figures 4-6. Specimens from Austin Chalk of Texas; Pl. 18, fig. 8 (from sample 12), side view; electron micrograph, ×5,000; Pl. 22, fig. 1-3 (from sample 9), side (1-2) and distal (3) views, electron micrographs, ×5,000; Pl. 23, fig. 4-6 (from sample no. 5), side (4), distal (5), and proximal (6) views, electron micrographs, ×5,000.——Plate 25, figures 12-14; Plate 26, figure 2. Specimens from Eagle Ford Shale (sample 2) of Texas; Pl. 25, fig. 12-14, side (12-13) and distal views, electron micrographs, ×5,000; Pl. 26, fig. 2, distal view, light micrographs, phase contrast (2a), transmitted light (2b), cross-polarized light (2c), ×2,500.

PREDISCOSPHAERA SPINOSA (Bramlette & Martini)

Deflandrius spinosus BRAMLETTE & MARTINI, 1964, p. 301, pl. 2, fig. 17-20.

Discussion.—To the characterization of this species by BRAMLETTE & MARTINI can be added the observation that the crossbars are not perfectly aligned with the major and minor axes of the elliptical disc but are rotated about 5° clockwise when viewed proximally. Also, at the junction of the inner margin of the disc and the crossbars the bars tend to curve and expand in a clockwise direction. The crossbars appear to be of a double construction, a feature best seen in corroded specimens.

Maximum diameter of disc.—3.8-8.0 μ.

Height of stem.—7.0-9.2 μ.

Occurrence.—BRAMLETTE & MARTINI recorded the species from the type Maastrichtian and from equivalent deposits in Denmark, southwestern France, Tunisia, Alabama, and Arkansas. Specimens figured here are from samples ARK from the Arkadelphia Formation and COR from the Corsicana Marl, both of Navarroan age, and from sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 2, figures 15-16; Plate 3, figures 9-10. Specimens from Arkadelphia Formation (sample ARK) of Arkansas; Pl. 2, fig. 15-16, proximal and distal views, electron micrographs, ×5,000; Pl. 3, fig. 9-10, proximal and side views, light micrographs, phase contrast (9a, 10a), cross-polarized light (9b, 10b), ×2,500.——Plate 5, figures 7-9; Plate 6, figure 16. Specimens from Corsicana Marl (sample COR) of Texas; Pl. 5, fig. 7-9, distal (7) and proximal (8-9) views, electron micrographs, ×5,000;

Pl. 6, fig. 16, distal (16a-c) and side (16d) views, light micrographs, phase contrast (16a,d), transmitted light (16b), cross-polarized light (16c), ×2,500.——Plate 11, figure 17. Distal view of specimen from Taylor Marl (sample CKL-127) of Texas, light micrographs, phase contrast (17a), transmitted light (17b), cross-polarized light (17c), ×2,500.

PREDISCOSPHAERA? ORBICULOFENESTRA Gartner, new species

Elliptical placolith with large central opening spanned by 2 crossbars that may be surmounted by stem; crossbars divide central area into 4 circular openings.

Description.—The 2 cycles of the regularly elliptical disc are constructed of 40 to 50 elements which imbricate very slightly dextrally and have their sutures arranged radially. The cycles are of nearly equal size, with the proximal cycle slightly smaller. The open central area is spanned by crossbars aligned with the major and minor axes of the ellipse. The crossbars are double, and at the junction with the inner rim of the disc they spread out until they meet the spreading arm of the adjacent crossbar. In this manner a nearly circular opening is formed in each quadrant of the elliptical central area. At their intersection the crossbars may be surmounted by a hollow circular stem. The stem, if present, is very peculiarly constructed. It is massive and fluted, with regularly spaced circumferential rows of low rectangular calcite prisms standing out in relief.

Discussion.—This species differs from others of *Prediscosphaera* in having a much larger number of elements in each shield and in having circular openings in each quadrant of the central area. The taxonomic position of this species is not entirely clear, but the 2-cycle construction of the basal disc places the species definitely in the subfamily Prediscosphaeroideae.

Maximum diameter.—8-9 μ.

Type specimen.—UI-H-2576 (Pl. 25, fig. 25) from the Eagle Ford Shale.

Occurrence.—Sample 2 from the Eagle Ford Shale.

Illustrations.—Plate 25, figures 23-25; Plate 26, figure 8. Specimens from Eagle Ford Shale (sample 2) of Texas; Pl. 25, fig. 23-25, side (23) and distal (24-25) views, electron micrographs, ×5,000; Pl. 26, fig. 8, proximal (8a-c) and side (8d) views, light micrographs, phase contrast (8a), transmitted light (8b,d), cross-polarized light, ×2,500.

Genus CRETARHABDUS Bramlette & Martini, 1964

Type species.—*Cretarhabdus conicus* Bramlette & Martini, 1964.

Rhabdoliths in which basal disc is constructed of two cycles of elements separated by groove; central area covered by subradially arranged ribs that support crossbars aligned with major and minor axes of ellipse; crossbars intersect at center and may be surmounted by short spine or well-developed stem.

CRETARHABDUS LORIEI Gartner, new species

Arkhangelskiella striata Stradner, Stover, 1966, p. 137, pl. 2, fig. 3-4.

Two cycle elliptical basal disc; crossbar aligned with major and minor axes and supported by parallel bars in each quadrant.

Description.—The elliptical basal disc is constructed of 2 cycles, of which the proximal cycle is smaller. The central area is large and traversed by relatively delicate crossbars aligned with the major and minor axes of the ellipse. In each quadrant of the ellipse a set of parallel bars extends from the inner margin of the rim to the crossbars. A stem has not been observed in this species.

Discussion.—This species resembles superficially *Pontilithus obliquicancellatus* Gartner, n. sp., but that species has a single cycle in the basal disc and is constructed entirely differently. *Cretarhabdus loriei* is similar to large specimens of *C. conicus* Bramlette & Martini but differs in having structurally and crystallographically parallel ribs supporting the crossbars. Stover (1966) identified this species as *Arkhangelskiella striata* Stradner, but the species has only 2 cycles in the basal disc and distinct crossbars, as opposed to the grooved sutures of *Arkhangelskiella*. Thus, the species is assigned to *Cretarhabdus*.

Maximum diameter.—12.0 μ.

Type specimen.—UI-H-2550 (Pl. 24, fig. 9, 10) from the Eagle Ford Shale.

Occurrence.—Sample 2, Eagle Ford Shale.

Illustrations.—Plate 24, figures 9-10. Proximal (9a-d) and side (10) views of type specimen from Eagle Ford Shale (sample 2) of Texas, light micrographs, phase contrast (9a), transmitted light (9b, 10), cross-polarized light (9c,d), specimen oriented at about 45° to vibration direction of nicols in fig. 9d, ×2,500.

CRETARHABDUS CONICUS Bramlette & Martini

Cretarhabdus conicus Bramlette & Martini, 1964, p. 299, pl. 3, fig. 5-8.

Discussion.—The elliptical basal disc consists of 2 distinct cycles, of which the proximal is the smaller. Each cycle is constructed of 25 to 35 elements. The central structure consists of subradially arranged ribs attached to the inner margin of the distal cycle, and may overlap onto the distal side of that cycle. In many specimens the ribs coalesce and form a solid structure that is perforated by 2 or 3 rows of concentrically arranged holes. The ribs support a set of crossbars that are aligned with the major and minor axes of the elliptical disc and which in turn support a stem at their intersection.

Numerous specimens were studied in the electron microscope and the light microscope. Most of these do not belong clearly to *Cretarhabdus conicus* or to *C. crenulatus* Bramlette & Martini, but fall somewhere between. So far as has been observed, these species always occur together, which further suggests that in fact they may belong to one highly variable species.

Occurrence.—This species was recorded by Bramlette & Martini from the type Maastrichtian and from equivalent deposits in Denmark, France, Tunisia, Alabama, and Arkansas. In this study the species was found in all samples examined; Eagle Ford Shale, Austin Chalk, Taylor Marl, and the Navarro Group.

Illustrations.—Plate 1, figures 10-11; Plate 3, figures 5-6. Specimens from Arkadelphia Formation (sample ARK) of Arkansas; Pl. 1, fig. 10-11, distal views, electron micrographs, ×5,000; Pl. 3, fig. 5-6, proximal (5a-c), distal (6a-c) and side (6d) views, light micrographs, phase contrast (5a, 6a), transmitted light (5b, 6b,d), cross-polarized light (5c, 6c), ×2,500.——Plate 4, figures 9-12; Plate 6, figures 3-4. Specimens from Corsicana Marl (sample COR) of Texas; Pl. 4, fig. 9-12, distal (9-11) and proximal (12) views, electron micrographs, ×5,000; Pl. 6, fig. 3-4, proximal and side views, light micrographs, phase contrast (3a, 4a), transmitted light (3b, 4b), cross-polarized light (3c), ×2,500.——Plate 11, figure 12; Plate 14, figures 7-9; Plate 15, figure 9. Specimens from Taylor Marl of Texas; Pl. 11, fig. 12 (from sample CKL-127), proximal view, light micrograph, phase contrast (12a), transmitted light (12b), cross-polarized light (12c), ×2,500; Pl. 14, fig. 7-9 (from sample 13), distal (7, 9) and proximal (8) views, electron micrographs, ×5,000; Pl. 15, fig. 9 (from sample 13), distal (9a-c) and side (9d) views, light micrographs, phase contrast (9a), transmitted light (9b,d) cross-polarized light (9c), ×2,500.——Plate 16, figures 12-14; Plate 17, figure 10; Plate 20, figures 8-9; Plate 22, figures 20-21. Specimens from Austin Chalk of Texas; Pl. 16, fig. 12-14 (from sample 12), distal views (13-14, *C.* sp. cf. *C. conicus*), electron micrographs, ×5,000; Pl. 17, fig. 10 (from sample 9), proximal view, light micrograph, phase contrast (10a), transmitted light (10b), cross-polarized light (10c), ×2,500; Pl. 20, fig. 8-9 (from sample 9), distal and proximal views, electron micrographs, ×5,000; Pl. 22, fig. 20-21 (from sample 5), distal and proximal views, electron micrographs, ×5,000.——Plate 24, figure 11; Plate 25, figures 3-4. Specimens from Eagle Ford Shale (sample 2) of Texas; Pl. 24, fig. 11, proximal view, light micrograph, phase contrast (11a), transmitted light (11b), cross-polarized light (11c), ×2,500; Pl. 25, fig. 3-4, distal views, electron micrographs, ×5,000.

CRETARHABDUS CRENULATUS Bramlette & Martini

Cretarhabdus crenulatus BRAMLETTE & MARTINI, 1964, p. 300, pl. 2, fig. 21-24.

Discussion.—Proximal views of the elliptical basal disc indicate that it has 2 cycles, each constructed of 18 to 35 elements. The proximal cycle is somewhat smaller than the distal one but otherwise they are similar. The central structure consists of subradial ribs which at one end are attached to the inner margin of the distal cycle and at the other end support crossbars that are aligned with the major and minor axes of the ellipse. In some specimens the crossbars are surmounted by a stem at their intersection. For a further discussion of the status of this species see *Cretarhabdus conicus* BRAMLETTE & MARTINI.

Occurrence.—This species was recorded by BRAMLETTE & MARTINI from the type Maastrichtian and from equivalent deposits in Denmark, southwestern France, Tunisia, Alabama, and Arkansas. In this study it was found in every Upper Cretaceous sample; Eagle Ford Shale, Austin Chalk, Taylor Marl, and the Navarro Group.

Illustrations.—Plate 1, figures 8-9. Proximal views of specimens from Arkadelphia Formation (sample ARK) of Arkansas, electron micrographs, ×5,000.——Plate 6, figure 6. Proximal view of specimen from Corsicana Marl (sample COR) of Texas, light micrographs, phase contrast (6a), transmitted light (6b), cross-polarized light (6c), ×2,500.——Plate 19, figure 11; Plate 20, figures 10-11. Specimens from Austin Chalk (sample 9) of Texas, identified as *C.* sp. cf. *C. crenulatus*; Pl. 19, fig. 11, proximal (11a-c) and side (11d) views, light micrographs, phase contrast (11a), transmitted light (11b,d), cross-polarized light (11c), ×2,500; Pl. 20, fig. 10-11, distal and proximal views, electron micrographs, ×5,000.

CRETARHABDUS? DECORUS (Deflandre)

Rhabdolithus decorus DEFLANDRE in DEFLANDRE & FERT, 1954, p. 159, pl. 13, fig. 4-6, text-fig. 87.

Cretarhabdus decorus (Deflandre), BRAMLETTE & MARTINI, 1964, p. 300, pl. 3, fig. 9-12.

Discussion.—The basal disc of this species consists of 2 cycles of which the proximal cycle is the smaller. The elements of the proximal cycle appear to be smaller and more numerous than elements in the distal cycle, and at the inner margin they bend to form a connecting tube. The crossbars are double, very much as in *Prediscosphaera cretacea* (ARKHANGELSKY), with one set beneath and rotated about 10° from the other set.

The stem is made of numerous laths about 0.1 μ wide and 0.5-1.5 μ long. The laths are arranged spirally, subparallel to the axis of the stem, and in bundles, so that only the tips of adjacent bundles overlap. Toward the distal end the stem flares and terminates in a broad cone with a serrate rim.

The assignment of this species to *Cretarhabdus* may not be correct, but further study will be necessary to reveal its true taxonomic position.

Diameter of basal disc.—5.4-8.6 μ.

Height.—9.0 μ.

Occurrence.—BRAMLETTE & MARTINI recorded this species from the type Maastrichtian and from equivalent deposits in southwestern France, Tunisia, Siberia, Alabama, and Arkansas. The specimens figured here are from sample CKL-127 from the Taylor Marl and from sample COR from the Corsicana Marl.

Illustrations.—Plate 4, figures 15-16. Unspecified views of specimens from Corsicana Marl (sample COR) of Texas, electron micrographs, ×5,000.——Plate 8, figures 23-25. Distal view of basal disc and side views (24-25) of specimens from upper Taylor Marl (sample CKL-127) of Texas, electron micrographs, ×5,000.——Plate 11, figures 13-14. Side and proximal views of specimens from same Taylor Marl sample, light micrographs, phase contrast (13a, 14a), transmitted light (13b, 14b), cross-polarized light (13c, 14c), ×2,500.

Subfamily PARHABDOLITHOIDEAE Gartner, new subfamily

Rhabdoliths in which basal disc is constructed of single cycle of elements. The type genus of this subfamily, *Parhabdolithus* DEFLANDRE, 1952a, is a Jurassic and Lower Cretaceous genus most typical of this type of construction.

Genus ACTINOZYGUS Gartner, new genus

Type species.—*Tremalithus regularis* GORKA, 1957.

Description.—The basal disc of this genus is constructed of a single cycle of imbricate elements that form a distally extending rim. The stem supporting structure in the central area consists of regularly spaced radially arranged bars or spokes, the number of which varies with the species.

Discussion.—The genus *Actinozygus* is distinguished from all other genera of the subfamily Parhabdolithoideae (Figs. 4-5) in that it has regularly spaced radial bars or spokes making up the stem supporting structure.

ACTINOZYGUS? FENESTRATUS (Stover)

Zygolithus fenestratus STOVER, 1966, p. 147, pl. 3, fig. 21-22c; pl. 4, fig. 1; pl. 8, fig. 24.

Discussion.—It may be added to STOVER's description of this species that although the perforations in the central area are regularly spaced, they are arranged without symmetry. This makes the species readily recognizable in proximal or distal view. The species is here assigned provisionally to *Actinozygus* although it does not have the characteristic radial stem supports of that genus. It does not belong to *Zygolithus* (=*Neococcolithes*) and further study may indicate that it is sufficiently distinct to be set apart perhaps in a separate genus within the Parhabdolithoideae.

Maximum diameter.—5.8 μ.

Occurrence.—STOVER recorded this species from the Aptian through lower Cenomanian. In this study the species was found rarely in sample COR from the Corsicana Marl.

Illustrations.—Plate 7, figure 14. Distal view of specimen from Corsicana Marl (sample COR) of Texas, light micrographs, phase contrast (14a), transmitted light (14b), cross-polarized light (14c), ×2,500.

ACTINOZYGUS REGULARIS (Gorka)

Tremalithus regularis GORKA, 1957, p. 246, pl. 2, fig. 4.
Rhabdolithus regularis (Gorka), STRADNER, 1963, p. 14, pl. 5, fig. 5-5a.

Discussion.—This species is easily recognized in proximal or distal view by the 8 regularly spaced and symmetrically arranged arms extending from the center to the inner margin of the disc. STRADNER's illustration of the species is misleading in that he indicates a proximal rim, whereas the rim actually extends distally. The appearance of the stem between crossed nicols should not be taken to be diagnostic since more delicate stems attached to the same type of basal disc will generally have a different interference figure. The basal disc, however, yields a constant figure 8-like interference figure between crossed nicols, and is therefore a more useful criterion for determining this species.

Maximum diameter.—4.6-7.2 μ.

Occurrence.—The species was originally described from the upper Maastrichtian of Poland. In this study it was found in sample CKL-127 from the Taylor Marl, and from samples COR, Corsicana Marl, and ARK, Arkadelphia Formation, both of Navarroan age.

Illustrations.—Plate 3, figure 12. Distal (12a-c) and side (12d) views of specimens from Arkadelphia Formation (sample ARK) of Arkansas, light micrographs, phase contrast (12a), transmitted light (12b,d), cross-polarized light (12c), ×2,500.——Plate 5, figures 17-18. Distal and side views of specimens from Corsicana Marl (sample COR) of Texas, electron micrographs, ×5,000.——Plate 6, figures 17-18. Distal and side views of specimens from same Corsicana sample, light micrographs, phase contrast (17a, 18a), transmitted light (17b, 18b), cross-polarized light (17c, 18c), ×2,500. ——Plate 12, figure 11. Proximal view of specimen from upper Taylor Marl (sample CKL-127) of Texas, light micrographs, phase contrast (11a), transmitted light (11b), cross-polarized light (11c), ×2,500.

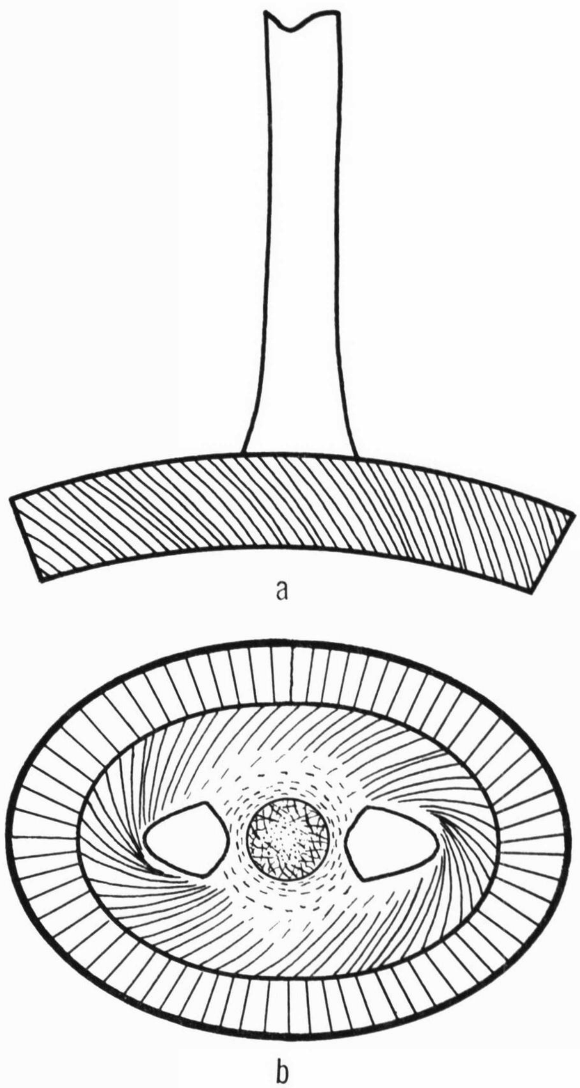
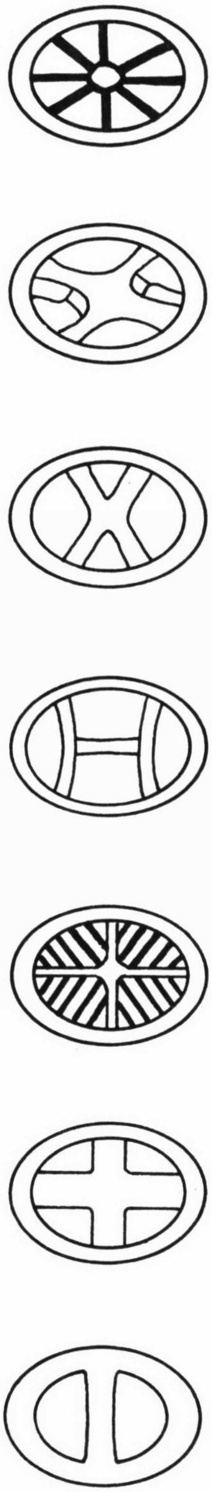


FIG. 4. Typical representative (*Zygodiscus*) of subfamily Parhabdolithoideae showing single-cycle construction of basal disc. *a*—Side view; *b*—proximal view.

ACTINOZYGUS? RHOMBOCAULIS Gartner, new species

Elliptical basal disc constructed of imbricate elements with distally flaring rim; buttressing arms support robust, complex stem.



Genus *Actinozygus*
radial spokes support stem

Genus *Eiffellithus*
crossbars x-shaped, asymmetrical with respect to long and short axes of ellipse

Genus *Chiastozygus*
crossbars x-shaped, symmetrical with respect to long and short axes of ellipse

Genus *Neococcolithes*
crossbars H-shaped, with short bar aligned with long axis of ellipse

Genus *Pontilithus*
crossbars aligned with long and short axes of ellipse; across each quadrant extends set of parallel ribs

Genus *Vekshinella*
crossbars aligned with long and short axes of ellipse

Genus *Zygodiscus*
single crossbar aligned with short axis of ellipse

FIG. 5. Genera of subfamily Parhabdolithoideae.

Description.—The base of this species consists of a disc with a flaring rim that extends distally. The disc and rim in one specimen are constructed in the usual manner, by dextrally imbricate elements. In another specimen the rim appears to have an annular or concentric structure, but apparently this is superimposed on an imbricate structure. From the inner margin of the disc arms or crossbars extend toward the center and distally, and support a uniformly tapering, robust stem. The stem is constructed of calcite rods arranged at a slight angle to the axis of the stem so that the stem appears twisted. Between crossed nicols the stem has a cross-striated pattern so that the surface appears to be covered by diamond-shaped scales.

Discussion.—The basal disc of this species has not yet been identified in proximal or distal view, and the central structure is largely inferred. Consequently the taxonomic position of the species is subject to revision. The species can be distinguished easily from other rhabdolith-like species by the diagonally cross-hatched appearance of the stem.

Maximum diameter.—6.5-8.5 μ.

Type specimen.—UI-H-2193 (Pl. 5, fig. 5), from the Corsicana Marl.

Occurrence.—Sample COR from the Corsicana Marl.

Illustrations.—Plate 5, figures 5-6; Plate 7, figure 6. Specimens from Corsicana Marl (sample COR) of Texas; Pl. 5, fig. 5-6, side views of type and another specimen, electron micrographs, ×5,000; Pl. 7, fig. 6, side view, light micrograph, phase contrast (6a), transmitted light (6b), cross-polarized light (6c), ×2,500.

ACTINOZYGUS SPLENDENS (Deflandre)

Rhabdolithus splendens Deflandre, 1953, p. 1786, fig. 4-6.—— Deflandre & Fert, 1954, p. 158, fig. 88, 89; pl. 13, fig. 1-3.
Cretarhabdus splendens (Deflandre), Bramlette & Martini, 1964, p. 300, pl. 3, fig. 13-16.

Discussion.—This species of *Actinozygus* has a solid basal disc that is perforated only at the center of the stem. In light micrographs of the basal disc, however, the radial stem supports can be seen. Although the exact number is difficult to determine and appears to differ from specimen to specimen, there are generally more than 10 of these spokes. The disc has the shape of an elongated ellipse, with the long sides nearly parallel. The stem is constructed of helically arranged calcite rods that imbricate dextrally. Distal views of the basal disc with part of the stem still attached indicate that the stem is hollow and probably open at both ends.

Maximum diameter.—7.5-8.8 μ.

Occurrence.—Originally described from the Lutetian of Donzacq, France (probably reworked, according to Bramlette & Martini), this species has also been recorded from Maastrichtian equivalents in southwestern France, Tunisia, Alabama, and Arkansas. In this study the species was found in sample COR from the Corsicana Marl and in sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 5, figures 15-16; Plate 7, figures 1-2. Specimens from Corsicana Marl (sample COR) of Texas; Pl. 5, fig. 15-16, distal and side views, electron micrographs, ×5,000; Pl. 7, fig. 1-2, side and proximal views, light micrographs, phase contrast (1a, 2a), transmitted light (1b, 2b), cross-polarized light (1c, 2c), ×2,500.——Plate 10, figure 1; Plate 11, figure 15. Specimens from Taylor Marl (sample CKL-127) of Texas; Pl. 10, fig. 1, distal view, electron micrograph, ×5,000; Pl. 11, fig. 15, distal view, light micrographs, phase contrast (15a), transmitted light (15b), cross-polarized light (15c), ×2,500.

Genus EIFFELLITHUS Reinhardt, 1965

Type species.—*Zygolithus turriseiffeli* Deflandre, 1954.

Basal disc constructed of single cycle of imbricate elements which form distally expanding rim; central area commonly open and spanned by two intersecting crossbars; which are slightly asymmetrical with respect to major and minor axes of ellipse, or rarely, are nearly aligned with these axes; at their intersection crossbars may be surmounted by complex stem.

EIFFELLITHUS OCTORADIATUS (Gorka)

Discolithus octoradiatus Gorka, 1957, p. 259, pl. 4, fig. 10.
Zygolithus octoradiatus (Gorka), Stradner, 1963, p. 14, pl. 5, fig. 2-2a.
Zygolithus? octoradiatus (Gorka), Bramlette & Martini, 1964, p. 304, pl. 4, fig. 15-16.

Discussion.—The elliptical disc is constructed of 45 to 60 dextrally imbricate elements. The crossbars spanning the open central area are paired in 4 sets. Each set consists of 2 members which diverge and widen at their junction with the inner margin of the disc. In well-preserved specimens each member of the crossbars appears as single solid element, but in corroded specimens it can be seen that each member is constructed of several elements. The crossbars are not aligned perfectly with the major and minor axes of the ellipse but are rotated a few degrees clockwise when viewed proximally. In some specimens the crossbars are surmounted by a hollow stem.

Maximum diameter.—6.5-7.7 μ.

Occurrences.—This species was originally described from the Maastrichtian of Poland. In this study it was found in samples ARK from Arkadelphia Formation, and COR from the Corsicana Marl, both of Navarroan age, and in sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 2, figures 17-21; Plate 3, figure 11. Specimens from Arkadelphia Formation (sample ARK) of Arkansas; Pl. 2, fig. 17-21, distal (17-18), proximal (19-20), and side (21) views, electron micrographs, ×5,000; Pl. 3, fig. 11, proximal view, light micrographs, phase contrast (11a), transmitted light (11b), cross-polarized light (11c), ×2,500.——Plate 5, figure 20. Distal view of specimen from Corsicana Marl (sample COR) of Texas, electron micrograph, ×5,000.——Plate 12, figure 10. Distal views of specimen from Taylor Marl (sample CKL-127) of Texas, light micrographs, phase contrast (10a), transmitted light (10b), cross-polarized light (10c), ×2,500.

EIFFELLITHUS TURRISEIFFELI (Deflandre)

Zygolithus turriseiffeli DEFLANDRE in DEFLANDRE & FERT, 1954, p. 149, fig. 65, pl. 13, fig. 15-16.

Rhabdosphaera elliptica VEKSHINA, 1959, p. 74, pl. 1, fig. 10; pl. 2, fig. 14a-b.

Zygrhablithus turriseiffeli (Deflandre), DEFLANDRE, 1959, p. 135. ——MANIVIT, 1965, p. 191, pl. 1, fig. 1.

Zygrhablithus? turriseiffeli (Deflandre), BRAMLETTE & MARTINI, 1964, p. 304, pl. 3, fig. 18-21; pl. 4, fig. 1-2.

Eiffellithus turriseiffeli (Deflandre), REINHARDT, 1965, p. 32.

Clinorhabdus turriseiffeli (Deflandre), STOVER, 1966, p. 138, pl. 3, fig. 9.

Discussion.—The elliptical disc is constructed of 60 to 80 dextrally imbricate elements. On the periphery a flaring rim extends distally. The central area may be partially or completely covered over on the proximal side, and the central opening can vary from a large elliptical opening to a small diamond-shaped perforation in the center of the intersecting crossbars. Each arm of the x-shaped crossbars is constructed of 2 or more calcite elements arranged parallel. Generally in specimens in which the crossbars are delicate no stem is present, and the crossbars are arranged nearly symmetrically with respect to the major and minor axes of the ellipse. Specimens with sturdy crossbars commonly have a complex stem, and they generally have the crossbars arranged slightly asymmetrical with respect to the major and minor axes of the ellipse to nearly aligned with these axes. The hollow stem that surmounts the crossbars is constructed of bundles of calcite laths or rods. The laths are not arranged helically as has been interpreted from light micrographs but are parallel to the axis of the stem.

The specimen illustrated by ARKHANGELSKY as a coccolith of the family Syracosphaerinae (1912, pl. 7, fig. 10) is probably a disc of *Eiffellithus turriseiffeli* (DEFLANDRE). *Discosphaera lohmanni* ARKHANGELSKY (1912, pl. 6, fig. 9) appears to be a side view of the same species also; if this is the case, *D. lohmanni* is a senior synonym. ARKHANGELSKY, however, apparently misinterpreted the species and thought that he was looking at a trumpet-shaped rhabdolith-like structure such as is found in *D. tubifer* (MURRAY & BLACKMAN).

Maximum diameter.—7.0-10.0 μ.

Height of stem.—15-20 μ.

Occurrence.—Originally described from the Senonian of England this species was found in every sample from the Upper Cretaceous; Eagle Ford Shale, Austin Chalk, Taylor Marl, and Navarro Group.

Illustrations.—Plate 2, figures 22-23; Plate 3, figure 13. Specimens from Arkadelphia Formation (sample ARK) of Arkansas; Pl. 2, fig. 22-23, distal views, electron micrographs, ×5,000; Pl. 3, fig. 13, distal view, light micrographs, phase contrast (13a), transmitted light (13b), cross-polarized light (13c).——Plate 5, figure 19; Plate 7, figure 5. Specimens from Corsicana Marl (sample COR) of Texas; Pl. 5, fig. 19, distal view, electron micrograph, ×5,000; Pl. 7, fig. 5, distal view, light micrographs, phase contrast (5a), transmitted light (5b), cross-polarized light (5c), ×2,500.——Plate 9, figures 6-10; Plate 13, figures 1-2; Plate 16, figures 1-2; Plate 17, figure 3. Specimens from Taylor Marl of Texas; Pl. 9, fig. 6-10 (from sample CKL-127), distal (6-8) and side (9-10) views, electron micrographs, ×5,000; Pl. 13, fig. 1-2 (from sample CKL-127), side and distal views, light micrographs, phase contrast (1a, with lower nicol inserted, 2a), transmitted light (2b), plain polarized light (1b), cross-polarized light (1c, 2c), ×2,500; Pl. 16, fig. 1-2 (from sample 13), side and distal views, electron micrographs, ×5,000; Pl. 17, fig. 3 (from sample 13), distal (3a-c) and side (3d) views, light micrographs, phase contrast (3a), transmitted light (3b,d), cross-polarized light (3c), ×2,500.——Plate 18, figures 9-11; Plate 19, figures 1-2; Plate 22, figure 4; Plate 23, figures 7-11; Plate 24, figures 1-2. Specimens from Austin Chalk of Texas; Pl. 18, fig. 9-11 (from sample 12), proximal (9) and distal (10-11) views, electron micrographs, ×5,000; Pl. 19, fig. 1-2 (from sample no. 12), proximal (1a-c, 2a-c) and side (1d) views, light micrographs, phase contrast (1a, 2a), transmitted light (1b,d, 2b), cross-polarized light (1c-2c), ×2,500; Pl. 22, fig. 4 (from sample 9), distal view, electron micrograph, ×5,000; Pl. 23, fig. 7-11 (from sample 5), distal (7-8, 10-11) and proximal (9) views, electron micrographs, ×5,000; Pl. 24, fig. 1-2 (from sample 5), side and proximal views, light micrographs, phase contrast (1a-2a), transmitted light (1b-2b), cross-polarized light (1c-2c), ×2,500.——Plate 25, figures 15-16; Plate 26, figures 3-4. Specimens from Eagle Ford Shale (sample 2) of Texas; Pl. 25, fig. 15-16, distal views, electron micrographs, ×5,000; Pl. 26, fig. 3-4, side and proximal views, light micrographs, phase contrast (3a-4a), transmitted light (3b), bright field (4b), cross-polarized light (3c-4c), ×2,500.

Genus CHIASTOZYGUS Gartner, new genus

Type species.—*Zygodiscus? amphipons* BRAMLETTE & MARTINI, 1964.

Description.—The elliptical basal disc is constructed of a single cycle of imbricate elements which form a slightly flaring peripheral rim that extends distally. The elliptical central area is open and is spanned by x-shaped crossbars that are arranged symmetrically with respect to the major and minor axes of the ellipse. At their intersection the crossbars may be surmounted by a spine or complex stem.

Discussion.—*Chiastozygus* differs from *Zygodiscus* BRAMLETTE & SULLIVAN *(emend.)* in that it has x-shaped crossbars rather than a single crossbar aligned with the minor axis of the ellipse. It differs from *Eiffellithus* REINHARDT in that the crossbars are symmetrical with respect to the major and minor axes of the ellipse. *Zygrhablithus* DEFLANDRE is superficially similar, but the type species of that genus, *Z. bijugatus* (DEFLANDRE), appears to be a highly specialized or aberrant form with massively constructed disc, crossbars, and stem.

CHIASTOZYGUS AMPHIPONS (Bramlette & Martini)

Zygodiscus? amphipons BRAMLETTE & MARTINI, 1964, p. 302, pl. 4, fig. 9-10.

Discussion.—The basal disc of this species is constructed of about 35 dextrally imbricate elements, and on the periphery a flaring rim extends distally. The x-shaped crossbars that span the open central area may be surmounted by a hollow circular stem at their intersection.

Maximum diameters.—4.5-5.8 μ.

Occurrence.—BRAMLETTE & MARTINI have recorded this species from the type Maastrichtian and from equivalents in Denmark, southwestern France, Tunisia, Alabama, and Arkansas. The specimens figured here are from samples nos. 5 and 12 from the Austin Chalk and from sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 8, figures 11-14; Plate 11, figure 9. Specimens from upper Taylor Marl (sample CKL-127) of Texas; Pl. 8, fig. 11-14, distal (11, 13), proximal (12), and side (14) views, electron micrographs, ×5,000; Pl. 11, fig. 9, distal view, light micrographs, phase contrast (9a), transmitted light (9b), cross-polarized light (9c), ×2,500.——Plate 22, figures 10-11. Specimens from Austin Chalk (sample 5) of Texas; distal and proximal views (fig. 11, *C.* sp. cf. *C. amphipons*), electron micrographs, ×5,000.

CHIASTOZYGUS ANTHOPHORUS (Deflandre)

Rhabdolithus anthophorus DEFLANDRE, 1959, p. 137, pl. 1, fig. 21-22.

non Cretarhabdus anthophorus (Deflandre), BRAMLETTE & MARTINI, 1964, p. 299, pl. 3, fig. 1-4.

Discussion.—This species differs from *Zygolithus elegans* GARTNER, n. sp., in that it has a widely flaring petaloid termination on the distal end of the stem but has no trace of the submarginal notches found on the disc of *Zygodiscus elegans*. The specimen from the base of the Taylor Marl appears to have a more complex stem and a more clearly defined petaloid termination. The basal disc of that specimen is somewhat obscured by the stem and cannot be seen clearly.

Maximum diameter.—8.4-11.4 μ.

Occurrence.—Samples CKL-127 and no. 13, both from the Taylor Marl.

Illustrations.—All from Taylor Marl (sample CKL-127, Pl. 11; sample 13, Pl. 14-15) of Texas.——Plate 11, figures 5-6. Side and proximal views, light micrographs, phase contrast (5a-6a), transmitted light (5b-6b), cross-polarized light (5c-6c), ×2,500.——Plate 14, figure 6. Side view, electron micrograph, ×5,000.——Plate 15, figures 5-7. Side (5), distal (6), and proximal (7) views, light micrographs, transmitted light (5a-6-7b), cross-polarized light (5b, 7c), phase contrast (7a), ×2,500.

CHIASTOZYGUS LATERCULUS Gartner, new species

A species of *Chiastozygus* with a secondary cycle of small elements on the proximal periphery.

Description.—The elliptical disc is constructed of 40 to 60 dextrally imbricate elements. On the proximal surface a cycle of small, tilelike calcite rhombs marks what appears to be the proximal periphery and inside this secondary cycle a sloping depression surrounds the central opening. The x-shaped crossbars are constructed of numerous small calcite rods, and at their intersection they are thickened to form the base for a hollow stem.

Discussion.—In light micrographs of the side view, this species appears to have 2 cycles in the basal disc, but the heavy line is probably due to a change in thickness of the elements along this line because the electron micrographs indicate that the disc is constructed of a single cycle of elements. This species differs from *Chiastozygus amphipons* (BRAMLETTE & MARTINI) in that it has the secondary cycle of elements on the proximal surface, a smaller opening in the central area, and a higher rim.

Maximum diameter.—6.5-8.4 μ.

Type specimen.—UI-H-2534 (Pl. 23, fig. 23) from the Eagle Ford Shale.

Occurrence.—Sample 2, middle Eagle Ford Shale.

Illustrations.—All specimens from Eagle Ford Shale (sample 2) of Texas.——Plate 23, figures 23-24. Proximal views of type and another specimen, electron micrographs, ×5,000.——Plate 24, figure 7. Proximal (7a-c) and side (7d) views, light micrographs, phase contrast (7a), transmitted light (7b,d), cross-polarized light (7c), ×2,500.

CHIASTOZYGUS PLICATUS Gartner, new species

A species of *Chiastozygus* with large number of elements; the proximal surface of the crossbars is crenulate at their intersection.

Description.—The elliptical disc is constructed of 60 to 70 dextrally imbricate elements and has a flaring rim. The central area commonly is closed by secondary? calcification. The crossbars are constructed of small calcite rods which in a distal view appear to be gathered like folds around intersection of the crossbars. A stem has not been observed, although it is suggested by the sturdy crossbars.

Discussion.—*Chiastozygus plicatus* differs from *C. amphipons* (BRAMLETTE & MARTINI) in having a larger number of elements in the ring, and in that the crossbars have a peculiar clustering of calcite rods at their intersection which is quite diagnostic in both light and electron micrographs.

Maximum diameter.—6.6-8.1 μ.

Type specimen.—UI-H-2451 (Pl. 20, fig. 6) from the Austin Chalk.

Occurrence.—Samples 5, 9, and 12 from the Austin Chalk and sample 13 from the base of the Taylor Marl.

Illustrations.—All specimens from Austin Chalk of Texas.——Plate 16, figures 10-11 (sample 12). Distal views, electron micrographs, ×5,000.——Plate 17, figure 9 (sample 9). Distal (9a-c) and side (9d) views, light micrographs, phase contrast (9a), transmitted light (9b,d), cross-polarized light (9c), ×2,500.——Plate 19, figure 9 (from sample 9). Distal (9a-c) and side (9d) views, light micrographs, phase contrast (9a), transmitted light (b,d), cross-polarized light (9c), ×2,500.——Plate 20, figure 6 (from sample 9). Distal view of type specimen, electron micrograph, ×5,000.——Plate 21, figure 9 (from sample 5). Distal (9a-c) and side (9d) views, light micrographs, phase contrast (9a), transmitted light (9b,d), cross-polarized light (9c), ×5,000.——Plate 22, figure 12 (from sample 5). Distal view, electron micrograph, ×5,000.

CHIASTOZYGUS PSEUDAMPHIPONS Gartner, new species

A species of *Chiastozygus* with indistinct rim and secondary cycle of elements on the proximal surface.

Description.—The basal disc of this species is constructed of about 65 small, dextrally imbricate elements. It is slightly wider distally but lacks a distinct rim. On the proximal surface of the disc part of a second cycle of elements is visible. The cross bars are constructed of very small calcite elements.

Discussion.—In the light microscope this species is very difficult to separate from *Chiastozygus amphipons* (BRAMLETTE & MARTINI) but differs in being constructed of more numerous but much smaller elements and in lacking a distinct rim on the periphery.

Maximum diameter.—5.4-7.0 μ.

Type specimen.—UI-H-2117 (Pl. 1, fig. 13) from the Arkadelphia Formation.

Occurrence.—Sample ARK, Arkadelphia Formation, Navarroan.

Illustrations.—Specimens from Arkadelphia Formation (sample ARK) of Arkansas.——Plate 1, figure 13. Proximal view of type specimen, electron micrograph, ×5,000.——Plate 3, figure 1. Proximal (1a-c) and side (1d) views, light micrographs, phase contrast (1a), transmitted light (1b,d), cross-polarized light (1c), ×2,500.

CHIASTOZYGUS PUMILUS Gartner, new species

A small species of *Chiastozygus* with thickened rim and a complex stem.

Description.—The elliptical disc has a thickened rim, flaring slightly and extending distally. The open central area is relatively large, and the crossbars are surmounted at their intersections by a complexly constructed stem.

Discussion.—This species was observed only with the light microscope, and because of its minute size it is difficult to characterize adequately. Its similarity to other specimens of the genus suggests that the disc and rim are probably constructed of imbricate elements and that the stem is built of calcite rods parallel to the axis of the stem. The species differs from other members of the genus primarily by its small size. Any other differences would not be within the resolving power of the light microscope.

Maximum diameter.—4.4 μ.

Type specimen.—UI-H-2238 (Pl. 7, fig. 12-13) from the Corsicana Marl.

Occurrence.—Sample COR, Corsicana Marl, Navarroan.

Illustrations.—Plate 7, figures 12-13. Proximal and side views of type specimen, light micrographs, phase contrast (12a-13a), transmitted light (12b-13b), cross-polarized light (12c-13c), ×2,500.

CHIASTOZYGUS QUADRIPERFORATUS Gartner, new species

A species of *Chiastozygus* with crossbars modified to appear nearly parallel and surmounted by a complex stem; the central area is divided into 2 small and 2 large openings.

Description.—The elliptical disc is constructed of 40 to 50 dextrally imbricate elements. Distally the disc has a slightly flaring rim. The x-shaped crossbars spanning the central area are modified so that the 2 bars appear nearly parallel on either side of the minor axis of the ellipse. This configuration of the crossbars leaves 2 large openings along the major axis of the ellipse and 2 smaller openings along the minor axis of the ellipse. The crossbars are surmounted in the center by a stem constructed of radially arranged calcite rhombs that probably appear as laths in side view. The stem appears to have an axial canal in some cases, and has a parallelogram-like cross section at its base.

Discussion.—In light micrographs this species closely resembles *Zygodiscus diplogrammus* (DEFLANDRE) but differs in that the crossbars are fused at the center rather than at their ends. The small angle that the crossbars make with the minor axis separates this species from all other species of *Chiastozygus.*

Maximum diameter.—5.3-7.4 μ.

Type specimen.—UI-H-2256 (Pl. 8, fig. 16) from the Taylor Marl.

Occurrence.—Sample CKL-127, Taylor Marl; sample COR, Corsicana Marl, Navarroan.

Illustrations.—Plate 7, figure 7. Unspecified view of specimen from Corsicana Marl (sample COR) of Texas, light micrographs, phase contrast (7a), transmitted light (7b), cross-polarized light (7c), ×2,500.——Plate 8, figures 15-17; Plate 11, figure 10. Specimens from Taylor Marl (sample CKL-127) of Texas; Pl. 8, fig. 15-17, distal (15-16) and side (17) views, electron micrographs, ×5,000; Pl. 11, fig. 10, distal view, light micrographs, phase contrast (10a), transmitted light (10b), cross-polarized light (10c), ×2,500.

CHIASTOZYGUS SCIPIO Gartner, new species

A species of *Chiastozygus* in which the rim thickens distally.

Description.—The elliptical disc is constructed of about 60 dextrally imbricate elements. On the periphery of the disc a flaring rim extends distally. The rim is thin proximally but thickens distally. The x-shaped crossbars that span the central area are surmounted at their intersection by a short? stem. The stem is constructed of parallel calcite rods aligned with the axis of the stem.

Discussion.—This species differs from *Chiastozygus pseudamphipons* GARTNER, n. sp., in having a distally thickening rim and smaller central area. In light micrographs the stem of this species appears to have an axial canal; the electron micrographs, however, are at such an angle that this cannot be confirmed.

Maximum diameter.—7.8-9.0 μ.

Type specimen.—UI-H-2199 (Pl. 5, fig. 10) from the Corsicana Marl.

Occurrence.—Sample COR, Corsicana Marl, Navarroan.

Illustrations.—Specimens from Corsicana Marl (sample COR) of Texas.——Plate 5, figures 10-11. Distal and side views, electron micrographs, ×5,000.——Plate 7, figures 15-16. Proximal and side views, light micrographs, phase contrast (15a-16a), transmitted light (15b-16b), cross-polarized light (15c), ×2,500.

Genus NEOCOCCOLITHES Sujkowski, 1931

Type species.—Neococcolithes lososnensis SUJKOWSKI, 1931.

Disc consisting of rim and crossbars, rim narrow and constructed of single cycle of small, indistinct elements; open central area spanned by two crossbars arranged subparallel to minor axis of ellipse and connected at their midpoints by short bar that is aligned with long axis of ellipse.

NEOCOCCOLITHES SP. aff. N. DUBIUS (Deflandre)

Zygolithus dubius Deflandre, DEFLANDRE & FERT, 1954, p. 35, text-fig. 43-44, 68.

Discussion.—The specimens figured here are very similar to that illustrated by DEFLANDRE in that the rim is constructed of very small elements so that they cannot be distinguished in the light microscope and the rim appears as one solid structure. Two crossbars extend over the elliptical central opening, and are connected by a short bar that is aligned with the long axis of the ellipse. The specimens differ from DEFLANDRE's in that they are smaller and do not have any kind of spine or stem.

Maximum diameter.—2-5 μ.

Occurrence.—The specimens figured here are from sample COR from the Corsicana Marl.

Illustrations.—Plate 5, figures 12-13. Plan views, electron micrographs, ×5,000.——Plate 7, figure 9. Distal (9a,b) and side (9c) views, light micrographs, phase contrast (9a,c), cross-polarized light (9b), ×2,500.

Genus PONTILITHUS Gartner, new genus

Type species.—Pontilithus obliquicancellatus GARTNER, n. sp.

Description.—The elliptical basal disc is constructed of a single cycle of imbricate elements and has a distally extending peripheral rim. The central area is open and has crossbars aligned with the major and minor axes of the ellipse. In each of the four quadrants of the central area a set of parallel ribs extends from the inner margins of the disc to the crossbars, and the ribs in diametrically opposite quadrants are also parallel.

Discussion.—Stemmed forms have not been observed in this genus although the structure spanning the central opening suggests that such forms exist. This genus is easily distinguished from other genera of the subfamily Parhabdolithoideae by the parallel ribs in each of the four quadrants.

PONTILITHUS OBLIQUICANCELLATUS Gartner, new species

Elliptical basal disc with ring and rim of small imbricate elements; large central area traversed by crossbars from which 2 sets of parallel ribs extend to rim.

Description.—The elliptical disc is constructed of about 40 dextrally imbricate elements. A flaring rim extends distally. Crossbars extend across the elliptical central area, and are aligned with the major and minor axes of the ellipse. From these crossbars 4 sets of parallel bars or ribs, one set in each quadrant, extend to the inner margin of the disc and make an angle of 45° to 60° with the major axis of the ellipse. The ribs in diametrically opposite quadrants have the same orientation.

Discussion.—The central structure of this species is similar to that of *Cretarhabdus loriei* GARTNER, n. sp., but the latter species has 2 cycles in the basal disc. The parallel bars in each quadrant of the ellipse of the basal disc of *Pontilithus obliquicancellatus* distinguishes it from all other species in the subfamily Parhabdolithoideae.

Maximum diameter.—6.6 μ.

Type specimen.—UI-H-2550.5 (Pl. 23, fig. 25) from the Eagle Ford Shale.

Occurrence.—Sample 2, Eagle Ford Shale.

Illustration.—Plate 23, figure 25. Proximal view of type specimen, electron micrograph, ×5,000.

Genus VEKSHINELLA Loeblich & Tappan, 1963 (emend.)

Type species.—Vekshinella acutifera (VEKSHINA), 1959.

Description.—The elliptical basal disc is constructed of a single cycle of imbricate elements. The disc is usually somewhat smaller in diameter on the proximal side, and flares slightly distally. On the distal side there may be a rim on the periphery. The elliptical open area in the center is spanned by two crossbars that may be of simple or complex construction, and are aligned with the major and minor axes of the ellipse. The crossbars may be surmounted by a simple spine or a complex, hollow stem or such a structure may be lacking.

Discussion.—In the emendation of this genus emphasis is placed on large scale similarities in architecture while much of the detail apparent in electron micrographs should be considered important only on a specific level. The genus is distinguished from other genera of the subfamily Parhabdolithoideae by the alignment of the crossbars with the major and minor axes of the ellipse.

VEKSHINELLA ARA Gartner, new species

A species of *Vekshinella* with serrate margin and delicate crossbars.

Description.—The elliptical disc is constructed of 50 to 60 sinistrally imbricate elements that terminate in irregular points, and give the disc a serrate outline. The disc expands distally and appears to have a peripheral rim on the distal side. The delicate crossbars are not aligned exactly with the major and minor axes of the ellipse, but are rotated slightly, and consequently only the diagonally opposite quadrants of the enclosed elliptical area are identical. The crossbars themselves are constructed of parallel calcite rods, and in some specimens are surmounted by a spine.

Discussion.—This species differs from the type species of the genus *Vekshinella acutifera* (Vekshina) in that the stem does not protrude on the proximal side and the crossbars are more delicate.

Maximum diameter.—6.0 μ.

Type specimen.—UI-H-2146 (Pl. 2, fig. 24) from the Arkadelphia Formation.

Occurrence.—This species was found in samples ARK from the Arkadelphia Formation.

Illustrations.—Specimens from Arkadelphia Formation of Arkansas.——Plate 2, figure 24. Proximal view of type specimen, electron micrograph, ×5,000.——Plate 3, figure 15. Proximal (15a-c) and side (15d) views, light micrographs, phase contrast (15a), transmitted light (15b,d), cross-polarized light (15c), ×2,500.

VEKSHINELLA DIBRACHIATA Gartner, new species

A species of *Vekshinella* with a prominent suture in the center of the crossbars.

Description.—The elliptical disc is constructed of numerous elements arranged in a radial pattern only faintly visible. On the periphery of the disc a slightly flaring rim extends distally. The elliptical central opening is relatively small. The crossbars are thick and consist of 2 parts separated by a prominent longitudinal groove.

Discussion.—This species differs from *Vekshinella ara* Gartner, n. sp., in having a smaller open area in the center, thicker crossbars, and a longitudinal groove in the middle of the crossbars. The figured specimens appear to be somewhat calcified although this may be a normal state for this species. The disc shows some concentric structure but the primary structure appears to be on a radial pattern. The specimen from the Taylor Marl is very similar in the construction of the crossbars but has a somewhat different disc.

Maximum diameter.—5.0-5.2 μ.

Type specimen.—UI-H-2211 (Pl. 5, fig. 23) from the Corsicana Marl.

Occurrence.—Sample COR from the Corsicana Marl, sample CKL-127 from the Taylor Marl, and sample 9 from the Austin Chalk.

Illustrations.—Plate 5, figures 23-24; Plate 7, figure 8. Specimens from Corsicana Marl (sample COR) of Texas; Pl. 5, fig. 23-24, distal views, electron micrograph, ×5,000; Pl. 7, fig. 8, unspecified view, light micrograph, phase contrast (8a), transmitted light (8b), cross-polarized light (8c), ×2,500.——Plate 9, figure 15. Specimen identified as *V.* sp. cf. *V. dibrachiata* from Taylor Marl (sample CKL-127) of Texas, distal view, electron micrograph, ×5,000.——Plate 19, figure 8; Plate 22, figure 8. Specimens from Austin Chalk (sample 9) of Texas; Pl. 19, fig. 8, *V.* sp. cf. *V. dibrachiata*, proximal (8a-c) and side (8d) views, light micrographs, phase contrast (8a), transmitted light (8b,d), cross-polarized light (8c), ×2,500; Pl. 22, fig. 8, proximal view, electron micrograph, ×5,000.

VEKSHINELLA ELLIPTICA Gartner, new species

A species of *Vekshinella* with a small central area, thick crossbars, and a perforation at the intersection of the crossbars.

Description.—The elliptical disc is constructed of 38 to 40 dextrally imbricate elements. The inclination of the sutures is slightly counter-clockwise at the periphery but bends sharply and becomes inclined clockwise at the inner margin. A wide, low rim is developed on the distal periphery of the disc. The elements terminate in sharp points that protrude beyond the periphery and give the disc a serrate outline. The relatively small elliptical opening in the center is spanned by 2 thick crossbars that are aligned with the major and minor axes of the ellipse. The crossbars cover nearly the entire central opening and appear to be complexly constructed. At their intersection the crossbars are perforated and surmounted by a hollow stem. The stem generally is broken near its base.

Discussion.—This species differs from *Vekshinella dibrachiata* in having thicker crossbars and a large perforation at the intersection of the crossbars.

Maximum diameter.—5.6-6.2 μ.

Type specimen.—UI-H-2577 (Pl. 25, fig. 26) from the Eagle Ford Shale.

Occurrence.—Sample 2 from the Eagle Ford Shale, and sample 13 from the Taylor Marl.

Illustrations.—Plate 17, figure 5. Specimen from Taylor Marl (sample 13) of Texas, distal (5a-c) and side (5d) views, light micrographs, phase contrast (5a), transmitted light (5b,d), cross-polarized light (5c), ×2,500.——Plate 25, figures 26-27; Plate 26, figure 7. Specimens from Eagle Ford Shale (sample 2) of Texas; Pl. 25, fig. 26-27, distal views, electron micrographs, ×5,000; Pl. 26, fig. 7, proximal (7a-c) and side (7d) views, light micrographs, phase contrast (7a), transmitted light (7b,d), cross-polarized light (7c), ×2,500.

VEKSHINELLA IMBRICATA Gartner, new species

A species of *Vekshinella* constructed of large elements with crossbars of numerous parallel calcite rodlets.

Description.—The disc is constructed of 40 to 50 dextrally imbricate elements that incline slightly counter-clockwise when viewed distally. The rim on the distal side of the periphery is wide and prominent. The crossbars spanning the elliptical central opening are aligned very nearly with the major and minor axes of the ellipse. They are sturdy and are constructed of numerous small calcite rods aligned with the long dimension of the crossbars. At their intersection the crossbars are surmounted by a spine or stem, which may have a square cross section, and appears to be constructed of radially arranged calcite rhombs.

Discussion.—This species differs from *Vekshinella elliptica* in having a smooth periphery, crossbars made of numerous calcite rodlets and in lacking a perforation at the intersection of the crossbars.

Type specimen.—UI-H-2281 (Pl. 9, fig. 16), from the Taylor Marl.

Occurrence.—Sample CKL-127, from the Taylor Marl.

Illustrations.—Plate 9, figures 16-17. Distal views, electron micrographs, ×5,000.——Plate 13, figures 8-9. Distal and side views, light micrographs, phase contrast (8a-9a), transmitted light (8b-9b), cross-polarized light (8c-9c), ×2,500.

VEKSHINELLA SCHIZOBRACHIATA Gartner, new species

A species of *Vekshinella* in which the crossbars have 2 or 3 branches at their junction with the disc.

Description.—The elliptical disc is constructed of 40 to 50 dextrally imbricate elements. On the periphery a slightly expanding rim extends distally. The crossbars that span the large open central area are split at their junction with the ring so that the crossbar aligned with the short axis of the ellipse has two arms attaching it to the disc at both ends, and the crossbar aligned with the long axis of the ellipse has 3 arms attaching it to the disc at both ends. At their intersection the crossbars may be surmounted by a stem similar to that of *Zygodiscus pseudanthophorus* BRAMLETTE & MARTINI.

Discussion.—This species is distinguished easily from all other members of *Vekshinella* by the branching of the crossbars.

Maximum diameter.—8-9 μ.

Type specimen.—UI-H-2346 (Pl. 13, fig. 10, 11) from the Taylor Marl.

Occurrence.—Sample 9, Austin Chalk, and sample CKL-127, Taylor Marl.

Illustrations.—Plate 13, figures 10-11. Distal and side views of type specimen, electron micrographs, ×5,000.——Plate 20, figure 5. Distal view of specimen from Austin Chalk (sample 9) of Texas, electron micrograph, ×5,000.

Genus ZYGODISCUS Bramlette & Sullivan, 1961 (emend.)

Type species.—*Zygodiscus adamas* BRAMLETTE & SULLIVAN, 1961.

Description.—The basal disc is constructed of a single cycle of imbricate elements. The proximal side of the disc is generally smaller than the distal side, and is usually concave. The distal side of the disc may be nearly parallel to the proximal side, or it may have a depression surrounded by a rim. In the center of the disc is an elliptical opening spanned by a single crossbar in the direction of the short axis of the ellipse. The crossbar may be constructed of one or several sets of elements, and it may be surmounted by a spine or a complex stem which extends distally.

Discussion.—It is intended that forms with stems and forms without stems be included in this genus provided that the morphology of the basal disc conforms to the above description. Among similar Recent coccolithophorids dimorphism is frequently expressed by the presence of a stem on some of the coccoliths of the coccosphere, and it may be assumed that the same is true for fossil forms also. Therefore, the presence or lack of a stem is not considered taxonomically significant in the absence of any other evidence.

In emending the definition of this genus primary emphasis is on gross morphology that can be seen both with the light microscope and the electron microscope. Appearance of a specific detail of a form in polarized light is considered to be of secondary importance, as it is subject to influence by a number of variables such as thickness, orientation, and construction.

ZYGODISCUS BIPERFORATUS Gartner, new species

A species of *Zygodiscus* with strongly imbricate elements and sharply inclined sutures; central area nearly closed.

Description.—The elliptical disc is constructed of 55 to 65 elements which have a strong dextral imbrication. The sutures are inclined very sharply clockwise and the rim is well developed. In some specimens a thin plate covers the proximal surface except for a diamond-shaped opening in the center. In other specimens this plate is poorly developed or lacking. On the distal side elements of the disc close the central area nearly completely, leaving only two small openings on either side of the crossbar. The crossbar is constructed of numerous calcite elements and may be surmounted by a solid or hollow, circular stem. The stem, if present, is constructed of radially arranged minute calcite crystallites with long dimension aligned with the axis of the stem.

Discussion.—This species is easily distinguished from all species of *Zygodiscus* with the light microscope as well as with the electron microscope by the strong imbrication of the elements and the highly inclined sutures. Between crossed nicols the species has a characteristic recurved pseudointerference figure. This species is somewhat similar to *Discolithus rimosus* CARATINI, but the latter species, according to CARATINI, has a 4-part division of the central area by a peculiar set of sutures, which *Z. biperforatus* does not have.

Maximum diameter.—8.2-10.8 μ.

Type specimen.—UI-H-2362 (Pl. 14, fig. 16), from the Taylor Marl.

Occurrence.—Samples nos. 9 and 12 from the Austin Chalk, and sample no. 13 from the Taylor Marl.

Illustrations.—Plate 14, figures 15-16; Plate 17, figures 1-2. Specimens from Taylor Marl (sample 13) of Texas; Pl. 14, fig. 15-16, distal and proximal views, electron micrographs, ×5,000; Pl. 17, fig. 1-2, distal (1a-2c) and side (2d) views, light micrographs, phase contrast (1a-2a), transmitted light (1b-2b,d), cross-polarized light (1c-2c), ×2,500.——Plate 18, figures 20-21; Plate 19, figure 4; Plate 20, figures 19-20; Plate 21, figure 5. Specimens from Austin Chalk of Texas; Pl. 18, fig. 20-21 (sample 12), distal views, electron micrographs, ×5,000; Pl. 19, fig. 4 (sample 12), distal

(4a-c) and side (4d) views, light micrographs, phase contrast (4a), transmitted light (4b,d), cross-polarized light (4c), ×2,500; Pl. 20, fig. 19-20 (sample 9), proximal and distal views, electron micrographs, ×5,000; Pl. 21, fig. 5 (sample 9), distal (5a-c) and side (5d) views, light micrographs, phase contrast (5a), transmitted light (5b,d), cross-polarized light (5c), ×2,500.——Plate 26, figure 5. Distal (5a-c) and side (5d) views of doubtfully identified specimen from Eagle Ford Shale (sample 2) of Texas, light micrographs, phase contrast (5a), transmitted light (5b,d), cross-polarized light (5c), ×2,500.

ZYGODISCUS CRASSICAULIS Gartner, new species

A species of *Zygodiscus* with very high rim and short, thick stem.

Description.—The elliptical disc is constructed of dextrally imbricate elements that extend distally to form a very high, slightly flaring rim. The crossbar extending over the elliptical central opening is surmounted by a thick fluted stem that has a diameter from one-third to one-half that of the basal disc. The stem is constructed of elongate calcite prisms which have their long axes parallel to the axis of the stem and, when viewed in cross section, are arranged radially.

Discussion.—This species is probably closely related to *Zygodiscus lacunatus* Gartner, n. sp., but differs in having a higher rim and a thicker stem.

Maximum diameter.—8.8-11.6 μ.

Type specimen.—UI-H-2513 (Pl. 23, fig. 3) from the Austin Chalk.

Occurrence.—Sample 5, from the Austin Chalk.

Illustrations.—Specimens from Austin Chalk (sample 5) of Texas.——Plate 21, figure 14. Proximal (14a-c) and side (14d) views, light micrographs, phase contrast (14a), transmitted light (14b,d), cross-polarized light (14c), ×2,500.——Plate 23, figure 3. Side view of type specimen, electron micrograph, ×5,000.

ZYGODISCUS DIPLOGRAMMUS (Deflandre)

Zygolithus diplogrammus Deflandre in Deflandre & Fert, 1954, p. 148, pl. 10, fig. 7, text-fig. 57.——Bramlette & Martini, 1964, p. 304, pl. 4, fig. 11-12.

Discussion.—Electron micrographs show that this species is constructed of 30 to 55 dextrally imbricate elements. The elliptical central opening is spanned by a set of parallel crossbars aligned with the short axis of the ellipse. The crossbars may be separated by a slit, or they may be partially or completely fused. In some specimens a short hollow or solid stem may surmount the crossbars in the center.

Maximum diameter.—5.5-6.6 μ.

Occurrence.—*Zygodiscus diplogrammus* was described by Deflandre from Miocene deposits in Algeria but Bramlette & Martini believe that it was reworked from Cretaceous deposits. Bramlette & Martini have recorded the species from the type Maastrichtian and from equivalent deposits in France, Tunisia, and Alabama. In this study the species was found in sample 2 from the Eagle Ford Shale, samples 5, 9, 12, from the Austin Chalk, and sample 13, from the Taylor Marl.

Illustrations.—Plate 14, figure 18; Plate 17, figure 4. Specimens from Taylor Marl (sample 13) of Texas; Pl. 14, fig. 18, distal view, electron micrograph, ×5,000; Pl. 17, fig. 4, distal (4a-c) and side (4d) views, light micrographs, phase contrast (4a), transmitted light (4b,d), cross-polarized light (4c), ×2,500.——Plate 19, figure 3; Plate 21, figure 2; Plate 22, figure 7; Plate 23, figures 12-14; Plate 24, figure 6. Specimens from Austin Chalk of Texas; Pl. 19, fig. 3 (sample 12), proximal (3a-c) and side (3d) views, light micrographs, phase contrast (3a), transmitted light (3b,d), cross-polarized light (3c), ×2,500; Pl. 21, fig. 2 (sample 9), proximal (2a-c) and side (2d) views, light micrographs, phase contrast (2a), transmitted light (2b,d), cross-polarized light (2c), ×2,500; Pl. 22, fig. 7 (sample 9), distal view, electron micrograph, ×5,000; Pl. 23, fig. 12-14 (sample 5), distal views, electron micrographs, ×5,000; Pl. 24, fig. 6 (sample 5), proximal (6a-c) and side (6d) views, light micrographs, phase contrast (6a), transmitted light (6b,d), cross-polarized light (6c), ×2,500.——Plate 25, figures 17-18. Distal views of specimens from Eagle Ford Shale (sample 2) of Texas, electron micrographs, ×5,000.

ZYGODISCUS ELEGANS Gartner, new species

Cretarhabdus? anthophorus (Deflandre), Bramlette & Martini, 1964, p. 299, pl. 3, fig. 1-4.

A species of *Zygodiscus* with a flat disc and with submarginal notches and ridges developed on the disc.

Description.—The disc is constructed of about 40 dextrally imbricate elements; when viewed distally, the sutures incline counter-clockwise. On the distal side of the disc a flat peripheral rim is developed. Inside this rim is a row of shallow depressions alternating with ridges that give this portion of the disc a notched appearance in the light microscope. The crossbar spanning the elliptical central opening is surmounted by a sturdy stem. The stem is constructed of calcite rods, about 0.2 μ wide and about 1.0 μ long, arranged parallel to the axis of the stem so as to give it a fluted appearance. At the distal end the stem flares slightly and is deeply notched on its side. There is no evidence of an axial canal in the stem.

Discussion.—Bramlette & Martini identified this species with *Rhabdolithus anthophorus* Deflandre and assigned it provisionally to the genus *Cretarhabdus*. The species differs from the type of that genus in having only one cycle of elements in the basal disc and a single crossbar. *R. anthophorus* [=*Chiastozygus anthophorus* (Deflandre)] has x-shaped crossbars and a more distinct flare on the distal end of the stem.

Maximum diameter of basal disc.—7.1-11.0 μ.

Type specimen.—UI-H-2290 (Pl. 10, fig. 5), from the Taylor Marl.

Occurrence.—Bramlette & Martini (1964) record the species from the lower Maastrichtian of Holland, Tunisia, and Alabama. In this study the species was found in sample CKL-127 from the Taylor Marl.

Illustrations.—All specimens from Taylor Marl (sample CKL-127) of Texas.——Plate 10, figures 3-6, side (3-4), distal (5) and proximal (6) views, electron micrographs, ×5,000.——Plate 12, figures 3-4, side and proximal views, light micrographs, phase contrast (3a-4a), transmitted light (3b-4b), cross-polarized light (3c-4c), ×2,500.——Plate 27, figure 1. Side view of specimen, stereoscopic pair of electron micrographs, ×10,000.

ZYGODISCUS LACUNATUS Gartner, new species

A large species of *Zygodiscus* with high rim and fluted stem.

Description.—The large elliptical disc is constructed of 60 to 80 dextrally imbricate elements. The flaring rim that extends distally is relatively high. The complex crossbar spanning the elliptical central opening is surmounted by a sturdy stem which generally does not extend more than a few microns above the rim. It is constructed of radially arranged calcite rhombs and its surface is fluted with longitudinal furrows.

Discussion.—*Zygodiscus lacunatus* is similar to *Z. crassicaulis* Gartner, n. sp., but differs in having a lower rim and a thinner stem. *Z. pseudanthophorus* Bramlette & Martini probably developed from *Z. lacunatus* but has a larger central opening, a greater number of elements in the disc, and usually a thinner but longer stem.

Maximum diameter.—12-14 μ.

Type specimen.—UI-H-2526 (Pl. 23, fig. 15) from the Austin Chalk.

Occurrence.—Samples 5, 9, 12 from the Austin Chalk, and sample 13 from the Taylor Marl.

Illustrations.—Plate 17, figure 6. Proximal (6a-c) and side (6d) views of specimen from Taylor Marl (sample 13) of Texas, light micrographs, phase contrast (6a), transmitted light (6b,d), cross-polarized light (6c), ×2,500.——Other figured specimens all from Austin Chalk of Texas. Plate 18, figures 15-16 (sample 12), side and distal views, electron micrographs, ×5,000.——Plate 19, figure 5 (sample 12), proximal (5a-c) and side (5d) views, light micrographs, phase contrast (5a), transmitted light (5b,d), cross-polarized light (5c), ×2,500.——Plate 23, figures 15-16 (sample 5), oblique and distal views, electron micrographs, ×5,000.——Plate 24, figure 3 (sample 5), proximal (3a-c) and side (3d) views, light micrographs, phase contrast (3a), transmitted light (3b,d), cross-polarized light (3c), ×2,500.

ZYGODISCUS LAURUS Gartner, new species

A species of *Zygodiscus* with distinctly serrate margin and complex crossbar.

Description.—The basal disc of this species is constructed of 30 to 40 sinistrally imbricate elements. The disc appears to be of uniform thickness and lacks a peripheral rim. The elements making up the disc have a pointed termination, giving the periphery a serrate outline which appears ragged and irregular in the light microscope. In proximal view the sutures are almost radial but bend sharply near the periphery and incline counter-clockwise. There is no evidence of a stem on the crossbar spanning the elliptical central opening.

Discussion.—This species differs from other members of the genus in that it has sinistrally imbricate elements. It is easily recognized by its serrate periphery and absence of a rim.

Maximum diameter.—4.9-6.2 μ.

Type specimen.—UI-H-2149 (Pl. 2, fig. 28) from the Arkadelphia Formation.

Occurrence.—Sample ARK from the Arkadelphia Formation.

Illustrations.—Plate 2, figures 27-28. Proximal and distal views, electron micrographs, ×5,000.——Plate 3, figure 16. Proximal (16a-c) and side (16d) views, light micrographs, phase contrast (16a), transmitted light (16b,d), cross-polarized light (16c), ×2,500.

ZYGODISCUS SP. aff. ZYGODISCUS LAURUS Gartner

Discussion.—These small specimens of *Zygodiscus* resemble *Zygodiscus laurus* in construction, but the elements of the ring imbricate dextrally, whereas in *Z. laurus* the elements imbricate sinistrally.

Maximum diameter.—4.4-4.7 μ.

Occurrence.—Samples 5 and 9 from the Austin Chalk.

Illustrations.—Plate 21, figure 4. Distal view of specimen from sample 9, light micrographs, phase contrast (4a), transmitted light (4b), cross-polarized light (4c), ×2,500.——Plate 23, figures 21-22. Proximal views of specimens from sample 5, electron micrographs, ×5,000.

ZYGODISCUS NANUS Gartner, new species

Small species of *Zygodiscus* with auxiliary cycle of elements on proximal surface.

Description.—The elliptical disc is constructed of about 35 dextrally imbricate elements. The disc expands distally but no distinct rim is formed. On the proximal surface is a second cycle of about 35 elements, also dextrally imbricate and completely attached to the primary ring without a notch between the 2 cycles. The crossbar spanning the elliptical central opening is surmounted by a slender stem.

Discussion.—*Zygodiscus nanus* differs from *Z. spiralis* Bramlette & Martini in that it has strongly imbricate elements and from *Z. laurus* Gartner, n. sp., in that it has a smooth periphery.

Maximum diameter.—4.4 μ.

Type specimen.—UI-H-2420 (Pl. 18, fig. 12), from the Austin Chalk.

Occurrence.—Sample 12, from the Austin Chalk.

Illustrations.—Plate 14, figure 17. Proximal view of specimen identified as *Z.* sp. cf. *Z. nanus*, from Taylor Marl (sample 13) of Texas, electron micrograph, ×5,000.——Plate 18, figures 12-14. Specimens from Austin Chalk (sample 12) of Texas, proximal (12), distal (13), and side (14) views, electron micrographs, ×5,000.

ZYGODISCUS PSEUDANTHOPHORUS Bramlette & Martini

Zygodiscus? pseudanthophorus Bramlette & Martini, 1964, p. 303, pl. 3, fig. 17; pl. 4, fig. 17-18.

Discussion.—The elliptical disc of this large form is constructed of about 100 small, dextrally imbricate elements that form a distally expanding rim. The single crossbar extending across the large elliptical central opening is complexly constructed and may be surmounted by a long stem. In cross section the stem is seen to be constructed of numerous radially arranged calcite rhombs. The stem may have a longitudinal canal but this is not clear from any of the light micrographs or electron micrographs. The species is here assigned to the genus *Zygodiscus* emended.

Maximum diameter.—10.3-14.4 μ.

Maximum height of stem.—23 μ.

Occurrence.—This species was recorded by BRAMLETTE & MARTINI from the Gulpen Chalk of Holland and Maastrichtian equivalents in Denmark, southwestern France, Tunisia, Alabama, and Arkansas. In this study the species was found in sample ARK from the Arkadelphia Formation, and sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 2, figures 25-26; Plate 3, figure 14. Specimens from Arkadelphia Formation (sample ARK) of Arkansas; Pl. 2, fig. 25-26, proximal and distal views, electron micrographs, ×5,000; Pl. 3, fig. 14, distal view, light micrographs, phase contrast (14a), transmitted light (14b), cross-polarized light (14c), ×2,500.——Plate 13, figures 6-7. Side and proximal views of specimens from upper Taylor Marl (sample CKL-127) of Texas, light micrographs, phase contrast (6a-7a), transmitted light (6b-7b), cross-polarized light (6c-7c), ×2,500.

ZYGODISCUS SIPHONIS Gartner, new species

A species of *Zygodiscus* with low rim and hollow stem and calcite rhombs on proximal surface.

Description.—The elliptical disc is constructed of about 40 dextrally imbricate elements that form a low rim distally on the periphery of the disc. Viewed distally the sutures incline slightly counter-clockwise on the rim, but make a sharp bend and incline sharply clockwise inside the rim. On the proximal surface calcite rhombs are arranged concentrically on the disc. The crossbar spanning the elliptical central opening is arched and surmounted by a circular stem. The stem is constructed of calcite rods aligned with the axis of the stem. It is fluted on the surface and has an axial canal.

Discussion.—This species differs from *Zygodiscus elegans* GARTNER, n. sp., in having a distinct distally expanding rim and in lacking submarginal notches inside the rim. In addition the species is generally smaller and has a more slender, hollow stem.

Maximum diameter.—4.8-6.3 μ.

Height of stem.—5 μ.

Type specimen.—UI-H-2277 (Pl. 9, fig. 13) from the Taylor Marl.

Occurrence.—Sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 9, figures 11-13. Side, proximal, and distal views, electron micrographs, ×5,000.

ZYGODISCUS SISYPHUS Gartner, new species

A variably shaped species of *Zygodiscus* with long elliptical outline and slender stem.

Description.—The elliptical disc is constructed of 30 to 35 dextrally imbricate elements that form a low, expanding distal rim. The crossbar extending across the elliptical central area is surmounted by a short stem that is constructed of radially arranged calcite rhombs and has discontinuous longitudinal grooves on the surface.

Discussion.—This species contains a hopeless diversity of forms, some with a smooth periphery and others with a strongly serrate outline. In some specimens the stem has an axial canal, whereas others lack such a canal.

All have about the same number of elements in the disc and have a single, though complex, crossbar to which a stem is attached.

The species is similar to *Zygodiscus lacunatus* GARTNER, n. sp., but differs in having a smaller number of elements that are larger and in having a more delicate stem. The two species are easily distinguished in electron micrographs and light micrographs. Between crossed nicols *Z. lacunatus* is divided into 4 unequal parts by the sharp, nearly radial arms of the pseudointerference figure, whereas the arms of the pseudointerference figure in *Z. sisyphus* are diffuse and somewhat indistinct.

Maximum diameter.—5.5-10.5 μ.

Type specimen.—UI-H-2573 (Pl. 25, fig. 22), from the Eagle Ford Shale.

Occurrence.—Sample 2 from the Eagle Ford Shale, samples 5, 9, and 12 from the Austin Chalk, and sample 13 from the Taylor Marl.

Illustrations.—Plate 14, figure 19. Distal view of specimen from Taylor Marl (sample 13) of Texas, electron micrograph, ×5,000. ——Plate 18, figures 17-19; Plate 21, figure 6; Plate 22, figures 5-6; Plate 23, figures 17-18. Specimens from Austin Chalk of Texas; Pl. 18, fig. 17-19 (sample 12), proximal (17, 19) and distal (18) views, electron micrographs, ×5,000; Pl. 21, fig. 6 (sample 9), distal (6a-c) and side (6d) views, light micrographs, phase contrast (6a), transmitted light (6b,d), cross-polarized light (6c), ×2,500; Pl. 22, fig. 5-6 (sample 9), distal and proximal views, electron micrographs, ×5,000; Pl. 23, fig. 17-18 (sample 5), distal views, electron micrographs, ×5,000.——Plate 25, figures 19-22; Plate 26, figure 6. Specimens from Eagle Ford Shale (sample 2) of Texas; Pl. 25, fig. 19-22, distal (19, 21-22) and proximal (20) views, electron micrographs, ×5,000; Pl. 26, fig. 6, distal (6a-c) and side (6d) views, light micrographs, phase contrast (6a), transmitted light (6b,d) cross-polarized light (6c), ×2,500.

ZYGODISCUS SP. aff. ZYGODISCUS SISYPHUS Gartner, new species

Discussion.—The specimens in the two electron micrographs appear to have more than one cycle of elements, and the specimens also have a smoother outline than do other specimens of *Zygodiscus sisyphus*. The great variation among specimens of that species has already been mentioned, and it is possible, therefore, that these two specimens may belong to it.

Maximum diameter.—6.8-7.0 μ.

Occurrence.—Sample 5, lower Austin Chalk.

Illustrations.—Plate 23, figures 19-20. Proximal views, electron micrographs, ×5,000.

ZYGODISCUS SPIRALIS Bramlette & Martini

Zygodiscus spiralis BRAMLETTE & MARTINI, 1964, p. 303, pl. 4, fig. 6-8.

Discussion.—Electron micrographs of the distal view of this species indicate that it is made of about 30 nearly radially arranged elements. On the distal side the surface is covered by a layer of keystone-shaped elements arranged in a radial pattern. The arched crossbar is surmounted by a solid stem which in cross section shows a radial arrangement of elements and is probably constructed of calcite rods arranged parallel to the axis of the stem.

Maximum diameter.—5.1 μ.

Occurrence.—This species was recorded by BRAMLETTE & MARTINI from the type Maastrichtian and from equivalent deposits in Denmark, southwestern France, Tunisia, Alabama, and Arkansas. The species appears to be restricted to deposits of this age, as it was found only in sample COR from the Corsicana Marl.

Illustrations.—Plate 5, figures 21-22. Proximal and distal views, electron micrographs, ×5,000.——Plate 7, figure 3. Distal view, light micrographs, phase contrast (3a), transmitted light (3b), cross-polarized light (3c), ×2,500.

Subfamily STEPHANOLITHOIDEAE Vekshina, 1959

Genus STEPHANOLITHION Deflandre, 1939

Type species.—Stephanolithion bigoti DEFLANDRE, 1939.

Elliptical to elongate polygonal discs consisting of an open rim that may have radial spines on its periphery and irregularly spaced crossbars that intersect at the center and may support a short spine or stem.

STEPHANOLITHION SP. aff. STEPHANOLITHION LAFFITEI Noël

Stephanolithion laffitei Noël, NOËL, 1958, p. 161, pl. 1, fig. 1 (not fig. 2).

Discussion.—Stephanolithion laffitei was named and described by NOËL in 1956, but the two illustrations that accompany her description have little resemblance to each other. As no type designation was made, the status of the species is very unsatisfactory. In 1958 NOËL again illustrated two specimens of *S. laffitei,* both of which resemble superficially one of the earlier illustrations (pl. 1, fig. 1). The specimens illustrated here are identified with NOËL's later illustration (1958, pl. 1, fig. 1), but they differ from it in that a short stem surmounts the central structure and the peripheral spines or protuberances are not as well developed. Both of these differences may be only of infraspecific importance.

Maximum diameter.—4.5 μ.

Occurrence.—Specimens illustrated here are from sample 5 from the Austin Chalk, and from sample COR from the Corsicana Marl.

Illustrations.—Plate 5, figure 14. Plan view of specimen from Corsicana Marl (sample COR) of Arkansas, electron micrograph, ×5,000.——Plate 22, figure 18. Plan view of specimen from Austin Chalk (sample 5) of Texas, electron micrograph, ×5,000.

Genus COROLLITHION Stradner, 1961

Type species.—Corollithion exiguum STRADNER, 1961.

Circular or regularly polygonal disc consisting of rim and open center with radial spokes; in center where spokes meet they may be surmounted by short stem or spine. On periphery of disc short nodes or spines may be developed, protuberances being directed radially and distally on disc.

COROLLITHION EXIGUUM Stradner

Corollithion exiguum STRADNER, 1961, p. 83, fig. 58-61.——BRAMLETTE & MARTINI, 1964, p. 308, pl. 5, fig. 8-9.

Discussion.—The electron micrograph of this specimen shows features common to *Corollithion exiguum* and *Stephanolithion laffitei* NOEL (of STRADNER, 1963). The regular hexagonal outline of 6 radial arms indicate that it is a specimen of *C. exiguum;* the protuberances on the periphery probably are sites of excess calcification. The vestige of a stem in the center, as well as shadows cast by the peripheral protuberances, indicate that the specimen figured is viewed distally.

Diameter.—5.5 μ.

Occurrence.—Originally described from the Upper Cretaceous (Senonian) of Austria by STRADNER, it has also been recorded by BRAMLETTE & MARTINI from the type Maastrichtian and from equivalent deposits in France, Tunisia, and Alabama. The specimen figured here is from sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 10, figure 26. Distal view, electron micrograph, ×5,000.

COROLLITHION OCTORADIATUM Gartner, new species

Stephanolithion laffitei Noël, STRADNER, 1963, p. 12, pl. 1, fig. 14-14a,b.

Small ring constructed of multiple elements with 8 evenly spaced arms extending radially from the center.

Description.—The ring is constructed of about 20 keystone-shaped elements. Attached to this ring are 8 regularly spaced radial arms that support a central complex sometimes surmounted by a short stem or spine. In addition, spines or protuberances can be seen frequently with the light microscope on the periphery of the ring, disposed like the points of a crown, but irregular in their distribution.

Discussion.—This species differs from *Corollithion exiguum* STRADNER in having a circular rather than a hexagonal outline and in having 8 instead of 6 radial arms.

Diameter.—5.5 μ.

Type specimen.—UI-H-2297 (Pl. 10, fig. 14) from the Taylor Marl.

Occurrence.—First recorded from the Upper Cretaceous (Senonian) of Austria by STRADNER, in this study the species was found in sample no. 5 from the Austin Chalk, in sample CKL-127 from the Taylor Marl, and in sample COR from the Corsicana Marl, Navarroan.

Illustrations.—Plate 6, figure 5. Plan view of specimen from Corsicana Marl (sample COR), light micrographs, phase contrast (5a), transmitted light (5b), cross-polarized light (5c), ×2,500.——Plate 10, figures 14-15; Plate 11, figure 7. Specimens from Taylor Marl (sample CKL-127) of Texas; Pl. 10, fig. 14-15, ?distal and side views, electron micrographs, ×5,000; Pl. 11, fig. 7, unspecified view, light micrographs, phase contrast (7a), transmitted light (7b), cross-polarized light (7c), ×2,500.——Plate 22, figure 19. Unspecified view of specimen from Austin Chalk (sample 5) of Texas, electron micrograph, ×5,000.

Family SYRACOSPHAERACEAE Lemmermann, 1903

Subfamily SYRACOSPHAEROIDEAE Kamptner, 1928

Genus CRETADISCUS Gartner, new genus

Type species.—*Cretadiscus polyporus* GARTNER, n. sp.

Description.—The elliptical lopadolith has a low but pronounced rim constructed of large elements that imbricate slightly. The rim extends distally, and flares so that its distal diameter is larger than its proximal diameter. On the proximal periphery a narrow keel is developed. The area enclosed by the rim is perforated by numerous small holes usually arranged in concentric cycles.

Discussion.—*Cretadiscus* differs from *Discolithina* LOEBLICH & TAPPAN in having the rim constructed of relatively large elements and in having a narrow keel on the proximal periphery. This last feature indicates that it is related to the modern genus *Syracosphaera* LOHMANN (see, for example, HALLDAL & MARKALI, 1954).

CRETADISCUS COLATUS Gartner, new species

A species of *Cretadiscus* with 5 to 7 cycles of small perforations in the central area.

Description.—The low rim of this elliptical lopadolith is constructed of about 30 elements that imbricate slightly sinistrally. The central area is pierced by numerous small holes arranged in 5 to 7 concentric cycles.

Discussion.—This species differs from *Cretadiscus polyporus* GARTNER, n. sp., in having a narrower rim that is constructed of smaller elements, more numerous perforations, and a less pronounced proximal keel.

The specimen from sample no. 9 (Pl. 19, fig. 10) appears to be a closely related form but differs in being smaller and in having fewer holes in the center and a relatively wider rim that is constructed of larger elements.

Maximum diameter.—6.4 μ.

Type specimen.—UI-H-2293 (Pl. 10, fig. 8) from the Taylor Marl.

Occurrence.—Sample 12 from the Austin Chalk, and sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 10, figures 7-8; Plate 12, figures 5-6. Specimens from Taylor Marl (sample CKL-127) of Texas; Pl. 10, fig. 7-8, distal views, electron micrographs, ×5,000; Pl. 12, fig. 5-6, proximal (5-6a) and side (6b) views, light micrographs, phase contrast (5a-6a,b), transmitted light (5b), cross-polarized light (5c), ×2,500.——Plate 19, figure 10. Specimen from Austin Chalk (sample 9) of Texas identified as *C.* sp. cf. *C. crenulatus*, proximal (10a-c) and side (10d) views, light micrographs, phase contrast (10a), transmitted light (10b,d), cross-polarized light (10c), ×2,500.

CRETADISCUS POLYPORUS Gartner, new species

Elliptical lopadolith with low rim of large elements and narrow keel on proximal periphery; 3 to 5 cycles of perforations in central area.

Description.—The elliptical lopadolith has a low distal rim constructed of about 24 large elements that imbricate slightly sinistrally. Because of the narrow keel developed on the proximal periphery of the rim, a broad, shallow furrow is formed on the side of the rim. A plate extends over the area enclosed by the rim, and this plate is perforated by numerous small, subcircular holes which are arranged in 3 to 5 crudely concentric cycles.

Discussion.—Seen with the light microscope this species superficially resembles *Cribrosphaerella ehrenbergi* (ARKHANGELSKY), particularly in proximal or distal view. Side views in the light microscope and electron micrographs, which resolve the details of the rim structure, make the difference between the two obvious.

Maximum diameter.—7.1-9 μ.

Type specimen.—UI-H-2121 (Pl. 1, fig. 17) from the Arkadelphia Formation.

Occurrence.—This species was found in samples ARK from the Arkadelphia Formation, and in sample COR from the Corsicana Marl, both of Navarroan age.

Illustrations.—Plate 1, figures 17-19. Distal views of specimens from Arkadelphia Formation (sample ARK) of Arkansas, electron micrographs, ×5,000.——Plate 4, figure 13. Distal view of specimen from Corsicana Marl (sample COR) of Texas, electron micrograph, ×5,000.——Plate 25, figure 5. Distal view of specimen from Eagle Ford Shale (sample 2) of Texas identified as *C.* sp. cf. *C. polyporus*, electron micrograph, ×5,000.

Genus DISCOLITHINA Loeblich & Tappan, 1963

Type species.—*Discolithus vigintiforatus* KAMPTNER, 1948.

Elliptical disc with or without distinct rim, generally perforated.

DISCOLITHINA MULTICAVA (Gorka)

Discolithus multicavus GORKA, 1957, p. 256, pl. 4, fig. 2.

Discussion.—This species is characterized by the narrow rim and the numerous small perforations. A suggestion of a fissure runs through the center of the disc aligned with the long axis of the ellipse. The species was not encountered, however, in the light microscope and this structure could not be studied between crossed nicols.

Maximum diameter.—6.0 μ.

Occurrence.—Sample COR from the Corsicana Marl, Navarroan.

Illustration.—Plate 4, figure 14. Plan view of specimen, electron micrograph, ×5,000.

Subfamily ARKHANGELSKIELLOIDEAE Gartner, new subfamily

Elliptical discs with multilayered rim.

Genus ARKHANGELSKIELLA Vekshina, 1959

Type species.—*Arkhangelskiella cymbiformis* Vekshina, 1959.

Elliptical disc consisting of distinct rim and central area; rim constructed of four or (in some) three tiers, which if counted starting on concave or proximal side, first tier is smallest and tier immediately preceding last one is largest; last or distal tier continuous with plate that extends across central portion of disc; such plate may be perforated and traversed by longitudinal and transverse suture.

ARKHANGELSKIELLA CONCAVA Gartner, new species

Elliptical disc with 4 closely appressed rim tiers, longitudinal and transverse sutures lined with small crystallites; central area imperforate.

Description.—The central plate is constructed of irregular elements that originate at the suture lines of the central area and terminate in a regular fashion as the most distal rim tier. On the distal surface, the irregularly constructed central plate has pits along the secondary sutures where perforations are found in other species. Viewed proximally 3 progressively larger rim tiers can be distinguished, each made of 56 to 80 elements, the first or proximal tier appearing to have at least 2 cycles of elements. The fourth or distal tier cannot be seen in proximal view.

The longitudinal suture of the central plate is aligned with the major axis of the ellipse; the transverse suture is rotated about 5° clockwise from the short axis of the ellipse when viewed proximally. The sutures are lined on each side with relatively small crystallites, which may form a low but sharp ridge on the proximal side. The remainder of the central plate is covered by randomly arranged relatively large coarse crystals.

Discussion.—In the light microscope *Arkhangelskiella concava* has some similarity to *Discolithus decoratus* Caratini which almost certainly belongs to *Arkhangelskiella.*

Arkhangelskiella concava differs from *A. costata* Gartner, n. sp., in that the ridges lining the sutures are not nearly as well developed and in that the central area of *A. concava* is not perforated. In the light microscope these two species are very difficult to separate because the differences between them are largely beyond the resolution limit of light optics. It is very probable that *A. costata* developed from *A. concava* rather directly.

Maximum diameter.—7.0-10.0 μ.

Minimum diameter.—5.4-7.6 μ.

Type specimen.—UI-H-2383 (Pl. 16, fig. 6), from the Austin Chalk.

Occurrence.—*Arkhangelskiella concava* occurs in samples 5, 9, and 12 from the Austin Chalk, and in sample 13 from the Taylor Marl.

Illustrations.—Plate 14, figures 2-3. Specimens from Taylor Marl (sample 13) of Texas, proximal and distal views, electron cmicrographs, ×5,000.——Other figured specimens from Austin Chalk of Texas. Plate 16, figures 5-7. Proximal (5-6) and distal (7) views (sample 12), electron micrographs, ×5,000.——Plate 17, figure 7. Distal (7a-c) and side (7d) views (sample 12), light micrographs, phase contrast (7a), transmitted light (7b,d), cross-polarized light (7c), ×2,500.——Plate 18, figures 22-23. Distal and proximal views (sample 9), electron micrographs, ×5,000.——Plate 19, figure 6. Distal (6a-c) and side (6d) views (sample 9), light micrographs, phase contrast (6a), transmitted light (6b,d), cross-polarized light (6c), ×2,500.——Plate 21, figure 7. Distal view (sample 9), light micrographs, phase contrast (7a), transmitted light (7b), cross-polarized light (7c), ×2,500.——Plate 22, figures 13-15. Distal (13) and proximal (14-15) views (sample 5), electron micrographs, ×5,000.

ARKHANGELSKIELLA COSTATA Gartner, new species

Elliptical disc with 4 closely appressed rim tiers; sutures in central area bordered by ridge and lined with perforations.

Description.—The central plate is distal, as in all species of *Arkhangelskiella.* In distal views, this plate is seen to consist of a rim of imbricate elements which forms the distal tier of the rim and a central area of less definite structure. When viewed proximally, the rim consists of 3 progressively larger tiers. The fourth and most distal tier is smaller than the third one and, therefore, not visible in proximal view. The tiers are made up of 60 to 70 elements and apparently more than one cycle of elements may be present in the first or proximal tier.

The longitudinal suture is aligned with the major axis of the ellipse and the transverse suture is rotated about 5° clockwise from the minor axis of the ellipse when seen proximally. Each suture is bordered by a row of crystallites which form a double ridge. These ridge-lined sutures show up particularly well between crossed nicols of a light microscope. Adjacent to the ridges are regularly spaced perforations. Transverse bars extend partially or completely across the perforations. These bars are aligned with the axis which they border.

Discussion.—*Arkhangelskiella costata* differs from *A. cymbiformis* Vekshina in the complex construction of the rim and in having distinct ridges along the sutures. It differs from *A. concava* GARTNER, n. sp., in being smaller and having sutures lined with perforations.

Maximum diameter.—5.6-6.5 μ.

Minimum diameter.—4.0-5.0 μ.

Type specimen.—UI-H-2242 (Pl. 8, fig. 2) from the Taylor Marl.

Occurrence.—Sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 8, figures 1-3. Proximal (1-2) and distal (3) views, electron micrographs. ×5,000.——Plate 11, figure 1. Distal view, light micrographs, phase contrast (1a), transmitted light (1b), cross-polarized light (1c), ×2,500.——Plate 28, figure 2. Specimen apparently constructed entirely of crystallites, showing narrow sharp ridges lining each side of longitudinal and transverse sutures of central area, electron micrograph, ×30,000.

ARKHANGELSKIELLA CYMBIFORMIS Vekshina

"Coccoliths of uncertain affinity" ARKHANGELSKY, 1912, v. 25, pl. 6, fig. 24.

Arkhangelskiella cymbiformis VEKSHINA, 1959, p. 66, pl. 2, fig. 3a-b.——STRADNER, 1963, p. 12, pl. 1, fig. 4-4a,b.——BRAMLETTE & MARTINI, 1964, p. 297, pl. 1, fig. 3-9.

Discussion.—The rim of the elliptical disc usually consists of 4 closely appressed tiers, each made of one cycle except the most proximal tier, which may be constructed of more than one cycle. In most specimens only 3 and in some only 2 tiers can be seen. Occasionally all 4 tiers are visible in proximal view of highly curved specimens. The first or proximal tier is invariably smallest; the third tier from the proximal surface is largest, and the second and fourth tiers are of intermediate size. The number of elements in each cycle ranges from 50 in small specimens to 70 in large ones.

The central area is continuous with the fourth tier and is divided into 4 quadrants by suture lines subparallel to major and minor axes of the ellipse. Each quadrant is further subdivided by sutures at about 45° to the major and minor axes and several irregular sutures. The perforations in the central area appear to lie along such secondary sutures, and in some well-developed specimens 1 or 2 bars may extend across the perforations.

Maximum diameter.—7.5-12.0 μ.

Minimum diameter.—5.8-9.0 μ.

Occurrence.—*Arkhangelskiella cymbiformis* was described from Cretaceous deposits in western Siberia. It has been recorded also by BRAMLETTE & MARTINI from the type Maastrichtian and from equivalent deposits in Denmark, southwestern France, Tunisia, Alabama, and Arkansas. The specimens figured here are from the Arkadelphia Formation in Arkansas, where *A. cymbiformis* is the most abundant species, and from the Corsicana Marl in Texas, both of Navarroan age.

Illustrations.—Plate 1, figures 1-6. Proximal (1-3), distal (4-5), and rim without central area (6) views of specimens from Arkadelphia Formation (sample ARK) of Arkansas, electron micrographs, ×5,000.——Plate 4, figures 1-4. Proximal (1-2) and distal (3-4) views of specimens from Corsicana Marl (sample COR) of Texas, electron micrographs, ×5,000.——Plate 6, figure 1. Proximal view of specimen from Corsicana Marl (sample COR) of Texas, light micrographs, phase contrast (1a), transmitted light (1b), cross-polarized light (1c), ×2,500.——Plate 27, figure 2. Positive and negative prints, proximal view of specimen from Corsicana Marl (sample COR), electron micrograph, ×10,000.

ARKHANGELSKIELLA MAGNACAVA Gartner, new species

Elliptical disc with multiple rim tiers; sutures in central area perpendicular to each other, and aligned with major and minor axes of ellipse.

Description.—In the electron micrographs most of the structural detail of this species is obscured by an amorphous layer which may be part of the original structure or may be a layer of fine clay particles. Two or possibly 3 tiers can be distinguished in the rim in proximal view, and very probably a fourth tier is hidden by the larger third tier. The tiers are constructed of about 40 elements which are also largely obscured by the amorphous layer. The sutures, although somewhat obscured, are aligned almost perfectly with major and minor axes of the ellipse. Relatively large perforations line each side of the sutures.

Discussion.—This species and *Arkhangelskiella parca* STRADNER are the only species of the genus in which one suture is aligned exactly with the minor axis of the ellipse and it is possible that these species are closely related.

Maximum diameter.—5.5-7.2 μ.

Type specimen—UI-H-2432 (Pl. 18, fig. 24) from the Austin Chalk.

Occurrence.—Samples 5 and 9 from the Austin Chalk.

Illustrations.—Plate 18, figures 24-25. Proximal views of specimens from sample 9, electron micrographs, ×5,000.——Plate 22, figure 9. Distal view of specimen from sample 5, electron micrograph, ×5,000.

ARKHANGELSKIELLA PARCA Stradner

Arkhangelskiella parca STRADNER, 1963, p. 10, pl. 1, fig. 3.——BRAMLETTE & MARTINI, 1964, p. 298, pl. 1, fig. 1-2.

Discussion.—*Arkhangelskiella parca* is constructed on the same plan as *A. cymbiformis* VEKSHINA in that the rim shows 3 increasingly larger tiers when seen proximally. In the light microscope a fourth tier can be seen distally but is hidden in the electron micrographs by the larger third tier. Each tier is constructed of about 50 elements. The central area is diamond-shaped and traversed by sutures aligned with major and minor axes of the ellipse. The sutures are bordered by circular perforations on each side.

Maximum diameter.—10.0-12.5 μ.

Occurrence.—This species was originally described by STRADNER from the upper Campanian of Austria. It has also been recorded by BRAMLETTE & MARTINI from lower Maastrichtian deposits in Holland, Tunisia, and Alabama. The specimens figured here are from sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 8, figures 4-5. Proximal views, electron micrographs, ×5,000.——Plate 11, figure 2. Distal view, light micrographs, phase contrast (2a), transmitted light (2b), cross-polarized light (2c), ×2,500.

ARKHANGELSKIELLA SCAPHA Gartner, new species

Elliptical disc with 4 closely appressed rim tiers; central area imperforate and made of large crystallites.

Description.—The central plate is constructed of irregular elements or large irregular crystallites. The margin of the central plate is constructed of regularly arranged elements forming the distal rim tier. On the distal surface pits or slits mark the places where perforations are located in other species. On the proximal side 3 progressively larger rim tiers can be seen, each made of 60 to 80 elements. The first or proximal tier has a secondary cycle of elements with a serrate margin on its surface.

One of the 2 sutures trasversing the central area is aligned almost perfectly with the major axis of the ellipse. The other suture may be rotated a few degrees clockwise or counter-clockwise from the minor axis of the ellipse. The central area is imperforate.

Discussion.—In electron micrographs *Arkhangelskiella scapha* is very similar to *A. concava* GARTNER, n. sp., but differs in lacking an elevated ridge on either side of the suture lines. Also, *A. scapha* is always larger than *A. concava*. In the light microscope, the difference between the two is very pronounced. Between crossed nicols *A. scapha* looks very much like *A. cymbiformis* VEKSHINA and *A. specillata* VEKSHINA in that the central area is sharply divided into 8 alternating light and dark regions. In *A. concava* these areas are diffuse and poorly defined. Also in the latter species and in *A. costata* GARTNER, n. sp., the elevated ridges on each side of the sutures commonly are clearly visible in polarized light.

Maximum diameter.—10.2-12.8 μ.

Minimum diameter.—7.0-9.4 μ.

Type specimens.—UI-H-2446 (Pl. 20, fig. 1) from the Austin Chalk.

Occurrence.—This species was found in samples 5, 9, and 12 from Austin Chalk, and in sample 13 from the Taylor Marl. Some of the pre-Maastrichtian occurrences of *A. cymbiformis* are no doubt referable to this species.

Illustrations.—Plate 14, figure 1; Plate 15, figure 1. Specimens from Taylor Marl (sample 13) of Texas; Pl. 14, fig. 1, distal view, electron micrograph, ×5,000; Pl. 15, fig. 1, distal (1a-c) and side (1d) views, light micrographs, phase contrast (1a), transmitted light (1b,d), cross-polarized light (1c), ×2,500.——Plate 17, figure 8; Plate 20, figures 1-3. Specimens from Austin Chalk (sample 9) of Texas; Pl. 17, fig. 8, proximal (8a-c) and side (8d) views, light micrographs, phase contrast (8a), transmitted light (8b,d), cross-polarized light (8c), ×2,500; Pl. 20, fig. 1-3, proximal (1) and distal (2-3) views, electron micrographs, ×5,000.

ARKHANGELSKIELLA SPECILLATA Vekshina

Arkhangelskiella specillata VEKSHINA, 1959, p. 67, pl. 2, fig. 5.

Discussion.—Both electron micrographs of this species represent distal views. The distal rim tier is somewhat narrower than the one adjacent to it and is continuous with the central plate. One suture across the central plate is very nearly aligned with the major axis of the ellipse. The other suture is rotated about 10° clockwise from the minor axis of the ellipse when the specimen is viewed proximally. Perforations less than 0.5 μ in diameter pierce the central plate along each side of the 2 sutures and along the inner margin of the rim. The rim is narrower than in *Arkhangelskiella cymbiformis* VEKSHINA. In the light microscope, *A. specillata* is very similar to *A. cymbiformis* but differs in having a narrower rim, one strongly oblique suture, and perforations along the inner margin of the rim.

Maximum diameter.—8.8-12.0 μ.

Minimum diameter.—7.0-9.0 μ.

Occurrence.—This species was first described from Cretaceous deposits of western Siberia. In this study, it was found only in sample CKL-127, from the Taylor Marl.

Illustrations.—Plate 8, figures 6-7. Distal views, electron micrographs, ×5,000.——Plate 11, figure 4. Distal view, light micrographs, phase contrast (4a), transmitted light (4b), cross-polarized light (4c), ×2,500.

Genus KAMPTNERIUS Deflandre, 1959

Type species.—*Kamptnerius magnificus* DEFLANDRE, 1959.

Elliptical disc consisting of central plate, rim, and asymmetrical flange or fringe; central plate perforated and traversed by single suture aligned with major axis of ellipse, this plate constructed of subradially arranged irregular calcite laths that terminate regularly and form distalmost of rim tiers; rim consisting of three or four tiers, of which proximal one is smallest and next to last tier largest, smallest tier appearing to be constructed of more than one cycle of elements; flange or fringe constructed of subparallel laths and continuous with distal rim tier. It may be narrow and inconspicuous or wide and highly asymmetrical.

KAMPTNERIUS MAGNIFICUS Deflandre

Kamptnerius magnificus DEFLANDRE, 1959, p. 135, pl. 1, fig. 1-4. ——STRADNER, 1963, p. 12, pl. 2, fig. 2.

Kamptnerius punctatus STRADNER, 1963, p. 11, pl. 2, fig. 3.

Kamptnerius magnificus Deflandre, BRAMLETTE & MARTINI, 1964, p. 301, pl. 2, fig. 1-3.——REINHARDT, 1966, p. 22, pl. 17, fig. 1, 2; pl. 18, fig. 1, 2.

Discussion.—This species consists of 3 distinct parts: central plate, rim, and fringe. The most prominent feature of the central plate is a suture aligned with the long axis of the ellipse. From this suture, irregular secondary sutures extend subradially, forming equally irregular elements. Minute holes or slits perforate the central plate. These perforations may be along the secondary sutures or located entirely within an element. Toward the periphery the elements become uniform and form the most distal rim tier. The rim is constructed of 3 tiers, of which the proximal one is smallest and the distal tier largest. The proximal tier may consist of more than one cycle of elements. The fringe is constructed of subparallel laths which are continuous with elements of the distal tier of the rim and the central plate. The fringe is commonly relatively narrow and inconspicuous, but in some specimens it is well developed and may be as large as the entire disc.

Older representatives of this species are generally larger and tend to be more calcified. These two features may, however, be largely environmental as the older specimens are from chalky deposits, whereas the younger specimens are from more clayey deposits. The younger specimens also have holes developed in the central plate more commonly, although this is not always true. The highly asymmetrical fringe tends to be more developed in younger forms and appears to be a significant feature. The older representatives are almost always asymmetrical, but not nearly to such an extreme degree as are the younger forms.

Maximum diameter.—8.0-16.0 μ.

Occurrence.—This species was described by DEFLANDRE from the Maastrichtian of France. It was also recorded by him from the Senonian of France and Australia and from the Santonian (Bonham Marl) of Texas. BRAMLETTE & MARTINI recorded the species from the type Maastrichtian and equivalents in Denmark, France, Tunisia, Alabama, and Arkansas. In this study, the species was found in samples 5, 9, and 12 from the Austin Chalk, samples 13 and CKL-127 from the Taylor Marl, samples COR from the Corsicana Marl, and sample ARK from the Arkadelphia Formation.

Illustrations.—Plate 2, figures 1-2; Plate 3, figure 7. Specimens from Arkadelphia Formation (sample ARK) of Arkansas; Pl. 2, fig. 1-2, proximal views, electron micrographs, ×5,000; Pl. 3, fig. 7, distal view, light micrographs, phase contrast (7a), transmitted light (7b), cross-polarized light (7c), ×2,500.——Plate 6, figure 10. Distal view of specimen from Corsicana Marl (sample COR) of Texas, light micrographs, phase contrast (10a), transmitted light (10b), cross-polarized light (10c), ×2,500.——Plate 10, figures 11-13; Plate 12, figure 9; Plate 14, figures 11-12; Plate 15, figure 10. Specimens from Taylor Marl of Texas; Pl. 10, fig. 11-13 (sample CKL-127), distal (11) and proximal (12-13) views, electron micrographs, ×5,000; Pl. 12, fig. 9 (sample CKL-127), unspecified view, light micrograph, phase contrast (9a), transmitted light (9b), cross-polarized light (9c), ×2,500; Pl. 14, fig. 11-12 (sample 13), distal views, electron micrographs, ×5,000; Pl. 15, fig. 10 (sample 13), proximal view, light micrograph, phase contrast (10a), transmitted light (10b), cross-polarized light (10c), ×2,500.——Plate 16, figures 17-19; Plate 17, figures 11-12; Plate 21, figure 12. Specimens from Austin Chalk of Texas; Pl. 16, fig. 17-19 (sample 12), distal views, electron micrographs, ×5,000; Pl. 17, fig. 11-12 (sample 9), proximal and distal views, light micrographs, phase contrast (11a-12a), transmitted light (11b-12b), cross-polarized light (11c-12c), ×2,500; Pl. 21, fig. 12 (sample 5), distal view, light micrograph, phase contrast (12a), transmitted light (12b), cross-polarized light (12c), ×2,500.

Genus CRIBROSPHAERELLA Deflandre, 1952

Type species.—*Cribrosphaera ehrenbergi* ARKHANGELSKY, 1912.

Elliptical disc consisting of cribrate central plate and rim with two or three tiers, each tier constructed of single cycle of large elements that meet along somewhat irregular sutures; central plate of some specimens appearing to be made of discrete closely packed elements and having perforation at their center; in other specimens this plate appears to be continuous, with regularly spaced perforations in rows or in cycles.

CRIBROSPHAERELLA EHRENBERGI (Arkhangelsky)

Cribrosphaera ehrenbergi ARKHANGELSKY, 1912, p. 412, pl. 6, fig. 19.

Cribrosphaerella ehrenbergi (Arkhangelsky), DEFLANDRE, 1952, p. 111, text-fig. 54a (not 54b).

Discolithina cf. *D. numerosa* (Gorka), BRAMLETTE & MARTINI, 1964, p. 301, pl. 1, fig. 23-24.

Discussion.—ARKHANGELSKY described this species as "coccoliths consisting of two plates, of which the distal is strongly reduced." He appears to have been mistaken in his orientation of the specimen as this particular construction has not been observed in any form of the group. The species is not a true placolith in the same sense as are members of the genus *Coccolithus* but is more closely allied to forms such as *Arkhangelskiella.* The rim consists of 2 tiers, each constructed of a single cycle of large elements. The proximal tier is smaller than the distal tier. Extending over the elliptical central area is a complex, perforated plate that appears to be at the level of the distal rim tier.

BRAMLETTE & MARTINI illustrated a specimen of *Cribrosphaerella,* although their description is of a very similar species of *Discolithina* or possibly *Cretadiscus.* The two are difficult to tell apart with a light microscope in fixed mounts where the specimens can be seen only in proximal or distal view. In viscous mounts where the specimens can be examined in side view, or in electron micrographs where the details of the rim structure can be resolved the difference is distinct.

Maximum diameter.—7.0-12.0 μ.

Occurrence.—The species was first described from the Upper Cretaceous of Russia. It was recorded by BRAMLETTE & MARTINI from the type Maastrichtian and from equivalents in Denmark, France, Tunisia, Alabama, and Arkansas. In the present study, it was noted in samples 13 and CKL-127 from the Taylor Marl, and in samples ARK from the Arkadelphia Formation, and COR from the Corsicana Marl, both of Navarroan age.

Illustrations.—Plate 1, figures 14-15; Plate 3, figure 2. Specimens from Arkadelphia Formation (sample ARK) of Arkansas; Pl. 1, fig. 14-15, proximal views, electron micrographs, ×5,000; Pl. 3, fig. 2, proximal view, light micrographs, phase contrast (2a), transmitted light (2b), cross-polarized light (2c), ×2,500.——Plate 6, figure 7. Plan view of specimen from Corsicana Marl (sample COR) of Texas, light micrographs, phase contrast (7a), transmitted light (7b), cross-polarized light (7c), ×2,500.——Plate 12, figure 2; Plate 15, figure 11. Specimens from Taylor Marl of Texas; Pl. 12, fig. 2 (sample CKL-127), proximal (2a-c) and side (2d) views, light micrographs, phase contrast (2a), transmitted light (2b,d), cross-polarized light (2c), ×2,500; Pl. 15, fig. 11 (sample 13), proximal (11a-c) and side (11d) views, light micrographs, phase contrast (11a), transmitted light ((11b,d), cross-polarized light (11c), ×2,500.

CRIBROSPHAERELLA LINEA Gartner, new species

A species of *Cribrosphaerella* in which the central plate consists of a meshwork with irregularly shaped perforations.

Description.—The rim is made of 2 closely appressed tiers of which the distal is larger. The tiers are made of 16 to 20 interlocking elements with irregular sutures. The rim is wide, and encloses a relatively small central area. In electron micrographs the central area is covered by a meshwork with irregularly shaped perforations. In light micrographs the perforations are seen to be arranged in 2 concentric cycles.

Discussion.—*Cribrosphaerella linea* differs from *C. ehrenbergi* (ARKHANGELSKY) in that it has a wider rim and a smaller central area and fewer perforations in the central area.

Maximum diameter.—7.0-7.5 μ.

Type specimen.—UI-H-2120 (Pl. 1, fig. 16), from the Arkadelphia Formation.

Occurrence.—This species was found in sample ARK from the Arkadelphia Formation, Navarroan, and sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 1, figure 16; Plate 3, figure 4. Specimens from Arkadelphia Formation (sample ARK) of Arkansas; Pl. 1, fig. 16, proximal view of type specimen, electron micrograph, ×5,000; Pl. 3, fig. 4, distal (4a-c) and side (4d) views, light micrographs, phase contrast (4a), transmitted light (4b,d), cross-polarized light (4c), ×2,500.——Plate 11, figure 16. Plan view of specimen from Taylor Marl (sample CKL-127) of Texas, light micrographs, phase contrast (16a), transmitted light (16b), cross-polarized light (16c), ×2,500.

CRIBROSPHAERELLA PELTA Gartner, new species

A species of *Cribrosphaerella* with 3 rim tiers and small central area.

Description.—On the proximal side of this elliptical disc 3 progressively larger tiers can be seen in the rim, with the most proximal tier the smallest. The tiers are made of about 18 more or less radially arranged elements that terminate evenly at the periphery. Imbrication of elements and inclination of sutures is not clear. The shadows cast by the specimen show that the proximal side is strongly concave and that the proximal tier may consist of more than one cycle of elements. The area enclosed by the rim is relatively small and the plate extending across it appears to be at the level of the second or third rim tier. The central plate is pierced by small holes arranged in longitudinal rows, so that one row coincides with the major axis of the ellipse.

Discussion.—This species differs from other species of *Cribrosphaerella* in having 3 tiers in the rim instead of the usual 2.

Maximum diameter.—5.7 μ.

Type specimen.—UI-H-2306 (Pl. 10, fig. 21), from the Taylor Marl.

Occurrence.—Sample CKL-127, Taylor Marl.

Illustrations.—Plate 10, figures 24-25. Proximal views, electron micrographs, ×5,000.

CRIBROSPHAERELLA SP.

Discussion.—These specimens undoubtedly belong to the genus *Cribrosphaerella* since they have 2 distinct rim tiers. The tiers are constructed of large, wedge-shaped, sinistrally imbricate elements. About 18 elements occur in the smaller proximal tier. The central area is largely obscured in the micrographs but several perforations can be seen near the inner margin of the rim. The specimens are similar to *Cribrosphaerella linea* GARTNER, n. sp., but differ in that the rim tiers are of nearly equal size and the central area appears to be more solidly constructed.

Maximum diameter.—6.4 μ.

Occurrence.—Sample COR from the Corsicana Marl, sample 13 from the Taylor Marl, and sample 9 from the Austin Chalk.

Illustrations.—Plate 4, figure 17. Proximal view of specimen from Corsicana Marl (sample COR) of Texas, electron micrograph, ×5,000.——Plate 14, figure 10. Proximal view of specimen from Taylor Marl (sample 13) of Texas, electron micrograph, ×5,000.——Plate 20, figure 7. Proximal view of specimen from Austin Chalk (sample 9) of Texas, electron micrograph, ×5,000.

Genus PROLATIPATELLA Gartner, new genus

Type species.—*Prolatipatella multicarinata* GARTNER, n. sp.

Description.—The elliptical disc consists of a narrow rim and a central plate. The rim of the disc is constructed of several tiers. The elements making up the central plate and the rim tiers must be less than 0.5 μ in size since they cannot be resolved with the light microscope. Very probably, the elements are arranged in a subradial pattern along a median longitudinal fissure.

Discussion.—The multitier rim of this species indicates relationship to *Arkhangelskiella* or *Kamptnerius.* The central plate, however, is constructed differently from that of any species of these two genera and also appears to be imperforate.

PROLATIPATELLA MULTICARINATA Gartner, new species

Elliptical disc with narrow, multitiered rim and imperforate central area.

Description.—The central plate of this elliptical disc is divided into 2 equal parts by a median suture. This suture is aligned with the major axis of the ellipse and can best be seen in the light microscope between crossed nicols. The narrow rim consists of at least 3 tiers, of which the proximal tier is smallest, and the second and third tiers are progressively larger. The central plate appears to be on the level of the distal rim tier and is probably continuous with it.

Discussion.—The picture taken between crossed nicols indicates that the disc is probably constructed by some sort of radial arrangement of elements, and the rim tiers are probably similar to the rim tiers in *Arkhangelskiella* although constructed of smaller elements. It is also possible that a fourth rim tier is present on the distal side but cannot be seen in side view as is often observed in *Arkhangelskiella.* Unfortunately, no electron micrographs were obtained of this species so that a more restricted definition of this species is not now possible.

Maximum diameter.—11.0 μ.

Minimum diameter.—8.0 μ.

Type specimen.—UI-H-2237 (Pl. 7, fig. 10, 11) from the Corsicana Marl.

Occurrence.—This species was found only in sample COR from the Corsicana Marl.

Illustrations.—Plate 7, figures 10-11. Distal (10a-c), side (10d), and proximal (11) views, light micrographs, phase contrast (10a), transmitted light (10b,d-11), cross-polarized light (10c), ×2,500.

Family DISCOASTERACEAE Vekshina, 1959

Genus MARTHASTERITES Deflandre, 1959

Type species.—*Discoaster furcatus* DEFLANDRE, 1954.

Simple triradiate asterolith, small calcareous object without distinct center, but consisting of three arms of about equal length radiating in same plane at about 120° to each other; arms may be rounded or pointed at their termination or, more commonly, they bifurcate at an angle to plane of asterolith; arms may also terminate in many small finger-like extensions.

MARTHASTERITES FURCATUS (Deflandre)

Discoaster? furcatus DEFLANDRE in DEFLANDRE & FERT, 1954, p. 168, pl. 13, fig. 14.

Marthasterites furcatus (Deflandre), DEFLANDRE, 1959, p. 139, pl. 2, fig. 3-12; pl. 3, fig. 1, 5.

Diameter.—5.0-12.0 μ.

Occurrence.—Originally described from Campanian deposits of southern France by DEFLANDRE, this species was also recorded by him from the Bonham Marl of Texas. In this study, it was found in samples 5, 9, and 12, all from the Austin Chalk, but was not found in deposits above or below this unit

Illustrations.—Plate 18, figures 5-6. Plan views of specimens from sample 12, electron micrographs, ×5,000.——Plate 20, figure 18. Plan view of specimen from sample 9, electron micrograph, ×5,000.——Plate 21, figure 3. Plan view of specimen from sample 9, light micrograph, transmitted light, ×2,500.——Plate 23, figure 2. Plan view of specimen from sample 5, electron micrograph, ×5,000.

MARTHASTERITES FURCATUS Deflandre BRAMLETTEI Deflandre

Marthasterites furcatus DEFLANDRE var. *bramlettei* DEFLANDRE, 1959, p. 139, pl. 3, fig. 2.

Discussion.—The specimen figured here is more massive than DEFLANDRE's specimen, but the delicate spines on the tips of the arms indicate that it belongs to this subspecies.

Diameter.—9.3 μ.

Occurrence.—DEFLANDRE has recorded this form only from the Bonham Marl. The specimen figured here was obtained from sample 5 near the base of the Austin Chalk.

Illustration.—Plate 21, figure 15. Plan view of specimen, light micrograph, transmitted light, ×2,500.

MARTHASTERITES FURCATUS (Deflandre) CRASSUS Deflandre

Marthasterites furcatus (DEFLANDRE) var. *crassus* DEFLANDRE, 1959, p. 139, pl. 2, fig. 17; pl. 3, fig. 3, 4.

Diameter.—8 μ.

Occurrence.—DEFLANDRE described this variety from Senonian Chalk and questionably referred specimens from the Bonham Marl to it. The specimen figured here is from sample 5, near the base of the Austin Chalk.

Illustration.—Plate 21, figure 16. Plan view of specimen, light micrograph, transmitted light, ×2,500.

MARTHASTERITES INCONSPICUUS Deflandre

Marthasterites inconspicuus DEFLANDRE, 1959, p. 140, pl. 3, fig. 6-14.——STRADNER, 1963, p. 12, pl. 3, fig. 12 (not 12a).——BRAMLETTE & MARTINI, 1964, p. 314, pl. 6, fig. 6.

Discussion.—The specimens on which DEFLANDRE based this species are all very nearly triangular and without distinct arms. STRADNER, however, and later BRAMLETTE & MARTINI placed forms with distinct arms in this species on the basis of occurrence of such forms in association with typical representatives of the species. Such an association was not found in any of the samples used in this study, and only the form with 3 distinct arms was encountered. It is possible that 2 species are involved, but the evidence is inconclusive.

Diameter.—3.0-6.8 μ.

Occurrence.—This species was recorded by DEFLANDRE from Maastrichtian chalk of France, the Bonham Marl of Texas, and Senonian chalk of Poland. BRAMLETTE & MARTINI recorded it from Maastrichtian deposits of Denmark and from equivalent deposits in Tunisia and Alabama. In this study, it was noted in sample CKL-127 from the Taylor Marl and sample ARK from the Arkadelphia Formation.

Illustrations.—Plate 2, figure 9. Plan view of specimen from Arkadelphia Formation (sample ARK) of Arkansas, electron micrograph, ×5,000.——Plate 10, figure 10. Plan view of specimen from upper Taylor Marl (sample CKL-127) of Texas, electron micrograph, ×5,000.

Genus TETRALITHUS Gardet, 1956

Type species.—*Tetralithus pyramidus* GARDET, 1956.

Calcareous bodies consisting of from three to eight discrete parts that are crystallographically continuous and are arranged in a radial pattern.

TETRALITHUS GOTHICUS Deflandre

Tetralithus gothicus DEFLANDRE, 1959, p. 138, pl. 3, fig. 25.

Discussion.—This species appears to be constructed of 8 pyramid-shaped pieces of calcite that are arranged to form a cube-shaped block. The corners of the cube may be normal, or they may be slightly elongate and pointed. The pyramids that make up the cube are radially oriented.

Maximum diameter.—8.0 μ.

Occurrence.—DEFLANDRE described this species from Maastrichtian chalk in France. The specimen figured here is from sample 5 from the Austin Chalk.

Illustrations.—Plate 24, figure 4. Plan view of specimen, light micrograph, phase contrast (4a), transmitted light (4b), cross-polarized light (4c), transmitted light at 90° to 4a-c (4d), ×2,500.

TETRALITHUS NITIDUS Martini

Tetralithus nitidus MARTINI, 1961, p. 4, pl. 1, fig. 5; pl. 4, fig. 41.

Tetralithus gothicus Deflandre, STRADNER, 1963, p. 14, pl. 6, fig. 1.

Discussion.—The 3- and 4-rayed specimens figured in the light micrographs do not show the distinctive central structure of MARTINI's specimens, but in the electron micrograph of the 3-rayed specimen a central platform can be seen. STRADNER's 4-rayed specimen (1963, pl. 6, fig. 1) is different in that the 2 sets of arms are unequal in length but his 3-rayed specimen is identical to the one figured here.

Occurrence.—MARTINI described the species from upper Eocene deposits. Associated other typically Cretaceous forms, however, indicate that the specimen may be reworked. STRADNER recorded the species from the Campanian and the specimens figured here are from sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 9, figure 14. Plan view, electron micrograph, ×5,000.——Plate 13, figures 3-4. Plan views, light micrographs, phase contrast (3a-4a), transmitted light (3b-4b), cross-polarized light (3c-4c), ×2,500.

TETRALITHUS SP. aff. TETRALITHUS ACULEUS (Stradner)

Zygrhablithus aculeus STRADNER, 1961, p. 81, fig. 53-57.

Discussion.—STRADNER considered these small dart-like objects to be the counterpart of the distal appendage of *Prediscosphaera cretacea* (ARKHANGELSKY) [=*Zygrhablithus intercisus* DEFLANDRE, =*Deflandrius intercisus* (DEFLANDRE)]. It is not possible to tell from STRADNER's drawings whether the objects are constructed of a single piece of calcite, 2 pieces, or more. The specimens figured here, when seen between crossed nicols, show suture lines near the center. In electron micrographs no such suture lines can be seen, which indicates that the suture lines seen with the light microscope are caused by the different crystallographic orientation of the structural elements that make up this peculiar object.

Maximum length.—7.0 μ.

Occurrence.—Sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 9, figure 5. Plan view, electron micrograph, ×5,000.——Plate 13, figure 5. Plan view, light micrographs, phase contrast (5a), transmitted light (5b), cross-polarized light (5c), phase contrast at 90° to 5a-c, ×2,500.

Family MICRORHABDULACEAE Deflandre, 1959

Genus LITHRAPHIDITES Deflandre, 1963

Type species.—*Lithraphidites carniolensis* DEFLANDRE, 1963.

Calcareous rods uniformly tapered to blunt point at both ends; if viewed on end, rod has plus-shaped cross section and appears to be constructed of four laths that are at about 90° to each other.

LITHRAPHIDITES CARNIOLENSIS Deflandre

Lithraphidites carniolensis DEFLANDRE, 1963, p. 3486, fig. 1-8.

Discussion.—These small calcareous rods have 4 equal keels that run the whole length of the rod and are oriented at about 90° to each other. Both ends of the rod taper uniformly and end in a blunt point. The keels may have ridges or carinae developed on them. Considerable variation is found in size and proportions, but in general short specimens have wider keels than long ones. In the Navarroan short specimens appear to grade into *Lithraphidites quadratus* BRAMLETTE & MARTINI, but they can be distinguished from this species by the uniform taper on each end and the continuation of the keel to the tip of the specimen.

Length.—8.0-16.0 μ.

Width.—0.9-2.4 μ.

Occurrence.—This species was found in sample 2 from the Eagle Ford Shale, samples 5, 9, and 12 from the Austin Chalk, samples 13 and CKL-127 from the Taylor Marl, and sample COR from the Corsicana Marl.

Illustrations.—Plate 5, figure 4; Plate 6, figure 8. Specimens from Corsicana Marl (sample COR) of Texas; Pl. 3, fig. 4, side view, electron micrograph, ×5,000; Pl. 6, fig. 8, side view, light micrograph, phase contrast (8a), cross-polarized light (8b), ×2,500.——Plate 10, figures 16-17; Plate 12, figure 8. Specimens from Taylor Marl (sample CKL-127) of Texas; Pl. 10, fig. 16-17, side views, electron micrographs, ×5,000; Pl. 12, fig. 8, side view, light micrographs, phase contrast (8a), transmitted light (8b), cross-polarized light (8c), ×2,500.——Plate 22, figures 24-25. Side views of specimens from Austin Chalk (sample 5) of Texas, electron micrographs, ×5,000.——Plate 25, figure 9. Side view of specimen from Eagle Ford Shale (sample 2) identified as *L.* sp. cf. *L. carniolensis,* electron micrograph, ×5,000.

LITHRAPHIDITES QUADRATUS Bramlette & Martini

Lithraphidites quadratus BRAMLETTE & MARTINI, 1964, p. 310, pl. 6, fig. 16-17; pl. 7, fig. 8.

Discussion.—Specimens from the Arkadelphia Formation are very similar to those figured by BRAMLETTE & MARTINI. Specimens from the Corsicana Marl have shorter and wider keels and in one specimen spikes or spines are developed on each end of every keel. The keels are not always at right angles to each other and in some specimens adjacent keels are also not of the same width.

Length.—7.5-11 μ.

Occurrence.—BRAMLETTE & MARTINI recorded the species from the type Maastrichtian and from equivalent deposits in Denmark, southwestern France, Tunisia, and Alabama. The species appears to be restricted to deposits of this age as it was found only in samples ARK from the Arkadelphia Formation and sample COR from the Corsicana Marl, both of Navarroan age.

Illustrations.—Plate 2, figure 3; Plate 3, figure 3. Specimens from Arkadelphia Formation (sample ARK) of Arkansas; Pl. 2, fig. 3, side view, electron micrograph, ×5,000; Pl. 3, fig. 3, side view, light micrographs, phase contrast (3a), transmitted light (3b), cross-polarized light (3c), ×2,500.——Plate 5, figures 1-2; Plate 6, figure 9. Specimens from Corsicana Marl (sample COR) of Texas; Pl. 5, fig. 1-2, side views, electron micrographs, ×5,000; Pl. 6, fig. 9, side view of specimen identified as *L.* sp. cf. *L. quadratus,* light micrographs, phase contrast (9a), transmitted light (9b), ×2,500.

Genus MICRORHABDULUS Deflandre, 1959

Type species.—*Microrhabdulus decoratus* DEFLANDRE, 1959.

Calcareous rods, cylindrical or fusiform, bluntly pointed or sharp at both ends, and complexly constructed.

MICRORHABDULUS BELGICUS Hay & Towe

Microrhabdulus belgicus HAY & TOWE, 1963, p. 95, pl. 1.
Microrhabdulus margaritatus DEFLANDRE, 1963, p. 3486, fig. 12-18.
Microrhabdulus nodosus STRADNER, 1963, p. 11, pl. 4, fig. 13.

Discussion.—The specimens figured here are smaller than those figured by HAY & TOWE and by DEFLANDRE and also have fewer cycles of nodes on their surface. The nodes also are smaller. The delicate pointed ends are almost invariably terminated irregularly, indicating that they have broken off.

Length.—8-10 μ.

Occurrence.—HAY & TOWE described the species from the Campanian deposits of Fox-les-Caves in Belgium and DEFLANDRE'S specimens came from the Senonian of Gingin, Australia. STRADNER recorded the species from Turonian deposits of lower Austria. In Gulf Coast deposits, the species was found in samples 5 and 9 from the Austin Chalk and sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 6, figure 13. Side view, light micrograph, phase contrast (13a), transmitted light (13b), cross-polarized light (13c), ×2,500.——Plate 10, figures 21-23; Plate 12, figure 13. Specimens from Taylor Marl (sample CKL-127) of Texas; Pl. 10, fig. 21-23, side views, electron micrographs, ×5,000; Pl. 12, fig. 13, side view, light micrographs, phase contrast (13a), transmitted light (13b), cross-polarized light (13c), ×2,500.——Plate 22, figure 27. Side view of specimens from Austin Chalk (sample 5) of Texas, electron micrograhp, ×5,000.

MICRORHABDULUS CONSTRICTUS Stradner

Microrhabdulus constrictus STRADNER, 1963, p. 11, pl. 4, fig. 16.

Discussion.—This distinctive species is easily recognized with the light microscope. It tapers slightly and comes to a rounded point at one end. The other end is terminated irregularly and appears to be broken off. When seen between crossed nicols, the swelled portions alternate in brightness and are slightly staggered in their position.

Occurrence.—STRADNER described the species from Campanian marl of the Netherlands. The specimen figured here is from sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 12, figure 12. Side view, light micrograph, phase contrast (12a), transmitted light (12b), cross-polarized light (12c), ×2,500.

MICRORHABDULUS DECORATUS Deflandre

Microrhabdulus decoratus DEFLANDRE, 1959, p. 140, pl. 4, fig. 1-5.
——BRAMLETTE & MARTINI, 1964, p. 314, pl. 6, fig. 1-2.

Discussion.—This calcareous rod is constructed of longitudinally arranged calcite elements. The elements are notched at regular intervals and this gives the species the diagnostic segmented appearance between crossed nicols. The broken end visible in oblique view does not agree with the cross section of DEFLANDRE in that a central canal appears to be absent.

Occurrence.—DEFLANDRE noted the species from the Santonian through Maastrichtian. The specimens figured here are from samples ARK from the Arkadelphia Formation and COR from the Corsicana Marl. Similar specimens were found also in sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 2, figure 4. Side view of specimen from Arkadelphia Formation (sample ARK) of Arkansas, electron micrograph, ×5,000.——Plate 5, figure 3; Plate 6, figure 12. Specimens from Corsicana Marl (sample COR) of Texas; Pl. 5, fig. 3, side view, electron micrograph, ×5,000; Pl. 6, fig. 12, side view, light micrograph, phase contrast (12a), transmitted light (12b), cross-polarized light (12c), ×2,500.——Plate 28, figure 1. Side view of specimen from Corsicana Marl, showing regularly spaced notches on surface which cannot be resolved using light microscope with transmitted light, though their presence is indicated by a cross-polarized light image, electron micrograph, ×10,000.

MICRORHABDULUS? ELONGATUS Gartner, new species

Microrhabdulus sp. BRAMLETTE & MARTINI, 1964, p. 316, pl. 6, fig. 5.

Slender calcite rods tapering to a point at one end and terminated with a disc at the other end.

Description.—The long cylindrical rod is pointed at one end and terminated with a small disc at the other end. The rod is constructed of spirally arranged calcite laths that make an angle of 5° to 10° with the axis of the rod. The laths are of unequal size. At the narrowest portion of the rod they are less than 0.1 μ wide and only 0.2-0.3 μ long. At the widest part of the rod the laths are 0.3 μ wide and up to 7 μ long.

Discussion.—When seen between crossed nicols, the spiral-lath structure gives the rod the appearance of being covered by elongate rhomb-shaped scales. The specimen illustrated by BRAMLETTE & MARTINI shows some traces of this structure although it is not clear from the single micrograph. This species differs from all other species of *Microrhabdulus* by the nature of the stem and particularly by having a basal disc. The construction of the stem of this species is similar to the construction of the stem of *Rhabdosphaera claviger* (MURRAY & BLACKMAN), the type species of *Rhabdosphaera,* but in cross-polarized light the stem of *R. claviger* has a very simple interference figure.

Length.—33 μ.

Type specimen.—UI-H-2285 (Pl. 9, fig. 21) from the Taylor Marl.

Occurrence.—BRAMLETTE & MARTINI recorded the species from the type Maastrichtian and equivalents in southwestern France, Tunisia, Alabama, and Texas. The specimens figured here are from sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 9, figure 21. Side view of type specimen, electron micrograph, ×5,000.——Plate 12, figure 15, side view, light micrograph, phase contrast (15a), transmitted light (15b), cross-polarized light (15c), ×2,500.

MICRORHABDULUS STRADNERI Bramlette & Martini

Microrhabdulus stradneri BRAMLETTE & MARTINI, 1964, p. 316, pl. 6, fig. 3-4.

Discussion.—The longitudinal striations faintly visible on this species in transmitted light or plain polarized light sets it apart from other species of *Microrhabdulus.*

Occurrence.—BRAMLETTE & MARTINI recorded this species from the upper Maastrichtian. In this study it was found in sample COR from the Corsicana Marl and in sample CKL-127 from the Taylor Marl.

Illustrations.—Plate 12, figure 14. Unspecified view, light micrograph, phase contrast (14a), transmitted light (14b), cross-polarized light (14c), ×2,500.

MICRORHABDULUS SP.

Discussion.—These calcareous rods appear to be constructed similarly to several species of *Microrhabdulus;* however, they are larger than other species of this genus, and it is possible that they are the stems or rods of such forms as *Eiffellithus turriseiffeli* (DEFLANDRE) or *Zygodiscus lacunatus* GARTNER, n. sp., with which they are associated.

Occurrence.—Samples 5 and 9 from the Austin Chalk.

Illustrations.—Plate 20, figure 16; Plate 23, figure 1. Specimens from Austin Chalk of Texas; Pl. 20, fig. 16, side view, electron micrograph, ×5,000; Pl. 23, fig. 1, side view, electron micrograph, ×5,000.

Genus LUCIANORHABDUS Deflandre, 1959

Type species.—*Lucianorhabdus cayeuxi* DEFLANDRE, 1959.

Calcareous rods with coarse irregular surface, straight or curved, usually tapered and terminating in blunt point at one end; opposite end usually with vestigial basal disc, often appearing only as rimlike thickening on rod.

LUCIANORHABDUS CAYEUXI Deflandre

Lucianorhabdus cayeuxi DEFLANDRE, 1959, p. 142, pl. 4, fig. 11-25. ——STRADNER, 1961, p. 6, fig. 45-48, 50.——BRAMLETTE & MARTINI, 1964, p. 312, pl. 5, fig. 10-12.

Discussion.—This species has been described and characterized in minute detail from optical study by DEFLANDRE. Electron micrographs show that the crude stem almost invariably has a basal disc or part of a basal disc at one end. The size of the disc seems to bear no relationship to the size of the stem although its diameter is usually less than twice that of the stem. A significant exception is a small specimen (Pl. 10, fig. 15) which has a rudimentary stem attached to a well-developed basal disc. In most specimens, however, the basal disc is little more than a thickening at the end of the stem and often goes undetected in the light microscope.

Length.—4-20 μ.

Occurrence.—DEFLANDRE recorded the species from the Maastrichtian in France and from the Senonian in France, England, Poland, and Australia. BRAMLETTE & MARTINI point out that it is conspicuously absent in the upper Maastrichtian although extremely abundant in the lower Maastrichtian. In this study the species was found in samples 9 and 12 from the Austin Chalk, and in sample 13 and CKL-127 from the Taylor Marl.

When the species first appears in the middle of the Austin Chalk (sample 9), most specimens are short and stubby and have a prominent base (Pl. 20, fig. 14). At the top of the Austin Chalk specimens are more slender and curved. These specimens also are larger and have a blunt point at one end. Specimens from the upper Taylor Marl are uniformly tapered and may have a sharply pointed end.

Illustrations.—Plate 10, figures 18-20; Plate 12, figure 7; Plate 16, figures 3-4. Specimens from Taylor Marl of Texas; Pl. 10, fig. 18-20 (sample CKL-127), side views, electron micrographs, ×5,000; Pl. 12, fig. 7 (sample CKL-127), side view, light micrographs, phase contrast (7a), transmitted light (7b), cross-polarized light (7c), ×2,500; Pl. 16, fig. 3-4 (sample 13), side views, electron micrographs, ×5,000.——Plate 18, figures 3-4; Plate 20, figure 14. Specimens from Austin Chalk of Texas; Pl. 18, fig. 3-4 (sample 12), side views, electron micrographs ×5,000; Pl. 20, fig. 14 (sample 9), side view, electron micrograph, ×5,000.

Family BRAARUDOSPHAERACEAE Deflandre, 1947

Genus BRAARUDOSPHAERA Deflandre, 1947

Type species.—*Pontosphaera bigelowi* (GRAN & BRAARUD), 1935.

The coccosphere of the organism is made of five-sided calcareous plates or pentaliths. Each plate consists of five segments and each segment is a crystallographic unit. The five segments of each pentalith are joined along straight sutures that radiate from the pentalith center.

BRAARUDOSPHAERA BIGELOWI (Gran & Braarud)

Pontosphaera bigelowi GRAN & BRAARUD, 1935, p. 388, fig. 67.
Braarudosphaera bigelowi (Gran & Braarud), DEFLANDRE, 1947, p. 439, fig. 1-5.

Discussion.—Some of the pentaliths found in Cretaceous deposits have imbricate segments; that is, each segment overlaps slightly onto the next one, except that one segment is overlapped from both sides (Pl. 4, fig. 5). This was first pointed out by HAY & TOWE (1962) who thought that the Cretaceous form may be a distinct species. As most Cretaceous specimens do not show this imbrication and overlap, it is probably not taxonomically significant.

Maximum diameter.—6.5-10.5 μ.

Occurrence.—This species was found in samples 5, 9, and 12 from the Austin Chalk, in samples 13, and CKL-127 from the Taylor Marl, and in samples COR from the Corsicana Marl and ARK from the Arkadelphia Formation.

Illustrations.—All plan views.——Plate 4, figure 5. Specimen from Corsicana Marl (sample COR) of Texas, electron micrograph, ×5,000.——Plate 15, figure 3. Specimen from Taylor Marl (sample 13) of Texas, light micrograph, transmitted light, ×2,500. ——All other specimens from Austin Chalk of Texas. Plate 16, figure 9. Specimen from sample 12, electron micrograph, ×5,000. ——Plate 19, figure 7. Specimen from sample 9, light micrographs, phase contrast (7a), transmitted light (7b), cross-polarized light (7c), ×2,500.——Plate 20, figure 4. Specimen from sample 9, electron micrograph, ×5,000.——Plate 21, figure 8. Specimen from sample 5, light micrograph, transmitted light, ×2,500.

Genus BIANTHOLITHUS Bramlette & Martini, 1964

Type species.—*Biantholithus sparsus* BRAMLETTE & MARTINI, 1964.

Circular disc constructed of radially arranged wedge-shaped elements, each element being a distinct crystallographic unit. In cross-polarized light a slightly rotated cross-shaped pseudointerference figure is formed.

BANTHOLITHUS RADIALIS (Caratini)

Cyclodiscolithus radialis CARATINI, 1963, p. 23, pl. 2, fig. 28-31.

Discussion.—CARATINI placed this species in the genus *Cyclodiscolithus,* "a primitive form of discolith," but it has no resemblance to the discoliths of *Discolithina* LOEBLICH & TAPPAN (1963) or to *Coccolithites leptos* KAMPTNER (1955), the type species of *Cyclodiscolithus.* In 1964, BRAMLETTE & MARTINI proposed the generic name *Biantholithus* for a similar species and placed the new genus in the family Braarudosphaeridae (Braarudosphaeraceae in botanical nomenclature). They also pointed out the similarity of *Biantholithus* to *Lithastrinus* STRADNER (1963).

The specimen figured here has 8 elements or rays as do the specimens illustrated by CARATINI. BRAMLETTE & MARTINI's species has 12 elements.

Diameter.—9.4 μ.

Occurrence.—CARATINI reported this species from the upper Cenomanian and Turonian from near Rouen, France. In this study, the species was found only in sample CKL-127 from the upper Taylor Marl.

Illustrations.—Plate 11, figure 3. Plan view, light micrographs, phase contrast (3a), transmitted light (3b), cross-polarized light (3c), ×2,500.

Family CALCIOSOLENIACEAE Kamptner, 1937

Genus SCAPHOLITHUS Deflandre, 1954

Type species.—*Scapholithus fossilis* DEFLANDRE, 1954.

Elongate four-sided parallelogram of which each side is a distinct crystallographic unit and opposite sides have the same crystallographic orientation.

SCAPHOLITHUS SP.

Scapholithus sp. BRAMLETTE & MARTINI, 1964, pl. 7, fig. 7.

Discussion.—This elongate, diamond-shaped form is constructed of 4 elements of calcite with the 2 opposite pairs having the same optical orientation. The laths across the central area which can be seen in electron micrographs cannot be resolved with the light microscope. This form is very small and is only rarely encountered. Because of its small size most specimens are probably separated from the bulk of the nannofossils in the concentrating process and that may be the reason why it is so rarely found.

Length.—5.6 μ.

Width.—1.2 μ.

Occurrence.—The genus is known primarily from modern oceans. BRAMLETTE & MARTINI recorded the species from the Clayton Formation, Paleocene (Danian) of Alabama. The specimen figured here is from sample COR from the Corsicana Marl.

Illustrations.—Plate 7, figure 4. Unspecified view, light micrograph, phase contrast (4a), transmitted light (4b), cross-polarized light (4c), ×2,500.

GENERA INCERTAE SEDIS

Genus CYLINDRALITHUS Bramlette & Martini, 1964

Type species.—*Cylindralithus serratus* BRAMLETTE & MARTINI, 1964.

Short cylinder flaring somewhat toward the open end where it is terminated in a serrate or irregular edge. At the opposite end a plate or other structure usually extends across the opening and on the outside of the cylinder a lip or ridge is developed.

CYLINDRALITHUS ACHYLOSUS (Stover)

Zygolithus maltanensis (Gorka), STRADNER, 1963, p. 12, pl. 2, fig. 10.

Chiphragmalithus achylosus STOVER, 1966, p. 137, pl. 6, fig. 26; pl. 7, fig. 1-3.

Discussion.—The short tapering cylinder is terminated at one end in a thickened rim of unknown structure. From this rim 2 robust crossbars extend diagonally across the opening at the narrow end of the cylinder, intersecting at about 90° at the center of the opening. From the rim laths extend out to form the flaring portion of the cylinder. The laths are terminated irregularly at the flaring end of the cylinder.

Diameter.—6.0-7.4 μ.

Height.—4.4 μ.

Occurrence.—STOVER recorded this species from the Albian of France and the Netherlands and STRADNER recorded this species from the upper Turonian to the Maastrichtian. In this study the species was found in sample 5 from the lower part of the Austin Chalk.

Illustrations.—Plate 21, figure 10. Distal (10a-c) and side (10d) views, light micrographs, phase contrast (10a), transmitted light (10b,d), cross-polarized light (10c), ×2,500.——Plate 22, figure 23. Distal view, electron micrograph, ×5,000.

CYLINDRALITHUS GALLICUS (Stradner)

Coccolithus gallicus STRADNER, 1963, p. 10, pl. 1, fig. 8, 8a.

Cylindralithus gallicus (Stradner), BRAMLETTE & MARTINI, 1964, p. 308, pl. 5, fig. 15-17.

Discussion.—The electron micrograph reveals a cylindrical structure with a broad base, constricted near the middle, and expanding slightly toward the top. The opening in the center does not extend completely through but appears to be closed near the middle of the cylinder. As BRAMLETTE & MARTINI pointed out, this species may be related to the *Lithastrinus* group.

Maximum diameter.—7.5 μ.

Occurrence.—STRADNER described the species from the Maastrichtian of southwestern France. BRAMLETTE & MARTINI have recorded the species from the type Maastrichtian and from upper

Maastrichtian equivalents in southwestern France, Tunisia, and Alabama and also from the lower Maastrichtian in Denmark. The specimens illustrated here are from sample ARK, Arkadelphia Formation, and COR, Corsicana Marl.

Illustrations.—Plate 1, figure 20. Plan view of specimen from Arkadelphia Formation (sample ARK) of Arkansas, electron micrograph, ×5,000.——Plate 6, figure 11. Unspecified view of specimen from Corsicana Marl (sample COR) of Texas, light micrographs, phase contrast (11a), transmitted light (11b), cross-polarized light (11c), ×2,500.

CYLINDRALITHUS SERRATUS Bramlette & Martini, 1964

Cylindralithus serratus BRAMLETTE & MARTINI, 1964, p. 310, pl. 5, fig. 18-20.

Discussion.—The coccolith of this species consists of a cylinder that flares at one end and is somewhat constricted near the other end. The flaring end of the cylinder, probably the distal end, has about 12 regular serrations. At the constricted end a serrate ring forms a lip on the cylinder.

The specimen illustrated here is nearly identical to *Hymenomonas roseola* STEIN illustrated by BRAARUD (1954, pl. 2, fig. a-e), but BRAARUD's specimen has an elliptical cross section whereas the type of specimen of *Cylindralithus serratus* has a circular cross section. Also the coccoliths of *H. roseola* are only one fourth the size of *C. serratus*. It should be noted in addition that *C. serratus* is known only from the Upper Cretaceous where it is associated with typical marine coccolithophores, whereas *H. roseola* is a modern fresh-water form and is not known as a fossil.

Maximum diameter.—4.8 μ.

Occurrence.—BRAMLETTE & MARTINI recorded this species from the Maastrichtian of Holland, Tunisia, and Alabama. The specimen figured here is from sample CKL-127 from the upper Taylor Marl.

Illustrations.—Plate 10, figure 9. Side view, electron micrograph, ×5,000.

Genus LITHASTRINUS Stradner, 1962

Type species.—*Lithastrinus grilli* STRADNER, 1962.

Short cylindrical or tabular bodies slightly constricted at the center and flaring at both ends. The cylinder is constructed of six to nine sections twisted like strands of a rope. The two faces of the cylinder have conical depressions that are closed at about the plane of constriction of the cylinder. The individual segments of the cylinder may extend slightly laterally at each end of the cylinder, giving it a stellate outline.

LITHASTRINUS FLORALIS Stradner

Lithastrinus floralis STRADNER, 1962, p. 370, pl. 2, fig. 6-11.

Discussion.—Much of the minute detail drawn into his illustrations by STRADNER cannot be seen with the electron microscope. Perhaps some of these minute details, all of which are at the limit of resolution of the light microscope, are interference phenomena and are not necessarily representative of true structure within the fossil. The overall architecture, however, is entirely in agreement with STRADNER's drawings of the species.

Maximum diameter.—4.5-6.5 μ.

Occurrence.—Although STRADNER has noted the species to occur from the Albian through the upper Senonian, in this study the species was found only in sample 5 from the Austin Chalk and sample 2 from the Eagle Ford Shale.

Illustrations.—Plate 21, figure 13; Plate 22, figures 28-29. Specimens from Austin Chalk of Texas; Pl. 21, fig. 13 (sample 5), plan (13a-c) and side (13d) views, light micrographs, phase contrast (13a), transmitted light (13b,d), cross-polarized light (13c), ×2,500; Pl. 22, fig. 28-29, plan view, electron micrograph, ×5,000.——Plate 24, figure 12. Plan (12a-c) and side (12d) views of specimen from Eagle Ford Shale (sample 2) of Texas, light micrographs, phase contrast (12a), transmitted light (12b,d), cross-polarized light (12c), ×2,500.

LITHASTRINUS GRILLI Stradner

Lithastrinus grilli STRADNER, 1962, p. 369, pl. 2, fig. 1-5.

Discussion.—The electron micrographs of this species show disappointingly little detail beyond what can be seen with the light microscope. Representatives of this species are generally very short and have a tabular rather than cylindrical shape. The segments are not evenly terminated and the species often has a ragged stellate outline.

Maximum diameter.—5.4-7.4 μ.

Occurrence.—STRADNER recorded this species from Turonian and Coniacian deposits. In this study, it was found in sample 2 from the Eagle Ford Shale, in samples 5, 9, and 12 from the Austin Chalk, and in sample 13 from the base of the Taylor Marl.

Illustrations.—Plate 18, figures 1-2; Plate 20, figure 17; Plate 21, figures 1, 11; Plate 22, figure 26. Specimens from Austin Chalk of Texas; Pl. 18, fig. 1-2 (sample 12), plan view, electron micrograph, ×5,000; Pl. 20, fig. 17 (sample 9), plan view, electron micrograph, ×5,000; Pl. 21, fig. 1 (sample 9), 11 (sample 5), plan (1a-c, 11a-c) and side (1d, 11d) views, light micrographs, phase contrast (1a, 11a), transmitted light (1b,d, 11b,d), cross-polarized light (1c, 11c), ×2,500; Pl. 22, fig. 26 (sample 5), plan view, electron micrograph, ×5,000.——Plate 25, figures 10-11. Plan and side views of specimens from Eagle Ford Shale (sample 2) of Texas, electron micrographs, ×5,000.

Genus MICULA Vekshina, 1959

Type species.—*Micula decussata* VEKSHINA, 1959.

Variously modified cube, usually with concave faces, and constructed of calcite laminae that are not crystallographically continuous with each other.

MICULA DECUSSATA Vekshina

Micula decussata VEKSHINA, 1959, p. 71, pl. 1, fig. 6; pl. 2, fig. 11.
Micula staurophora (Gardet), BRAMLETTE & MARTINI, 1964, p. 318, pl. 6, fig. 7-11.

Discussion.—VEKSHINA appears to have incorrectly interpreted her micrograph (pl. 1, fig. 6) in describing *Micula decussata* as a parallelogram with diagonal bars on it forming a cross. The object is a cube and almost invariably comes to rest on one of its faces. As a result, it always looks like a parallelogram. The diagonal bars forming the cross are actually internal and are all that remains in specimens in which the faces of the cube are deeply concave. In such specimens some or all of the points of the cube may be elongated.

The specimen from the Tertiary of Algeria described by GARDET (1955) as *Discoaster staurophorus* is similar to half of a specimen of *Micula decussata;* inasmuch as *Micula* does not range beyond the Cretaceous, GARDET's specimen is either a reworked fragment or is not related to that genus. In any case it seems undesirable to use the name for the Cretaceous species as it will only cause further confusion.

Diameter.—4.5-9.0 μ.

Occurrence.—This species reaches maximum development in the upper part of the Upper Cretaceous where it is a major constituent of the nannofossil assemblage. It is also common in the Austin Chalk but is less abundant toward the base of this unit. It was not found in the Eagle Ford Shale. Occurrences recorded from Tertiary deposits are probably due to reworking.

Illustrations.—Plate 2, figures 5-8. Specimens from Arkadelphia Formation (sample ARK) of Arkansas, figures 5, 6, 8, plan views, figure 7, side view, electron micrographs, ×5,000.——Plate 4, figure 18. Plan view, specimen from Corsicana Marl (sample COR) of Texas, electron micrograph, ×5,000.——Plate 9, figure 18-20; Plate 14, figure 13, 14. Specimens from Taylor Marl of Texas; Pl. 9, fig. 18-20 (sample CKL-127), figure 18, plan view, figure 19, oblique view, figure 20, edge view, electron micrographs, ×5,000.——Plate 18, figure 17, Plate 20, figure 15. Specimens from Austin Chalk of Texas; Pl. 18, fig. 7 (sample 12), plan view, electron micrograph, ×5,000; Pl. 20, fig. 15 (sample 9), plan view, electron micrograph, ×5,000.

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APPENDIX 1

GLOSSARY OF MORPHOLOGICAL TERMS

basal disc. Base of rhabdolith; elliptical or nearly circular disc of variable construction.

central area. Center of coccolith or discolith; center of basal disc of rhabdolith.

coccolith. Calcified skeletal particle having heliolithid or other complex construction; placolith.

collar or central tube. Central cylinder connecting two shields of placolith.

crossbar. Bar extending across central area.

cycle. Ring of elements.

cyatholith. Two shields connected by central tube; placolith.

dextrally imbricate. Each segment overlapping one to right.

discolith. Circular or elliptical disc with thickened rim.

distal. Convex side of coccolith; away from upper surface of organism.

element. Basic structural unit of coccoliths; crystallographically continuous unit of calcite.

inclination of sutures. Clockwise or counter-clockwise inclination with respect to radius.

lopadolith. Basket-shaped coccolith opening distally.

pentalith. Coccolith constructed of five elements.

placolith. Two shields connected by central tube.

proximal. Concave side of coccolith.

rhabdolith. Disc surmounted by stem; rod or stem.

shield. One of discs of placolith.

sinistrally imbricate. Each segment overlapping one to left.

sutures. Line along which elements are joined.

APPENDIX 2

SAMPLE LOCALITIES

Sample ARK. Five miles south of Arkadelphia on US 67 at junction with Ark. 26, Clark County, Arkansas. Arkadelphia Formation.

Sample COR. Pit at Corsicana Brick Co., 2 miles south of Corsicana, Navarro County, Texas. Corsicana Marl.

Sample CKL-127. 0.3 miles southeast of Gastonia, Kaufman County, Texas. Upper Taylor Marl.

Sample 2. Meander scar, west fork, Trinity River, about 500 feet east of intersection of Beltline Road and Dallas-Ft. Worth tollway; Grand Prairie, Dallas County, Texas; middle of exposure, middle(?) Eagle Ford Shale.

Sample 5. Exposure at U.F.W. Post 4477 on Loop 12, north of Illinois Avenue, Dallas County, Texas. Lower Austin Chalk.

Sample 9. Cut on US 75, 1.2 miles north-northwest of Hutchins, about 500 feet south of Langdon Drive, Dallas County, Texas. Middle Austin Chalk.

Sample 12. Bank of Cottonwood Creek at Millers Ferry Road, Dallas County, Texas. Austin Chalk (just below upper contact).

Sample 13. Location same as sample 12. Base of Taylor Marl.

INDEX

[Rejected names enclosed within square brackets.]

EXPLANATION OF PLATES

PLATE 1

[Calcareous nannofossils from the Arkadelphia Formation in Arkansas (sample ARK); electron micrographs, ×5,000.]

FIGURE

1-6. *Arkhangelskiella cymbiformis* VEKSHINA (p. 38).
7. *Biscutum blacki* GARTNER, n. sp. (p. 18).
8-9. *Cretarhabdus crenulatus* BRAMLETTE & MARTINI (p. 22).
10-11. *Cretarhabdus conicus* BRAMLETTE & MARTINI (p. 21).
12. *Coccolithus barnesae* (BLACK) (p. 17).
13. *Chiastozygus pseudamphipons* GARTNER, n. sp. (p. 28).
14-15. *Cribrosphaerella ehrenbergi* (ARKHANGELSKY) (p. 40).
16. *Cribrosphaerella linea* GARTNER, n. sp. (p. 40).
17-19. *Cretadiscus polyporus* GARTNER, n. sp. (p. 36).
20. *Cylindralithus gallicus* (STRADNER) (p. 46).

PLATE 2

[Calcareous nannofossils from the Arkadelphia Formation in Arkansas (sample ARK); electron micrographs, ×5,000.]

FIGURE

1-2. *Kamptnerius magnificus* DEFLANDRE (p. 39).
3. *Lithraphidites quadratus* BRAMLETTE & MARTINI (p. 43).
4. *Microrhabdulus decoratus* DEFLANDRE (p. 44).
5-8. *Micula decussata* VEKSHINA (p. 47).
9. *Marthasterites inconspicuus* DEFLANDRE (p. 42).
10-14. *Prediscosphaera cretacea* (ARKHANGELSKY) (p. 19).
15-16. *Prediscosphaera spinosa* (BRAMLETTE & MARTINI) (p. 20).
17-21. *Eiffellithus octoradiatus* (GORKA) (p. 25).
22-23. *Eiffellithus turriseiffeli* (DEFLANDRE) (p. 26).
24. *Vekshinella ara* GARTNER, n. sp. (p. 29).
25-26. *Zygodiscus pseudanthophorus* BRAMLETTE & MARTINI (p. 33).
27-28. *Zygodiscus laurus* GARTNER, n. sp. (p. 33).

PLATE 3

[Calcareous nannofossils from the Arkadelphia Formation in Arkansas (sample ARK); light micrographs, ×2,500.]

FIGURE

1. *Chiastozygus pseudamphipons* GARTNER, n. sp. (p. 28).
2. *Cribrosphaerella ehrenbergi* (ARKHANGELSKY) (p. 40).
3. *Lithraphidites quadratus* BRAMLETTE & MARTINI (p. 43).
4. *Cribrosphaerella linea* GARTNER, n. sp. (p. 40).
5-6. *Cretarhabdus conicus* BRAMLETTE & MARTINI (p. 21).
7. *Kamptnerius magnificus* DEFLANDRE (p. 39).
8. *Prediscosphaera cretacea* (ARKHANGELSKY) (p. 19).
9-10. *Prediscosphaera spinosa* (BRAMLETTE & MARTINI) (p. 20).
11. *Eiffellithus octoradiatus* (GORKA) (p. 25).
12. *Actinozygus regularis* (GORKA) (p. 23).
13. *Eiffellithus turriseiffeli* (DEFLANDRE) (p. 26).
14. *Zygodiscus pseudanthophorus* BRAMLETTE & MARTINI (p. 33).
15. *Vekshinella ara* GARTNER, n. sp. (p. 29).
16. *Zygodiscus laurus* GARTNER, n. sp. (p. 33).

PLATE 4

[Calcareous nannofossils from the Corsicana Marl of Texas (sample COR); electron micrographs, ×5,000.]

FIGURE

1-4. *Arkhangelskiella cymbiformis* VEKSHINA (p. 38).
5. *Braarudosphaera bigelowi* (GRAN & BRAARUD) (p. 45).
6-7. *Coccolithus barnesae* (BLACK) (p. 17).
8. *Coccolithus* sp. aff. *C. helis* STRADNER (p. 18).
9-12. *Cretarhabdus conicus* BRAMLETTE & MARTINI (p. 21).
13. *Cretadiscus polyporus* GARTNER, n. sp. (p. 36).
14. *Discolithina multicava* (GORKA) (p. 36).
15-16. *Cretarhabdus? decorus* (DEFLANDRE) (p. 22).
17. *Cribosphaerella* sp. (p. 41).
18. *Micula decussata* VEKSHINA (p. 47).
19-24. *Prediscosphaera cretacea* (ARKHANGELSKY) (p. 19).

PLATE 5

[Calcareous nannofossils from the Corsicana Marl of Texas (sample COR); electron micrographs, ×5,000.]

FIGURE

1-2. *Lithraphidites quadratus* BRAMLETTE & MARTINI (p. 43).
3. *Microrhabdulus decoratus* DEFLANDRE (p. 44).
4. *Lithraphidites carniolensis* DEFLANDRE (p. 43).
5-6. *Actinozygus? rhombocaulis* GARTNER, n. sp. (p. 23).
7-9. *Prediscosphaera spinosa* (BRAMLETTE & MARTINI) (p. 20).
10-11. *Chiastozygus scipio* GARTNER, n. sp. (p. 28).
12-13. *Neococcolithes* sp. aff. *N. dubius* (DEFLANDRE) (p. 29).
14. *Stephanolithion* sp. aff. *S. laffitei* NOEL (p. 35).
15-16. *Actinozygus splendens* (DEFLANDRE) (p. 25).
17-18. *Actinozygus regularis* (GORKA) (p. 23).
19. *Eiffellithus turriseiffeli* (DEFLANDRE) (p. 26).
20. *Eiffellithus octoradiatus* (GORKA) (p. 25).
21-22. *Zygodiscus spiralis* BRAMLETTE & MARTINI (p. 35).
23-24. *Vekshinella dibrachiata* GARTNER, n. sp. (p. 30).

PLATE 6

[Calcareous nannofossils from the Corsicana Marl of Texas (sample COR); light micrographs, ×2,500.]

FIGURE

1. *Arkhangelskiella cymbiformis* VEKSHINA (p. 38).
2. *Biscutum blacki* GARTNER, n. sp. (p. 18).
3-4. *Cretarhabdus conicus* BRAMLETTE & MARTINI (p. 21).
5. *Corollithion octoradiatum* GARTNER, n. sp. (p. 35).
6. *Cretarhabdus crenulatus* BRAMLETTE & MARTINI (p. 22).
7. *Cribrosphaerella ehrenbergi* (ARKHANGELSKY) (p. 40).
8. *Lithraphidites carniolensis* DEFLANDRE (p. 43).
9. *Lithraphidites* sp. cf. *L. quadratus* BRAMLETTE & MARTINI (p. 43).
10. *Kamptnerius magnificus* DEFLANDRE (p. 39).
11. *Cylindralithus gallicus* (STRADNER) (p. 46).
12. *Microrhabdulus decoratus* DEFLANDRE (p. 44).
13. *Microrhabdulus belgicus* HAY & TOWE (p. 44).
14-15. *Prediscosphaera cretacea* (ARKHANGELSKY) (p. 19).
16. *Prediscosphaera spinosa* (BRAMLETTE & MARTINI) (p. 20).
17-18. *Actinozygus regularis* (GORKA) (p. 23).

PLATE 7

[Calcareous nannofossils from the Corsicana Marl of Texas (sample COR); light micrographs, ×2,500.]

FIGURE

1-2. *Actinozygus splendens* (DEFLANDRE) (p. 25).
3. *Zygodiscus spiralis* BRAMLETTE & MARTINI (p. 35).
4. *Scapholithus* sp. (p. 46).
5. *Eiffellithus turriseiffeli* (DEFLANDRE) (p. 26).
6. *Actinozygus? rhombocaulis* GARTNER, n. sp. (p. 23).
7. *Chiastozygus quadriperforatus* GARTNER, n. sp. (p. 28).
8. *Vekshinella dibrachiata* GARTNER, n. sp. (p. 30).

9. *Neococcolithes* sp. aff. *N. dubius* (DEFLANDRE) (p. 29).
10-11. *Prolatipatella multicarinata* GARTNER, n. sp. (p. 41).
12-13. *Chiastozygus pumilus* GARTNER, n. sp. (p. 28).
14. *Actinozygus? fenestratus* (STOVER) (p. 23).
15-16. *Chiastozygus scipio* GARTNER, n. sp. (p. 28).

PLATE 8

[Calcareous nannofossils from the upper Taylor Marl of Texas (sample CKL-127); electron micrographs, ×5,000.]

FIGURE

1-3. *Arkhangelskiella costata* GARTNER, n. sp. (p. 37).
4-5. *Arkhangelskiella parca* STRADNER (p. 38).
6-7. *Arkhangelskiella specillata* VEKSHINA (p. 39).
8-10. *Biscutum blacki* GARTNER, n. sp. (p. 18).
11-14. *Chiastozygus amphipons* (BRAMLETTE & MARTINI) (p. 26).
15-17. *Chiastozygus quadriperforatus* GARTNER, n. sp. (p. 28).
18-22. *Coccolithus barnesae* (BLACK) (p. 17).
23-25. *Cretarhabdus decorus* (DEFLANDRE) (p. 22).

PLATE 9

[Calcareous nannofossils from the upper Taylor Marl of Texas (sample CKL-127); electron micrographs, ×5,000.]

FIGURE

1-4. *Prediscosphaera cretacea* (ARKHANGELSKY) (p. 19).
5. *Tetralithus* sp. aff. *T. aculeus* STRADNER (p. 43).
6-10. *Eiffellithus turriseiffeli* (DEFLANDRE) (p. 26).
11-13. *Zygodiscus siphonis* GARTNER, n. sp. (p. 34).
14. *Tetralithus nitidus* MARTINI (p. 42).
15. *Vekshinella* sp. cf. *V. dibrachiata* GARTNER, n. sp. (p. 30).
16-17. *Vekshinella imbricata* GARTNER, n. sp. (p. 30).
18-20. *Micula decussata* VEKSHINA (p. 47).
21. *Microrhabdulus? elongatus* GARTNER, n. sp. (p. 44).

PLATE 10

[Calcareous nannofossils from the upper Taylor Marl of Texas (sample CKL-127); electron micrographs, ×5,000.]

FIGURE

1. *Actinozygus splendens* (DEFLANDRE) (p. 25).
2. *Coccolithus horticus* STRADNER, ADAMIKER & MARESCH (p. 18).
3-6. *Zygodiscus elegans* GARTNER, n. sp. (p. 32).
7-8. *Cretadiscus colatus* GARTNER, n. sp. (p. 36).
9. *Cylindralithus serratus* BRAMLETTE & MARTINI (p. 47).
10. *Marthasterites inconspicuus* DEFLANDRE (p. 42).
11-13. *Kamptnerius magnificus* DEFLANDRE (p. 39).
14-15. *Corollithion octoradiatum* GARTNER, n. sp. (p. 35).
16-17. *Lithraphidites carniolensis* DEFLANDRE (p. 43).
18-20. *Lucianorhabdus cayeuxi* DEFLANDRE (p. 45).
21-23. *Microrhabdulus belgicus* HAY & TOWE (p. 44).
24-25. *Cribrosphaerella pelta* GARTNER, n. sp. (p. 41).
26. *Corollithion exiguum* STRADNER (p. 35).

PLATE 11

[Calcareous nannofossils from the upper Taylor Marl of Texas (sample CKL-127); light micrographs, ×2,500.]

FIGURE

1. *Arkhangelskiella costata* GARTNER, n. sp. (p. 37).
2. *Arkhangelskiella parca* STRADNER (p. 38).
3. *Biantholithus radialis* (CARATINI) (p. 46).
4. *Arkhangelskiella specillata* VEKSHINA (p. 39).
5-6. *Chiastozygus anthophorus* (DEFLANDRE) (p. 27).
7. *Corollithion octoradiatum* GARTNER, n. sp. (p. 35).
8. *Biscutum blacki* GARTNER, n. sp. (p. 18).
9. *Chiastozygus amphipons* (BRAMLETTE & MARTINI) (p. 26).
10. *Chiastozygus quadriperforatus* GARTNER, n. sp. (p. 28).
11. *Coccolithus barnesae* (BLACK) (p. 17).
12. *Cretarhabdus conicus* BRAMLETTE & MARTINI (p. 21).
13-14. *Cretarhabdus decorus* (DEFLANDRE) (p. 22).
15. *Actinozygus splendens* (DEFLANDRE) (p. 25).
16. *Cribrosphaerella linea* GARTNER, n. sp. (p. 40).
17. *Prediscosphaera spinosa* (BRAMLETTE & MARTINI) (p. 20).

PLATE 12

[Calcareous nannofossils from the upper Taylor Marl of Texas (sample CKL-127); light micrographs, ×2,500.]

FIGURE

1. *Prediscosphaera cretacea* (ARKHANGELSKY) (p. 19).
2. *Cribrosphaerella ehrenbergi* (ARKHANGELSKY) (p. 40).
3-4. *Zygodiscus elegans* GARTNER, n. sp. (p. 32).
5-6. *Cretadiscus colatus* GARTNER, n. sp. (p. 36).
7. *Lucianorhabdus cayeuxi* DEFLANDRE (p. 45).
8. *Lithraphidites carniolensis* DEFLANDRE (p. 43).
9. *Kamptnerius magnificus* DEFLANDRE (p. 39).
10. *Eiffellithus octoradiatus* (GORKA) (p. 25).
11. *Actinozygus regularis* (GORKA) (p. 23).
12. *Microrhabdulus constrictus* STRADNER (p. 44).
13. *Microrhabdulus belgicus* HAY & TOWE (p. 44).
14. *Microrhabdulus stradneri* BRAMLETTE & MARTINI (p. 44).
15. *Microrhabdulus? elongatus* GARTNER, n. sp. (p. 44).

PLATE 13

[Calcareous nannofossils from the upper Taylor Marl of Texas (sample CKL-127); light micrographs, ×2,500.]

FIGURE

1-2. *Eiffellithus turriseiffeli* (DEFLANDRE) (p. 26).
3-4. *Tetralithus nitidus* MARTINI (p. 42).
5. *Tetralithus* sp. aff. *T. aculeus* (STRADNER) (p. 43).
6-7. *Zygodiscus pseudanthophorus* BRAMLETTE & MARTINI (p. 33).
8-9. *Vekshinella imbricata* GARTNER, n. sp. (p. 30).
10-11. *Vekshinella schizobrachiata* GARTNER, n. sp. (p. 31).

PLATE 14

[Calcareous nannofossils from the Taylor Marl of Texas (sample 13); electron micrographs, ×5,000.]

FIGURE

1. *Arkhangelskiella scapha* GARTNER, n. sp. (p. 39).
2-3. *Arkhangelskiella concava* GARTNER, n. sp. (p. 37).
4-5. *Coccolithus barnesae* (BLACK) (p. 17).
6. *Chiastozygus anthophorus* (DEFLANDRE) (p. 27).
7-9. *Cretarhabdus conicus* BRAMLETTE & MARTINI (p. 21).
10. *Cribrosphaerella* sp. (p. 41).
11-12. *Kamptnerius magnificus* DEFLANDRE (p. 41).
13-14. *Micula decussata* VEKSHINA (p. 47).
15-16. *Zygodiscus biperforatus* GARTNER, n. sp. (p. 31).
17. *Zygodiscus* sp. cf. *Z. nanus* GARTNER, n. sp. (p. 33).
18. *Zygodiscus diplogrammus* (DEFLANDRE) (p. 32).
19. *Zygodiscus sisyphus* GARTNER, n. sp. (p. 34).
20-22. *Prediscosphaera cretacea* (ARKHANGELSKY) (p. 19).

PLATE 15

[Calcareous nannofossils from the Taylor Marl of Texas (sample 13); light micrographs, ×2,500.]

FIGURE

1. *Arkhangelskiella scapha* GARTNER, n. sp. (p. 39).
2. *Biscutum blacki* GARTNER, n. sp. (p. 18).
3. *Braarudosphaera bigelowi* (GRAN & BRAARUD) (p. 45).
4. *Chiastozygus plicatus* GARTNER, n. sp. (p. 27).

5-7. *Chiastozygus anthophorus* (DEFLANDRE) (p. 27).

8. *Coccolithus barnesae* (BLACK) (p. 17).
9. *Cretarhabdus conicus* BRAMLETTE & MARTINI (p. 21).
10. *Kamptnerius magnificus* DEFLANDRE (p. 39).
11. *Cribrosphaerella ehrenbergi* (ARKHANGELSKY (p. 40).

PLATE 16

[Calcareous nannofossils from the Taylor Marl (sample 13) and Austin Chalk (sample 12) of Texas; electron micrographs, ×5,000.]

FIGURE

1-2. *Eiffellithus turriseiffeli* (DEFLANDRE), Taylor (p. 26).
3-4. *Lucianorhabdus cayeuxi* DEFLANDRE, Taylor (p. 45).
5-7. *Arkhangelskiella concava* GARTNER, n. sp., Austin (p. 37).
8. *Biscutum blacki* GARTNER, n. sp., Austin (p. 18).
9. *Braarudosphaera bigelowi* (GRAN & BRAARUD), Austin (p. 45).
10-11. *Chiastozygus plicatus* GARTNER, n. sp., Austin (p. 27).
12. *Cretarhabdus conicus* BRAMLETTE & MARTINI, Austin (p. 21).
13-14. *Cretarhabdus* sp. cf. *C. conicus* BRAMLETTE & MARTINI, Austin (p. 21).
15. *Coccolithus barnesae* (BLACK), Austin (p. 17).
16. Coccosphere of *Coccolithus barnesae* (BLACK), Austin (p. 17).
17-19. *Kamptnerius magnificus* DEFLANDRE, Austin (p. 39).

PLATE 17

[Calcareous nannofossils from the Taylor Marl (sample 13) and Austin Chalk (samples 9, 12) of Texas; light micrographs, ×2,500.]

FIGURE

1-2. *Zygodiscus biperforatus* GARTNER, n. sp., Taylor (p. 31).
3. *Eiffellithus turriseiffeli* (DEFLANDRE), Taylor (p. 26).
4. *Zygodiscus diplogrammus* (DEFLANDRE), Taylor (p. 32).
5. *Vekshinella elliptica* GARTNER, n. sp., Taylor (p. 30).
6. *Zygodiscus lacunatus* GARTNER, n. sp., Taylor (p. 33).
7. *Arkhangelskiella concava* GARTNER, n. sp., Austin (p. 37).
8. *Arkhangelskiella scapha* GARTNER, n. sp., Austin (p. 39).
9. *Chiastozygus plicatus* GARTNER, n. sp., Austin (p. 27).
10. *Cretarhabdus conicus* BRAMLETTE & MARTINI, Austin (p. 21).
11-12. *Kampternerius magnificus* DEFLANDRE, Austin (p. 39).

PLATE 18

[Calcareous nannofossils from the Austin Chalk of Texas (samples 9, 12); electron micrographs, ×5,000.]

FIGURE

1-2. *Lithastrinus grilli* STRADNER, sample 12 (p. 47).
3-4. *Lucianorhabdus cayeuxi* DEFLANDRE, sample 12 (p. 45).
5-6. *Marthasterites furcatus* DEFLANDRE, sample 12 (p. 42).
7. *Micula decussata* VEKSHINA, sample 12 (p. 47).
8. *Prediscosphaera cretacea* (ARKHANGELSKY), sample 12 (p. 19).
9-11. *Eiffellithus turriseiffeli* (DEFLANDRE), sample 12, (p. 26).
12-14. *Zygodiscus nanus* GARTNER, n. sp., sample 12 (p. 33).
15-16. *Zygodiscus lacunatus* GARTNER, n. sp., sample 12 (p. 33).
17-19. *Zygodiscus sisyphus* GARTNER, n. sp., sample 12 (p. 34).
20-21. *Zygodiscus biperforatus* GARTNER, n. sp., sample 12 (p. 31).
22-23. *Arkhangelskiella concava* GARTNER, n. sp., sample 9 (p. 37).
24-25. *Arkhangelskiella magnacava* GARTNER, n. sp., sample 9, (p. 38).

PLATE 19

[Calcareous nannofossils from the Austin Chalk of Texas (samples 9, 12); light micrographs, ×2,500.]

FIGURE

1-2. *Eiffellithus turriseiffeli* (DEFLANDRE), sample 12 (p. 26).
3. *Zygodiscus diplogrammus* (DEFLANDRE), sample 12 (p. 32).
4. *Zygodiscus biperforatus* GARTNER, n. sp., sample 12 (p. 31).
5. *Zygodiscus lacunatus* GARTNER, n. sp., sample 12 (p. 33).
6. *Arkhangelskiella concava* GARTNER, n. sp., sample 9 (p. 37).
7. *Braarudosphaera bigelowi* (GRAN & BRAARUD), sample 9 (p. 45).
8. *Vekshinella* sp. cf. *V. dibrachiata* GARTNER, n. sp., sample 9 (p. 30).
9. *Chiastozygus plicatus* GARTNER, n. sp., sample 9 (p. 27).
10. *Cretadiscus* sp. cf. *C. colatus* GARTNER, n. sp., sample 9 (p. 36).
11. *Cretarhabdus* sp. cf. *C. crenulatus* BRAMLETTE & MARTINI, sample 9 (p. 22).
12. *Coccolithus barnesae* (BLACK), sample 9 (p. 17).

PLATE 20

[Calcareous nannofossils from the Austin Chalk of Texas (sample 9); electron micrographs, ×5,000.]

FIGURE

1-3. *Arkhangelskiella scapha* GARTNER, n. sp. (p. 39).
4. *Braarudosphaera bigelowi* (GRAN & BRAARUD) (p. 45).
5. *Vekshinella schizobrachiata* GARTNER, n. sp. (p. 31).
6. *Chiastozygus plicatus* GARTNER, n. sp. (p. 27).
7. *Cribrosphaerella* sp. (p. 41).

8-9. *Cretarhabdus conicus* BRAMLETTE & MARTINI (p. 21).
10-11. *Cretarhabdus* sp. cf. *C. crenulatus* BRAMLETTE & MARTINI (p. 22).
12-13. *Coccolithus barnesae* (BLACK) (p. 17).

14. *Lucianorhabdus cayeuxi* DEFLANDRE (p. 45).
15. *Micula decussata* VEKSHINA (p. 47).
16. *Microrhabdulus* sp. (p. 45).
17. *Lithastrinus grilli* STRADNER (p. 47).
18. *Marthasterites furcatus* DEFLANDRE (p. 42).

19-20. *Zygodiscus biperforatus* GARTNER, n. sp. (p. 31).

PLATE 21

[Calcareous nannofossils from the Austin Chalk of Texas (samples 5, 9; light micrographs, ×2,500.]

FIGURE

1. *Lithastrinus grilli* STRADNER, sample 9 (p. 47).
2. *Zygodiscus diplogrammus* (DEFLANDRE), sample 9 (p. 32).
3. *Marthasterites furcatus* (DEFLANDRE), sample 9 (p. 42).
4. *Zygodiscus* sp. aff. *Z. laurus* GARTNER, n. sp., sample 9 (p. 33).
5. *Zygodiscus biperforatus* GARTNER, n. sp., sample 9 (p. 31).
6. *Zygodiscus sisyphus* GARTNER, n. sp., sample 9 (p. 34).
7. *Arkhangelskiella concava* GARTNER, n. sp., sample 9 (p. 37).
8. *Braarudosphaera bigelowi* (GRAN & BRAARUD), sample 5 (p. 45).
9. *Chiastozygus plicatus* GARTNER, n. sp., sample 5 (p. 27).
10. *Cylindralithus achylosus* (STOVER), sample 5 (p. 46).
11. *Lithastrinus grilli* STRADNER, sample 5 (p. 47).
12. *Kamptnerius magnificus* DEFLANDRE, sample 5 (p. 39).
13. *Lithastrinus floralis* STRADNER, sample 5 (p. 47).
14. *Zygodiscus crassicaulis* GARTNER, n. sp., sample 5 (p. 32).

15. *Marthasterites furcatus* (Deflandre) *bramlettei* Deflandre, sample 5 (p. 42).
16. *Marthasterites furcatus* (Deflandre) *crassus* Deflandre, sample 5 (p. 42).

PLATE 22

[Calcareous nannofossils from the Austin Chalk of Texas (samples 5, 9); electron micrographs, ×5,000.]

FIGURE

1-3. *Prediscosphaera cretacea* (Arkhangelsky), sample 9 (p. 19).
4. *Eiffellithus turriseiffeli* (Deflandre), sample 9 (p. 26).
5-6. *Zygodiscus sisyphus* Gartner, n. sp., sample 9 (p. 34).
7. *Zygodiscus diplogrammus* (Deflandre), sample 9 (p. 32).
8. *Vekshinella dibrachiata* Gartner, n. sp., sample 9 (p. 30).
9. *Arkhangelskiella magnacava* Gartner, n. sp., sample 5 (p. 38).
10. *Chiastozygus amphipons* (Bramlette & Martini), sample 5 (p. 26).
11. *Chiastozygus* sp. cf. *C. amphipons* (Bramlette & Martini), sample 5 (p. 26).
12. *Chiastozygus plicatus* Gartner, n. sp., sample 5 (p. 27).
13-15. *Arkhangelskiella concava* Gartner, n. sp., sample 5 (p. 37).
16-17. *Coccolithus barnesae* (Black), sample 5 (p. 17).
18. *Stephanolithion* sp. aff. *S. laffitei* Noël, sample 5 (p. 35).
19. *Corollithion octoradiatum* Gartner, n. sp., sample 5 (p. 35).
20-21. *Cretarhabdus conicus* Bramlette & Martini, sample 5 (p. 21).
22. *Cyclolithus gronosus* Stover, sample 5 (p. 19).
23. *Cylindralithus achylosus* (Stover), sample 5 (p. 46).
24-25. *Lithraphidites carniolensis* Deflandre, sample 5 (p. 43).
26. *Lithastrinus grilli* Stradner, sample 5 (p. 47).
27. *Microrhabdulus belgicus* Hay & Towe, sample 5 (p. 44).
28-29. *Lithastrinus floralis* Stradner, sample 5 (p. 47).

PLATE 23

[Calcareous nannofossils from the Austin Chalk (sample 5) and the Eagle Ford Shale (sample 2) of Texas; electron micrographs, ×5,000.]

FIGURE

1. *Microrhabdulus* sp., Austin (p. 45).
2. *Marthasterites furcatus* Deflandre, Austin (p. 42).
3. *Zygodiscus crassicaulis* Gartner, n. sp., Austin (p. 32).
4-6. *Prediscosphaera cretacea* (Arkhangelsky), Austin (p. 19).
7-11. *Eiffellithus turriseiffeli* (Deflandre), Austin (p. 26).
12-14. *Zygodiscus diplogrammus* (Deflandre), Austin (p. 32).
15-16. *Zygodiscus lacunatus* Gartner, n. sp., Austin (p. 33).
17-18. *Zygodiscus sisyphus* Gartner, n. sp., Austin (p. 34).
19-20. *Zygodiscus* sp. aff. *Z. sisyphus* Gartner, n. sp., Austin (p. 34).
21-22. *Zygodiscus* sp. aff. *Z. laurus* Gartner, n. sp., Austin (p. 33).
23-24. *Chiastozygus laterculus* Gartner, n. sp., Eagle Ford (p. 27).
25. *Pontilithus obliquicancellatus* Gartner, n. sp., Eagle Ford (p. 29).
26-28. *Coccolithus coronatus* Gartner, n. sp., Eagle Ford (p. 17).

PLATE 24

[Calcareous nannofossils from the Austin Chalk (sample 5) and the Eagle Ford Shale (sample 2) of Texas; light micrographs, ×2,500.]

FIGURE

1-2. *Eiffellithus turriseiffeli* (Deflandre), Austin (p. 26).
3. *Zygodiscus lacunatus* Gartner, n. sp., Austin (p. 33).
4. *Tetralithus gothicus* Deflandre, Austin (p. 42).
5. *Coccolithus matalosus* Stover, Austin (p. 18).
6. *Zygodiscus diplogrammus* (Deflandre), Austin (p. 32).
7. *Chiastozygus laterculus* Gartner, n. sp., Eagle Ford (p. 27).
8. *Coccolithus barnesae* (Black), Eagle Ford (p. 17).
9-10. *Cretarhabdus loriei* Gartner, n. sp., Eagle Ford (p. 21).
11. *Cretarhabdus conicus* Bramlette & Martini, Eagle Ford (p. 21).
12. *Lithastrinus floralis* Stradner, Eagle Ford (p. 47).

PLATE 25

[Calcareous nannofossils from the Eagle Ford Shale of Texas (sample 2); electron micrographs, ×5,000.]

FIGURE

1-2. *Coccolithus barnesae* (Black) (p. 17).
3-4. *Cretarhabdus conicus* Bramlette & Martini (p. 21).
5. *Cretadiscus* sp. cf. *C. polyporus* Gartner, n. sp. (p. 36).
6-8. *Coccolithus horticus* Stradner, Adamiker & Maresch (p. 18).
9. *Lithraphidites* sp. cf. *L. carniolensis* Deflandre (p. 43).
10-11. *Lithastrinus grilli* Stradner (p. 47).
12-14. *Prediscosphaera cretacea* (Arkhangelsky) (p. 19).
15-16. *Eiffellithus turriseiffeli* (Deflandre) (p. 26).
17-18. *Zygodiscus diplogrammus* (Deflandre) (p. 32).
19-22. *Zygodiscus sisyphus* Gartner, n. sp. (p. 34).
23-25. *Prediscosphaera orbiculofenestra* Gartner, n. sp. (p. 21).
26-27. *Vekshinella elliptica* Gartner, n. sp. (p. 30).

PLATE 26

[Calcareous nannofossils from the Eagle Ford Shale of Texas (sample 2); light micrographs, ×2,500.]

FIGURE

1. *Coccolithus horticus* Stradner, Adamiker & Maresch (p. 18).
2. *Prediscosphaera cretacea* (Arkhangelsky) (p. 19).
3-4. *Eiffellithus turriseiffeli* (Deflandre) (p. 26).
5. *?Zygodiscus biperforatus* Gartner, n. sp. (p. 31).
6. *Zygodiscus sisyphus* Gartner, n. sp. (p. 34).
7. *Vekshinella elliptica* Gartner, n. sp. (p. 30).

PLATE 27

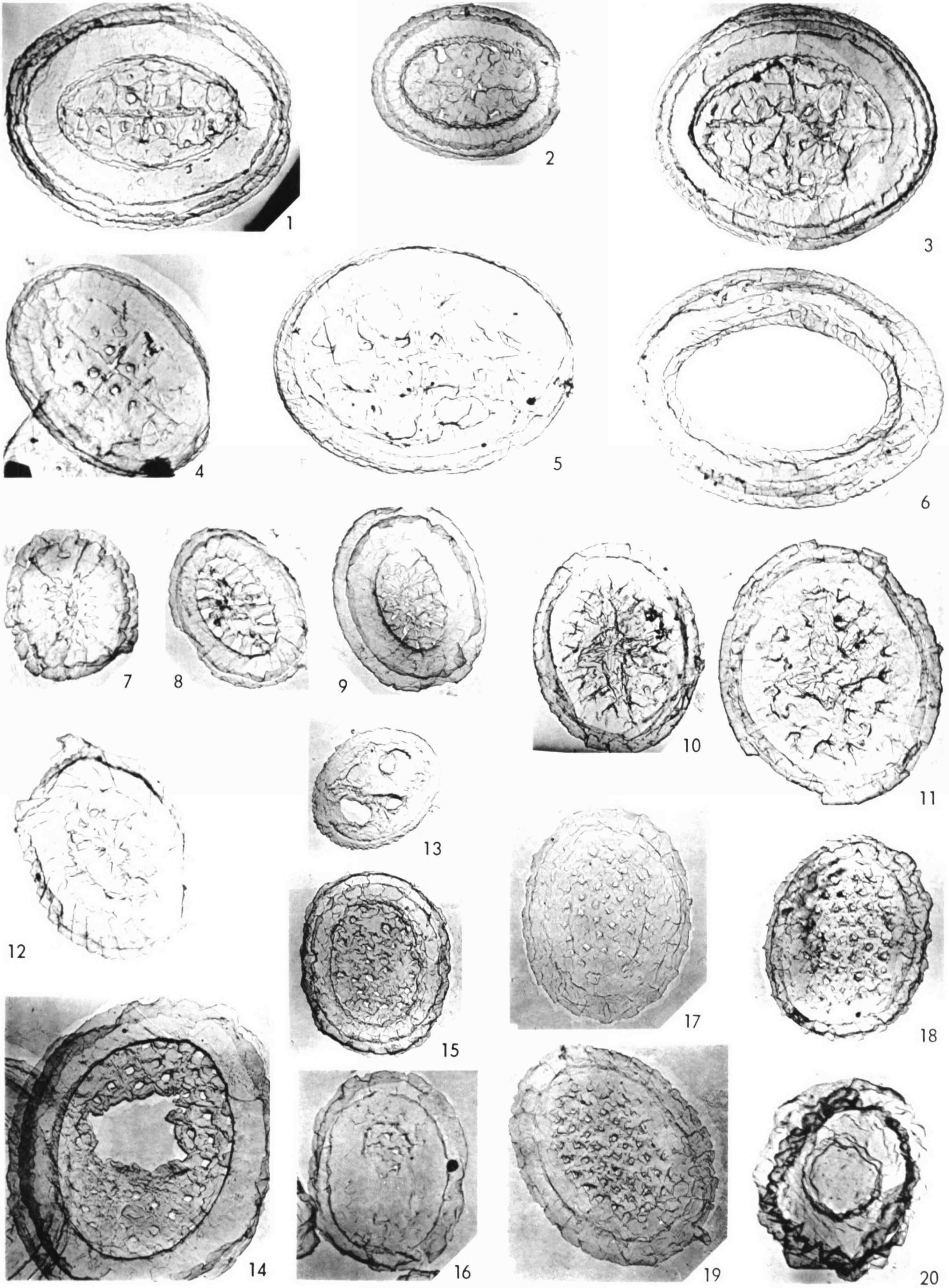
FIGURE

1. Stereoscopic pair of electron micrographs of *Zygodiscus elegans* Gartner, n. sp., ×10,000 (p. 32).
2. Positive and negative prints respectively of *Arkhangelskiella cymbiformis* Vekshina, ×10,000 (p. 38).

PLATE 28

FIGURE

1. *Microrhabdulus decoratus* Deflandre, ×10,000 (p. 44).
2. *Arkhangelskiella costata* Gartner, n. sp., ×30,000 (p. 37).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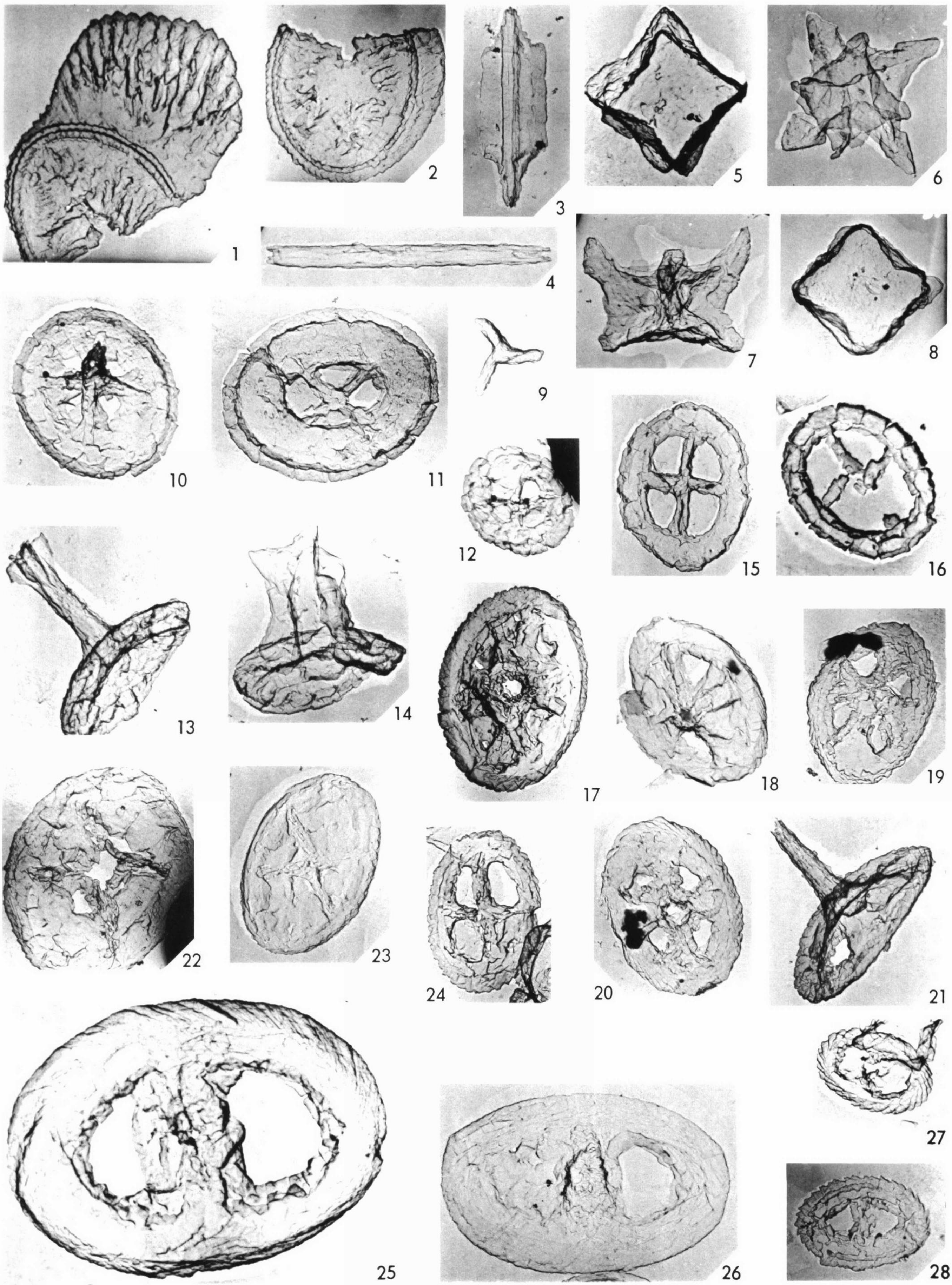
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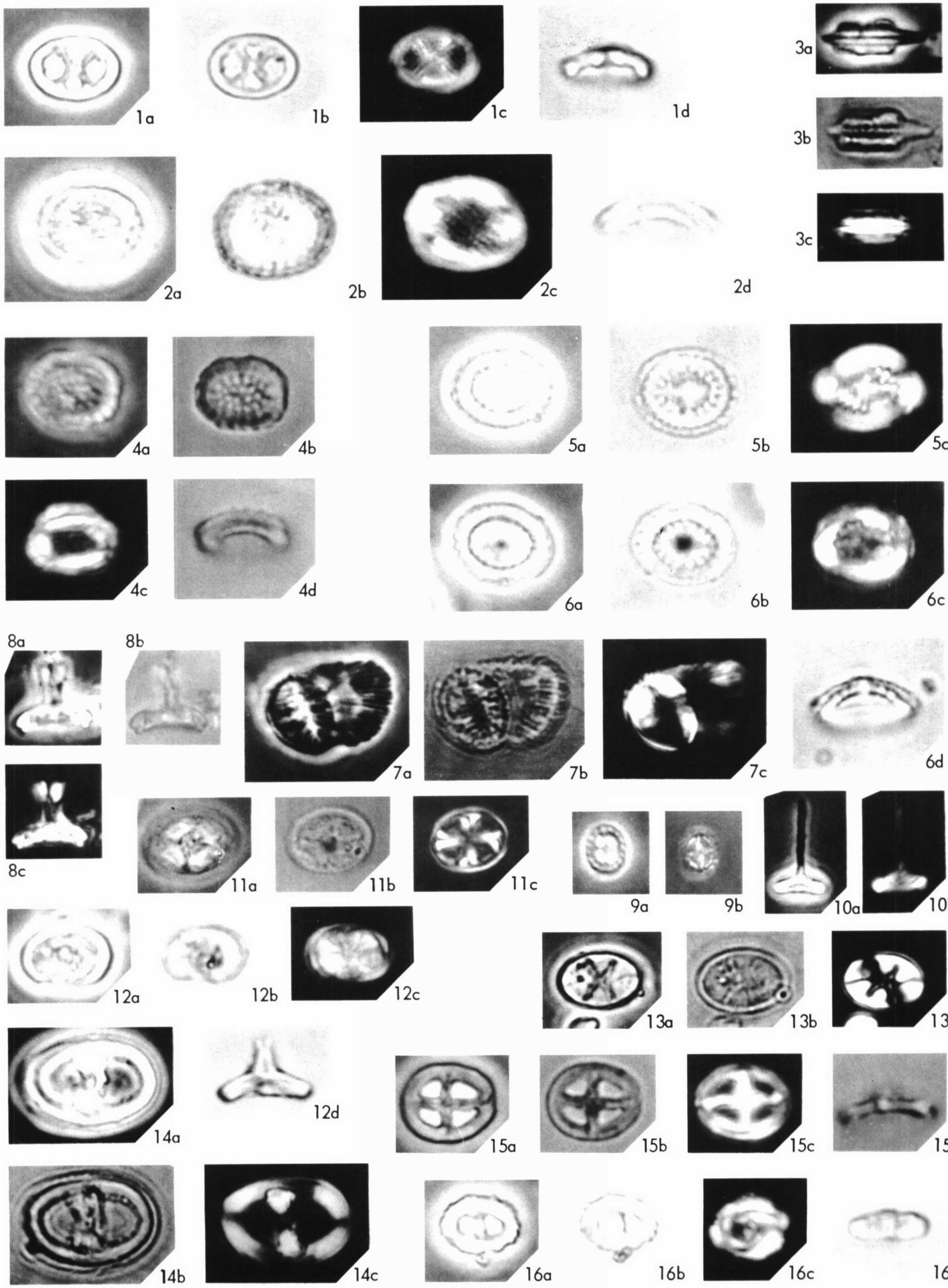
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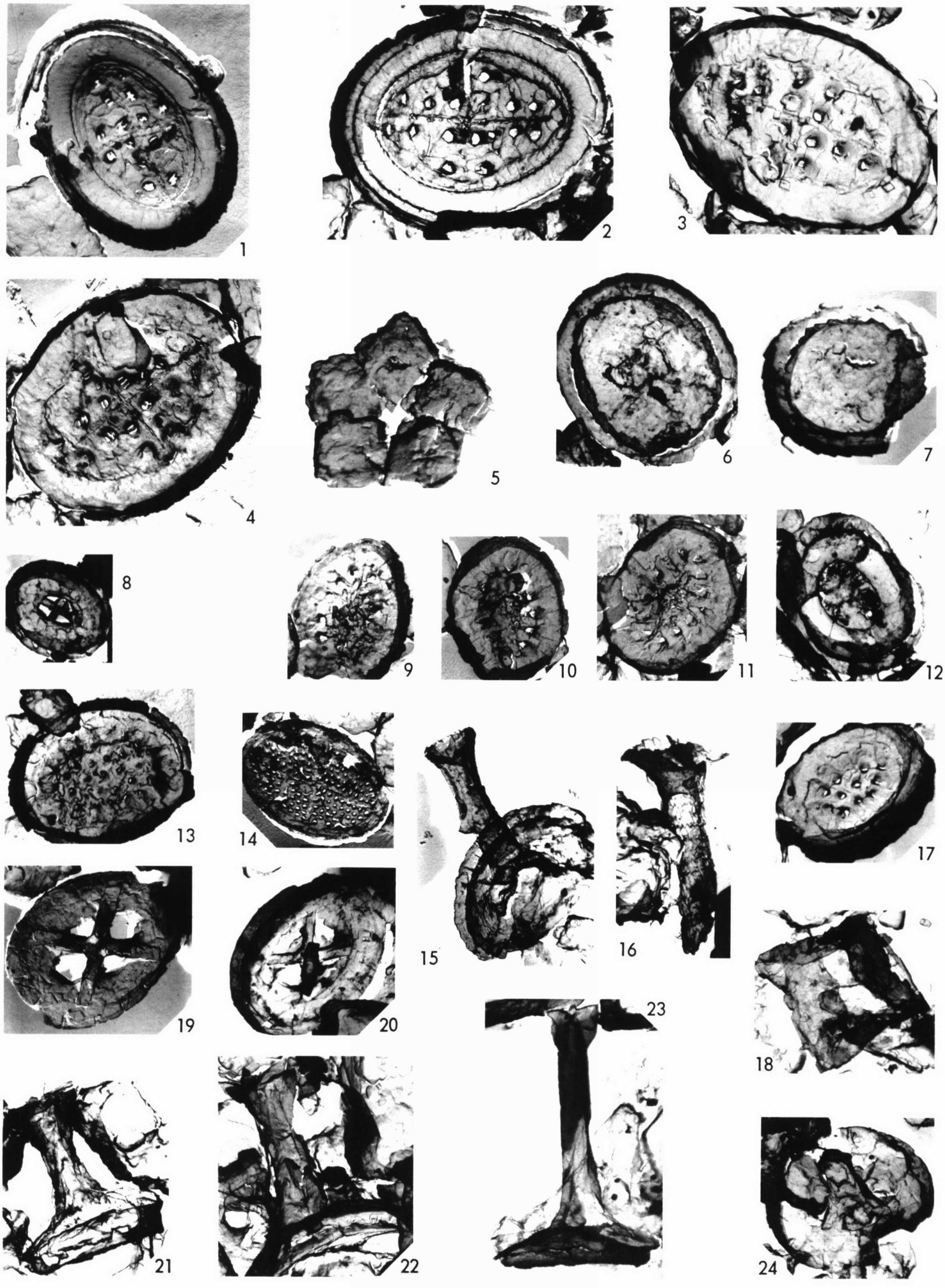

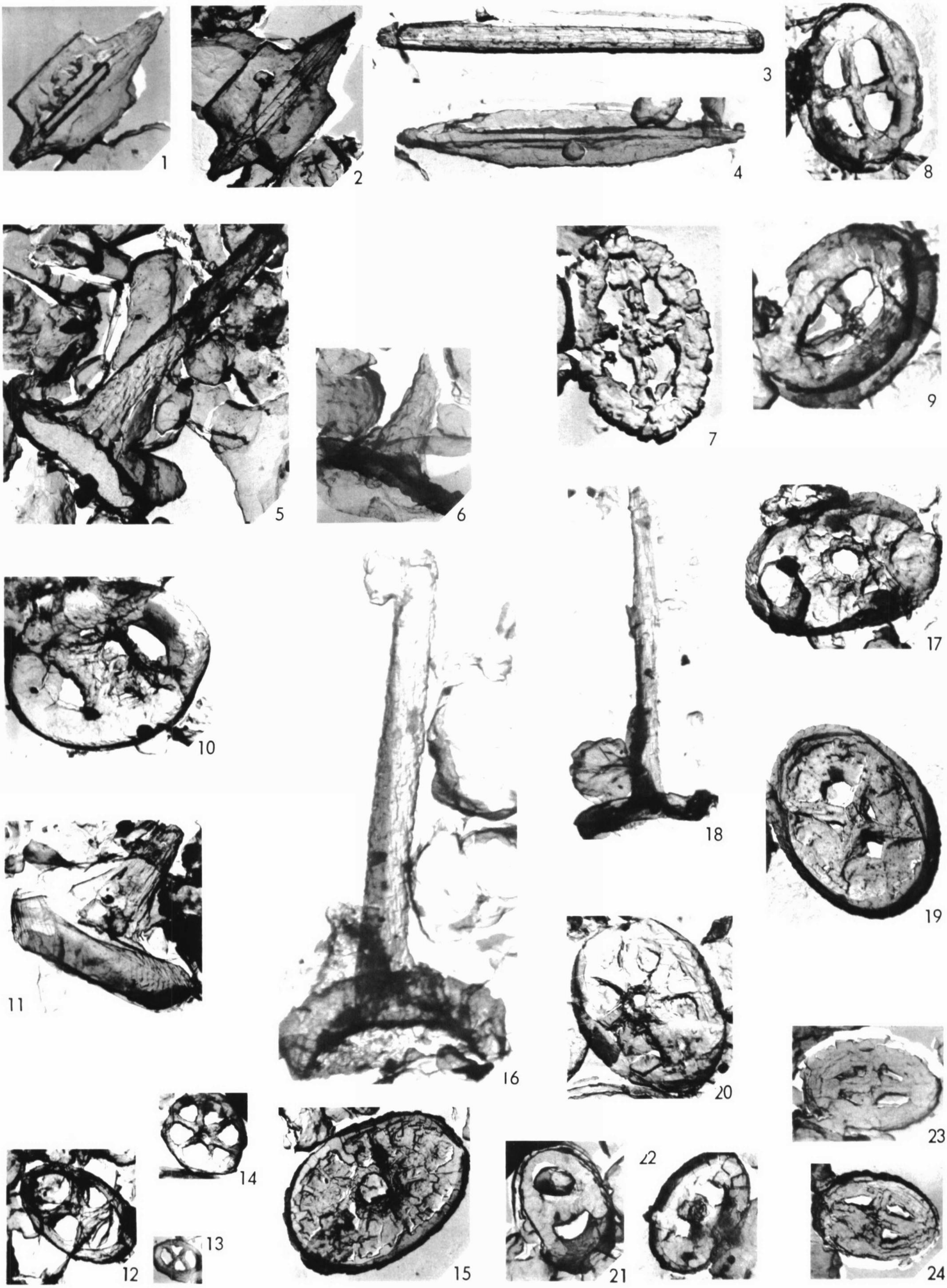
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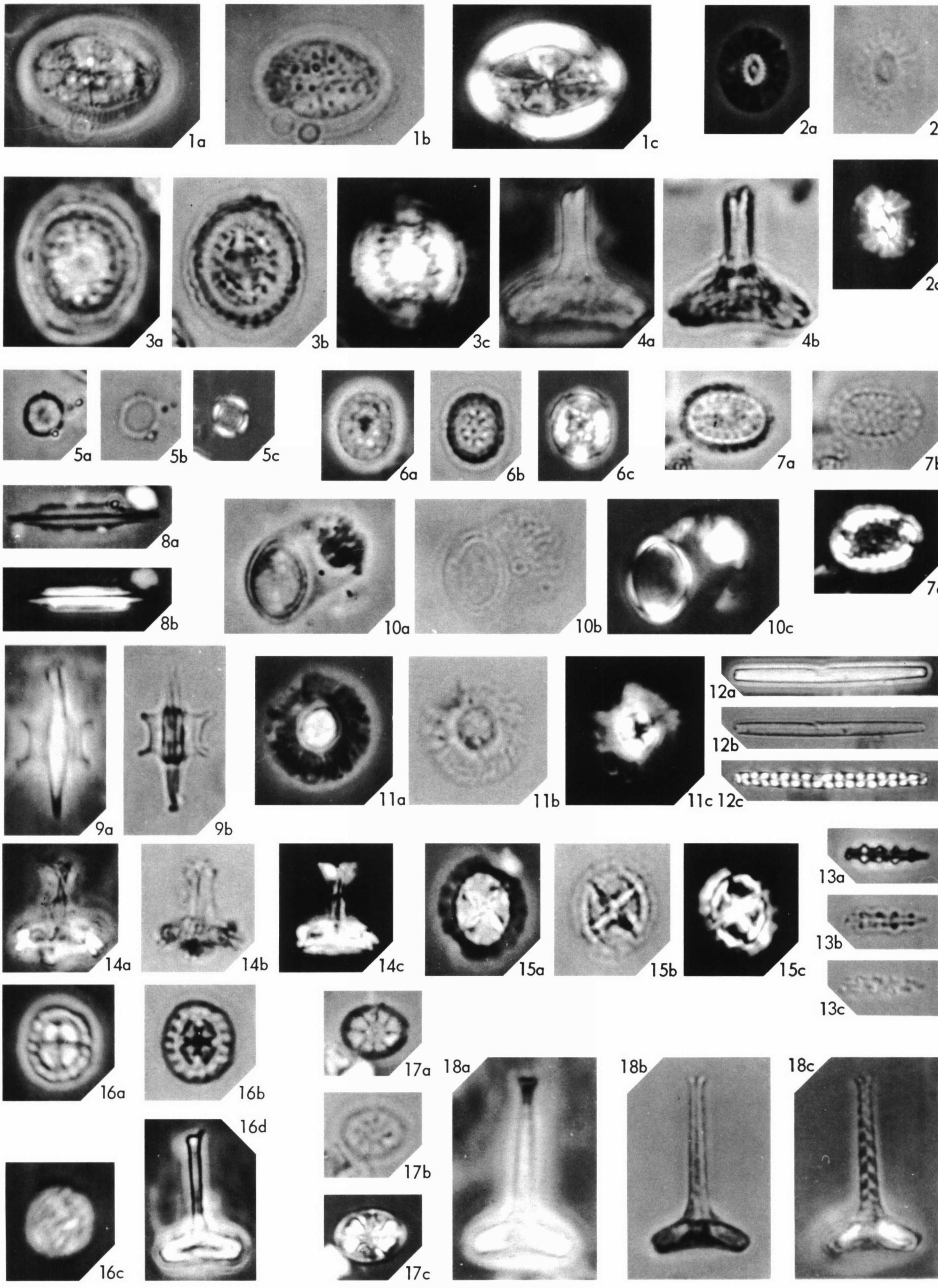
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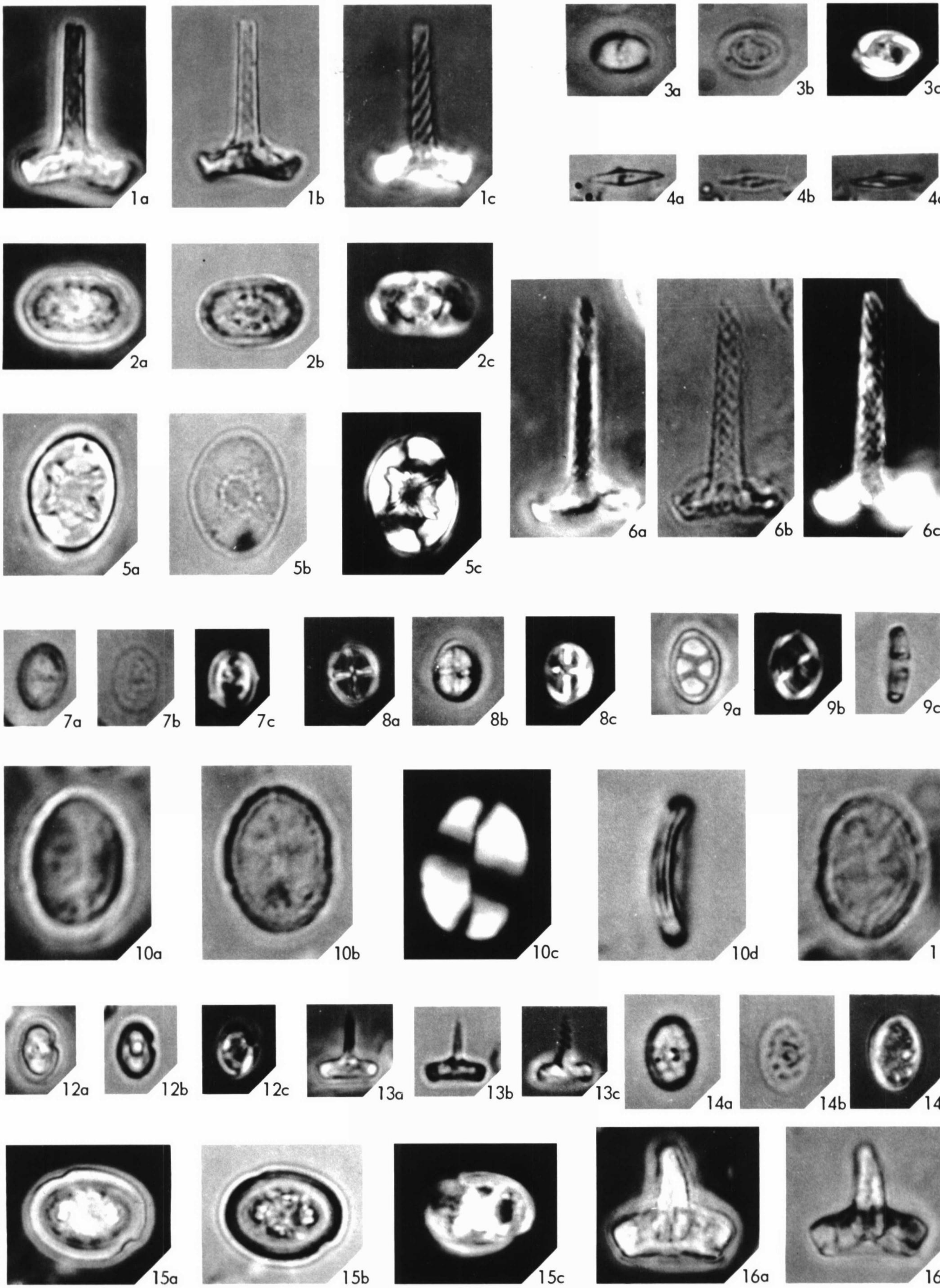
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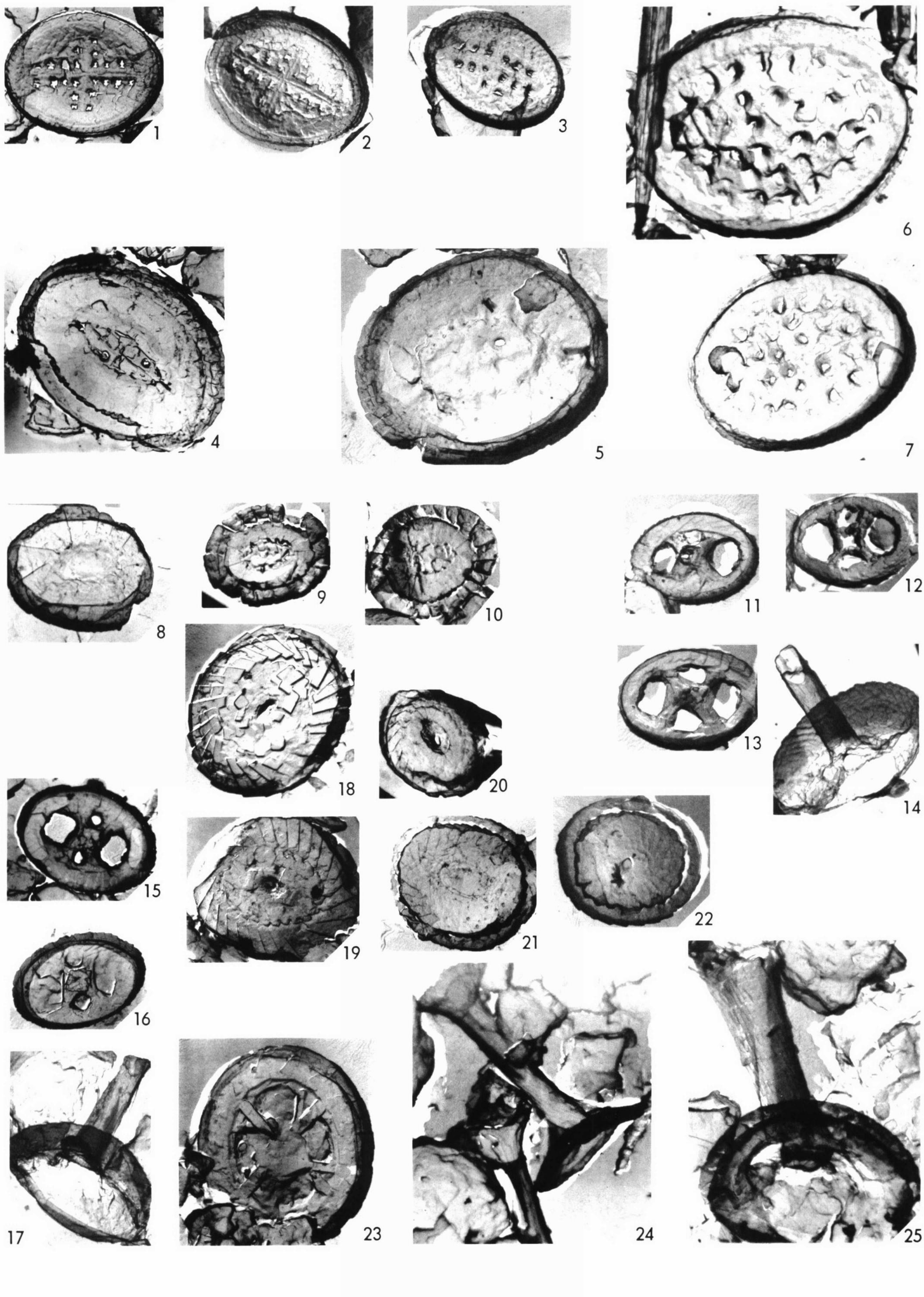
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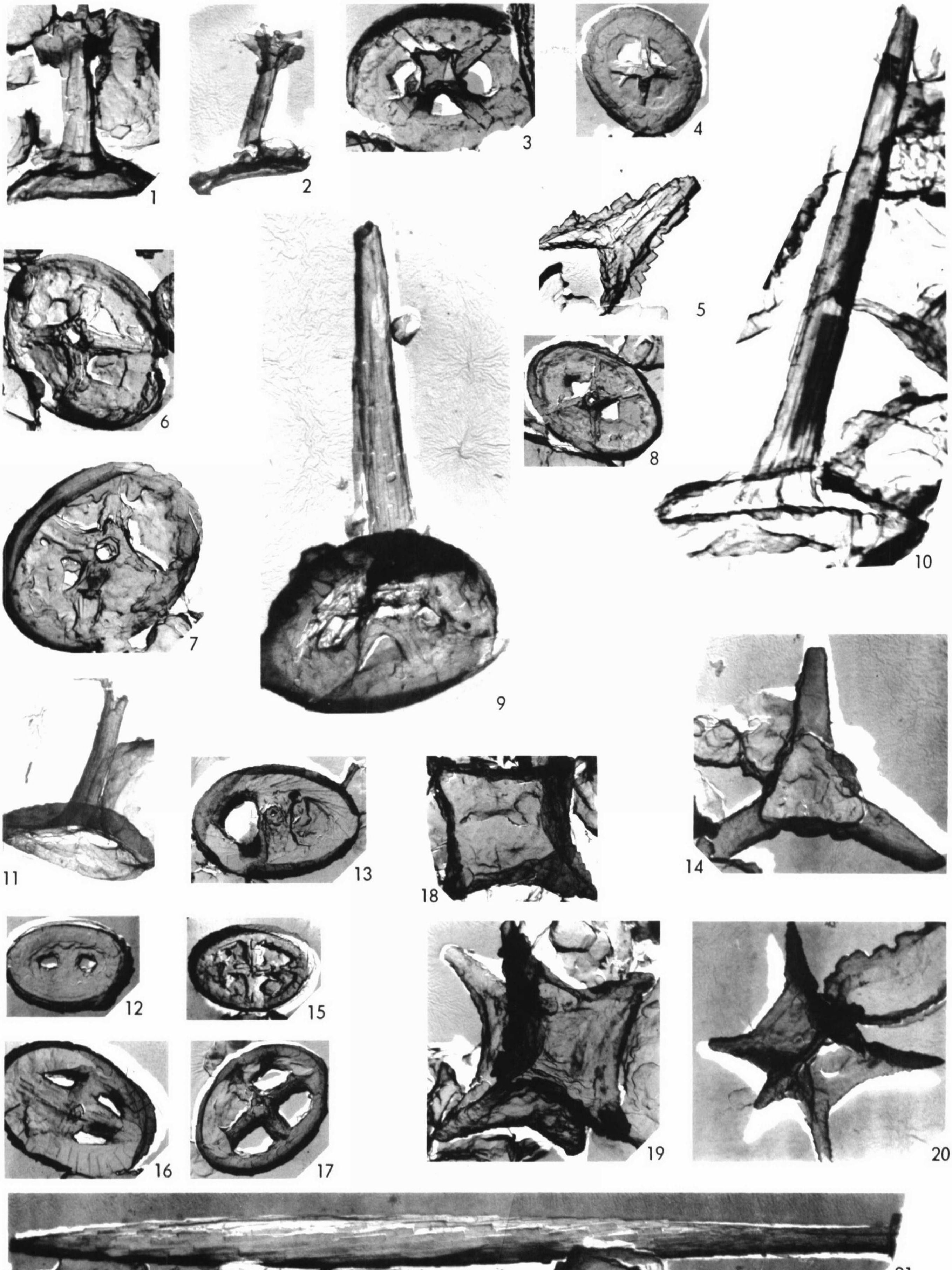
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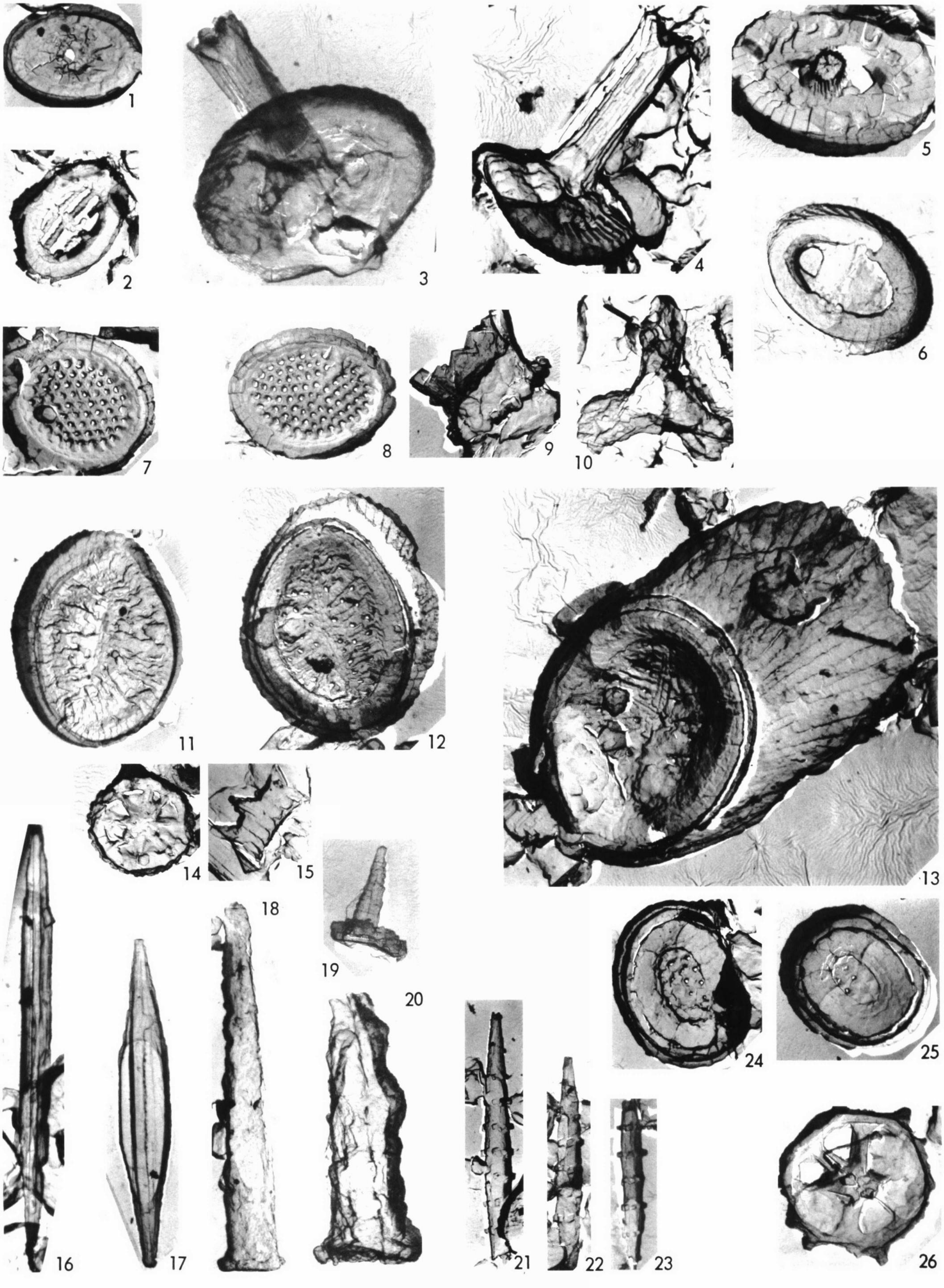
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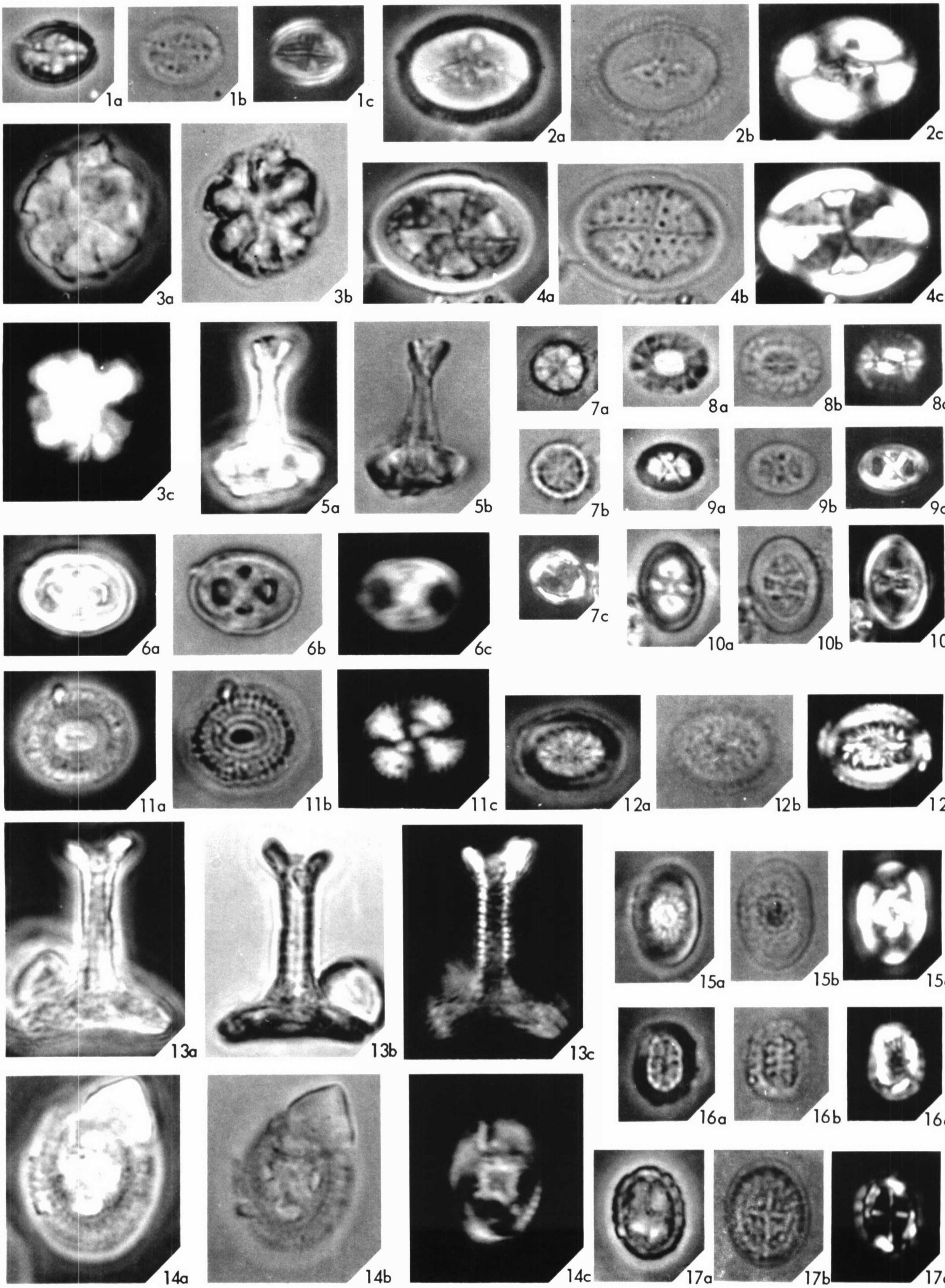
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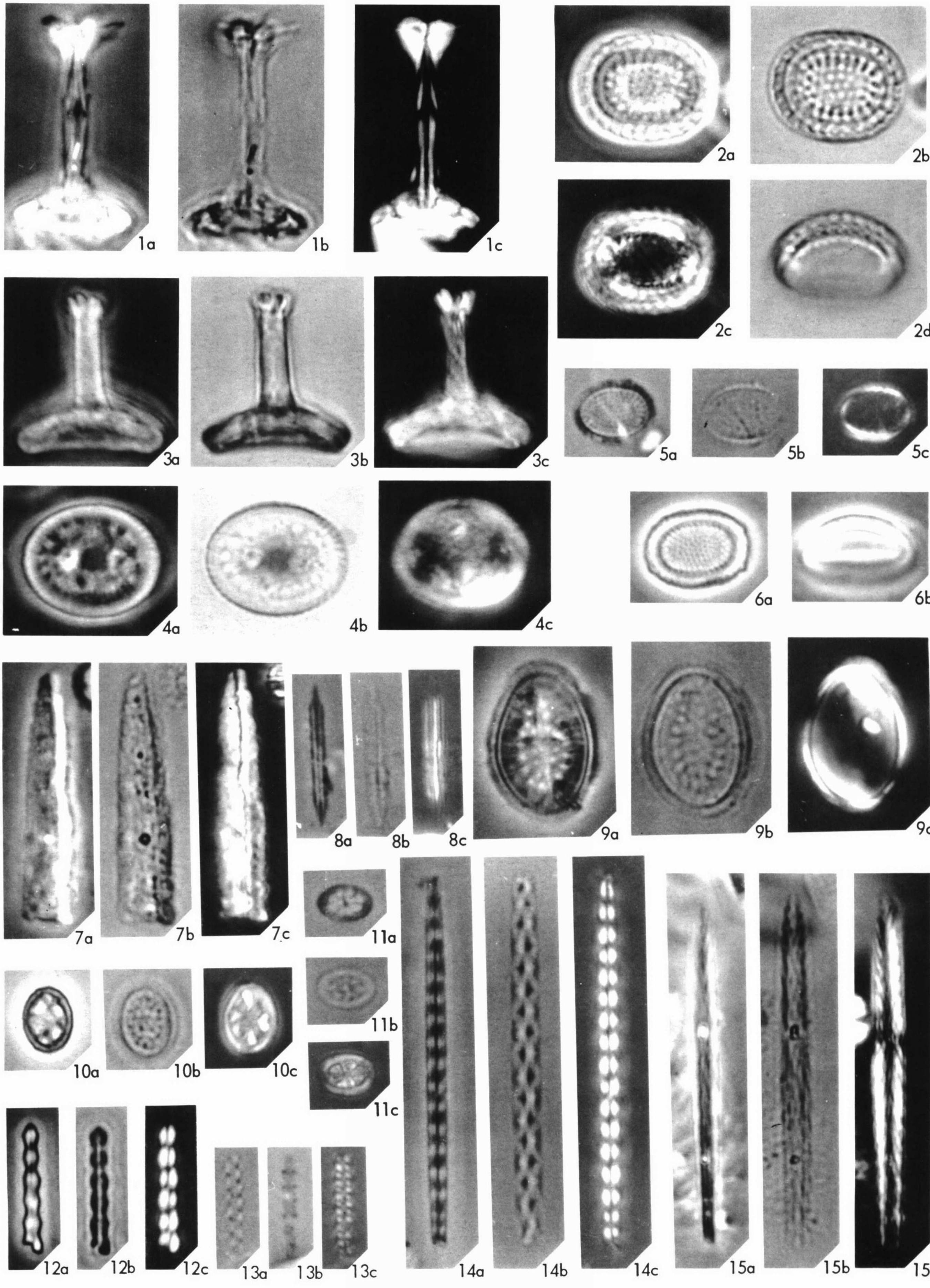
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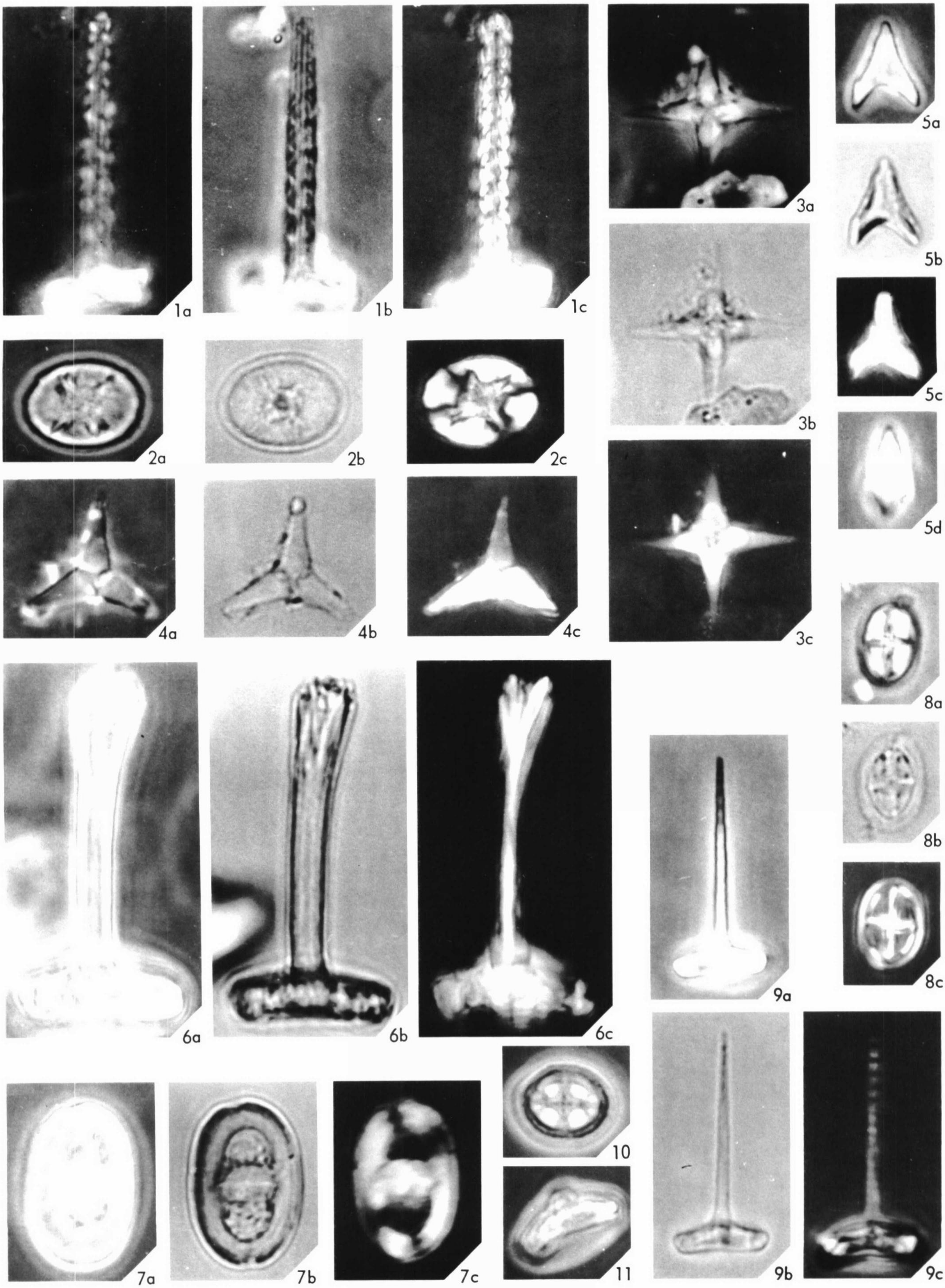
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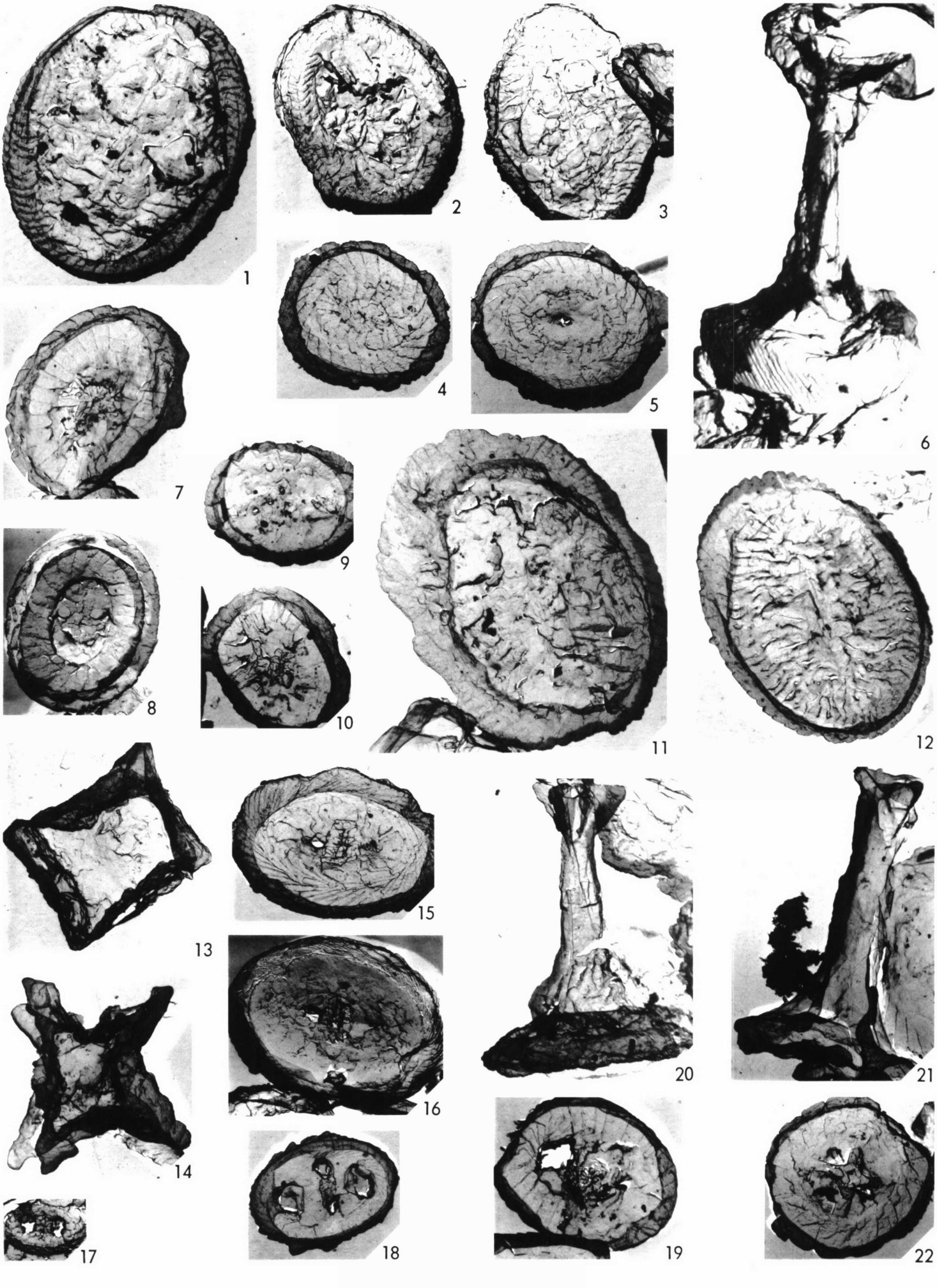
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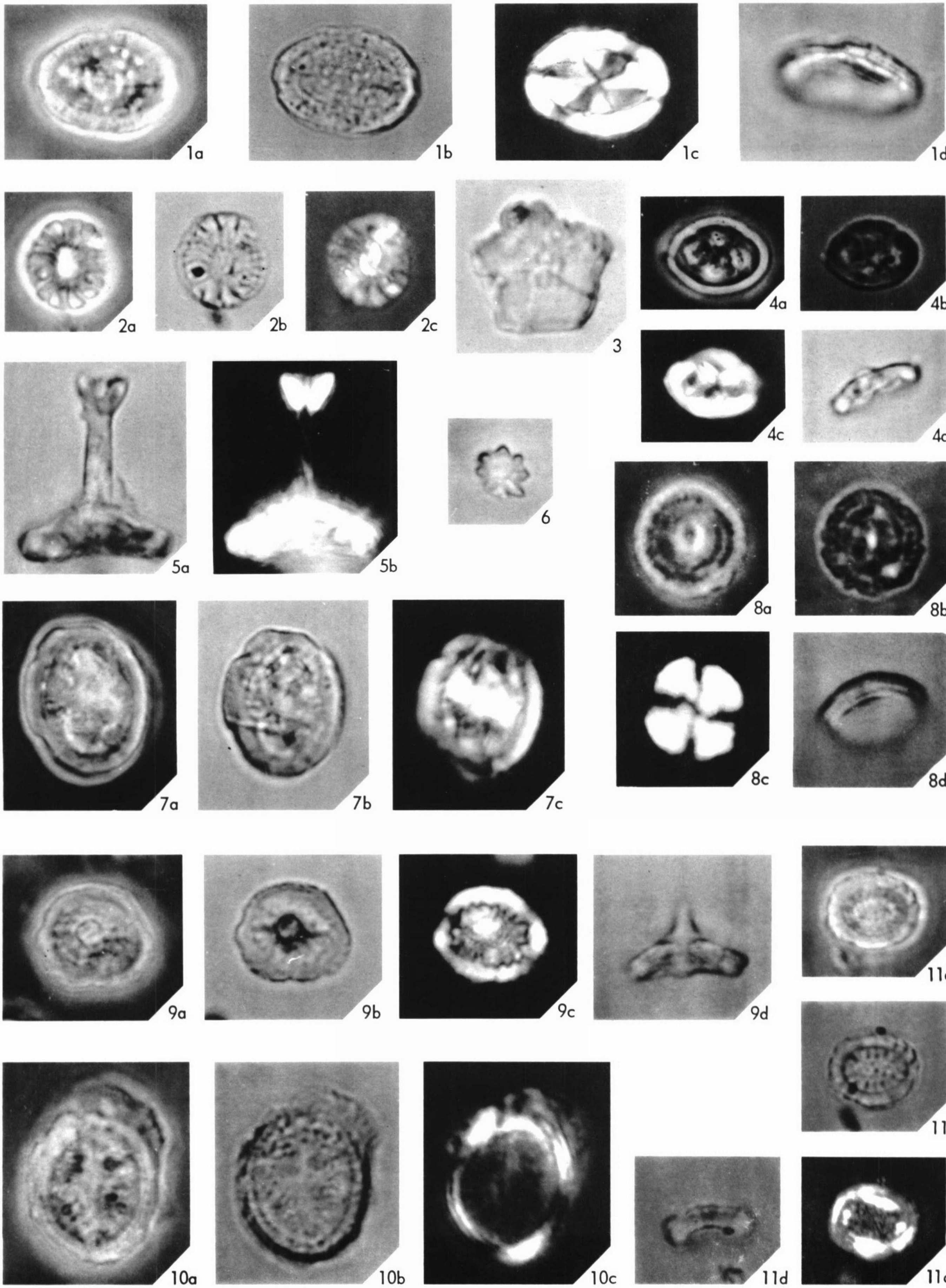
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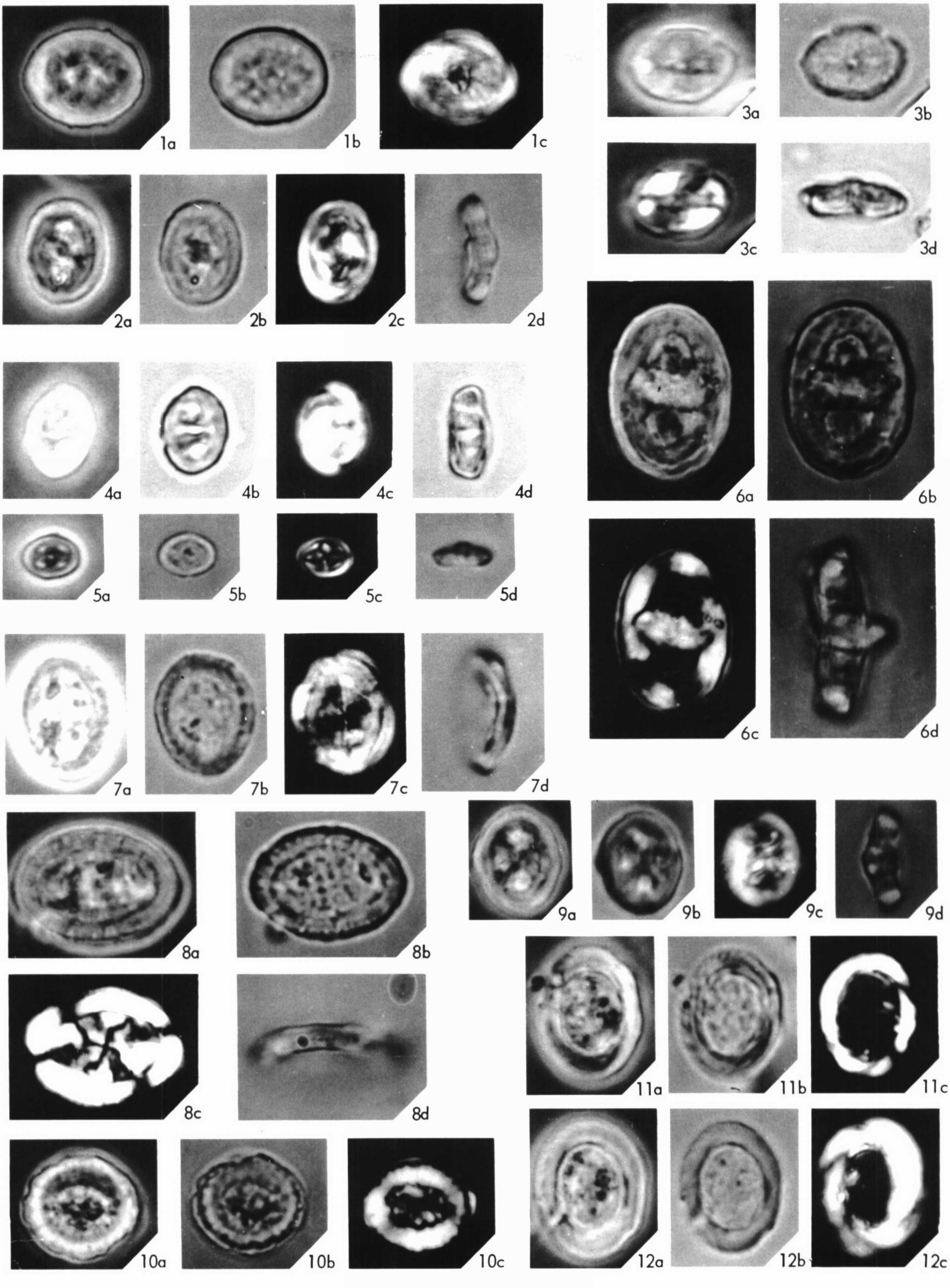
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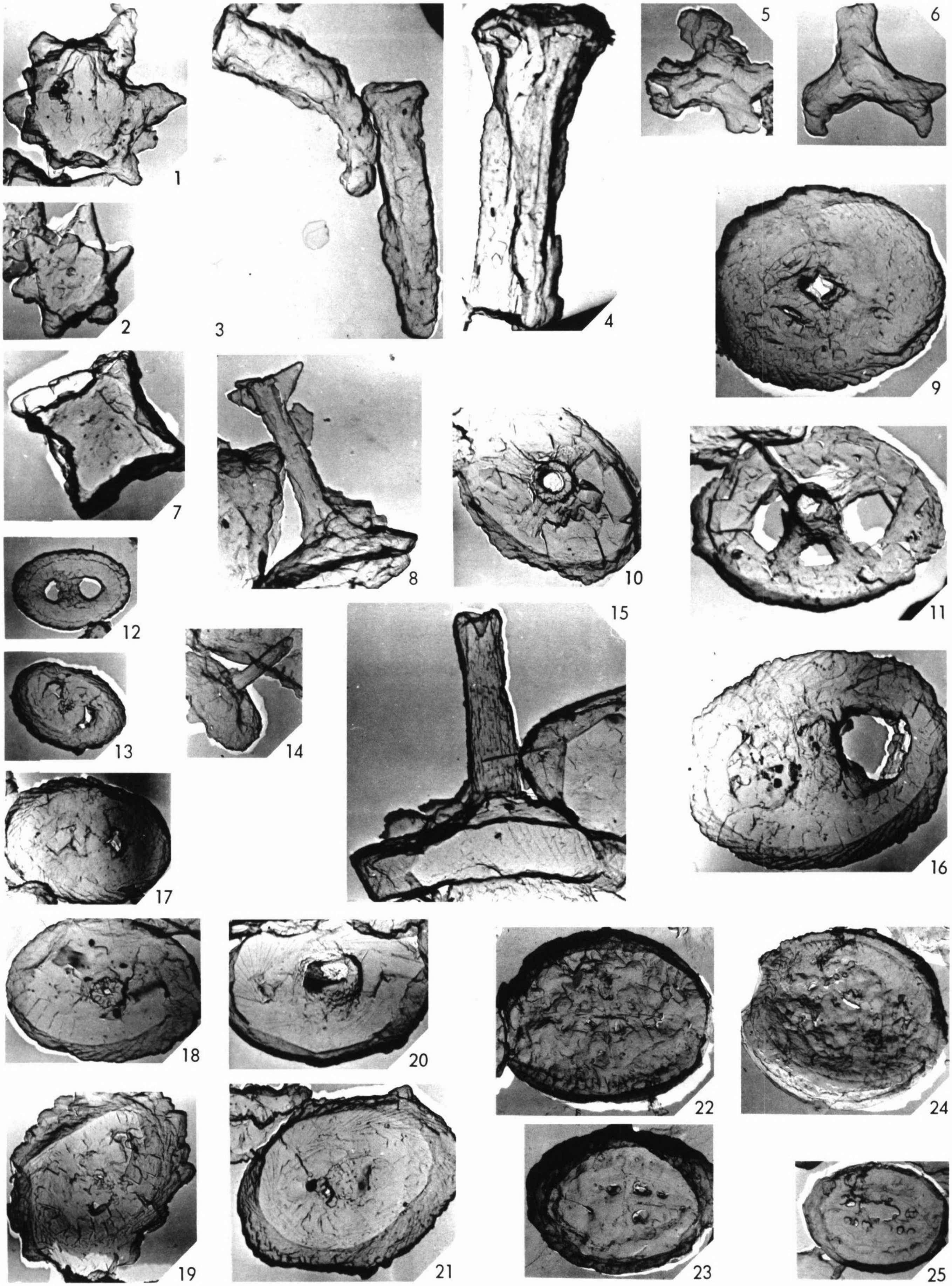

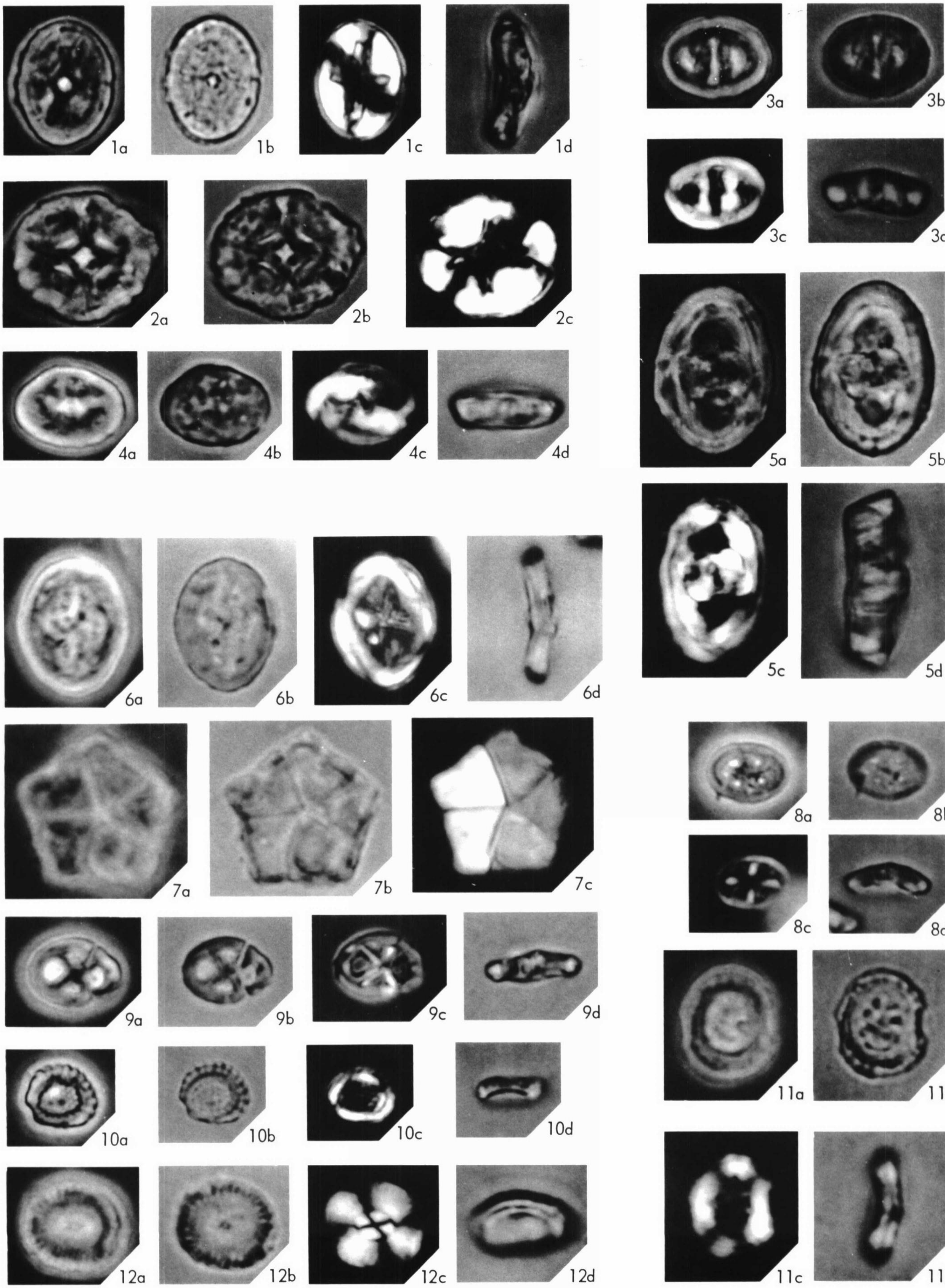
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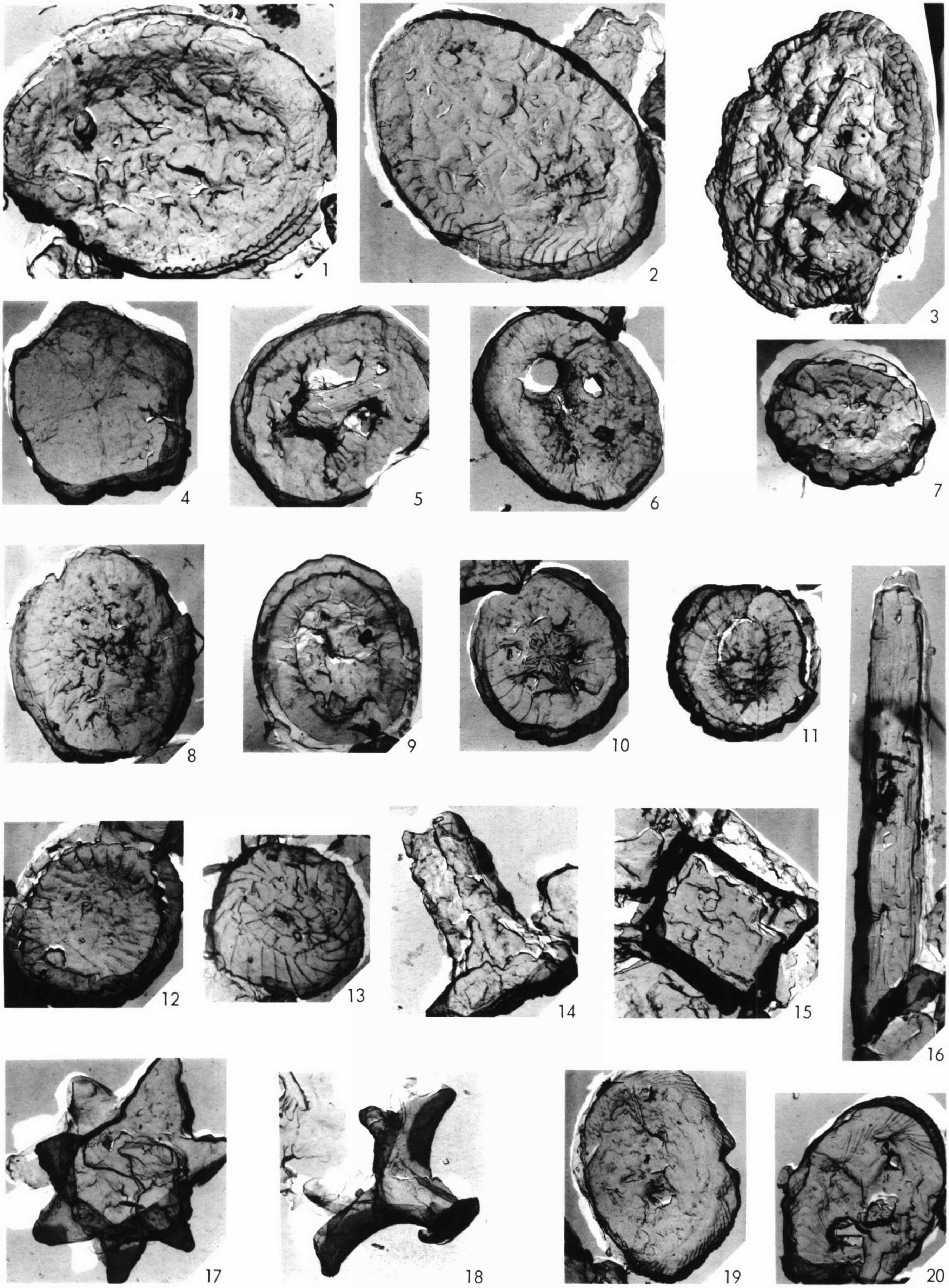
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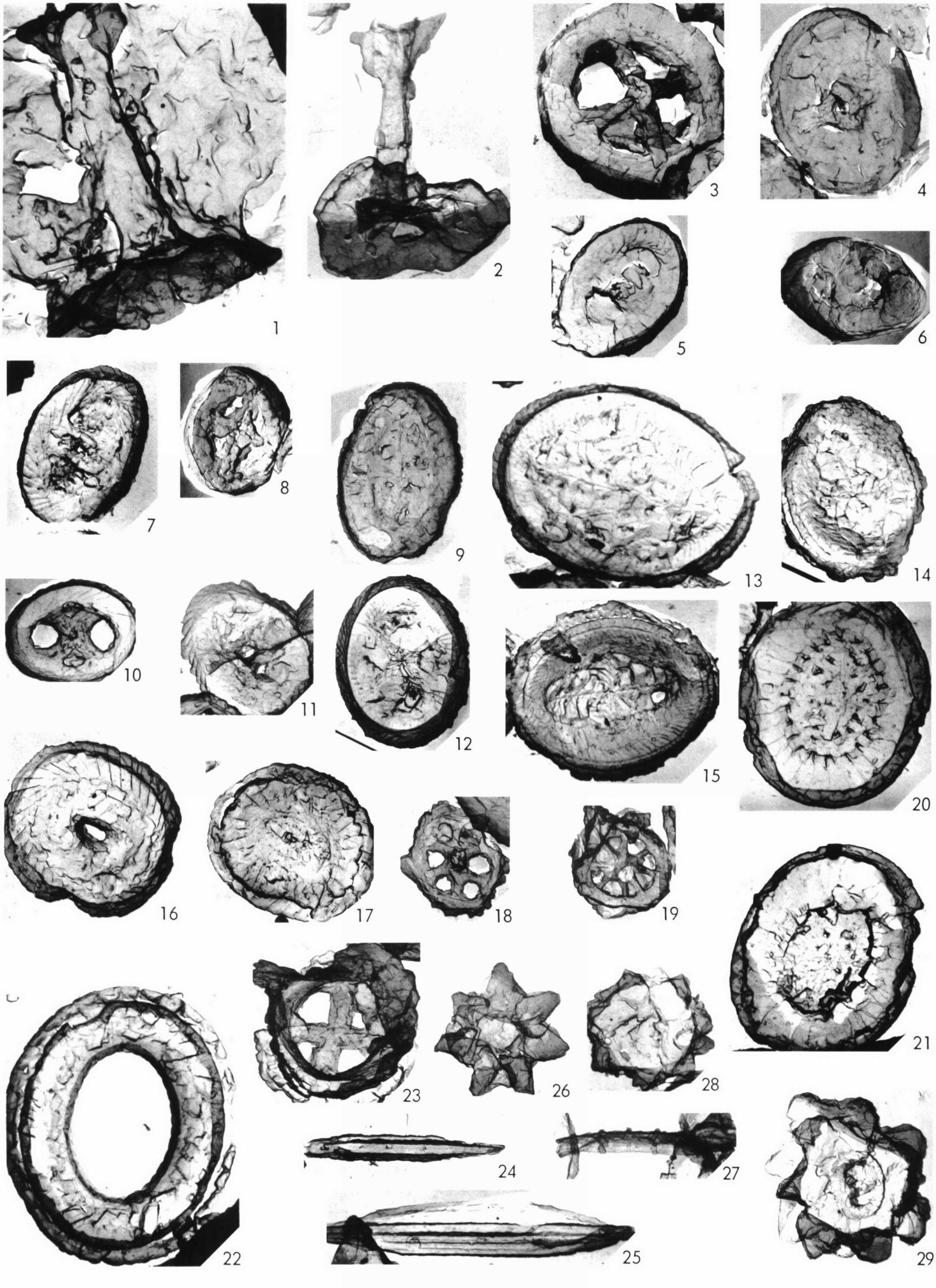
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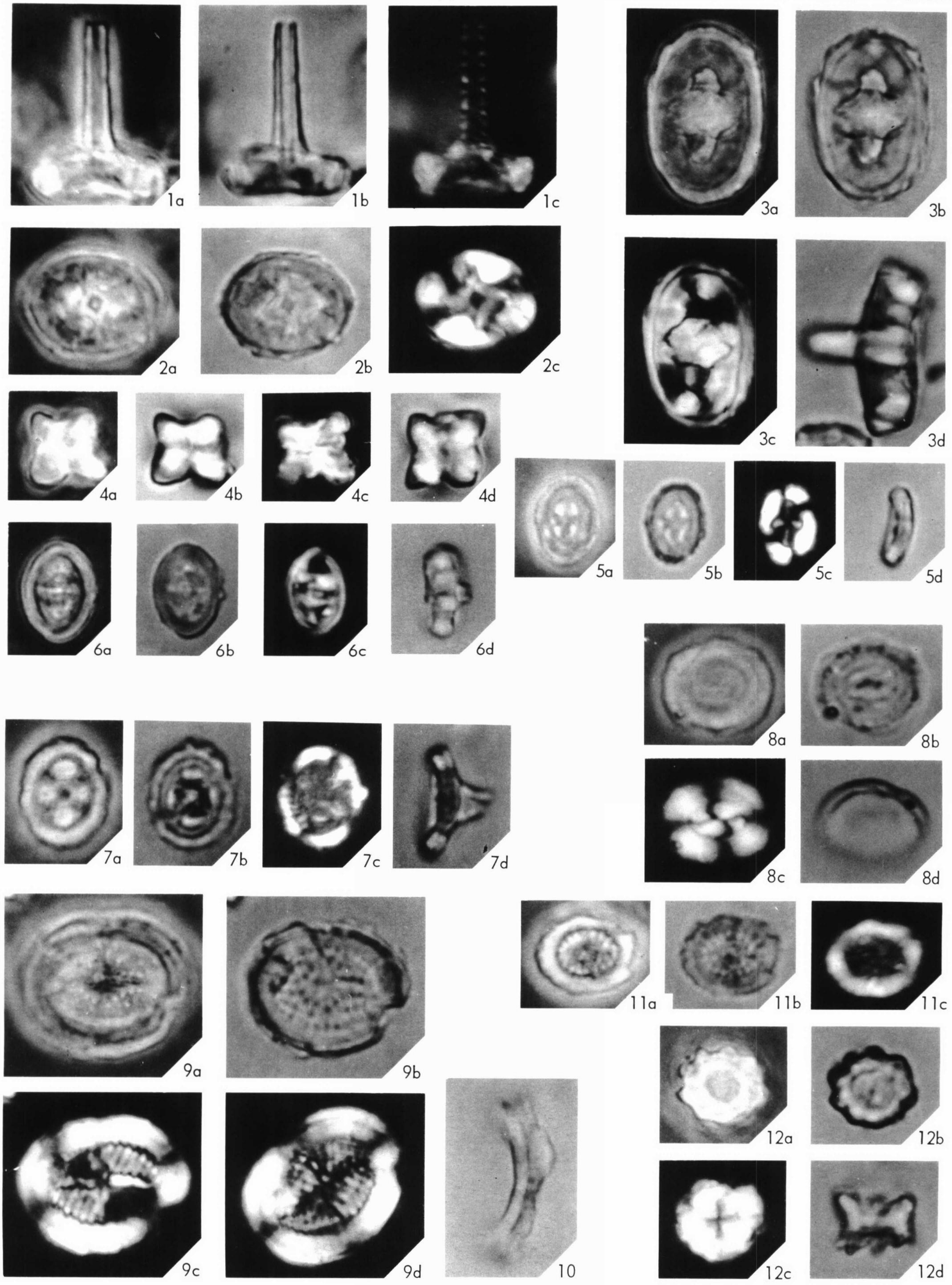
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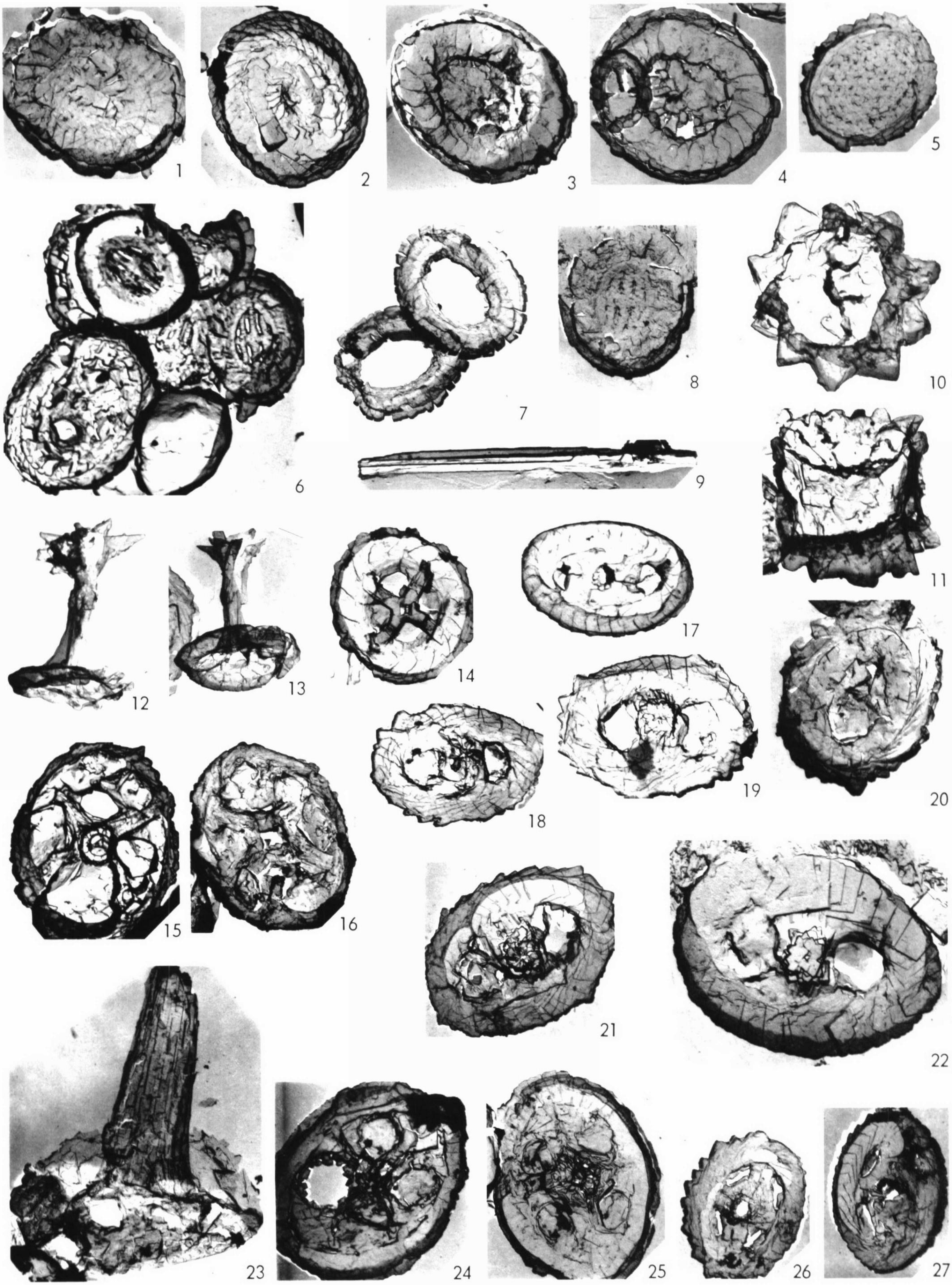
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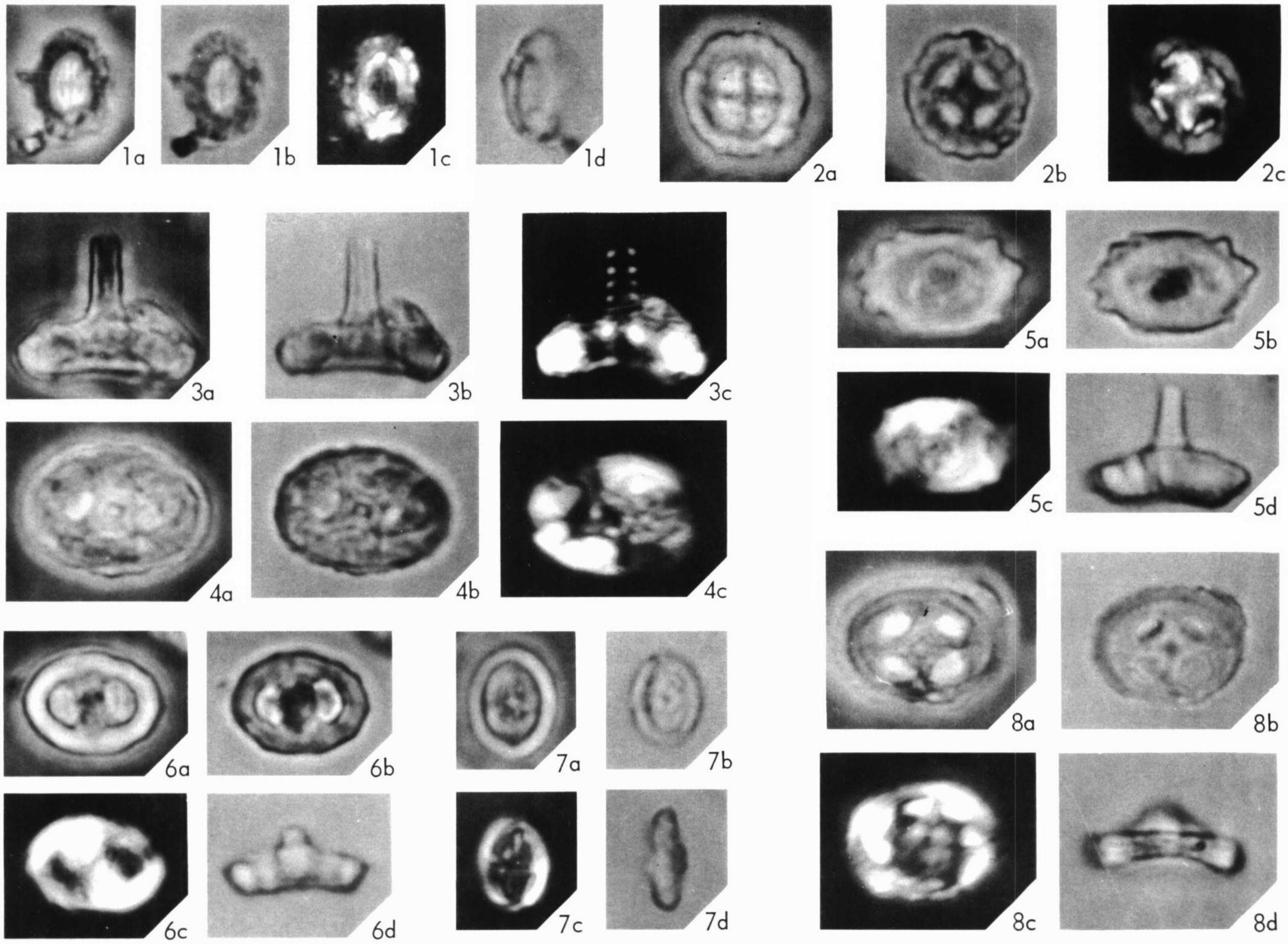
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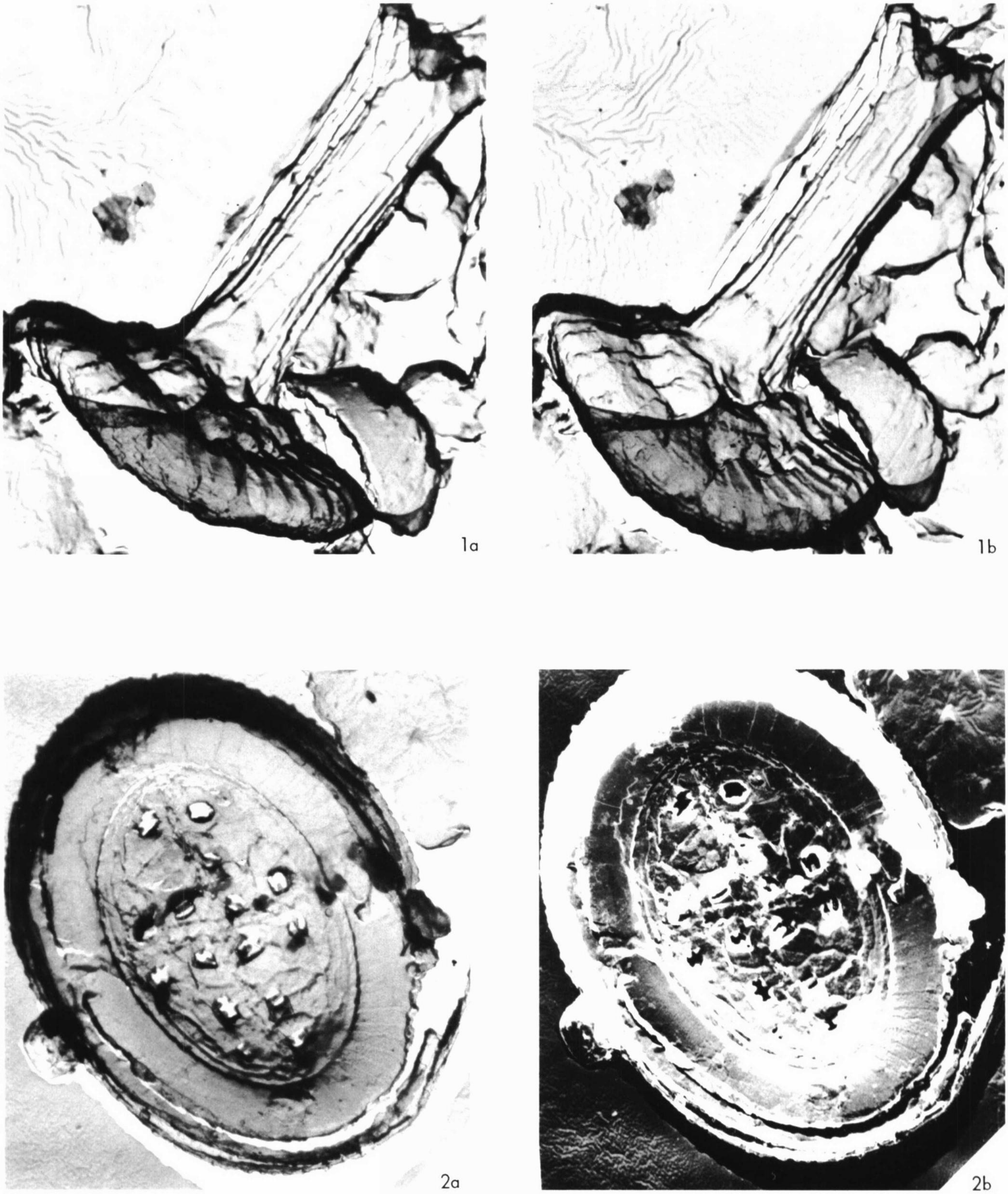
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