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ABSTRACT

Charophytes from the Dundee Limestone in Lucas County, Ohio, are identified as *Trochiliscus bellatulus* Peck, previously known only from the Columbus Limestone.

CONTENTS

INTRODUCTION

MORE THAN A DECADE AGO, the senior author collected some silicified charophytes from the Middle Devonian Dundee Limestone in the West Quarry of the France Stone Company at Silica, Ohio. In 1953 the quarry was enlarged and joined to the East Quarry by a pass under Centennial Road. In preparation for cutting the pass through rock strata, the glacial overburden was bulldozed away, exposing strata of the lower part of the Dundee Formation over a considerable area. Although most of the dolomite and limestone beds were nearly barren, excellently preserved brachiopods, pelecypods, crinoid columnals, ostracods, tentaculites, and other fossils were discovered in chert nodules.

Only where the bed containing the nodules was exposed from beneath the shallow layer of glacial drift was weathering so advanced that the fossils could be removed from the matrix. Numerous fossiliferous nodules were collected for future study and stored in the Museum of Paleontology of The University of Michigan. The ostracods were described by Kesling in 1954. At that time, some charophytes were pried loose with fine needles, cleaned, and saved for investigation. Others were marked and retained in matrix.

Charophytes occur abundantly in parts of the chert, but silicification has made them brittle. Many have been broken in removal. Those separated whole have some matrix adhering, which must be cleaned with small needles and ultrasonic vibration. From essentially undeformed specimens, 80 were measured for width and 90 for length. Others were sacrificed by grinding to reveal the thickness of the cell walls. The charophytes give no reaction when immersed in strong hydrochloric acid. They dissolve completely in hydrofluoric acid and give no trace of oospore membrane. Some specimens have hollow centers, like minature geodes with secondary silica, but others break in such a way that the spiral cells separate cleanly from the cast of the oosphere. These casts have polar extensions, the one evidently a mold of the apical pore and the other a cast of the node cell.

In the course of our investigation we learned through the kindness of Professor Raymond E. Peck of the University of Missouri that he and Dr. Gustavo Morales plan an extensive revision of Devonian and Mississippian charophytes, to be published within a year. We have no wish to publish any of their conclusions in advance. Undoubtedly, the revised classification will affect the species described here. Several specimens from the Dundee Limestone were presented to Dr. Peck.

All specimens illustrated in this paper are deposited and catalogued in the Museum of Paleontology of The University of Michigan. We are grateful to Professor C. A. Arnold and Professor L. B. Kellum for critical reading of the manuscript, to Mrs. Helen Mysyk for final typing, and to Mr. Karoly Kutasi for assistance in photography.

LOCALITY

All specimens are from the same locality and rock unit.

Middle Devonian Dundee Limestone, exposed in Northwestern Ohio about ¼ mile north of Sylvania Avenue and 200 feet west of Centennial Road; about ¾ mile north of Silica and 3 miles south-southeast of Sylvania, Lucas County, Ohio. Ehlers *et al.* show an aerial photograph (1952), (cover), aerial map (1951, 1952, Map 1), and sketches of the quarry area (1951, 1952, Fig. 1). Rocks of the area, involved in the Lucas County monocline, dip 6° S. 80° W. Bed containing charophytes is Unit 4 of Dundee Limestone (Ehlers *et al.*, 1951, 1952, p. 18). Chert nodules uncovered when a few inches of soil and glacial gravel were bulldozed off in enlargement of the France Stone Company West Quarry. In 1953 the bed with chert nodules was exposed for almost ½ mile along the N. 10° W. strike, immediately west of Centennial Road. Shortly thereafter, all of the weathered strata was quarried out. Chert, white to light buff, occurred as irregular lenses (at most 8 inches thick) and as small nodules, enclosed in a dolomitic, buff-gray limestone bed 1 foot 3 inches thick. Chert deeply weathered where exposed from beneath shallow glacial cover; elsewhere hard and dense. Fossils present throughout chert, but removable only from well-weathered parts. In addition to charophytes, chert contains the ostracods *Dizygopleura compsa* Kesling, *Barychilina periptyches* Kesling, *Endolophia chariessa* Kesling, *Trypetera barathrota* Kesling, and *Hollinella variopapillata* Kesling, the tentaculite *Tentaculies scalariformis* Hall, the brachiopod *Brevispirifer lucasensis* (Stauffer), the pelecypod *Glyptodesma erectum* (Conrad), numerous crinoid columnals, other brachiopods, and fragments of other invertebrates. Samples collected by G. M. Ehlers, C. A. Arnold, E. C. Stumm, and R. V. Kesling in 1952 and by C. A. Arnold and R. V. Kesling in 1953.

NATURE OF LIVING CHAROPHYTES

The Division Charophyta consists of one living family, Characeae, and nine extinct families (Grambast, 1962). The charophytes have complex antheridia and oogonia which set them apart from other plants. Their cytology appears similar to that of haplobiontic seaweeds (Croft, 1952). Some authors classify charophytes as Chlorophycae, whereas others place them in a separate division of unknown affinities.

Living charophytes are small, bushy plants from four inches to two feet high. Stalks are slender and branched. The reproductive bodies (antheridia and oogonia) develop at nodes of branchlets and at union of branchlets and stalk. Nearly all cells of the plant secrete calcium carbonate. In most charophytes, the vegetative cells and the antheridia deposit a thin layer of lime on the outer surface of cell walls; this lime covering breaks down when the plant dies, forming a calcareous mud, so that these organs are seldom preserved. Enveloping cells of the oogonia, however, deposit lime in the cell lumen, where it may become so thick as to replace practically all protoplasm of the cell. This material ensures preservation of the gyrogonite.

The two living genera of charophytes are *Chara* and *Nitella*. Around the apical pore, the coronula of *Chara* has five cells in one tier and that of *Nitella* has ten cells in two tiers. No extant charophyte has calcified coronula cells. Distribution is world-wide. Most species grow in quiet ponds of clear water, but a few species in the Baltic region can tolerate low salinity.

Charophytes may completely blanket the bottom of a body of water to the exclusion of all other bottom-dwelling plants. After a few years the entire colony may die, from some cause or other, and be replaced by other kinds of plants. The former presence of charophytes is attested by a limestone layer studded with thousands of gyrogonites (Groves, 1933). Such growth pattern helps explain the large numbers of gyrogonites found in some nonmarine limestones. Modern charophytes are sometimes found in dredgings far offshore, where they have been carried by winds, waves, and currents.

DEVONIAN CHAROPHYTES

Three orders of charophytes were present during the Devonian: the Trochiliscales, the Sycidiales, and the Charales. The first two are collectively referred to as trochilisks. The last order is represented by only one species, *Eochara wickendeni* Choquette, the only sinistrally coiled Devonian charophyte discovered to date. The Sycidiales have vertical enveloping cells. The Trochiliscales contains one family, Trochiliscaceae, which is divided into two genera, both with dextrally coiled enveloping cells—*Trochiliscus,* without a preserved coronula, and *Karpinskya,* with a tier of coronula cells surrounding the large apical pore.

Three authors investigated trochilisks in detail (Karpinsky, 1906; Peck, 1934b; Croft, 1952), and each concluded that they were charophytes, despite the dextral twist of spiral cells, the large number of enveloping cells, and the common occurrence in marine sediments.

Trochilisks have been found in Devonian strata of Podolia (on the Polish-Russian border), Germany, Russia, Estonia, and China. In North America they have been found in Michigan, Iowa, Ohio, Kentucky, and Missouri. They have been noted, but not described, from the Devonian of central western Canada (Fritz, 1939). What may be internal molds of trochilisk gyrogonites have been described from the Devonian of Texas (Ellison and Wynn, 1950).

During the Devonian, trochilisks became the dominant representatives of the calcareous algae. Pia (1940, 1942) was the first to recognize this ascent of trochilisks and decline of other forms of calcareous algae. One explanation offered for the rapid rise and spread of trochilisks is that they may have invaded a new environment when there was little competition from other plants. Church (1919) believed that marine plants must develop a resting spore protected by a resistant covering before they could succeed in ponds, lakes, and rivers. The Trochiliscaceae had such a protective coat in the oospore membrane and lime shell; they also had a food reserve, another necessity for survival in "terrestrial," intermittment bodies of water, in the form of starch grains (Croft, 1952).

It is now generally believed that trochilisks lived in a non-marine environment during Devonian, and that they originated in a marine environment. Croft (1952, p. 216) stated:

". . . their earliest representatives were already adapted to a land habitat in very ancient times. The fact that the remains of trochilisks have not been found along with marine calcareous algae in the extensively searched littoral deposits of Lower Palaeozoic may be due to inadequate collecting. If this is not so, it suggests either that the development and calcification of their highly specialized fruits were delayed until they began to adopt a land habit; or that they had already emerged from the sea and become established on the land some time before the beginning of the Devonian period."

The question of habitat is acute for paleoecological interpretations as well as stratigraphic correlations. If trochilisks lived in freshwater bodies in upland areas, presumably they could be carried by drainage systems into separated basins on opposite sides of the divide. In such event, they would provide a unique index for correlation of strata from one isolated basin to another.

Probably the first charophyte to be named in North America was *Moellerina greeni,* from the Falls of the Ohio at Louisville, Kentucky. It was described by Dr. E. O. Ulrich, paleontologist at that time for the Ohio Geological Survey, in 1886 (p. 34) as a foraminifer. His illustrations show spiral cells in a sinistral direction rather than dextral, but the drawing was probably reversed in the printing process. What led Ulrich to think these were foraminifera was the separation of the silicified oospore membrane from the silicified lime shell, whose inner wall appears to have been partly dissolved. Thus, the gyrogonite seemed to be double-chambered in cross section. Unfortunately, Ulrich's specimens cannot be located, and some doubt persists about their true nature. We believe they belong to the genus *Trochiliscus.*

Trochiliscus devonicus (Wieland) Peck was found in the Jeffersonville Limestone at the Falls of the Ohio. It is noncoronulate, spherical to subspherical, 600 to 800 microns in diameter, and provided with eight or nine intercellular ridges. Croft (1952) suggested that *T. devonicus* might be conspecific with *T. greeni* (Ulrich).

Trochiliscus lemoni (Knowlton) Karpinsky is a species of doubtful affinity, according to Croft (1952). Knowlton's figures and descriptions are unclear. However, the species comes from the same locality and possibly the same horizon as *T. greeni* (Ulrich), *T. lemoni* is noncoronulate, 1500 to 1800 microns wide and about 1700 microns long, and has 9 or 10 spiral cells. It is the largest trochilisk reported.

Trochiliscus minutus Peck, *T. convolutus* Peck, and *T. multivolvis* Peck, all from the Mineola Limestone, probably constitute one species. The first was described as having 9 spiral cells, the second 10, and the third 11. Each was said to be 300 to 400 microns in diameter.

Three species of *Karpinskya* have been described from the North American Middle Devonian. They are briefly characterized in Table I.

According to Peck (1953, p. 223), the evolution of the Trochiliscaceae during the Devonian period produced an increase in the size of gyrogonites,

TABLE I

TROCHILISKS REPORTED FROM MIDDLE DEVONIAN FORMATIONS OF CENTRAL NORTH AMERICA

Species	Formation	Diameter (Microns)	Average No. of Cells
Trochiliscus			
T. minutus.........	Mineola Ls.	300-400	9
T. convolutus......	Mineola Ls.	300-400	10
T. multivolvis	Mineola Ls.	300-400	11
T. devonicus.......	Jeffersonville Ls.	600-800	9
T. bellatulus.......	Columbus Ls.	1000	10
T. lemoni..........	Jeffersonville Ls.	1500-1800	10
Karpinskya			
K. herbertae........	Bell Shale	500-800	9
K. bilineata........	Columbus Ls.*	600-800	9
K. lirata...........	Columbus Ls.*	700-800	8

*Also reported from Upper Devonian Cerro Gordo Formation of Iowa.

decrease in the number of enveloping cells, and acquisition of the ability to calcify the coronula cells. In part, this evolutionary series was based on the assumption that the Mineola Limestone was Onondaga in age. Presently, the formation is regarded as late Middle Devonian, possibly equivalent to the Cedar Valley Limestone.

TERMINOLOGY

The following terms are used in this paper:

apical pore—the opening at the distal end or terminus of a gyrogonite.

basal claws—discontinuous structures representing calcification at base of wall of the node cell.

cage—structure formed like basal claws, but continuous around base of gyrogonite.

coronula—group of five or more cells, each of which is separated from the spiral enveloping cell below by a transverse septum. Coronulas are not calcified in living charophytes, as they were in many fossil species. Possibly, some gyrogonites described as non-coronulate possessed a coronula of uncalcified cells.

coronulate—having a coronula; in the case of fossil charophytes, having a coronula calcified and preserved.

dextral—coiling of enveloping cells to the right; all species of the Trochiliscales coil dextrally.

enveloping cells—cells which form an outer protection for the gyrogonite, enclosing the oosphere. In trochilisks, these cells are calcified to form the lime shell. The number of enveloping cells decreased through geologic time and became specifically stable at five.

equatorial axis—any diameter in an imaginary plane at right angles to the axis between apex and base passing through the greatest width of the gyrogonite.

furrow—depression between ridges; also called fossule. In the Trochiliscales, furrows spiral dextrally in either cellular or intercelluar positions.

gyrogonite—the charophyte fruit, the female reproductive body; in trochilisks, commonly used to refer to preserved parts. Also called oogonium, oogonite, or fructification. Each is composed of several layers, not all of which are preserved in fossil specimens. The outermost layer is the lime shell, or calcine; proximally, it is succeeded by the two sporostine layers (secreted by the spiral cells and formed from residual cell walls) and the oospore wall, or sporine layers (two membranes secreted by the oosphere). The oospore wall has not been found fossilized in trochilisks. Fossil gyrogonites are spherical, ellipsoidal, ovate, subcylindrical, and flask-shaped, with many variations from these basic shapes.

length—distance between poles of a gyrogonite.

lime shell—calcine (Horn af Rantzien, 1956, p. 231), the deposit of calcium carbonate secreted within enveloping cells. It may have a thin outer layer of structureless lime and a thicker inner layer of laminations. Thickness of the lime shell is measured along an equatorial axis from the bottom of a furrow to the inner boundary of the lime deposit.

node cell—small cell between the oospore and stalk, surrounded by bases of enveloping cells; its distal wall may calcify to form a basal plug, or its lateral wall to form a cage or basal claws.

non-coronulate—having no preserved coronula; typical of the genus *Trochiliscus*.

oosphere—egg-cell, the spherical capsule containing spores. Also called oogonium, although Horn af Rantzien (1956, p. 219) uses this term to include oosphere and sterile oogonial cells.

pole—apical or basal end of gyrogonite.

ridge—elevation on the lime shell following the direction of the enveloping cell, either cellular or intercellular in position. Ridges are separated by furrows. Ridges in the Trochiliscales are dextrally spiraled.

sinistral—coiling of enveloping cells to the left; all species of the Charales and Characeae coil sinistrally.

sporostine layers—two layers lining the enveloping cells, the outer (ectosporostine) secreted by the spiral cells and the inner (endosporostine) formed from residual cell walls; resistant, in many fossils replaced by cryptocrystalline silica.

stalk—stem by which a gryogonite is attached to the rest of the plant, composed of one or two cells, not commonly fossilized.

transverse septum—partition between a coronula cell and enveloping cell.

trochilisk—any species of the Trochiliscales or the Sycidiales, to date known only from gyrogonites. Taxonomic separation is based on the presence or absence of a coronula, the direction of the enveloping cells, shape of the gyrogonite, the number of enveloping cells (which may vary as much as two cells from the mean), and the size of the gyrogonite (within ± 20 per cent of the mean value).

SYSTEMATIC DESCRIPTION

Order TROCHILISCALES Mädler 1952

Family Trochiliscaceae Peck 1934

Genus *Trochiliscus* Karpinsky 1906

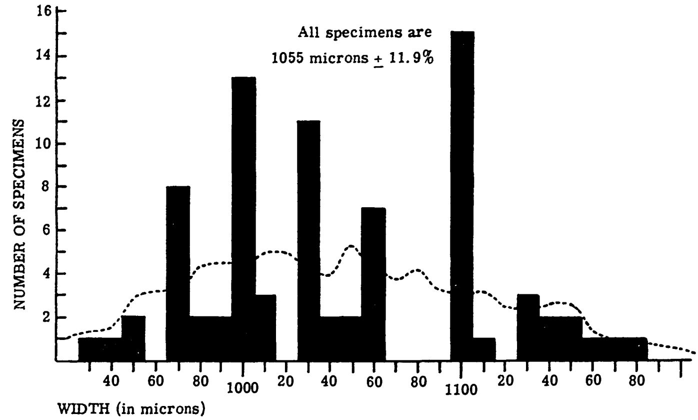
Trochiliscus bellatulus Peck 1934

(Pl. I, Figs. 1–32; Pl. II, Figs. 1–48; Pl. III, Figs. 1–48)

Trochiliscus bellatulus Peck, 1934, p. 115, Pl. 10, Figs. 21, 23, 24.

Description.—Gyrogonites about 1000 microns wide and long (Fig 1; Table II), slightly wider than long. Shape subspherical, variable, typically with base slightly protuberant and apex slightly truncate. Lime shell separating cleanly from cast of oosphere. Shell about 125 microns thick through ridges, 75 microns thick through furrows.

Ridges on enveloping cells spiraling dextrally. Of 50 specimens counted, 9 with nine ridges, 37 with ten ridges, and 4 with eleven ridges. In well-preserved and unabraded specimens, ridges with fairly sharp crests (Pl. I, Fig. 30; Pl. II, Figs. 6, 9, 21, 27, 33, 36, 39, 48); in much abraded specimens, crests broken and ridge appearing to be "double"-crested, particularly in polar areas (Pl. I, Fig. 32; Pl. II, Fig. 25; Pl. III, Figs. 7, 10, 12, 28, 33, 46); in specimens differentially calcified, silicified, or abraded, some ridges well-defined and others "double" (Pl. I, Fig. 6; Pl. II, Figs. 30, 42, 45). One specimen, UMMP 52331, with frilled structure around base, resembling a cage (Pl. I, Fig. 31; Pl. II, Fig. 24); however, scallops of "frill" aligned with ridges and separated from them by



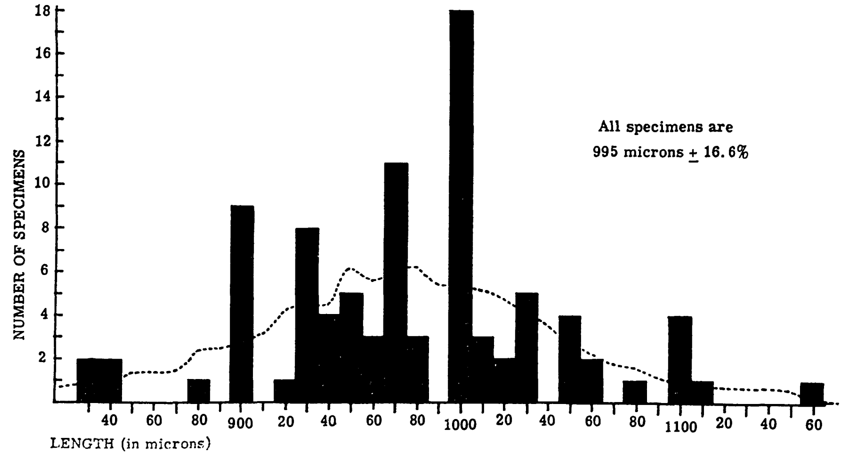


FIG. 1. *Trochiliscus bellatulus* Peck. Measurements of eighty specimens for width and ninety specimens for length. Dotted lines are weighted distributions.

poorly preserved zone; structure apparently the result of imperfect preservation, by which a ring within the enveloping cells was not fossilized. In UMMP 52345 (Pl. III, Fig. 6), area around basal pore with outer part of cells missing.

Each enveloping cell spiraling about 180 degrees around gyrogonite from pole to pole. Equatorial angle variable, dependent upon deformation of gyrogonite, averaging less than 45 degrees. Furrows broad and smooth, normally terminating apically in circular pits. Pits deeper than ridges, as shown on abraded specimen (Pl. I, Fig. 13) with ridges worn off but pits

TABLE II

PER CENT OF SPECIMENS IN FIFTY-MICRON INTERVALS OF WIDTH AND LENGTH.

Interval (In microns)	Per Cent of Specimens by	
	Height	Width
800-850	4.4	0
850-900	6.1	0
900-950	22.2	3.7
950-1000	31.7	24.4
1000-1050	23.4	29.4
1050-1100	7.8	19.4
1100-1150	3.3	18.1
1150-1200	1.1	5.0

clearly defined. In some specimens, pits in definite circle (Pl. I, Fig. 29; Pl. II, Fig. 46), but in most arranged in irregular oval or ellipse (Pl. II, Figs. 1, 4, 13, 28, 31, 40); in extreme irregularity, one pit completely displaced from ring of others (Pl. III, Fig 31). One specimen, UMMP 52325, with small, irregular pits in oral region, some furrows without pits (Pl. I, Fig. 21). Some pits with little demarkation from furrow (Pl. I, Fig. 28; Pl. III, Fig. 16); most delimited distally by a constriction (Pl. II, Figs. 1, 13, 25, 31, 46); and a few with complete encircling ridge (Pl. III, Fig. 28).

Central sphere of gyrogonite normally continuous with polar extensions representing mold of apical pore and cast of node cell (Pl. I, Figs. 10, 16). Sphere interpreted as cast of oosphere, nearly spherical, smooth. In most specimens, cast fragile and hollow; interior may contain secondary deposits in the manner of a miniature geode (Pl. I, Fig. 8). Polar extensions broken from many specimens, tending to adhere to the matrix. No distinct boundary observed in any specimen between node cell and oosphere.

Apical pore as preserved variable; some gyrogonites with rather wide funnel-shaped terminus of pore (Pl. I, Fig. 29; Pl. II, Figs. 25, 37, 46; Pl. III, Figs. 7, 28); others with relatively narrow terminus (Pl. I, Fig. 21; Pl. II, Figs. 1, 4, 19; Pl. III, Fig. 22).

One specimen with tubercles in a ring around the basal opening (Pl. III, Fig. 3), suggesting incipient claws secreted by an expanded node cell or possibly by node and stalk cells.

Remarks.—The variation in shape of the apical pore and the deep pits in the apical region suggest that coronula cells were attached there but not preserved. In several hundred specimens observed, none was found to have any coronula. Presumably, if a coronula was present, it did not calcify in the gyrogonite.

Occurence.—All specimens are from the locality and strata described above.

Illustrated hypotypes.—UMMP 52315-52358.

STRATIGRAPHY

The occurrence of *Trochiliscus bellatulus* Peck in the Columbus Limestone at Marblehead Quarry near Sandusky, Ohio, and in the Dundee Limestone at West Quarry of France Stone Company at Silica, Ohio, raises the possibility that these strata are equivalent.

In central Ohio in the type area, the Columbus Limestone consists of the Bellepoint (zones A-C), the Eversole (zone D), and the Delhi (zones E-H) members. Strata exposed in the Sandusky region, where *Trochiliscus bellatulus* was discovered, correlate with zone E, the lowest part of the Delhi member, and directly overlie the Detroit River dolomites. Trochilisks are also present in considerable numbers in the same zone on Kelley's Island in Lake Erie; although not as well preserved as those described herein, presumably the Kelley's Island specimens are also *T. bellatulus*.

Near Ingersoll, Ontario, in the Chemical Lime Company Quarry, the Columbus Limestone is exposed above the Detroit River strata (Ehlers and Stumm, 1951, p. 1879). There about 16 feet of Columbus beds are in contact with the Lucas Formation. Field relationships indicate that nearby the Columbus is overlain by the Delaware Limestone. The fauna is the same as that found in zone H, the uppermost part of the Delhi member.

Insofar as known, the Columbus Limestone is present only on the southeast side of the Findlay Arch, which existed in Columbus time, and it overlies Detroit River strata and underlies Delaware Limestone (Ehlers and Stumm, 1951, p. 1888). On the northwest side of the arch, including the site of the trochilisks described here, the Dundee Limestone overlies the Detroit River group, with no intervening strata of Columbus age indicated by the fauna. Ehlers and Stumm (1951, p. 1888) suggested that the Dundee Limestone might correlate with the Delaware Limestone on the other side of the Findlay Arch.

From the above relationships, it appears that the first beds of the Columbus Limestone were laid down in central Ohio and that the Columbus sea transgressed northward into central Ontario. Even at the maximum transgression, represented by zone H at the top of the formation, the sea did not cross over the narrow Findlay Arch. In the late stages of deposition, *Trochiliscus bellatulus* was carried by drainage into the sea in the region of Sandusky and Kelley's Island from nearby land, quite possibly from the emergent Findlay Arch. Knowing that this species is also present in the lower part of the Dundee Limestone on the opposite side of the arch, and bearing in mind that trochilisks are not present in great numbers in any other close stratigraphic position in either the Columbus Limestone or the Dundee Limestone basins, we suggest that the strata bearing *T. bellatulus* may have been nearly contemporaneous—that perhaps the lower part of the Dundee Limestone was laid down at about the time when the upper part of the Columbus Limestone was being deposited in an isolated basin nearby.

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EXPLANATION OF PLATE I

(Figures 27–32, × 40; all others × 20)

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FIGS. 1-6. Apical, lateral, and basal views of two gyrogonites, UMMP 52315, 52316.

FIG. 7. Lateral view of broken specimen, UMMP 52317. Proximal half of lime shell missing around cast of oosphere.

FIG. 8. View of broken specimen, proximal half missing, UMMP 52318. Oosphere is hollow, like a miniature geode; a thin line marks separation of lime shell and oosphere.

FIGS. 9-12. Apical and lateral views of casts of oospheres, UMMP 52319, 52320.

FIGS. 13-14. Apical and basal views of abraded gyrogonite, UMMP 52321.

FIGS. 15-16. Apical and lateral views of cast of oosphere, UMMP 52322.

FIGS. 17-18. Apical and basal views of cost of oosphere, UMMP 52323.

FIGS. 19-20. Lateral and basal views of gyrogonite, UMMP 52324.

FIGS. 21-26. Apical, lateral, and basal views of two gyrogonites, UMMP 52325, 52326. The former (Fig. 21) lacks the typically well-developed pits at the apical ends of the furrows.

FIG. 27. Apical view of gyrogonite, UMMP 52327. Apical pore has small funnel-shaped terminus.

FIG. 28. Apical view of gyrogonite, UMMP 52328. Apical pore partly filled with secondary material.

FIG. 29. Apical view of excellently preserved gyrogonite, UMMP 52329. Pits are all distinct, and apical pore has wide funnel-shaped terminus.

FIG. 30. Basal view of well-preserved gyrogonite, UMMP 52330.

FIG. 31. Inclined basal view of gyrogonite, UMMP 52331. Basal structure resembling a cage was not formed by secretion of the node cell; it seems to be the result of imperfect original calcification or subsequent preservation of the spiral cells in the adjacent area.

FIG. 32. Basal view of gyrogonite, UMMP 52332. Incomplete calcification in the enveloping cells and later abrasion produced "double"-crested ridges.

PLATE I

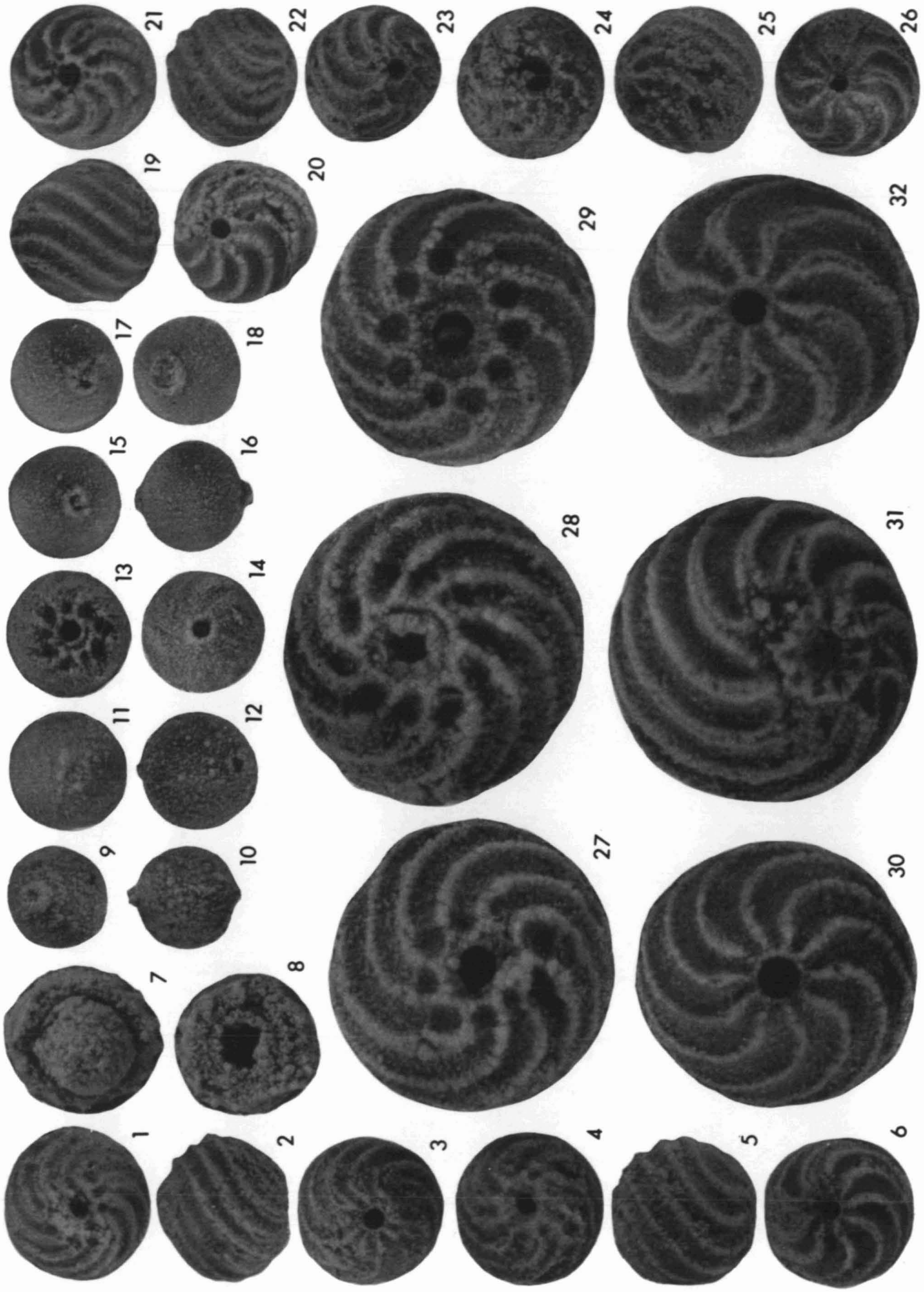
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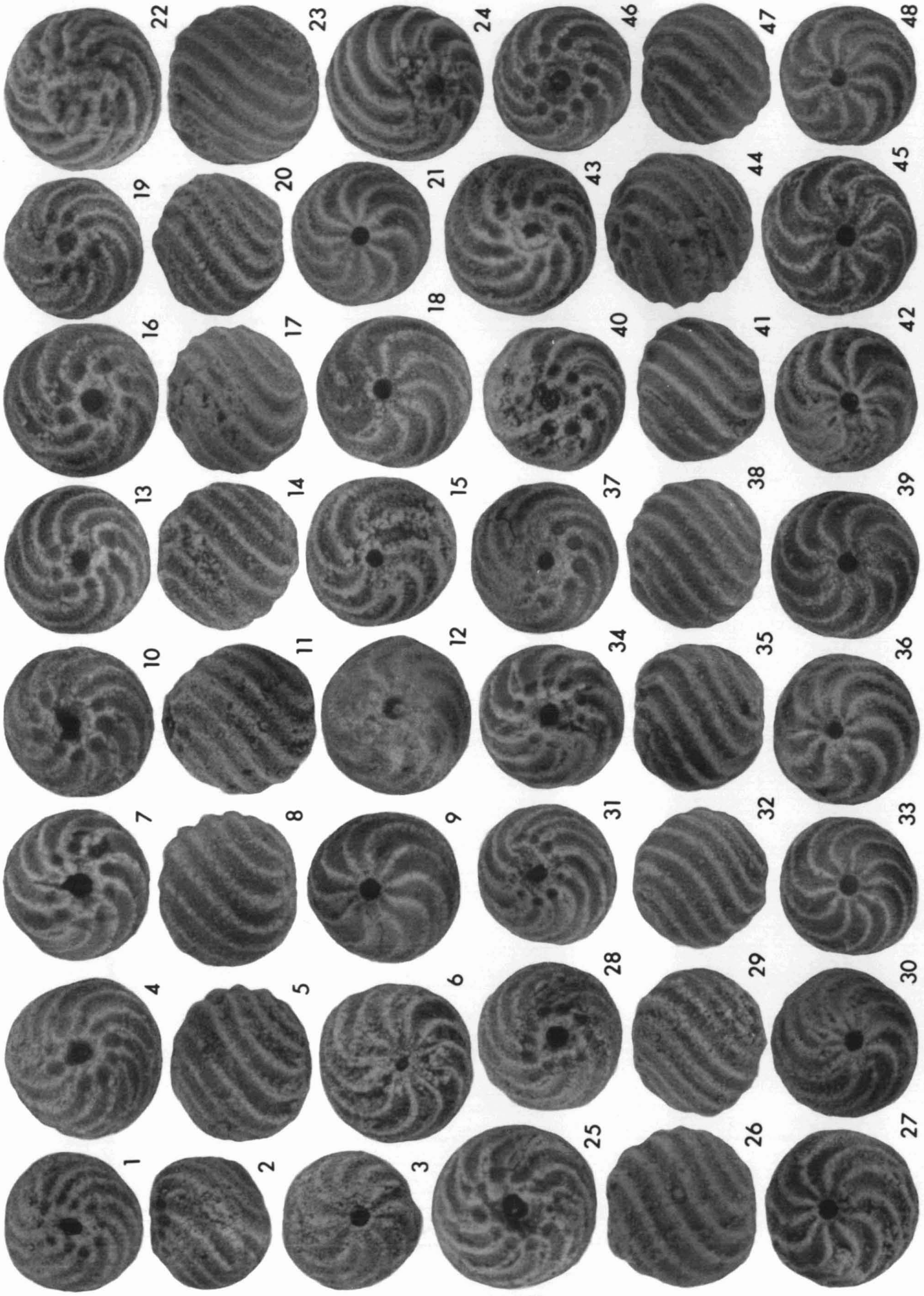
PLATE II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EXPLANATION OF PLATE II

(All figures × 20)

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FIGS. 1-12. Apical, lateral, and basal views of four gyrogonites, UMMP 52333, 52334, 52335, 52336.

FIGS. 13-24. Apical, lateral, and basal views of four gyrogonites, UMMP 52327, 52337, 52338, 52331.

FIGS. 25-36. Apical, lateral, and basal views of four gyrogonites, UMMP 52339, 52340, 52330, 52341.

FIGS. 37-48. Apical, lateral, and basal views of four gyrogonites, UMMP 52342, 52343, 52328, 52329.

EXPLANATION OF PLATE III

(All figures $\times$ 20)

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FIGS. 1-12. Apical, lateral, and basal views of four gyrogonites, UMMP 52344, 52345, 52346, 52332. The first (Fig. 3) has a ring of small tubercles around the basal opening which may be incipient basal claws, secreted by the expanded node cell.

FIGS. 13-24. Apical, lateral, and basal views of four gyrogonites, UMMP 52347, 52348, 52349, 52350.

FIGS. 25-36. Apical, lateral, and basal views of four gyrogonites, UMMP 52351, 52352, 52353, 52354.

FIGS. 37-48. Apical, lateral, and basal views of four gyrogonites, UMMP 52355, 52356, 52357, 52358.

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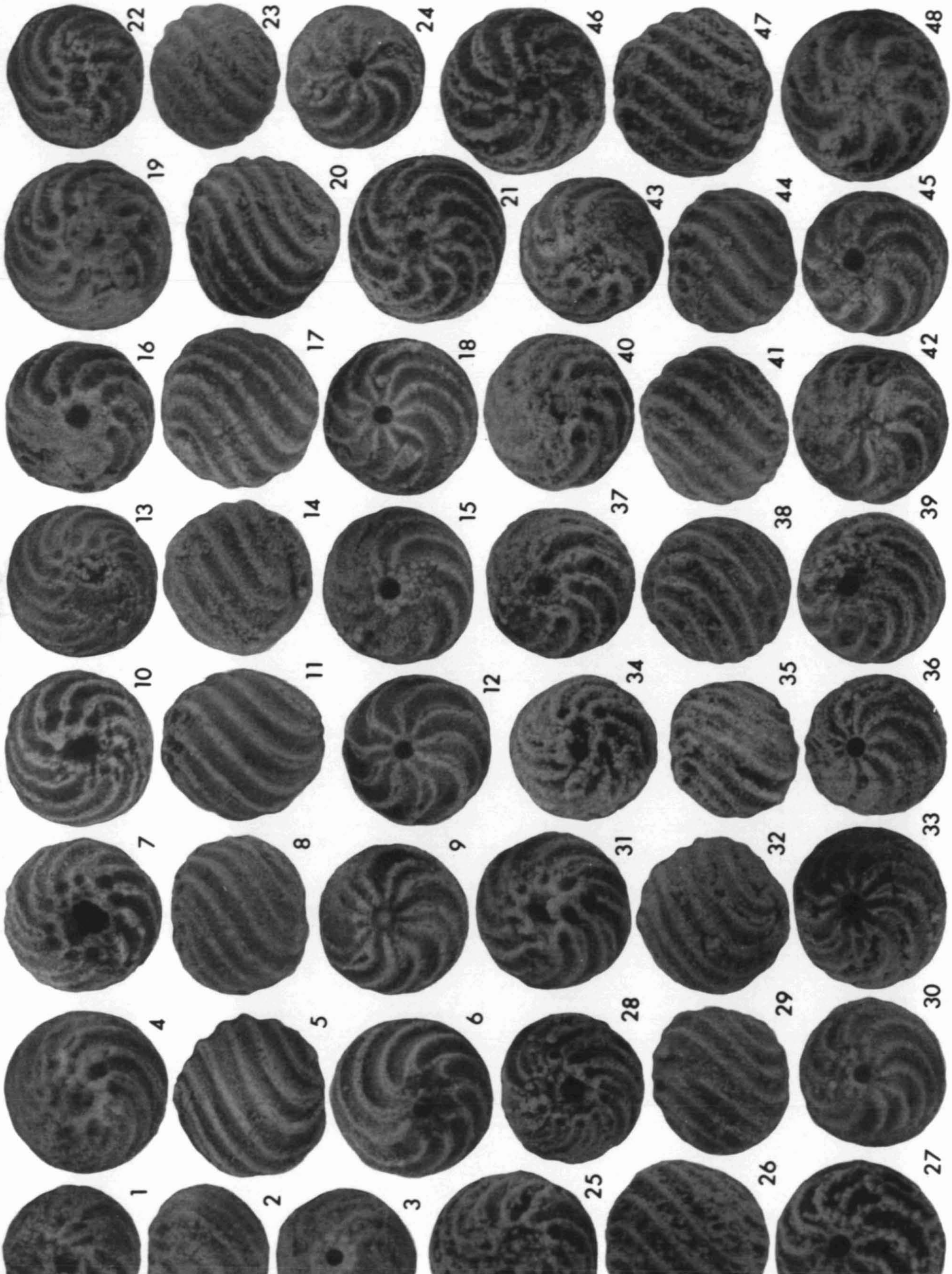
PLATE III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