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TWO NEW GENERA OF STRICKLANDID BRACHIOPODS

BY

A. J. BOUCOT and G. M. EHLERS

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TWO NEW GENERA OF STRICKLANDID BRACHIOPODS

BY
A. J. BOUCOT[1] and G. M. EHLERS[2]

CONTENTS

INTRODUCTION

THE NEW GENERA described in this paper provide information that contribute materially to the phylogeny of stricklandid brachiopods. Phylogenetic stages of these and other genera, as shown in subsequent pages, suggest significant correlations of certain strata of North America and other regions with divisions of the type Silurian section of England.

The authors thank the people and institutions who have assisted them. Mr. Alfred Ziegler, Oxford University, communicated very helpful information bearing on the internal structures of some stricklandids and the stratigraphic occurrence of others. Mrs. J. S. Stevenson, Curator of Geology, Redpath Museum, McGill University, lent the types of *"Stricklandia" billingsiana* Dawson. Dr. T. E. Bolton, Geological Survey of Canada, gave very helpful information bearing on the description of *"Stricklandia" billingsiana* Dawson. The State University of Iowa made available for study and illustration a specimen of *Stricklandia multilirata* Whitfield. Dr. G. Arthur Cooper, Head Curator, Department of Geology, Smithsonian Institution, sent the types of *Stricklandia planus* Foerste for comparison with other stricklandids. Drs. C. A. Arnold, L. B. Kellum, and R. V. Kesling critically read the manuscript. Mr. Karoly Kutasi of The University of Michigan, Museum of Paleontology assisted with the photography. Mrs. Helen Mysyk of this museum did the typing.

Specimens illustrated in this paper are distributed among three institutions, The University of Michigan Museum of Paleontology, the California Institute of Technology, and The State University of Iowa.

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PREVIOUS WORK

Alwyn Williams (1951, pp. 87–88) was the first to demonstrate the phylogenetic conclusions to be drawn from the Llandoverian unplicated stricklandids of the *Stricklandia lens* type and to point out the possibilities inherent in the phylogenetic scheme for inter-regional correlation. Williams' study was based almost exclusively on British material, but Boucot has since been able to establish the utility of this work on unpublished material from the Appalachians, chiefly the Northern Appalachians in Quebec and the Southern Appalachians in Alabama, ranging in age from about C_1 through C_5. Williams restricted himself to the developmental significance of changes in the brachial plates, although commenting (1951, p. 98) that the smooth *S. lens* stock probably gave rise to the costellate *Costistricklandia lirata* stock (see Pl. 5, Figs. 11–12). The studies of Alwyn Williams (1951, pp. 86–88) and T. W. Amsden (1953, p. 144) indicate that there is a transition from the poorly plicate *S. lens ultima* present in beds of C_4–C_5 age to the abundantly plicate types present in strata of C_6 and early Wenlock age. (*C. lirata* pars of Davidson 1867, including Pl. XX, Figs. 1–2, 7, 8, but excluding Pl. XX, Figs. 3–6; *C. gaspiensis*; *C. Brevis*; and *C. canadensis*). See Figure 1. All of these aforementioned shells possess a relatively large septum and spondylium in the pedicle valve, relatively large cardinalia in the brachial valve, and relatively short interareas in both valves.

It is of some interest to note that Nikiforova (*in* Sarycheva, 1960, Pl. XXI, Figs. 14–15) reports that beds from Novaya Zemlya correlated with the Wenlock contain abundantly costellate stricklandids of the *C. lirata* type, as well as moderately costellate shells of the *C. brevis* type. Unfortunately, little information is available regarding the associated fauna or basis for correlating the Novaya Zemlya occurrences with the standard succession.

Large stricklandids of the *Stricklandia lens* and *Costistricklandia lirata* types have not been recognized in North America west of the Appalachian Mountains or the Niagara Peninsula of eastern Ontario. In the mid-continent region both smooth and costate stricklandids of different type are present in strata of about C_4 to early Wenlock age. These mid-continent shells are characterized by never reaching more than about one-third the maximum dimensions achieved by either *Stricklandia* or *Costistricklandia,* and in having relatively much smaller internal structures in both valves than are present in similar sized shells of either *Stricklandia* or *Costistricklandia.* The costate mid-continent shells are assigned to the new genus *Plicostricklandia* and the smooth ones to the new genus *Microcardinalia.* Species of *Plicostricklandia* have been found only in strata younger than those containing *Microcardinalia*

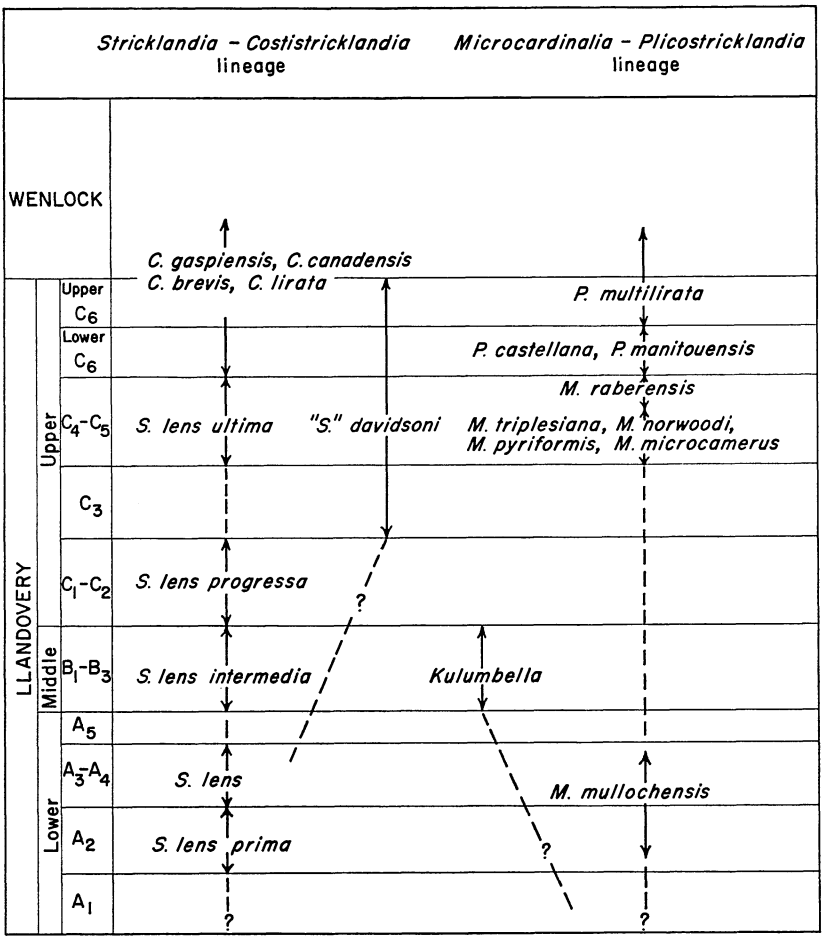

FIG. 1. Stratigraphic distribution of the Stricklandidae.

in much the same manner as the relationship found to exist between the species of *Stricklandia* and *Costistricklandia*. Species of *Microcardinalia* have been recognized in the Appalachians and in Great Britain.

The stratigraphic and phylogenetic relations of the generically assignable stricklandids are shown in Figure 1. The ancestry of the Stricklandidae is presently uncertain, but it is clear that the group was well differentiated by Early Llandovery time. In this connection it is of interest to realize that both the Virgianidae and Pentameridae have well-developed representatives in strata of Ashgillian age.

Nikiforova's genus *Kulumbella* (1960, pp. 61–65) is more closely related to *Microcardinalia* than to *Stricklandia,* as indicated by the presence in *Kulumbella* of relatively small cardinalia, small spondylium, and broad interareas. As pointed out by Nikiforova (1960, p. 62) the unique ornamentation of *Kulumbella* has much in common with that of both "*Stricklandia*" *davidsoni* Billings (1868, pp. 59–61; 1874, pp. 86–87) and "*Stricklandia*" *davidsoni* var. *striata* Twenhofel (1928, p. 202), but the relatively short interareas of the Late Llandovery forms from Anticosti suggest closer affinities with *Stricklandia* than with *Microcardinalia* although our almost complete ignorance of the Anticosti shells precludes certainty about their affinities. It is possible that "*S.*" *davidsoni* is a parallel development of the *Kulumbella* type of ornamentation at a later date, that is, Late rather than Middle Llandovery in the parallel *Stricklandia-Costistricklandia* lineage.

The external form of "*S.*" *melissa* Billings (1874, p. 89, Pl. 7, Fig. 4, 4*a–b*) is somewhat like that of *Microcardinalia* but lack of information regarding the internal structures makes generic assignment impossible, as is the case also with "*S.*" *salteri* Billings (1868 pp. 61–62, Pl. 4, Figs. 2, 2a; 1874, pp. 87–89, Pl. 7, Fig. 1) from Anticosti. "*C.*" *lirata* var. *diota* Lamont and Gilbert (1945, pp. 654–55, Pl. 4, Fig. 6, Text-fig. 4) is also suggestive as figured of a costellate species of *Microcardinalia* with a wide hinge line, but lack of knowledge of its internal structures prevents generic assignment and Alfred Ziegler (written communication, 1962) reports, "... *lirata diota* Lamont is within the normal range of variation of *lirata* as some 'eared' forms have turned up in a big collection that I have been preparing. ..." "*C.*" *lirata* var. *pacheia* Lamont and Gilbert (1945, p. 655; also illustrated in Lamont 1946, Pl. II, Fig. 2) is generically unassignable because the character of its interarea and internal structures is unknown. "*S.*" "*lirata*" var. *scotica* Reed probably belongs to *Stricklandia* as suggested by the presence of a very short interarea (Reed, 1917, p. 932, Pl. 23, Figs. 1–4); its "radial plications" appear to be weak, like those found intermittently throughout the *S. lens* lineage. Perhaps the interior of *S.* "*lirata*" *scotica* when investigated will be found to be similar to that of *S. lens progressa,* as might be expected from the stratigraphic position of the Scottish shell.

Amsden (1953, pp. 143–44) erected the genus *Costistricklandia,* based on "*S.*" *gaspiensis,* for abundantly costellate stricklandids. With the new information now showing the transition at the specific level from smooth or poorly costellate stricklandids into abundantly costellate in two stocks, the *Stricklandia-Costistricklandia* lineage and the *Microcardinalia-Plicostricklandia* lineage, it appears confusing to employ a generic concept based on presence of abundant radial ornamentation, which cuts directly across sev-

eral lineages. When setting up *Costistricklandia,* Amsden (*ibid.*) pointed out the parallel of the possible relationship in presence of smooth and costate forms between *Stricklandia* and *Costistricklandia* on the one hand with *Pentamerus* and *Conchidium* (*Rhipidium* would have been a better example, because *Conchidium* is best compared with *Harpidium* in this regard) on the other hand. In the case of the pentamerinids, however, we as yet have no positive information regarding the hypothetical transitional forms between smooth and costate shells, and are still not in a position to predict whether smooth forms gave rise to costate forms or vice versa.

This being the case we judge it advisable to revise the concept of *Costistricklandia* to include only those costate stricklandids otherwise similar to *Stricklandia.* The relationship of the new plicate genus *Plicostricklandia* to the new smooth genus *Microcardinalia* is analogous.

SYSTEMATIC DESCRIPTIONS

Phylum BRACHIOPODA
Superfamily Pentameracea
Family Stricklandidae

Microcardinalia Boucot and Ehlers, gen. nov.

Type species.— ——— *triplesiana* Foerste, 1885, p. 89, Pl. 14, Figs. 13–14; *Stricklandia triplesiana* Foerste, 1890, p. 323 and 1893, p. 594, Pl. 26, Figs. 13–14.

Diagnosis.—Microcardinalia is characterized externally in large part by the possession of a smooth shell (it may bear sparse, broad costae), subpentagonal outline, and relatively long apsacline interarea in the pedicle valve together with an apsacline interarea in the brachial valve. Internally the pedicle valve is characterized by a relatively small spondylium and very short median septum, and the brachial valve by small cardinalia consisting of brachial processes and inner plates, and strongly impressed, elongate, separate adductor impressions. Outer plates are unknown in the Late Llandovery species of this genus.

Comparison.—Stricklandia possesses internal structures which are relatively two or three times larger than those present in *Microcardinalia.* Furthermore, *Microcardinalia* possesses a relatively pentagonal or pyriform outline as opposed to the subcircular or elliptical outline present in *Stricklandia.* The interareas of both valves are relatively much wider in *Microcardinalia* than in *Stricklandia. Microcardinalia* is relatively smooth as contrasted with the abundantly costate genera *Costistricklandia* and *Plicostricklandia. Microcardinalia* never reaches more than a third the maximum size of *Stricklandia.*

Species Assigned

Pentamerus microcamerus M'Coy, 1851, pp. 390–91; 1855, p. 210.
Stricklandia mullochensis Reed, 1917, pp. 932–33, Pl. XXIII, Figs. 5–8.
Stricklandia norwoodi Foerste, 1906, pp. 324–26, Pl. 1, Figs. 1*a–d*.
Stricklandia pyriformis Savage, 1916, pp. 317–19, Pl. 16, Figs. 6–9.
Microcardinalia raberensis, sp. nov.
Stricklandia triplesiana Foerste, 1885, p. 89, Pl. 14, Figs. 13*a–b*, 14.

Foerste's (1890, p. 324) species *Stricklandinia lens* var. *planus* from the "Clinton group" of Collinsville, Alabama, subsequently designated *S. planus* by Foerste (1893, explanation Pl. 30, Figs. 1, 2, 2*a*, 3 and 4), probably should be assigned to *Microcardinalia triplesiana*, inasmuch as Boucot has found numerous specimens of *M. triplesiana* from the Red Mountain formation of Alabama which appear to be identical to Foerste's Alabama material.

Species Rejected

Stricklandinia billingsiana Dawson, 1881, p. 341 and faunal list 336; listed, apparently through error as *S. billingsi*, p. 335.

Through the courtesy of Mrs. J. S. Stevenson, Curator of Geology, Redpath Museum, McGill University, we have been enabled to borrow the type lot of Dawson's species "*Stricklandinia*" *billingsiana*. Although the types were never figured, "*S.*" *billingsi* has been customarily included in listings of species assigned to *Stricklandia*. McLearn (1924), pp. 89–90) was the first to recognize that "*S.*" *billingsiana* belonged to *Meristina*. The type lot consists of two specimens including a pedicle valve of *Meristina* (Redpath Museum No. 1431 with old number "48") and a complete steinkern of *Meristina* (Redpath Museum No. 1431*a* with old number "48"). The complete steinkern bears a red star and is presumably the holotype. The presence of a cruralium supported by a long median septum in the brachial valve, which has a well-developed fold, and of short dental lamellae together with the typical trapezoidal muscle field in the pedicle valve, which has a well-developed sulcus, leaves no doubt about the generic identity of "*S.*" *billingsiana*. It is probable that Dawson confused the internal structures of the brachial valve with the spondylose interior of *Stricklandia*. An additional specimen (Redpath Museum No. 1434) labeled "*Stricklandia*? sp." is actually a brachial valve of a coarsely costellate *Atrypa "reticularis."*

It is of interest that Dawson's faunal list includes the only cited pentameroids from the Silurian rocks of Pictou or Antigonish Counties, Nova Scotia, and also includes a citation of *Rensselaeria* which, if correctly identified, would be the only known Silurian terebratuloid in the world. The specimen (Redpath Museum No. 1469) labelled *Rensselaeria aequiradiata* from East River is actually an impression of a linguloid brachiopod possess-

ing prominent radial ornamentation. In the same collection are three specimens (Redpath Museum Nos. 1473, 10,048, 10,049) labelled "*Pentamerus*" from East River, two of which (Nos. 10,048 and 10,049) are brachial valves of *Meristina billingsi* and the other which consists of two pedicle valves of *M. billingsi.* The fossils are preserved as casts and molds in sedimentary iron ore containing a number of angular, well-sorted quartz grains together with *Cornulites* sp. and *Leptaena "rhomboidalis."* The locality given on the label is merely "East River," but in the paper both "Webster and Blanchard locations" are cited. It is probable that the species comes from one of the iron ore beds in the Kerrowgare formation. *Meristina billingsi* is probably specifically identical with the form found in the iron-ore bed from the lower part of the McAdams formation on Arisaig Brook, Antigonish Co.

Microcardinalia raberensis Boucot and Ehlers, sp. nov.

(Pl. II, Figs. 1–8; Pl. III, Figs. 1–2,11–13)

Exterior.—The valves are subequally biconvex with the brachial valve being about half the depth of the evenly convex pedicle valve. Both valves are subpentagonal in outline, the posterior straight hinge line joining the relatively straight, anterolaterally directed posterior halves of the lateral margins which are sharply inflected anteriorly into the gently curved anterior and anterolateral margins. The interarea of the pedicle valve is strongly apsacline, concave, and relatively long. The interarea of the brachial valve is also strongly apsacline, planar, and relatively long. The interarea of the brachial valve is peculiar in that it is depressed below the posterolateral margins of the valve as opposed to the condition normal to most brachiopods in which the anterior margin of the interarea is at the level of the posterolateral margins. The position of maximum width is about midlength of shell. The anterior commissure is rectimarginate. The shells are smooth to weakly costate, mimicking the condition present in the parallel stock in *S. lent ultima.* The delthyrium and notothyrium appear to be unmodified. Concentric growth lines are not prominent except on the interareas of both valves, which are noticeably striate.

Interior of pedicle valve.—A relatively small spondylium is present supported by a very short median septum. The median septum is present only in the posterior part of the delthyrial cavity leaving the anterior two-thirds of the spondylium free. The hinge teeth are relatively small and situated at the anterior corners of the delthyrium, adjacent to the interarea.

Interior of brachial valve.—The cardinalia consist of rodlike brachial processes cemented basally to the floor of the valve and laterally bounded by a pair of flaring inner plates. The inner plates medially bound very

narrow, posteriorly convergent dental sockets. Outer plates are absent as in *S. lens ultima*. The paired adductor impressions are longitudinally elongate, medially bisected by a low myophragm, and situated somewhat anterior to the cardinalia. The adductor impressions are deeply impressed into a heavy deposit of secondary material present in the posterior portion of the valve.

Distribution.—*M. raberensis* is known only from the lower part of the Cordell dolomite of the Manistique group of Michigan.

Remarks.—The degree of external costation and the type of cardinalia are remarkably parallel to the condition found in *S. lens ultima*. However, the pyriform shape of *M. raberensis* combined with the relatively small size of its cardinalia and spondylium clearly separate it from this species. The older species of *Microcardinalia* including *M. triplesiana, M. mullochensis, M. norwoodi, M. pyriformis,* and *M. microcamerus* are non-costate.

The lower part of the Cordell dolomite is inferred to be of C_4–C_5 age because of the evolutionary stage of *M. raberensis,* and the upper part of the Cordell to be of C_6 age because of the stage of *Plicostricklandia castellana.*

Types.—Holotype No. 45338; paratypes Nos. 45332–45337, Museum of Paleontology, The University of Michigan.

Microcardinalia pyriformis (Savage, 1916)

(Pl. I, Figs. 1–9)

Stricklandia pyriformis Savage, 1916, pp. 317–19, Pl. 16, Figs. 6–9.

Exterior.—The valves are unequally biconvex with the brachial valve being about one-half the depth of the pedicle valve. Both valves are subpentagonal in outline. The junction of the straight hinge line and the posterolateral margins is sharp and angular. The position of maximum width is well anterior of the mid-length. Both valves are exceptionally elongate. The interarea of the pedicle valve is strongly apsacline, whereas that of the brachial valve is apsacline and relatively short. The anterior commissure is rectimarginate.

Interior of pedicle valve.—A relatively small spondylium is present supported by a very short median septum.

Interior of brachial valve.—The cardinalia consist of rodlike brachial processes cemented basally to the floor of the valve, and laterally bounded by a pair of flaring inner plates. The adductor impressions are deeply impressed into a heavy deposit of secondary material present in the posterior portion of the valve.

Distribution.—*M. pyriformis* is abundant in the upper part of the Kankakee dolomite.

Comparison.—*M. pyriformis* has far more elongate outline and more deeply convex valves than any of the other species of *Microcardinalia.*

Types.—Hypotypes Nos. 45330–45331, Museum of Paleontology, The University of Michigan.

Plicostricklandia Boucot and Ehlers, gen. nov.

Type species. *Stricklandia multilirata* Whitfield, 1878, p. 81.

Diagnosis.—Costellate stricklandids otherwise similar to *Microcardinalia.*

Comparison.—*Plicostricklandia* is identical in all respects to *Microcardinalia* except that the latter is smooth rather than costellate.

Species Assigned

Stricklandia castellana White, 1876, p. 30.
Stricklandia chapmani Hall and Clarke, 1893, Pl. 83, Fig. 40.
Stricklandia manitouensis Williams, 1919, p. 124, Pl. 20, Figs. 2–3.
Stricklandia multilirata Whitfield, 1878, p. 81; 1882, pp. 315–16, Pl. 23, Figs. 3–5.

Species Questionably Assigned

Stricklandia lirata Davidson, 1867, pp. 159–61 *pars,* Pl. 20, Figs. 4–6; not Figs. 1–3, 7–13. *Non* Sowerby, *in* Murchison, 1839, pp. 638 and 708, Pl. 22, Fig. 6.

Plicostricklandia multilirata (Whitfield, 1878)

(Pl. V, Figs. 1–10, 13–14)

Stricklandia multilirata Whitfield, 1878, p. 81; 1882, pp. 315–16, Pl. 23, Figs. 3–5.
Stricklandia multilirata Hall and Clarke, 1893, p. 251, Pl. 73, Figs. 1–2.

Exterior.—The valves are subequally biconvex with the brachial valve being about two-thirds the depth of the evenly convex pedicle valve. Both valves are subpentagonal in outline. The straight hinge line joins the relatively straight, anterolaterally directed posterior halves of the lateral margins sharply. The posterolateral margins are sharply inflected anteriorly into the gently curved anterior and anterolateral margins. The interarea of the pedicle valve is apsacline, concave, and very short; that of the brachial valve is also apsacline and relatively short. The interarea width is about two-thirds the maximum width, which is approximately at mid-length. The anterior commissure is weakly uniplicate and crenulate. The shells are abundantly costellate. Concentric growth lines of most shells are not prominent. The brachial valve bears a broad, low fold and the pedicle valve a corresponding sulcus.

Interior of pedicle valve.—A relatively small spondylium is present and supported by a very short median septum.

Interior of brachial valve.—The cardinalia consist of rodlike brachial

processes cemented basally to the floor of the valve, and laterally bounded by a pair of flaring inner plates. Outer plates appear to be absent.

Remarks.—*P. multilirata* is the most abundantly costellate member of the genus, particularly as contrasted with *P. chapmani, P. castellana,* and *P. manitouensis.*

P. multilirata is known from the uppermost part of the Hopkinton dolomite of Iowa, the Racine dolomite of Wisconsin, and the lower 40 feet of the Engadine dolomite in Michigan. In all of these states the species occurs not far below strata of Ludlow age implying strongly that this species is of Wenlock age, as mentioned under the following section entitled "Stratigraphic Implications."

Types.—Hypotype No. 6-675, The State University of Iowa Hypotype No. 140455, U. S. National Museum; Hypotypes Nos. 44492 and 44493, Museum of Paleontology, The University of Michigan.

Plicostricklandia castellana (White, 1876)
(Pl. III, Figs. 9–10; Pl. IV, Figs. 1–18)

Stricklandia castellana White, 1876, p. 30.

Exterior.—The valves are unequally biconvex with the pedicle valve having the greater degree of convexity. The shells are subpentagonal to subcircular in outline. Both valves are ornamented by relatively large costellae which may bifurcate anteriorly. The interareas are straight and almost equal to the maximum width, which is situated posterior of the midlength. The pedicle valve tends to be weakly sulcate anteriorly and the brachial valve to bear a corresponding fold. The anterior margin is evenly rounded and crenulate. The posterolateral margins are relatively straight and are anterolaterally directed, being inflected medially at the point of maximum width. The interarea of the pedicle valve is strongly apsacline and longer than the short, apsacline interarea of the brachial valve.

Interior of pedicle valve.—A small spondylium supported by a very short median septum is present. The interior is strongly crenulated by the impress of the external ornamentation.

Interior of brachial valve.—The cardinalia are similar to those present in the other species of both *Microcardinalia* and *Plicostricklandia.*

Distribution.—*P. castellana* is present in the upper part of the Hopkinton dolomite of Iowa (the lower part contains *Microcardinalia*; see Pl. I, Figs. 10–13), and probably in the upper part of the Cordell dolomite in Michigan.

Comparison.—*P. castellana* is more coarsely costellate than any of the other species of the genus.

Types.—Figured specimen, No. 44529, Museum of Paleontology, The

University of Michigan; Hypotypes Nos. 1942B, 1942A, 1942C, 1943, California Institute of Technology; Hypotype No. 32582, Museum of Paleontology, The University of Michigan.

Plicostricklandia manitouensis (Williams, 1919)
(Pl. III, Figs. 3–8)

Stricklandia manitouensis, Williams, 1919, p. 124, Pl. 20, Figs. 2–3.

Exterior.—The valves are subequally biconvex with the pedicle valve being deeper than the brachial valve. The valves are subpentagonal to subcircular in outline. The point of maximum width is posterior of the midlength. The ornamentation consists of costellae. The brachial valve may bear a weak fold and the pedicle valve a corresponding sulcus.

Interior.—The internal structures of both valves are similar to those of the other species assigned to the genus.

Distribution.—Middle or upper part of Cordell dolomite of Michigan, and the upper part of the Fossil Hill formation of Ontario.

Comparison.—*P. manitouensis* is more abundantly costellate than *P. castellana,* but less abundantly costellate than *P. multilirata.*

Type.—Hypotype No. 44498, Museum of Paleontology, The University of Michigan.

STRATIGRAPHIC IMPLICATIONS

Little can be added to the information that Alwyn Williams (1951, pp. 87–88) has already provided for the relatively smooth *S. lens* lineage. For the moderately to strongly costellate members of the lineage, however, there is a variety of new information to be considered. *Costistricklandia lirata* (see Pl. V, Figs. 11–12) occurs in the lower Visby marl of Gotland, which is of C_6 age, and similar shells (usually assigned to *"S." lirata*) have been found by Alfred Ziegler in lower C_6-age beds in England. Alfred Ziegler (written communication, 1961) has found *C. lirata* to be restricted in England to upper C_6 age beds and St. Joseph (1938, p. 333) reports *C. lirata* from 7c of the Oslo region, which is probably also of C_6 age. In North America the range of *C. gaspiensis* and *canadensis* can be inferred from the presence of overlying Ludlow-age beds, containing both Lower Ludlow-age graptolites and *Conchidium.* Berry and Boucot (in preparation) suggest a C_6 to early Wenlock correlation. *C. lirata* has been recognized in a small collection obtained by Boucot in 1947 from glacial debris at Savage Harbour, Savage Island, southeast Baffinland. (See Figure 1 for stratigraphic relationships.)

The oldest species of the genus *Microcardinalia* is *M. mullochensis* (Reed), a Lower Llandovery species which is characterized by relatively long outer plates (Reed, 1917, Pl. 33, Figs. 5–8) as compared with the Upper Llandovery species which appear to lack them. The North American Upper Llandovery species *M. triplesiana, M. norwoodi,* and *M. pyriformis* are found in the upper part of the Kankakee and Brassfield formations which are concluded to be of at least C_4–C_5 age because Boucot has recently found *M. triplesiana* associated with *S. lens ultima* in the Birmingham, Alabama, region in a new collection from strata which overlie those containing *S. lens progressa.* In addition, Boucot has found *M. triplesiana* in strata from Quebec which disconformably overlie others containing *S. lens progressa*; this suggests that *M. triplesiana* is of post-C_2 age. See Figure 1 for stratigraphic relationships.

M. raberensis is known only from the lower part of the Cordell dolomite in Michigan. From its having weakly developed costellae analogous to those present in *S. lens ultima* it is inferred to be of about C_5 age and probably younger than smooth species like *M. triplesiana* which occur in pre-Cordell age rocks in the mid-continent. The moderately plicate species *Plicostricklandia manitouensis* and *P. castellana* occur in upper Cordell equivalents, the upper part of the Fossil Hill formation of Ontario and the Hopkinton dolomite of Iowa, and are concluded to be of lower-C_6 age. There is no doubt, due to the position of the moderately plicate species of *Plicostricklandia* above weakly plicate forms of about C_5 age, that the moderately plicate ones are at least in C_6; the upper range of the moderately plicate shells is hard to place except by assuming a similar rate of evolution to that found in the *Stricklandia-Costistricklandia* lineage. If this assumption about rates of evolution be granted then it is reasonable to correlate the moderately plicate species of *Plicostricklandia* with those of lower C_6 and the abundantly plicate species with those of upper C_6 and early Wenlock beds. The upper limit of the abundantly plicate species of both *Plicostricklandia* and *Costistricklandia* is fixed by their occurrence beneath Ludlow age beds containing *Conchidium.* (See Figure 1 for stratigraphic relationships.)

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PLATES

EXPLANATION OF PLATE I

(All figures natural size, except as indicated)

PAGE

Microcardinalia pyriformis (Savage) 54

FIGS. 1–7. Specimen consisting of a steinkern on which are parts of replaced shell material. Figures 1, 2, views of pedicle and brachial valves, showing outline of valves, broad and very gently convex plicae, and growth lines. Figure 3, lateral view showing convexity of valves; pedicle valve at left. Figure 4, posterior view showing molds of spondylium and cardinalia. Figure 5, anterior view (pedicle valve below) showing convexity of valves; anterior contact of valves missing. Figure 6, posterior view showing molds of spondylium, short median septum of pedicle valve, brachial processes, and inner plates; × 4. Figure 7, latex cast made from mold illustrated in Figure 6, showing cardinalia, and spondylium supported by median septum; pedicle valve in this figure and Figure 6 is shown above the brachial valve; × 4. Formation and locality: near top of Kankakee formation; Rockville County, Illinois. Hypotype No. 45330, Museum of Paleontology, The University of Michigan.

FIGS. 8–9. Views of pedicle and brachial valves of a specimen having less distortion than that illustrated in Figures 1–7. Note the discrete adductor scars. Same horizon and locality as specimen illustrated in Figures 1–7. Hypotype No. 45331, Museum of Paleontology, The University of Michigan.

Microcardinalia sp. cf. *M. plana* (Foerste) and *M. triplesiana* (Foerste) 52

FIG. 10. Mold of small distorted pedicle valve with V-shaped cavity marking position of spondylium and median septum. Horizon and locality: *Cerionites* beds of Hopkinton dolomite; 1 mile northeast of Goose Lake, Iowa. Figured specimen No. 45327, Museum of Paleontology, The University of Michigan.

FIG. 11. Mold of a larger pedicle valve, exhibiting position of spondylium, median septum, and width of interarea. Same horizon and locality as specimen No. 45327. Figured specimen No. 45328, Museum of Paleontology, The University of Michigan.

FIGS. 12, 13. Partly eroded and broken brachial valve. Figure 12, view showing concentric rugae in posterior half of valve and indistinct fold extending from umbonal region to anterior margin. Figure 13, oblique posterior view showing small dark depressions in umbonal region interpreted as very imperfect molds of brachial processes; two light-colored, lobate areas anterior to molds mark position of adductor scars; × 2. Same horizon and locality as specimen No. 45327. Figured specimen No. 45329, Museum of Paleontology, The University of Michigan.

PLATE I

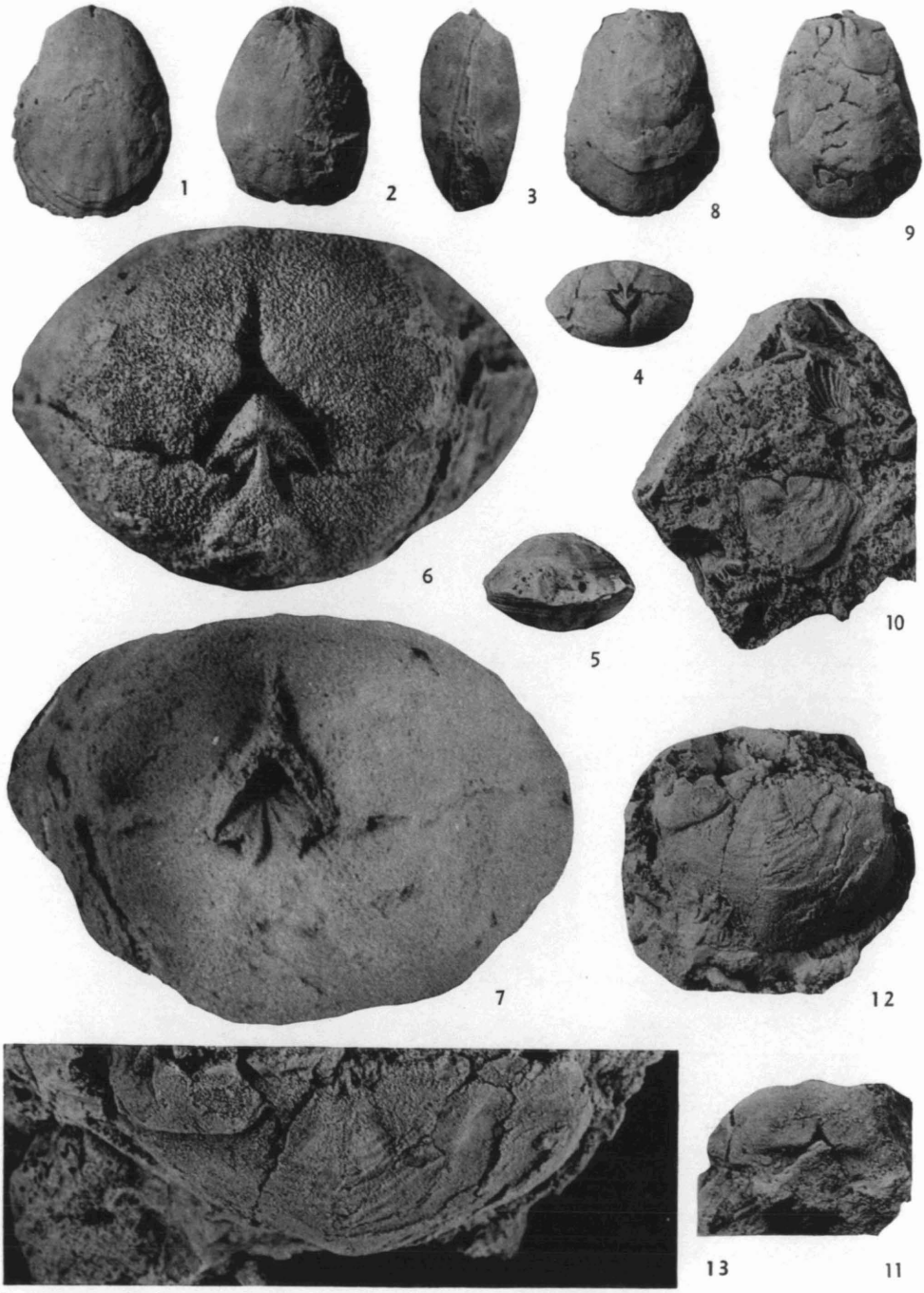
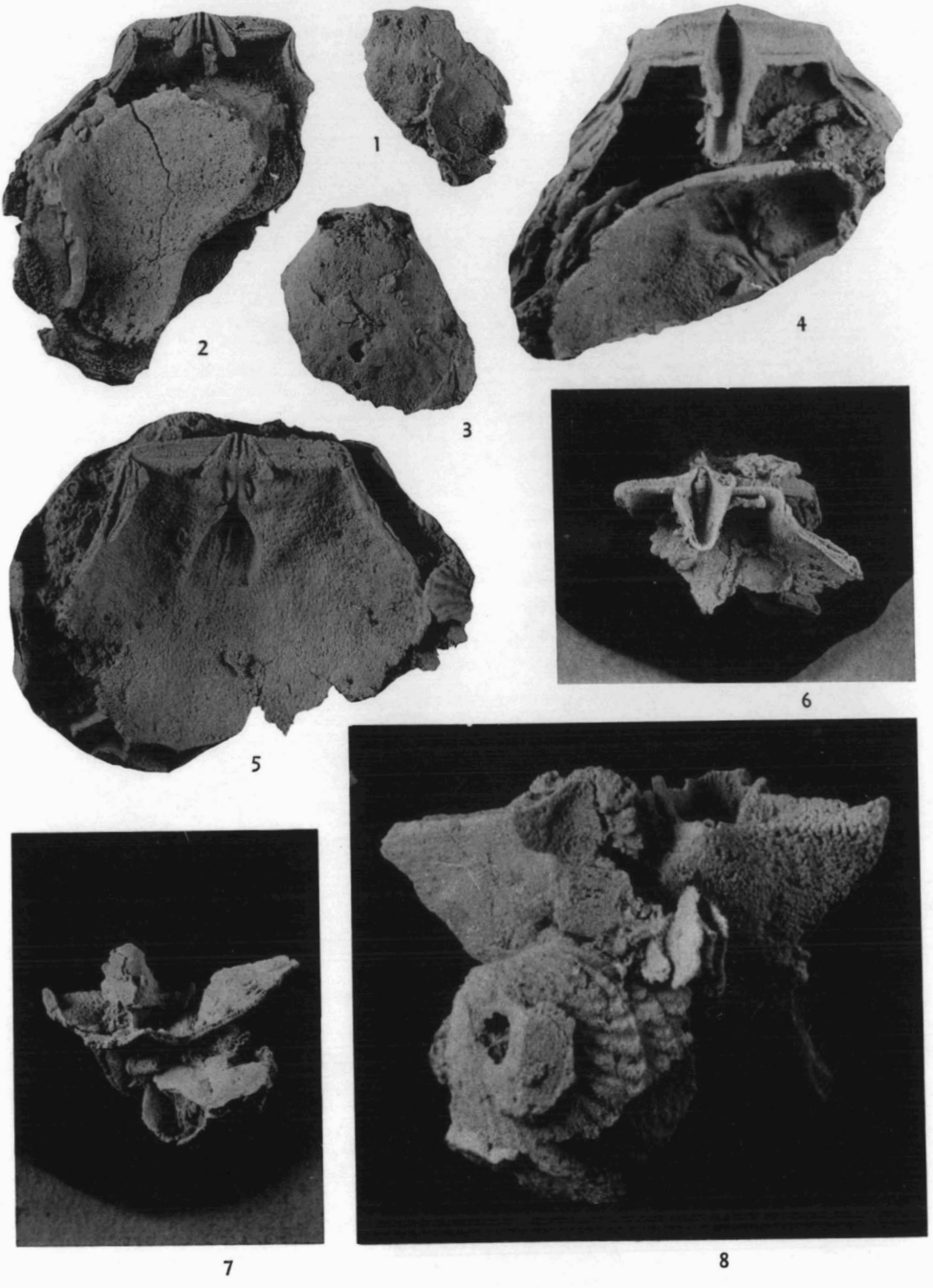


PLATE II



EXPLANATION OF PLATE II

(All figures natural size except as indicated)

PAGE

Microcardinalia raberensis, sp. nov. 53

FIGS. 1, 2. Exterior and interior views of an incomplete, silicified brachial valve. Figure 1 indicates outline of valve; a cyclostomatous bryozoan, ?*Hederella* sp., is attached to external surface. Figure 2, shows interarea and rodlike brachial processes cemented basally to floor of valve and laterally bounded by pair of flaring inner plates; × 2. Horizon and locality: basal part of Cordell dolomite of Manistique group; east-facing bluff in NE¼ sec. 3, T.42N., R.3E., about ¼ mile E. of the St. Mary's River and about 2¼ miles SE of Raber, Chippewa County, Michigan. Paratype No. 45332, Museum of Paleontology, The University of Michigan.

FIGS. 3, 4 Exterior and interior views of an incomplete, silicified pedicle valve. Figure 3 indicates outline of valve. Figure 4 shows interarea and spondylium; an oblique view of the brachial valve shown in lower part of Figure 4 is also illustrated in Figure 5; × 2. Found in the same block of dolomite as specimen illustrated in Figures 1–2. Paratype No. 45333, Museum of Paleontology, The University of Michigan.

FIG. 5. Interior view of brachial valve, shown in lower part of Figure 4; × 2. View shows striated interarea, brachial processes, flaring inner plates, dental sockets, and paired, longitudinally elongate adductor impressions, medially bisected by a low myophragm; ovarian pits lateral to muscle field. From same block of dolomite as preceding paratypes; same repository. Paratype No. 45334.

FIGS. 6–8. Incomplete pedicle valve. Figure 6, view of interior showing a nearly complete spondylium; × 2. Figure 7, view showing part of lower surface of spondylium and anterior edge of median septum that appears as a very narrow, light-colored band; part of spondylium, shown at left in Figure 7, is covered by a piece of firmly cemented silicified shell; × 2. Figure 8. Posterior view showing fractured beak, pair of teeth, and trough of spondylium; lower part of photograph shows part of an *Atrypa* that is firmly attached to the paratype; × 4. Same block of dolomite as preceding paratypes; same repository. Paratype No. 45335.

EXPLANATION OF PLATE III

(All figures natural size except as indicated)

PAGE

Microcardinalia raberensis, sp. nov. 53

FIGS. 1, 2. Incomplete, worn, silicified pedicle valve. Figure 1, exterior view; costae faintly shown on anterior and anterolateral borders of valve. × 2. Figure 2, lateral view, showing convexity of valve and profile of interarea; × 2. Horizon, locality, and repository same as all specimens illustrated in Plate II. Paratype, No. 45336.

Plicostricklandia manitouensis (Williams) 57

FIGS. 3–8. Shell, most of the posterior half of which has been removed by erosion. Figure 3 shows outline of pedicle valve and costae on anterior and anterolateral margins. Figure 4, oblique view giving a better illustration of the costae. Figure 5, brachial valve, showing imperfect molds of two elongate muscle impressions at posterior margin. Figure 6, lateral view, showing convexity of valves; pedicle valve at right. Figure 7, posterior view, showing profile of valves; depth of sulcus of pedicle valve is accentuated by partial erosion of the pedicle valve; small spondylium and short septum are indicated by cavities (molds) in a partially exposed steinkern; adductor muscle impressions are represented by ridges (molds) on the steinkern. Figure 8, anterior view, showing profiles of valves and anterior commissure. Formation and locality: middle or upper part of Cordell dolomite of Manistique group; Drummond Island, Chippewa County, Michigan. Hypotype, No. 44498, Museum of Paleontology, The University of Michigan.

Plicostricklandia sp. cf. *P. castellana* (White) 56

FIG. 9. View of much worn mold of interior of a brachial valve, showing costae and very indistinct outline of an elongate muscle field. Horizon and locality: probably upper part of Cordell dolomite, Manistique group: Drummond Island, Chippewa County, Michigan. Figured specimen, No. 44529, Museum of Paleontology, The University of Michigan.

Plicostricklandia castellana (White) 56

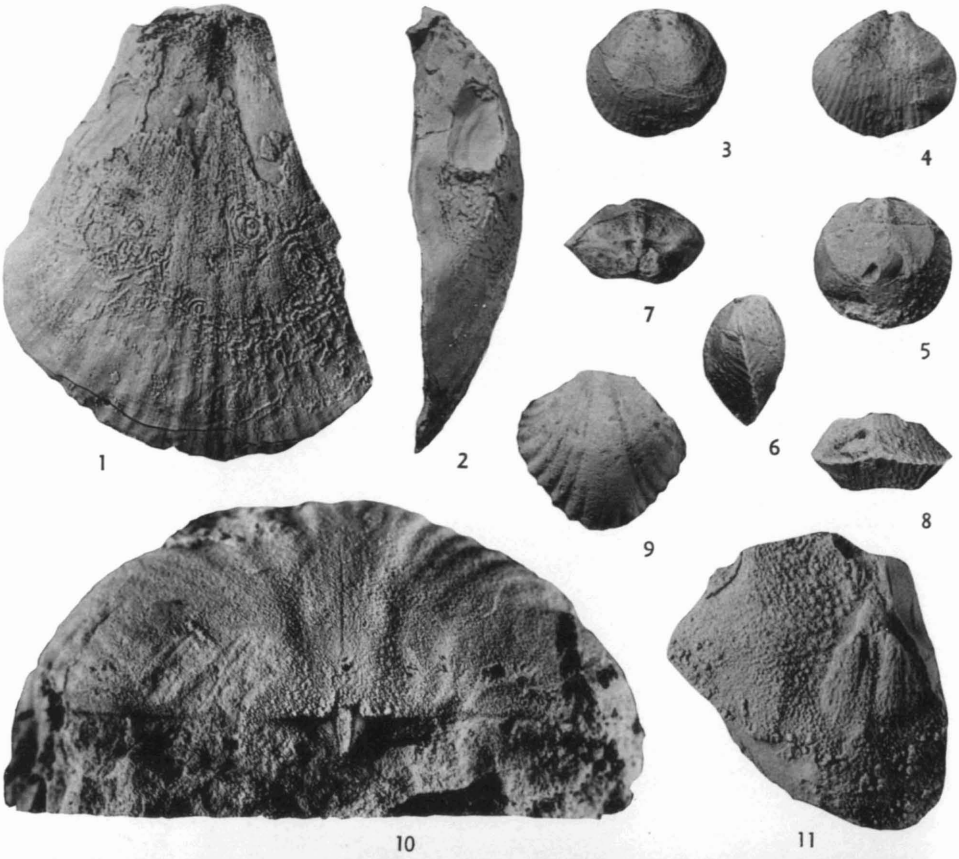
FIG. 10. Posterior view of mold of interior of a brachial valve, showing muscle field, impression of low myophragm and cardinalia; × 4. Horizon and locality: Hopkinton dolomite; Monticello, Iowa. Hypotype, No. 1942 B, California Institute of Technology.

Microcardinalia raberensis, sp. nov. 53

FIG. 11. Part of a steinkern, showing mold of muscle field of a brachial valve; × 2. Horizon, locality, and repository: same as all specimens illustrated in Plate II. Paratype, No. 45337.

FIGS. 12, 13. Views of interior of a brachial valve. Figure 12 shows interarea, brachial processses, flaring inner plates, dental sockets, and paired longitudinally elongate adductor impressions, medially bisected by a low myophragm; × 2. Figure 13, enlargement showing various structures in greater detail; note the relation of the interarea and the posterior portion of the lateral margin; × 4. Horizon, locality, and repository: same as specimens in Plate II. Holotype, No. 45338.

PLATE III



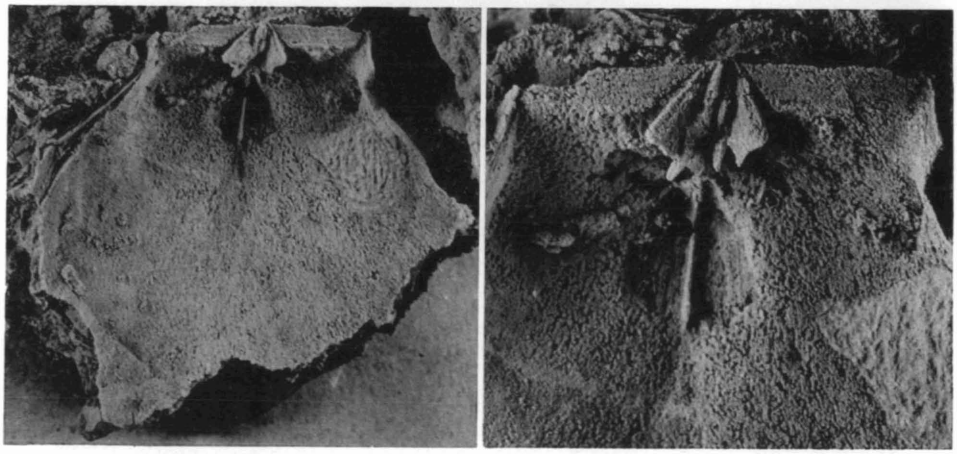
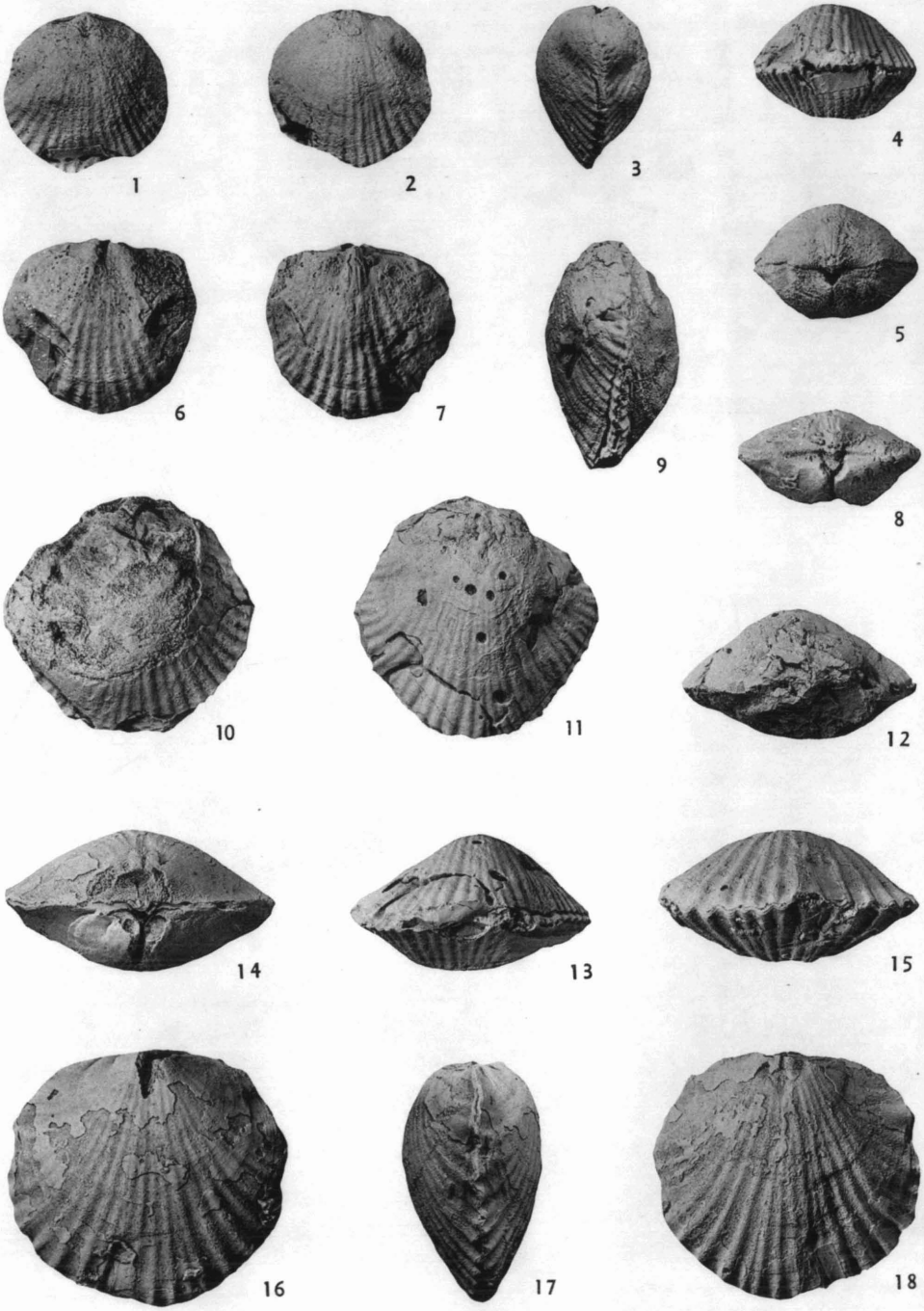


PLATE IV



EXPLANATION OF PLATE IV

(All figures natural size)

PAGE

Plicostricklandia castellana (White) 56

FIGS. 1–5. Small specimen with both valves. Figures 1–2, views of pedicle and brachial valves, showing outline of shell and costae. Figure 3, lateral view, illustrating convexity of valves; pedicle valve shown at right, brachial valve at left. Figures 4–5, anterior and posterior views, showing character of anterior margin, small spondylium and short septum, and poorly preserved, elongate adductor muscle scars of brachial valve. Horizon and locality: Hopkinton dolomite; Monticello, Iowa. Hypotype No. 1942A, California Institute of Technology.

FIGS. 6–8. Specimen having a shallow broad sulcus and a low broad fold. Figures 6–7, views of pedicle and brachial valves; mold of short septum shown in Figure 6 and molds of elongate adductor muscle scars in Figure 7. Figure 8, posterior view, showing profiles of sulcus and fold, molds of interarea of pedicle valve, spondylium, and short septum, and molds of adductor muscle scars. Formation and horizon: same as hypotype illustrated in Figures 1–5. Hypotype No. 1942C, California Institute of Technology.

FIGS. 9–13. Lateral, pedicle, brachial, posterior, and anterior views of a larger specimen than hypotypes Nos. 1942A and 1942C. The specimen is silicified; the valves are fractured and in part worn away. The pedicle valve is illustrated at the right in Figure 9. Molds of the spondylium and septum are shown in Figures 10 and 12. Circular holes in the brachial valve, Figure 11, were produced by an unknown boring organism, living contemporaneously with the brachiopod. Horizon and locality: Cordell dolomite, probably middle part, Manistique group; Drummond Island, Chippewa County, Michigan. Hypotype, No. 31582, Museum of Paleontology, The University of Michigan.

FIGS. 14–18. Posterior, anterior, pedicle, lateral, and brachial views of a large specimen, a steinkern of white, translucent quartz to which few fragments of silicified shell are adhering. Figure 14 shows molds of small spondylium and short septum, and very poorly preserved parts of cardinalia and elongate adductor muscle scars. Figure 16 exhibits pieces of worn, silicified shell material attached to steinkern. Pedicle valve is shown at right in Figure 17. Horizon and locality: Niagaran (probably Hopkinton dolomite): Iowa. Hypotype No. 1943, California Institute of Technology.

EXPLANATION OF PLATE V

(All figures natural size)

PAGE

Plicostricklandia multilirata (Whitfield) 55

FIGS. 1–5. Pedicle, brachial, lateral, posterior, and anterior views of a specimen consisting of incomplete, silicified valves adhering tightly to a steinkern of chert. Figures 1 and 2 show subpentagonal outline and abundantly costellate surfaces of valves. Figure 3, oriented with pedicle valve to right, exhibits nearly equal convexity of valves. Figure 4 indicates the existence of a small spondylium, a broad, low sulcus in the pedicle valve (below), and a corresponding fold in the brachial valve (above). Figure 5 shows the anterior commissure, which is weakly uniplicate and crenulate. Horizon and locality: Hopkinton dolomite, Delhi, Iowa. Hypotype No. 6-675, The State University of Iowa.

FIGS. 6–8. Pedicle, lateral, and posterior views of a much compressed and incomplete steinkern of another shell. Figure 6, a photograph of a mold of the inner surface of the pedicle valve, illustrates numerous costellae, a few strong growth lines, and location of the spondylium. Figure 7 gives only an approximate idea of the convexity of the valves. Figure 8 shows that the spondylium was small (medium septum very short) and that the width of the interarea of the pedicle valve was considerably less than the maximum width of this valve. Horizon and locality: lower 40 feet of Engadine dolomite; Cedarville quarry, Michigan Limestone Division of U.S. Steel Corporation, about 5 miles northeast of Cedarville, Mackinac County, Michigan. Hypotype No. 140455, U.S. National Museum.

FIGS. 9–10. Views of a much compressed and incomplete steinkern of another shell. Figure 9 presents a mold of the inner surface of the pedicle valve. Figure 10, an oblique lateral view, exhibits some of the numerous costellae. Horizon and locality: Engadine dolomite—lower 40 feet or from bed 40 to 55 feet above base of dolomite; quarry of Drummond Dolomite, Inc., southern part of sec. 36, T.42N., R.4E., southwestern part of Drummond Island, Chippewa County, Michigan. Hypotype No. 44493, Museum of Paleontology, The University of Michigan.

Costistricklandia lirata (Sowerby) 48

FIG. 11. Incomplete brachial valve, showing outline of valve, low, broad fold, and costae. Formation and locality: Lower Visby marl; Visby, Gotland, Sweden. Hypotype No. 45339, Museum of Paleontology, The University of Michigan.

FIG. 12. Incomplete pedicle valve, showing outline of valve, low, shallow fold, and costae. Formation and locality: same as hypotype No. 45339. Hypotype No. 45340, Museum of Paleontology, The University of Michigan.

Plicostricklandia multilirata (Whitfield) 55

FIGS. 13–14. Views of a slightly compressed brachial valve. Figure 13 is a lateral view illustrating convexity of valve. Figure 14 shows outline and numerous costellae of valve. Horizon and locality: Engadine dolomite—from bed 20 to 40 feet above base of dolomite; quarry of Drummond Dolomite, Inc., southern part of sec. 36, T.42N., R.4E., southwestern part of Drummond Island, Chippewa County, Michigan. Hypotype No. 44492, Museum of Paleontology, The University of Michigan.

PLATE V