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VARIATION IN SPECIES OF MUCROSPIRIFER FROM MIDDLE DEVONIAN ROCKS OF MICHIGAN, ONTARIO AND OHIO

by

John Robert Tillman

A dissertation submitted in partial fulfillment
of the requirements for the degree of
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Doctoral Committee:
Professor Erwin C. Stumm, Chairman
Associate Professor Donald F. Eschman
Professor Robert V. Kesling
Professor Henry van der Schalie
Professor James T. Wilson

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INTRODUCTION AND PREVIOUS WORK

The brachiopod genus Mucrospirifer was proposed by A. W. Grabau in 1931 using Delthyris mucronatus Conrad (1841) as the type species. Between 1841 and 1931, species of this genus were placed in the genus Spirifer. In 1910 and 1912 Grabau, in an abstract by Grabau & Reed in the Proceedings of the Seventh International Zoological Congress, named five species, two varieties and two mutations of the genus from the Middle Devonian Traverse group of Michigan. In 1915, Mook published a statistical study of the length/width ratios of three of Grabau's forms (which Mook called mutations) and added a sixth new form (mutation), which he accredited to Grabau. Shimer & Grabau, in 1902, described Spirifer mucronatus var. arkonensis and Spirifer mucronatus var. thedfordensis. In 1927, Stewart described Spirifer prolificus from the Silica formation of northwestern Ohio. Stumm, in 1956, found, illustrated and described the specimens upon which Grabau based his various forms, raising them all to the rank of species. He also placed Stewart's species in the genus Mucrospirifer.

In this study, measurements were made on the various species previously described. The data strongly suggest that only two of these species are valid and that the remainder are variations of these two. All specimens illustrated and measured are in the collections of the Museum of Paleontology, University of Michigan.

LIST OF LOCALITIES

Locality

A. South quarry of the Medusa Portland Cement Company, near Silica, Lucas County, Ohio. NE¼ sec. 18, T. 9S., R. 6E. Middle Devonian, Silica formation.

B. North quarry of the Medusa Portland Cement Company, near Silica, Lucas County, Ohio. SE¼ sec. 7, T. 9S., R. 6E. Middle Devonian, Silica formation.

C. North bank of the Ausable River on the farm of Robert Fraser, about 3 miles east of Arkona and about 1 mile north of road leading east from Arkona, West Williams Township, Middlesex County, Ontario. Middle Devonian, Arkona shale.

D. East side of county road about ½ mile southeast of intersection of Highway 21 and Port Frank Road, Bosanquet Township, Lambton County, Ontario. Middle Devonian, Widder formation.

E. North bank of the Ausable River at Hungry Hollow, about 2 miles east and about ¼ mile north of the center of Arkona, West Williams Township, Middlesex County, Ontario. Middle Devonian, Arkona shale.

F. Quarry on the campus of Colgate University, Hamilton, Madison County, New York. Middle Devonian, Skaneateles shale, Colgate member.

The following localities are those recorded for Middle Devonian rocks in Northern Michigan by the Geological Survey of Michigan in the summer of 1926, and by expeditions of the Museum of Paleontology, University of Michigan to February, 1940.

Locality

7b. Small pits in limestone about 1½ miles north of Norwood, Charlevoix County, Michigan. Near center of North line, sec. 27, T. 33N., R. 9W. Middle Devonian, Petoskey formation, upper part.

21. Kegomic quarry on south shore of Mud Lake just east of Harbor Springs road (M. 131) about ¼ mile north of its termination on US. 31 one mile east of Bay View, Emmet County, Michigan. SE¼ SW¼ sec. 27, T. 35N., R. 5W. Middle Devonian, Petoskey formation.

38. Abandoned quarry of Kelley's Island Lime and Transport Company at Rockport, Alpena County, Michigan. Sec. 6, T. 32N., R. 9E. Middle Devonian, upper part of Bell shale, Rockport Quarry limestone and lower part of Ferron Point formation.

40. Quarry of Huron Portland Cement Division of U. S. Gypsum Company, eastern edge of Alpena, Alpena County, Michigan. Sec. 13, T. 31N., R. 8E. Middle Devonian, upper part of Genshaw formation, Newton Creek limestone and Alpena limestone.

47. Exposures on banks and in bed of Thunder Bay River below Norway Point Dam, Alpena County, Michigan. NE¼ sec. 12, T. 31N., R. 7E. Middle Devonian, Norway Point formation.

51. Abandoned shale pit of former Alpena Portland Cement Company, about 1 mile east and one-eighth mile north of Genshaw school and 8 miles NE of Alpena, Alpena County, Michigan. SE¼ sec. 18, T. 32N., R. 9E. Middle Devonian, upper part of Ferron Point formation and lower part of Genshaw formation.

58. Ditches beside road at southern tip of Long Lake, Alpena County, Michigan. NE¼ sec. 22, T. 32N., R. 8E. Middle Devonian, Genshaw formation.

90. Excavations at the Alpena City Waterworks and ledges outcropping on beach at Stony Point, south edge of city of Alpena, Alpena County, Michigan. sec. 34, T. 31N., R. 8E. Potter Farm formation.

DISCUSSION

A graphic comparison of various morphologic characteristics of previously described species of Mucrospirifer (Table 1, p. 6-7) was made to define more clearly these features and their variations. The species studied were from the Traverse group of Michigan, the Arkona shale and Widder formation of Ontario and the Silica formation of northwestern Ohio.

In formations where more than one species has been described or reported, measurements of all species combined have been presented in a single histogram for any given character. Numbers appearing adjacent

to each histogram indicate the total number of specimens measured for a given character from each stratigraphic unit. Numbers appearing on some of the histograms indicate the percentage of the total number of specimens measured when the percentage is 75% or greater. The number of costae in 5 mm was measured 5 mm anteriorly from the posterior border along the first intercostate furrow and 5 mm at right angles to this point. The slope of the flanks of the valves was measured at right angles to the trend of the fold and sulcus.

As can be seen in Table 1, variation among the populations studied is greater for a given character in some stratigraphic units than in others. Also, there is considerable overlap in the range of variation between the species. On this basis, it is evident that no more than two species can actually be distinguished in the above mentioned stratigraphic units.

Previous descriptions have placed emphasis on the following characteristics: number of costae, width of costae (or number of costae per unit of measurment), length of interarea, presence or absence of medial ridge in the sulcus and medial groove on the fold, presence or absence and taper of mucronate points (cardinal extremities), size of shell, width/length ratios and shape of fold and sulcus. The shape of the fold and sulcus, and the shape and general proportions of the whole shell seem to be characters of greatest value in distinguishing between species.

In evaluating these and other morphologic characteristics, the following criteria need to be emphasized. (1) The total number of costae on a given shell depends on the age and/or size of the individual. In the upper part of the Ferron Point formation, specimens were

Table 1.—Characteristics of Mucrospirifers Studied in this Paper

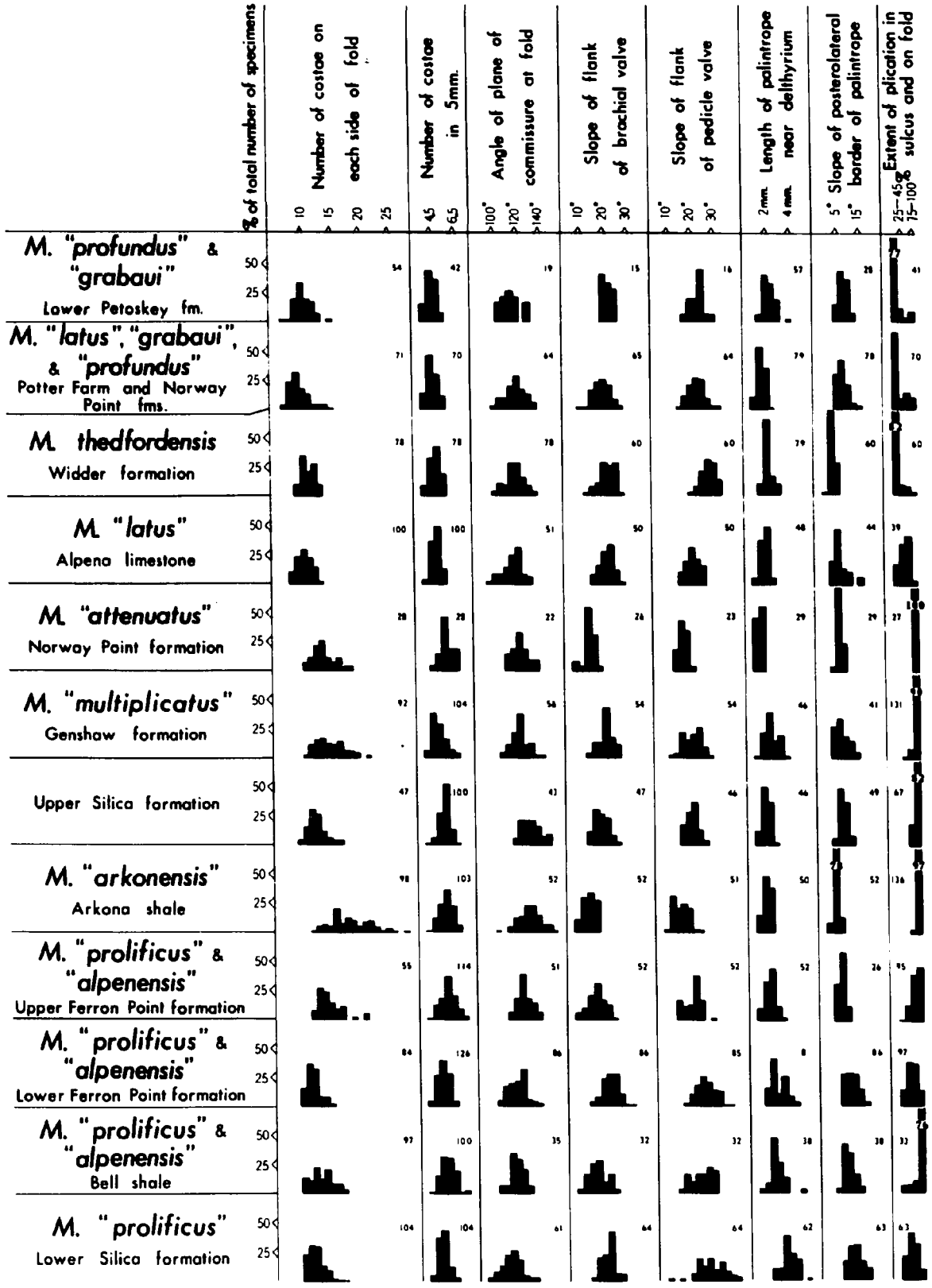
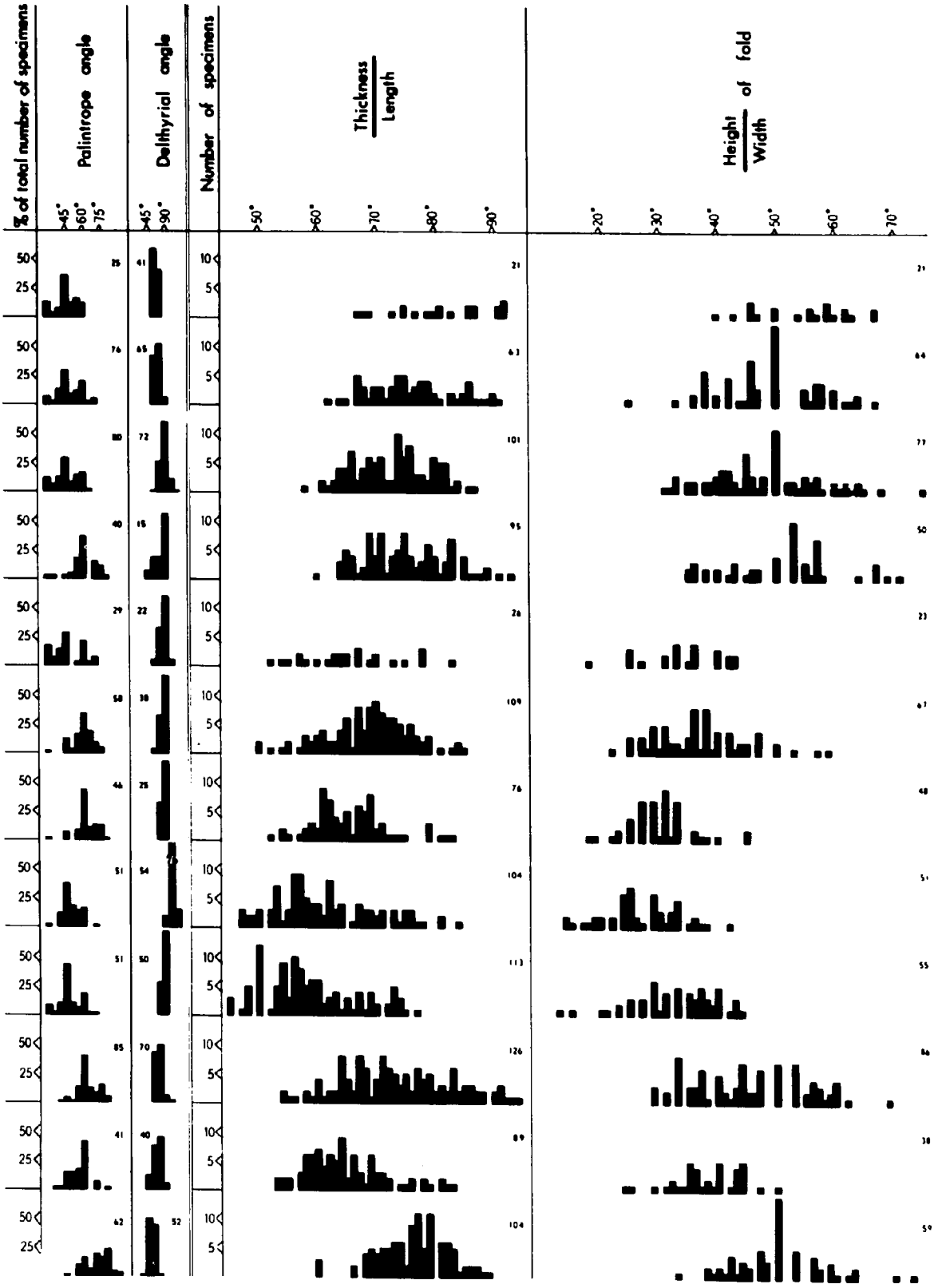
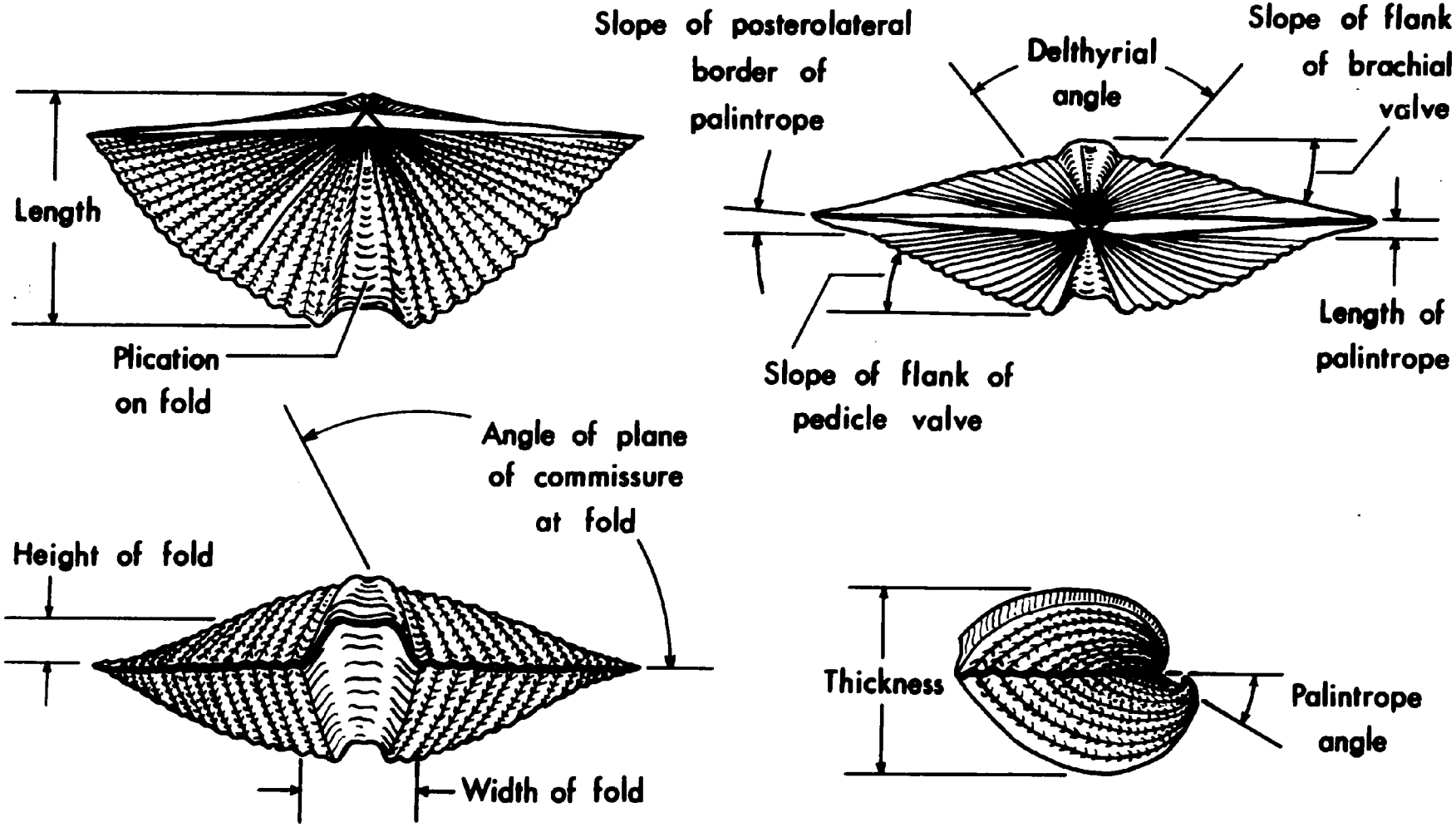


Table 1.— (Continued)





Text-fig. 1. Various views of Mucrospirifer showing where measurements, included in Table 1, were made.

found which show a complete ontogenetic series from one costa on each side of the fold to a maximum of twenty. Raymond (1904, p. 140-142, pl. VI, figs. 1-2) found a similar series in "...certain layers of impure, clayey limestone from Moscow (Hamilton) shales in a ravine near Canandaigua Lake, N. Y. ..." In general, larger specimens have a greater number of costae but this is not always the case. (2) The number of costae per unit of measurment is not constant even within a given population. It is, therefore, possible to find a relatively small specimen with a large number of costae and vice versa. (3) The length of the palintrope (or its exterior surface, the interarea) depends, in part, on the age and/or size of the individual. Shell material is added to the palintrope in much the same way as to the anterior shell borders, as indicated by growth lines (striations) parallel to the hinge line. (4) In the Arkona shale and Genshaw formation, specimens of Mucrospirifer are relatively consistent in that by far the majority have a relatively well-developed medial ridge in the sulcus and medial groove on the fold. In other stratigraphic units, however, this morphologic feature is quite variable. (5) An examination of the growth lines indicates that all the previously described species of Mucrospirifer are, at least in some stage of their development, mucronate. Some specimens from the Arkona shale appear to lack this feature but, as pointed out by Shimer & Grabau (1902, p. 171) in describing S. mucronatus var. arkonensis, "...individuals of this variety are strongly mucronate; this mucronation becoming obsolete only by the addition of later lamellae in the adult stage." This addition of later lamellae in the adult and gerontic stages tends to decrease the degree of deflection of the anterior border at the cardinal extrem-

ities and to increase shell thickness without appreciably altering the width or length of the specimen. This results in shells better described as acuminate than mucronate. (6) Width/length ratios are of doubtful value since the cardinal extremities (mucronate points) are rarely preserved and the growth lines are traced only with great difficulty, even on well-preserved specimens. At some localities, specimens show a remarkable development of the cardinal extremities. Specimens found in a layer of calcilutite in the lower part of the Gravel Point formation have cardinal extremities which extend beyond the deflection angle a distance equal to that from the midline of the fold to the deflection angle. (7) In general, as the angle made by the plane of commissure (where it turns to follow the edge of the fold) increases, the height of the fold decreases. This angle is quite variable in all populations studied and is, therefore, not a useful criterion for distinguishing between species.

To show the positions of the spiralia in Mucrospirifer mucronatus (Conrad), formerly M. alpenensis (Grabau), specimens were placed in dilute nitric acid to remove the outer shell layers. They were then photographed (text-fig. 2) using transmitted light with the specimens submersed in xylol. These specimens, from the upper part of the Ferron Point formation, are filled with nearly transparent calcite. Apparently the spiralia were selectively replaced by pyrite.

SYSTEMATIC DESCRIPTIONS

FAMILY Spiriferidae

Genus Mucrospirifer Grabau, 1931

Type species.-By original designation, Grabau, 1931, p. 247-48, Delthyris mucronatus Conrad, 1841, p. 54; Middle Devonian Hamilton group,

Skaneateles formation, in Hamilton Township, Madison County, New York.

Mucrospirifer mucronatus (Conrad)

Pl. 1, figs. 1-9; pl. 2, figs. 1, 3-6;
pl. 3, figs. 1-32; pl. 4, figs. 34-38

Delthyris mucronatus Conrad, 1841, p. 54.

Spirifer mucronatus var. arkonensis Shimer & Grabau, 1902, p. 170-71.

Spirifer mucronatus var. attenuatus Grabau in Grabau & Reed, 1910, p. 1-2.

Spirifer mucronatus var. multiplicatus Grabau in Grabau & Reed, 1910, p. 1-2.

Spirifer mucronatus var. attenuatus Grabau in Grabau & Reed, 1912, p. 767-68.

Spirifer mucronatus var. multiplicatus Grabau in Grabau & Reed, 1912, p. 767-68.

Spirifer mucronatus mut. alpenensis Grabau in Mook, 1915, p. 176-77.

Spirifer mucronatus mut. multiplicatus Grabau in Mook, 1915, p. 177-79.

Spirifer mucronatus mut. attenuatus Grabau in Mook, 1915, p. 184-86.

Spirifer mucronatus var. prolificum Stewart, 1927, p. 47-49, pl. IV, figs. 9-14.

Mucrospirifer alpenensis (Grabau), Stumm, 1956, p. 85, pl. I, figs. 13-18.

Mucrospirifer prolificus (Stewart), Stumm, 1956, p. 85-6, pl. I, figs. 1-12.

Mucrospirifer multiplicatus (Grabau), Stumm, 1956, p. 86-7, pl. II, figs. 1-11.

Mucrospirifer attenuatus (Grabau), Stumm, 1956, p. 87, pl. II, figs. 12-15.

Original description.-"Trigonal, compressed, with numerous ribs, crossed by prominent lines; cardinal line extremely elongated and mucronate at the extremities; mesial elevation flattened and divided by a longitudinal sulcus. Width 3 inches; from beak to base three-quarters of an inch." (Conrad, 1841, p. 54).

Revised description.-Very wide, greatest width along hinge line, at least twice length and in many specimens more, exclusive of cardinal extremities; cardinal extremities mucronate to acuminate; in brachial view, posterolateral borders gently to moderately concave anteriorly; lateral and anterolateral borders straight or convex anteriorly; anterior border slightly concave, slightly convex or straight. Surface lateral to fold and sulcus costate, maximum of about 30 costae on each side with a majority of adult specimens having 10 to 15. Measured 5mm anteriorly from the posterior border along the first intercostate furrow and 5mm at right angles to this, costae number 4 to 7 with a majority of specimens having 4.5 to 5.5. Costae and intercostate furrows V-shaped but with rounded apices; becoming progressively narrower and originating further anteriorly towards the cardinal extremities. Entire surface, except palintrope, filate and lamellose (pl. 2, fig. 1). Fila about same size as growth lines with which they form a finely reticulate pattern. Lamellae imbricate, becoming crowded anteriorly in gerontic specimens.

Valves moderately to gently convex in lateral profile with maximum convexity in umbonal region. Surface length of pedicle valve greater than that of brachial valve in most specimens. Anterior profile rhomboidal, exclusive of cardinal extremities. Flanks slightly convex to flat, sloping 5° to 30° away from fold and 7.5° to 37.5° from edge of sulcus. On most specimens flanks slope 10° to 20° away from fold and 15° to 25° from sulcus. Towards extremities slope decreases, giving

these portions of profile a concave appearance. Due to torsion of cardinal extremities, right flank of brachial valve and left flank of pedicle valve are, in some specimens, concave. Line of commissure makes an angle varying from 90° to 150° where it turns to follow edge of fold; most specimens measure 110° to 130°.

Sulcus broadly U-shaped with subangular edges in anterior view; expanding from umbo at about 25°; steep-sided; with flattened floor, except for faint to prominent medial ridge extending on some specimens the entire length of sulcus, on others only a fraction of the length; moderately deep to shallow anteriorly.

Pedicle palintrope length variable, with a maximum of 5mm measured perpendicular to hinge line just lateral to tooth; on most specimens palintrope measures 1.5 to 3mm, gradually shortening towards cardinal extremities; slightly concave, concavity greatest near beak; variably apsacline, inclination from horizontal from 30° to 90°, with a majority of specimens measuring 45° to 75°; posterolateral borders sharp, on most specimens angle of slope 5° to 10° from horizontal (text-fig. 1); striate parallel to hinge line. Beak small, projecting slightly posteriorly, slightly incurved.

Delthyrium triangular, borders straight to slightly concave; apical angle varies from 30° to 120° with a majority of specimens measuring 45° to 90°. Posterior ends of dental plates terminating just inside delthyrial borders forming what appear to be slightly recessed, narrow, triangular plates surmounted by the teeth. Lateral margins of deltidial plates set in against these recessed dental plates.

Deltidial plates (pl. 1, figs. 1-3) conjunct, wide distally, narrowing and flaring out toward apex of delthyrium to form circular to

oval foramen; marked by transverse growth lines parallel to hinge line. Distal edges of deltidial plates, exclusive of lateral margins, terminating against thin plates covering socket traces of brachial valve and curving around posterior end of cardinal process.

Fold of brachial valve originating at umbo and expanding anteriorly at about 20° to 25°; surface gently convex to flat except for faint to prominent medial groove extending on some specimens entire length of fold, on others only a fraction of its length. Beak extremely small, projecting only slightly past adjacent posterior border.

Pedicle interior with small blunt crescentic teeth, each bearing a shallow groove at posterolateral base for reception of anterior notothyrial edge of brachial palintrope, a continuation of this groove at posterior base of tooth for reception of lateral distal edge of deltidial plate (pl. 1, fig. 9) and, on its delthyrial side, a semicircular crural socket for accommodation of distal end of crus. Crural socket terminates a distally broad, shallow groove narrowing toward and originating in pedicle beak. Dental plates prominent to relatively weak; converging at variable angles to about half their length then curving and diverging to floor of valve, also at variable angles; extending about one-quarter to one-half length of muscle field. Umbonal cavities shallow to relatively deep. Dental plates and umbonal cavities becoming obsolete in mature to gerontic specimens due to thickening of floor of valve in umbonal cavities. Thickening extends along whole width of valve at posterior end but decreases laterally. Delthyrial cavity with callus deposits extending to floor of valve; lapping onto dental plates; thinning anterolaterally; in some specimens, with low, short, medial ridge (pl. 1, figs. 7-8) joined on each side by low ridge

diverging toward and merging with dental plate forming groove between itself and dental plate.

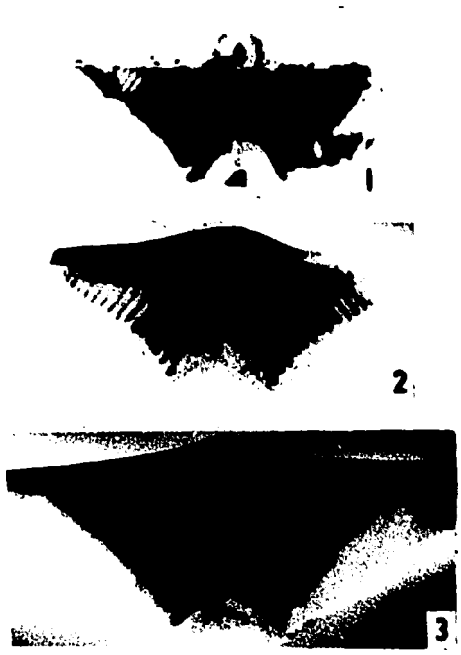
Muscle field of pedicle valve extending to mid valve; heart-shaped with apex directed posteriorly; depressed below level of valve floor posteriorly and laterally, merging with it anteriorly; in some specimens, bounded by a low ridge extending from anterior ends of dental plates. Adductor tracks in medial position, narrow, separated by a more or less prominent myophragm (Cloud, 1942, p. 14) and bounded by a low "lateral" myophragm on each side (pl. 1, fig. 4). Diductor tracks lateral to and curving around anterior end of adductors with additional "lateral" myophragms and numerous ridges radiating from myophragms bounding adductor tracks. Callus deposits of delthyrial cavity encroach upon posterior ends of muscle field, especially onto adductors.

Genital markings (pl. 1, figs. 4-8) covering whole floor of valve, except muscle field; consisting of very fine discontinuous ridges radiating anteriorly and anterolaterally from umbonal cavities and adjacent intersection of palintrope and valve floor; thickening and coalescing posteriorly to give, with increasing maturity, a papillose then pitted appearance.

Brachial interior (pl. 2, figs. 4-6) with short, slightly concave, orthocline palintrope striated parallel to hinge line. Notothyrial edges of palintrope slightly overhang sockets and their traces. Socket traces diverging from beak at about 100° to 110°, expanding anterolaterally and terminating in rounded sockets. Fulcral plates, forming floors of sockets and their traces, extending laterally along anterior edge of palintrope a distance about equal to length of crura; forming triangular depressed surfaces, the anterior edges of which become thick-

ened, in mature specimens, to form strong rims around anterior ends of sockets. Prominent crura forming inner wall of sockets and their traces tilted laterally to overhang them slightly. Cardinal process subquadrate to oval, surface convex except for an anteromedial depression in some specimens; composed of numerous subparallel, longitudinally corrugated plates (pl. 2, fig. 3) which thicken anteriorly. Cardinal process gives way anteriorly to callus deposits extending to floor of valve, diverging, thinning towards and terminating at or near extreme distal edges of crura. In more mature specimens, callus deposits diverging anterolaterally in two distinct branches (pl. 2, fig. 4) and abutting against crura on each side. Posterior branches abut against upper edges of anteromedial portions of crura, anterior branches abut against extreme distal lower edges of crura at which point spiralia are attached. Branching of callus deposits results in formation of two elongate grooves on each side parallel to crura and separated from one another by posterior branch of callus deposits. Posterior groove usually more prominent than anterior.

Spiralia (text-fig. 2) attached to distal lower edges of crura, extending from this point medially, approximately to edge of fold, at which point they turn abruptly and extend anteriorly roughly following edge of fold. At their anterior extremity, spiralia curve towards the pedicle valve and extend posteriorly in an almost medial position to a point almost directly above (pedically) their first deflection; from this point, they again curve and extend anteriorly to a position lateral to their first anterior extension, then curve and extend posteriorly to a position lateral to first deflection. This pattern maintains itself with each whorl decreasing in diameter until spiralia



Text-fig. 2. Spiralia in Mucrospirifer mucronatus (Conrad), formerly M. alpenensis (Grabau). 1-3, brachial, pedicle and pedicle views of hypotypes UMIP 44124, 44125 and 44126 respectively, X2.

terminate near cardinal extremities, in some specimens free, in others against surface of palintrope.

Brachial muscle field composed of at least four distinct tracks (pl. 2, figs. 4-6). Anterior pair occupying medial position, depressed below level of posterior pair, extending outward from low but distinct myophragm, heart-shaped in outline, wide anteriorly, narrowing posteriorly, bounded by very low ridges, especially posteriorly. Each track of posterior pair more or less comma-shaped with "tails" of commas diverging along posterolateral edges of anterior pair, bounded by prominent grooves which result from formation of adductor platform on floor of valve.

Genital markings same as on pedicle valve but generally less prominent.

Occurrence.-Middle Devonian; Silica formation, Lucas County, Ohio; Skaneateles shale, Madison County, New York; Bell shale, Alpena County, Michigan; Ferron Point formation, Alpena County, Michigan; Genshaw formation, Alpena County, Michigan; Norway Point formation, Alpena County, Michigan; Arkona shale, Middlesex County, Ontario.

Illustrated specimens.-Hypotypes UMMP 44089-44111, 44121-22, 44124-27; figured plaster casts UMMP 31536-37.

Remarks.-On many specimens of Mucrospirifer, especially those from the Arkona shale, Ferron Point formation and the Skaneateles shale, the cardinal extremities are twisted by torsion. Most specimens are twisted counterclockwise, some clockwise. The twisting seems to be inherent in the shell rather than the result of compaction by the enclosing sediments. Further study may reveal the exact cause.

The fila are, in most specimens, best preserved along the posterior margins. Spacing is irregular, but there are at least 10 fila per 1 mm. At intersections of fila and growth lines, very small prominences are present on well preserved specimens. Fila have been observed on specimens in all stratigraphic units from which collections were made with the exception of the Skaneateles shale of New York. In this case, however, specimens are not well enough preserved to show such fine surface features.

Layers of new shell material are added to the interior surfaces of each valve much like a pile of saucers of progressively increasing diameter until the gerontic stage is attained. With the beginning of the gerontic stage, additional layers of decreasing diameter are added, resulting in a withdrawal of the viscera from the cardinal extremities, as indicated by growth lines on the interior surfaces of some single valves. This whole process of shell growth and thickening ultimately results in the obsolescence of both the umbonal cavities and the dental plates of the pedicle valve.

The original plates of the cardinal process are formed in the apical region of the brachial umbo. Additional plates are added laterally, their posterior ends arising near the extreme posterior sides of the crura (pl. 2, figs. 2-3).

A few single valves from the lower part of the Silica formation have low broadly rounded crenulations along the hinge edge of the pedicle palintrope and corresponding crenulations on the surface of the brachial palintrope. These probably helped avoid rotation of the valves in the plane of commissure.

M. mucronatus (Conrad) differs from M. thedfordensis (Shimer & Grabau) in having a broadly U-shaped sulcus with flattened floor and subangular edges and a gently convex to flattened fold.

Mucrospirifer thedfordensis (Shimer & Grabau)

Pl. 2, fig. 2; pl. 4, figs. 1-33

Spirifer mucronatus var. thedfordensis Shimer & Grabau, 1902, p. 171.

Spirifer profundus Grabau in Grabau & Reed, 1910, p. 1-2.

Spirifer profundus mut. intermedia Grabau in Grabau & Reed, 1910, p. 2 (non Spirifer intermedius Brongnairt, 1829, p. 429, nec Spirifer intermedia Hall, 1859, p. 424).

Spirifer mucronatus mut. lata Grabau in Grabau & Reed, 1910, p. 2.

Spirifer profundus Grabau in Grabau & Reed, 1912, p. 767-68.

Spirifer profundus mut. intermedia Grabau in Grabau & Reed, 1912, p. 768.

Spirifer mucronatus mut. lata Grabau in Grabau & Reed, 1912, p. 768.

Spirifer mucronatus mut. profundus Grabau in Mook, 1915, p. 179-82.

Mucrospirifer profundus (Grabau), Stumm, 1956, p. 87-8, pl. III, figs. 1-7.

Mucrospirifer grabaui Stumm, 1956, p. 88, pl. III, figs. 8-17.

Mucrospirifer latus (Grabau), Stumm, 1956, p. 89, pl. III, figs. 21-27.

Description.-Wide, greatest width along hinge line, about twice length or greater, exclusive of cardinal extremities; cardinal extremities mucronate to acuminate; in brachial view, posterolateral borders moderately to strongly concave anteriorly; lateral and anterolateral borders straight or convex anteriorly; anterior border in most specimens concave or V-shaped, in others straight. Surface lateral to fold and

sulcus costate, maximum of about 15 costae on each side with a majority of specimens having 9 to 11. Measured 5 mm anteriorly from posterior border along first intercostate furrow and 5 mm at right angles to this, costae number 4 to 5.5 with a majority of specimens having 4.5 to 5. Costae and intercostate furrows V-shaped but with rounded apices becoming progressively narrower and originating further anteriorly towards cardinal extremities. Entire surface, except palintrope, filate and lamellose. Fila about same size as growth lines with which they form a finely reticulate pattern. Lamellae imbricate, becoming crowded anteriorly in gerontic specimens.

Both valves moderately convex in lateral profile with maximum convexity in umbonal region. Surface length of pedicle valve greater than that of brachial valve. Anterior profile rhomboidal, exclusive of cardinal extremities; flanks slightly convex to flat, sloping 10° to 27.5° away from fold and 15° to 32.5° away from edge of sulcus. On most specimens, flanks slope 17.5° to 25° from fold and 20° to 25° from sulcus. Towards extremities slope flattens giving those portions of profile a concave appearance. Line of commissure makes an angle of 95° to 135° where it turns to follow edge of fold, on a majority of specimens this angle measures 110° to 125°.

Sulcus U-shaped to V-shaped, never with flattened floor; deep; expanding from umbo at about 20° to 25°; with medial ridge originating in umbonal region well developed in a few specimens, weakly developed in others and absent in a majority of specimens.

Palintrope length variable, with a maximum length of 4 mm measured on a line perpendicular to hinge line just lateral to tooth; on most specimens, palintrope measures from 1.5 to 2.5 mm gradually shortening

towards cardinal extremities; slightly concave, concavity greatest near beak; variably apsacline, inclination from horizontal from 30° to 80° with a majority of specimens measuring 40° to 70°; posterolateral borders sharp, sloping up to 15° from horizontal but in most specimens sloping less than 10°; striated parallel to hinge line. Beak small, projecting slightly posteriorly, slightly incurved.

Delthyrium triangular, borders straight to slightly concave; apical angle varies from 45° to 120° with a majority of specimens measuring 60° to 90°. Posterior ends of dental plates terminating just inside delthyrial borders forming what appear to be slightly recessed, narrow, triangular plates surmounted by the teeth. Lateral margins of deltidial plates set in against these recessed dental plates. Deltidial plates observed but only fragmentally preserved.

Fold of brachial valve originating at umbo and expanding anteriorly at about 20° to 25°; relatively low; surface moderately convex; medial groove originating umbonally, well developed in a few specimens, weakly developed in others and absent in a majority. Beak extremely small and projecting only slightly past adjacent posterior border.

Pedicle interior with small, blunt, crescentic teeth, each bearing a shallow groove at posterolateral base for reception of anterior notothyrial edge of brachial palintrope, a continuation of this groove at posterior base of tooth for reception of lateral distal edges of deltidial plates and, on its delthyrial side, a semi-circular crural socket for accommodation of distal end of crus. Crural socket terminates a distally broad, shallow groove narrowing toward and originating in pedicle beak. Dental plates weak to moderately prominent, converging from tooth to half their length at variable angles then curving and

diverging to floor of valve, also at variable angles. Extending one-quarter to one-half length of muscle field. Umbonal cavities shallow to moderately deep. Delthyrial cavity with callus deposits extending to floor of valve; lapping onto dental plates; thinning anterolaterally; in many specimens, with low, short, medial ridge or knob joined on each side by a low ridge diverging toward and merging with dental plate, forming groove between itself and dental plate.

Muscle field of pedicle valve extending to about midvalve, heart-shaped in outline, depressed below level of valve floor posteriorly and laterally, merging with it anteriorly. Adductor tracks medial in position, narrow, generally separated by more or less prominent myophragm and bounded by low "lateral" myophragm on each side. Diductor tracks lateral to and curving around anterior end of adductors with additional "lateral" myophragms and numerous ridges radiating from myophragms bounding adductor tracks.

Genital markings covering whole valve floor except muscle field, consisting of very fine discontinuous ridges radiating anteriorly and anterolaterally from umbonal cavities and adjacent intersection of palintrope and valve floor, and thickening and coalescing posteriorly to change, with increasing maturity, from a papillose to a pitted appearance.

Brachial interior with short, concave, orthocline palintrope, striated parallel to hinge line. Notothyrial edges of palintrope overhang sockets and their traces. Socket traces diverging from beak at about 100° to 110°, expanding anterolaterally and terminating in rounded sockets. Fulcral plates forming floors of sockets and their traces, extending laterally along anterior edge of palintrope a distance about

equal to length of crura; forming triangular depressed surfaces, the anterior edges of which become thickened in mature specimens to form strong rims around anterior ends of sockets. Small triangular plates, against which deltidial plates rest, covering posterior two-thirds of socket traces and slightly depressed below surface of palintrope (pl. 2, fig. 2). Prominent crura forming inner wall of sockets and their traces, tilted laterally to overhang them slightly. Cardinal process subquadrate to oval, surface convex; composed of numerous, subparallel, longitudinally corrugated plates which thicken anteriorly. Cardinal process gives way anteriorly to callus deposits extending to floor of valve, diverging, thinning towards and terminating at or near extreme distal edges of crura, at which point spiralia are attached.

Brachial muscle field composed of at least four distinct tracks. Anterior pair occupying median position, depressed below level of posterior pair, extending outward from low but distinct myophragm, oval to heart-shaped in outline. Each track of posterior pair convex posterolaterally and curving around posterolateral borders of anterior pair.

Genital markings same as in pedicle valve but generally less prominent.

Occurrence.-Middle Devonian, Alpena limestone, Alpena County, Michigan; Norway Point formation, Alpena County, Michigan; Potter Farm formation, Alpena County, Michigan; Gravel Point formation, Charlevoix County, Michigan; lower part of the Petoskey formation, Emmet County, Michigan; Widder formation, Lambton County, Ontario.

Illustrated specimens.-Hypotypes UMMP 44112-44120.

Remarks.-M. thedfordensis (Shimer & Grabau) differs from M. mucronatus (Conrad) in having a U-shaped to V-shaped sulcus, never with a

flattened floor; a low moderately convex fold, never with flattened surface.

Specimens from the Norway Point and Potter Farm formations, formerly referred to M. profundus (Grabau), are nearly identical to immature specimens of M. thedfordensis (Shimer & Grabau) from the Widder formation of Ontario (pl. 4, figs. 21-32).

Mucrospirifer norwoodensis, n. sp.

Pl. 4, figs. 39-44

Description.-Wide, greatest width along hinge line, about one-third greater than length, exclusive of cardinal extremities; cardinal extremities mucronate; in brachial view, posterolateral borders moderately to strongly concave anteriorly, as indicated by growth lines; lateral and anterolateral borders broadly convex; anterior border straight or slightly concave. Surface lateral to fold and sulcus costate, maximum of about 13 on each side with a majority of specimens having about 9. Measured 5 mm anteriorly from posterior border along first intercostate furrow and 5 mm at right angles to this, costae number 4 to 6.5 with a majority of specimens having 6. Costae and intercostate furrows V-shaped but with rounded apices. Entire surface except palintrope, filate and lamellose. Fila about same size as growth lines with which they form a finely reticulate pattern (pl. 4, fig. 44). Lamellae becoming crowded anteriorly in gerontic specimens.

Both valves moderately convex in lateral profile with greatest convexity in umbonal region. Surface length of pedicle valve greater than that of brachial valve. Anterior profile rhomboidal, exclusive of cardinal extremities; flanks flat to slightly convex, sloping 17.5° to

30° from fold and 32.5° to 47.5° from sulcus. Line of commissure makes an angle of about 100° to 120° where it turns to follow edge of fold.

Sulcus broadly U-shaped with subangular edges, in anterior view; expanding from umbo at about 20° to 25°; steep-sided; with flattened or slightly concave floor; no medial ridge observed; relatively deep anteriorly.

Palintrope relatively long, with a maximum length of 2.5 mm measured on a line perpendicular to hinge line just lateral to tooth; on a majority of specimens, palintrope measures about 2 mm gradually shortening toward cardinal extremities; concave, concavity greatest near beak; variably apsacline, inclination from horizontal varying from 45° to 70° with a majority of specimens measuring 55° to 60°; posterolateral borders sharp, sloping 7.5° to 17.5° from horizontal; striated parallel to hinge line. Beak relatively more prominent than in other species of Mucrospirifer, projecting posteriorly, moderately incurved.

Delthyrium triangular, borders straight to slightly concave; apical angle varies from 45° to 60°. Posterior ends of dental plates terminate just inside delthyrial borders forming what appear to be slightly recessed, narrow, triangular plates surmounted by the teeth. Deltidial plates not observed but presumed to have been present.

Fold of brachial valve originating at umbo and expanding anteriorly at about 20° to 25°, relatively high anteriorly, surface flat to convex, no medial groove observed. Beak extremely small, projecting only slightly past adjacent posterior border.

A sectioned specimen shows the presence of a cardinal process and relatively strong dental plates, interior otherwise unknown.

Occurrence.-Middle Devonian, upper part of the Petoskey formation, Charlevoix County, Michigan.

Type.-Holotype UMMP 44123.

Remarks.-This species differs from M. thedfordensis (Shimer & Grabau) in having, in anterior view, a broadly U-shaped sulcus with subangular borders and a relatively high fold with flattened surface and subangular edges. Exclusive of the cardinal extremities, it is, relative to length, narrower than M. thedfordensis (Shimer & Grabau) and much narrower than M. mucronatus (Conrad). The outline of the shell in brachial or pedicle view is more rhomboidal and the pedicle beak is much more prominent than in either of those two species.

M. norwoodensis, n. sp., most closely resembles M. consobrinus (d'Orbigny). It differs in being smaller, having more costae per unit of measurement, a shorter palintrope and in lacking a plication on the fold and in the sulcus. The collection includes only 18 specimens and most of these are rather poorly preserved. Because the above mentioned characteristics have proven quite variable in other species, it may be found that these two species must be merged, when larger collections become available and more localities are represented.

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PLATES AND EXPLANATIONS OF

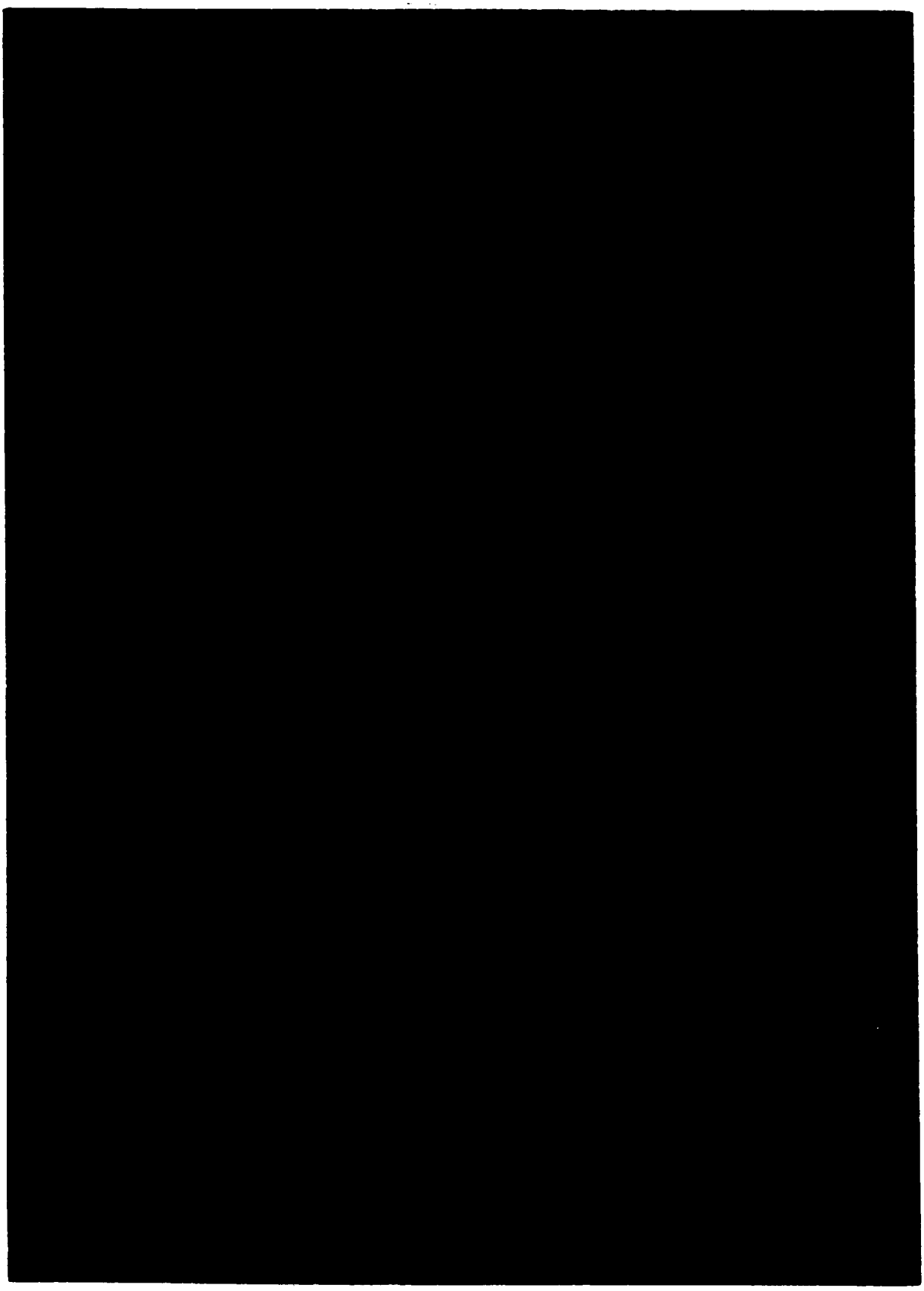
PLATES 1-4

Explanation of Plate 1

Figs. 1-3. Mucrospirifer mucronatus (Conrad) formerly M. alpenensis (Grabau). 1, posterior view of hypotype UMMP 44089 showing deltidial plates broken parallel to borders of delthyrium, X10. 2, posterior view of hypotype UMMP 44090 showing nature of pedicle foramen; central portions of deltidial plates missing, X10. 3, posterior view of hypotype UMMP 44091 showing complete deltidial plates on an immature specimen, X10. Ferron Point formation, upper part, Alpena County, Michigan, Loc. 51.

Figs. 4-9. Mucrospirifer mucronatus (Conrad) formerly M. prolificus (Stewart). 4, view of interior of pedicle valve, hypotype UMMP 44092, showing nature of muscle tracks and genital markings, X2.5. 5, view of interior of pedicle valve, hypotype UMMP 44093, X2.5. 6, view of interior of pedicle valve, hypotype UMMP 44094, X2.5. 7, view of interior of pedicle valve, hypotype UMMP 44095, showing nature of callus deposits in delthyrial cavity, X2.5. Silica formation, lower part, Lucas County, Ohio, Loc. B. 8, view of interior of pedicle valve, hypotype UMMP 44096, showing muscle tracks, genital markings and callus deposits in delthyrial cavity, X2.5. Bell shale, Alpena County, Michigan, Loc. 38. 9, posterior view of pedicle valve, hypotype UMMP 44097, showing grooves parallel to border of delthyrium for reception of deltidial plates and grooves at posterior base of teeth for reception of lateral distal edges of deltidial plates, X2.5. Silica formation, lower part, Lucas County, Ohio, Loc. B.

Plate 1



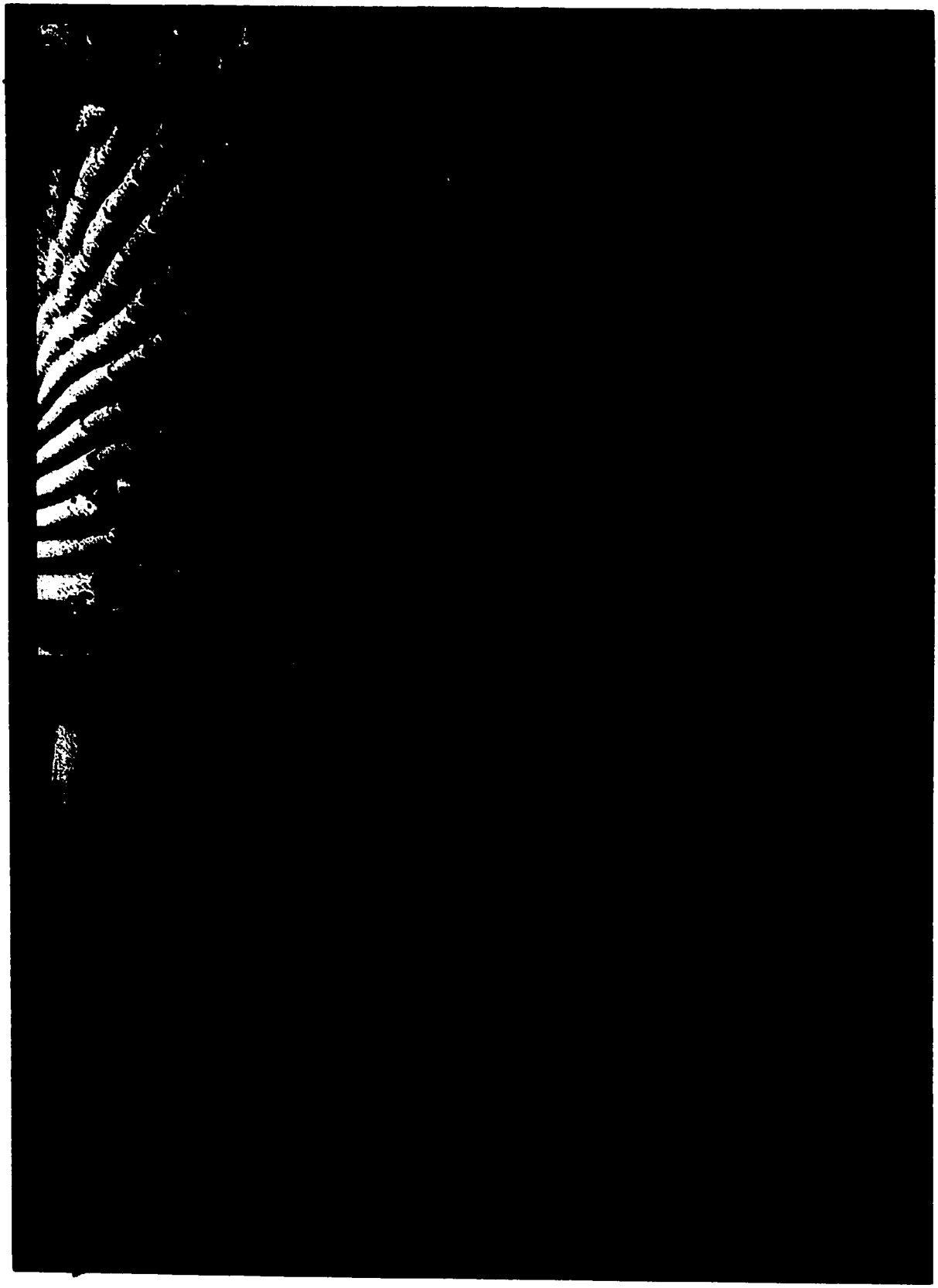
Explanation of Plate 2

Fig. 1. Mucrospirifer mucronatus (Conrad) formerly M. alpenensis (Grabau). View of portion of surface of pedicle valve, hypotype UMMP 44098, showing lamellae, growth lines and fila, X10. Ferron Point formation, upper part, Alpena County, Michigan, Loc. 51.

Fig. 2. Mucrospirifer thedfordensis (Shimer & Grabau) formerly M. latus (Grabau). View of interior of brachial valve, hypotype UMMP 44099, showing nature of cardinal process, muscle tracks and plates covering posterior portions of socket grooves, X10. Norway Point formation, Alpena County, Michigan, Loc. 47.

Figs. 3-6. Mucrospirifer mucronatus (Conrad) formerly M. prolificus (Stewart). 3, view of interior of brachial valve, hypotype UMMP 44100, showing corrugated plates of cardinal process, X20. 4, view of interior of brachial valve, hypotype UMMP 44101, showing nature of cardinal process, callus deposits anterior to cardinal process, muscle tracks and genital markings, X2.5. 5, view of interior of brachial valve, hypotype UMMP 44102, X2.5. 6, view of interior of brachial valve, hypotype UMMP 44103, X2.5. Silica formation, lower part, Lucas County, Ohio, Loc. B.

Plate 2



Explanation of Plate 3
All figures X1

Figs. 1-6, 25-26. Mucrospirifer mucronatus (Conrad) formerly M. prolificus (Stewart). 1-3, 25, brachial, pedicle, anterior and posterior views of hypotype UMMP 44104. Note faint groove in fold in fig. 25. Silica formation, lower part, Lucas County, Ohio, Loc. A. 4-6, 26, brachial, pedicle, anterior and posterior views of hypotype UMMP 44105. Note faint groove in fold in fig. 4. Bell shale, Alpena County, Michigan, Loc. 38.

Figs. 7-12, 27-28. Mucrospirifer mucronatus (Conrad) formerly M. alpenensis (Grabau). 7-9, 27, brachial, pedicle, anterior and posterior views of hypotype UMMP 44106. Ferron Point formation, lower part, Alpena County, Michigan, Loc. 38. 10-12, 28, brachial, pedicle, anterior and posterior views of hypotype UMMP 44107. Ferron Point formation, upper part, Alpena County, Michigan, Loc. 51.

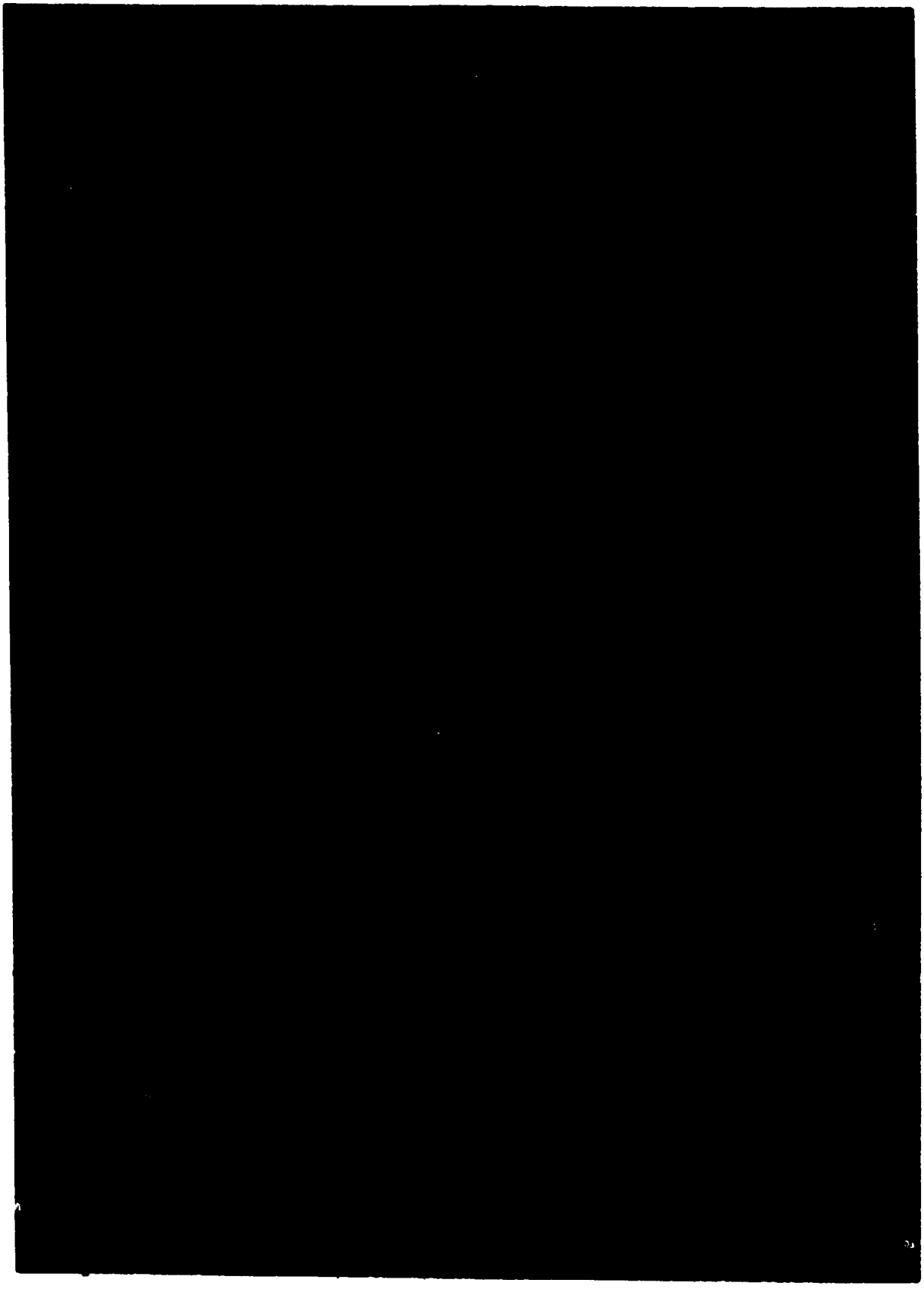
Figs. 13-15, 29. Mucrospirifer mucronatus (Conrad) formerly M. arkonensis (Shimer & Grabau). Brachial, pedicle, anterior and posterior views of hypotype UMMP 44108. Arkona shale, Middlesex County, Ontario, Loc. C.

Figs. 16-18, 30. Mucrospirifer mucronatus (Conrad). Brachial, pedicle, anterior and posterior views of hypotype UMMP 44109. Note groove in fold and ridge in sulcus. Silica formation, upper part, Lucas County, Ohio, Loc. A.

Figs. 19-21, 31. Mucrospirifer mucronatus (Conrad) formerly M. multiplicatus (Grabau). Brachial, pedicle, anterior and posterior views of hypotype UMMP 44110. Genshaw formation, lower part, Alpena County, Michigan, Loc. 58.

Figs. 22-24, 32. Mucrospirifer mucronatus (Conrad) formerly M. attenuatus (Grabau). Brachial, pedicle, anterior and posterior views of hypotype UMMP 44111. Norway Point formation, Alpena County, Michigan, Loc. 47.

Plate 3



Explanation of Plate 4
Fig. 44, X10; all others X1

Figs. 1-4, 9-16. Mucrospirifer thedfordensis (Shimer & Grabau) formerly M. latus (Grabau). 1-4, brachial, pedicle, anterior and posterior views of hypotype UMMP 44112. Alpena limestone, Alpena County, Michigan, Loc. 40. 9-12, brachial, pedicle, anterior and posterior views of hypotype UMMP 44114. Norway Point formation, Alpena County, Michigan, Loc. 47. 13-16, brachial, pedicle, anterior and posterior views of hypotype UMMP 44115. Potter Farm formation, Alpena County, Michigan, Loc. 90.

Figs. 5-8, 21-24, 33. Mucrospirifer thedfordensis (Shimer & Grabau). 5-8, brachial, pedicle, anterior and posterior views of hypotype UMMP 44113. 21-24, brachial, pedicle, anterior and posterior views of hypotype UMMP 44117. An immature specimen. 33, brachial view of hypotype UMMP 44120 showing development of faint groove on fold. A corresponding ridge is present in the sulcus of this specimen. Widder formation, Lambton County, Ontario, Loc. D.

Figs. 17-20. Mucrospirifer thedfordensis (Shimer & Grabau) formerly M. grabaui Stumm. Brachial, pedicle, anterior and posterior views of hypotype UMMP 44116. Petoskey formation, lower part, Emmet County, Michigan, Loc. 21.

Figs. 25-32. Mucrospirifer thedfordensis (Shimer & Grabau) formerly M. profundus (Grabau). 25-28, brachial, pedicle, anterior and posterior views of hypotype UMMP 44118. Norway Point formation, Alpena County, Michigan, Loc. 47. 29-32, brachial, pedicle, anterior and posterior views of hypotype UMMP 44119. Potter Farm formation, Alpena County, Michigan, Loc. 90.

Fig. 34. Mucrospirifer mucronatus (Conrad) formerly M. alpenensis (Grabau). View of brachial valve of hypotype UMMP 44121 showing development of groove in fold. A corresponding ridge is present in the sulcus of this specimen. Ferron Point formation, upper part, Alpena County, Michigan, Loc. 51.

Figs. 35-37. Mucrospirifer mucronatus (Conrad). 35, view of brachial valve, hypotype UMMP 44176. 36-37, views of brachial and pedicle valves of catalogued plaster casts, UMMP 31536 and 31537. These are plaster casts of specimens housed in the U. S. National Museum. Skaneateles shale, Colgate member, Madison County, New York, Loc. F.

Fig. 38. Mucrospirifer mucronatus (Conrad) formerly M. arkonensis (Shimer & Grabau). View of brachial valve of hypotype UMMP 44122. Arkona shale, Middlesex County, Ontario, Loc. E. Compare with figs. 34-37.

Figs. 39-44. Mucrospirifer norwoodensis, n. sp. 39-43, brachial, pedicle, posterior, anterior and lateral views of holotype UMMP 44123. 44, view of a portion of the surface of the pedicle valve of holotype UMMP 44123 showing growth lamellae, growth lines and fila. Petoskey formation, upper part, Charlevoix County, Michigan, Loc. 7b. Compare with pl. 2, fig. 1.

Plate 4

