
ETOILE DU NORD

Minneapolis, Minn. July 8 - 95. 188

To Museum Comparative Zoology.

I have the pleasure of presenting, in the name of the board of regents of the University of Minnesota, this copy of the ~~first~~ 3rd volume, pt. 1, of the *final report on the geological and natural history survey of Minnesota.*

N. H. WINCHELL,

State geologist.

THE UNIVERSITY OF MINNESOTA.

A REPORT

ON THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA:
MADE IN PURSUANCE OF AN ACT OF THE LEGISLATURE
OF THE STATE. APPROVED MARCH 1,
1872.

PUBLISHED BY AUTHORITY OF THE STATE.

BOARD OF REGENTS.

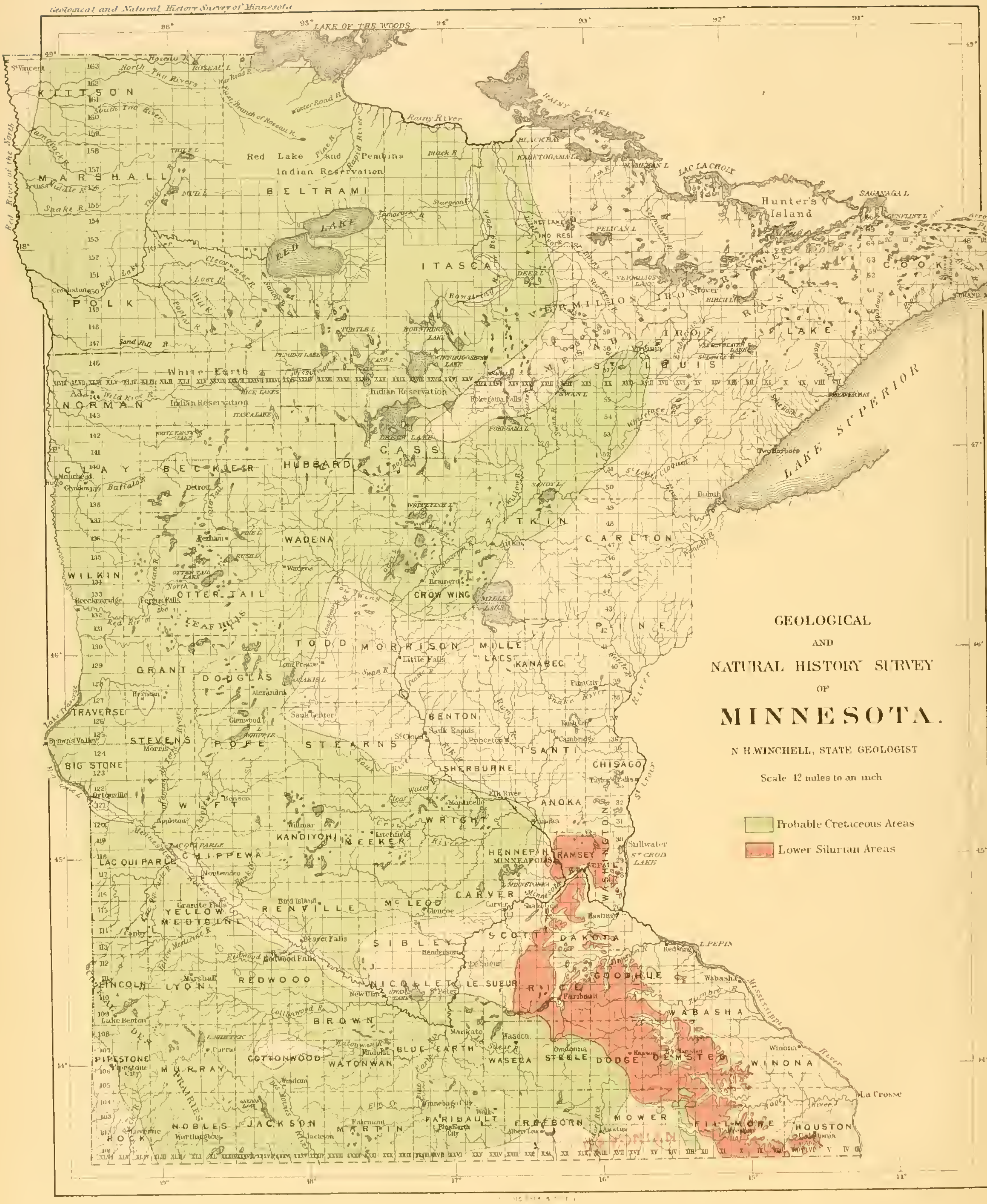
THE HON. STEPHEN MAHONEY, Minneapolis,	1895
THE HON. SIDNEY M. OWEN, Minneapolis,	1895
THE HON. WILLIAM H. YALE, Winona,	1896
THE HON. JOHN S. PILLSBURY, Minneapolis,	1896
THE HON. OZORA P. STEARNS, Duluth,	1897
THE HON. WILLIAM LIGGETT, Benson,	1897
THE HON. JOEL P. HEATWOLE, Northfield,	1897
THE HON. GREENLEAF CLARK, St. Paul,	1898
THE HON. CUSHMAN K. DAVIS, St. Paul,	1898
THE HON. DAVID M. CLOUGH, Minneapolis, *The Governor of the State.*	*Ex-Officio*
THE HON. W. W. PENDERGAST, Hutchinson, *The State Superintendent of Public Instruction.*	*Ex-Officio*
CYRUS NORTHROP, Minneapolis, *The President of the University.*	*Ex-Officio*

Officers of the Board.

THE HON. JOHN S. PILLSBURY,	*President*
THE HON. DAVID L. KIEHLE,	*Recording Secretary*
PRESIDENT CYRUS NORTHROP,	*Corresponding Secretary*
JOSEPH E. WARE, (Address care of St. Anthony Falls Bank, Minneapolis,)	*Treasurer*

The Executive Committee.

THE HON. JOHN S. PILLSBURY, *Chairman.*
PRESIDENT CYRUS NORTHROP,
THE HON. WILLIAM LIGGETT.


GEOLOGICAL
AND
NATURAL HISTORY SURVEY
OF
MINNESOTA.
N. H. WINCHELL, STATE GEOLOGIST
Scale 42 miles to an inch
Probable Cretaceous Areas
Lower Silurian Areas
LAKE OF THE WOODS
RAINY LAKE
LAKE SUPERIOR
Hunter's Island
Red Lake and Pembina Indian Reservation
White Earth Indian Reservation
KITTSON
MARSHALL
BELTRAMI
POLK
ITASCA
ST. LOUIS
LAKE
COOK
NORMAN
CASS
CLAY
BECKER
HUBBARD
WADENA
AITKIN
CARLTON
WILKIN
OTTER TAIL
CROW WING
PINE
TODD
MORRISON
MILLE LACS
KANABEC
GRANT
DOUGLAS
TRAVERSE
STEVENS
POPE
STEARNS
BENTON
ISANTI
CHISAGO
BIG STONE
SWIFT
SHERBURNE
ANOKA
KANDIYOHI
MEEKER
WRIGHT
HENNEPIN
RAMSEY
WASHINGTON
LAC QUI PARLE
CHIPPEWA
CARVER
YELLOW MEDICINE
RENVILLE
McLEOD
SCOTT
DAKOTA
SIBLEY
GOODHUE
LINCOLN
LYON
REDWOOD
NICOLLET
LE SUEUR
RICE
WABASHA
BROWN
PIPESTONE
MURRAY
COTTONWOOD
WATONWAN
BLUE EARTH
WASECA
STEELE
DODGE
OLMSTED
WINONA
ROCK
NOBLES
JACKSON
MARTIN
FARIBAULT
FREEBORN
MOWER
FILLMORE
HOUSTON

THE GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.
N. H. WINCHELL, STATE GEOLOGIST.

1885–1892.

THE GEOLOGY OF MINNESOTA.

VOL. III, PART I, OF THE FINAL REPORT.

PALEONTOLOGY.

BY LEO LESQUEREUX,
ANTHONY WOODWARD,
BENJAMIN W. THOMAS,
CHARLES SCHUCHERT,
EDWARD O. ULRICH,
NEWTON H. WINCHELL.

SUBMITTED NOV. 30, 1891, AND PUBLISHED UNDER THE DIRECTION
OF HON. FREDERICK P. BROWN,
SECRETARY OF STATE.

ILLUSTRATED BY FORTY-ONE PLATES
AND THIRTY-FOUR FIGURES.

MINNEAPOLIS, MINN.
HARRISON & SMITH, STATE PRINTERS.
1895.

TABLE OF CONTENTS.

[NOTE. Each plate is accompanied by a full description].

LETTER OF N. H. WINCHELL, STATE GEOLOGIST.

THE UNIVERSITY OF MINNESOTA,
November 30, 1891.

HON. JOHN S. PILLSBURY, *President of the Board of Regents:*

After an interval of six years I tender again a volume of the final report of the *geological and natural history survey of the state.* The materials for this volume have accumulated gradually since the survey began, and latterly they have been much increased through the coöperation of various collectors and assistants. This manuscript will make a large volume, and it may be found desirable to issue it in two parts. It pertains to the paleontology and systematic geology of the Lower Silurian, which is found in the southeastern portion of the state, already described in volumes I and II.

Very respectfully,
Your obedient servant,
N. H. WINCHELL,
State Geologist.

LETTER OF HON. JOHN S. PILLSBURY.

MINNEAPOLIS, MINN., Dec. 5, 1891.

PROF. N. H. WINCHELL, *State Geologist:*

I have the pleasure to acknowledge the receipt of your favor of the 30th ult., tendering the third volume of the final report of the survey, and to congratulate you on the completion of another considerable portion of the state survey. I trust there may be no delay in its publication.

Very truly yours,
JOHN S. PILLSBURY,
President of the Board of Regents of the University of Minnesota.

VOLUME III, PART I.

INTRODUCTION TO VOL. III, PART I.

HISTORICAL SKETCH OF INVESTIGATION OF THE LOWER SILURIAN IN THE UPPER MISSISSIPPI VALLEY.

BY N. H. WINCHELL AND E. O. ULRICH.

The paleontology of the Lower Silurian, as exemplified in the rocks of Minnesota and adjoining states, has been strangely overlooked and neglected. As a geological horizon the rocks of the Lower Silurian everywhere bear important relations to those which followed and to those which preceded them. The profuse fauna with which they are characterized is the first, after the Taconic, which displays its zoological affinities with distinctness, and at the same time with a sufficient number of well-preserved specimens to indicate the nature of the life which filled those Paleozoic seas. As a descendant from the Primordial fauna it manifests so great variations, and so great a number of species, that it holds an independent rank in the paleontological record equal in importance to any which followed, and superior to any that preceded. As the *second* great faunal epoch the Lower Silurian gives the first affirmative stamp to the idea of the evolution of species. The variation of forms which began in Primordial time, once established by a careful study of the "second fauna," the elucidation of all succeeding faunas by the application of the same research guided by the same laws, would follow as a necessary logical result. Too often this natural sequence has not been followed by paleontologists, but higher stages of variation, separated perhaps by many steps from the original forms, have been chosen for study and illustration. This has resulted sometimes in wrong conceptions concerning the sequence of change, or the manner of development from the comprehensive forms to those that are more specialized. To some species have been assigned what have proved to be unnatural progenitors, and imaginary progenitors have been assumed for others, while many apparently had no former ancestral species to which they could be traced. The examination of the intermediate links has shown where these errors have been committed. Such has been the function of the Lower Silurian fauna, as illustrated in numerous instances in the preparation of this volume.

REVIEW OF EARLIER LITERATURE.

The great pioneer work on this fauna in America was done by Prof. James Hall.* Compared with the recent work by the same author,§ it is at once apparent that great improvement has been made in the methods of research, and that remarkable advance has been the result of the work of numerous American paleontologists. Prof. Hall, however, never returned to a re-examination of the Lower Silurian fauna, as such, but continued to develop succeeding faunas of the Paleozoic. While it must be acknowledged that his pioneer volume constituted an important epoch in American paleontology, and especially in that of the Lower Silurian, it has to be admitted that Lower Silurian fossils have not received from him that full elucidation which has marked later his works on the Upper Silurian and the Devonian, and on the Carboniferous. Incidentally in his later work he has added numerically to the species known from the Trenton and Hudson River formations, ten being published from the Brachiopoda in vol. VIII, part 1; while the morphological values of all the generic names of the Brachiopoda have been reconsidered and fully analyzed in the same volume in the light of more recent advanced theories of biological paleontology.

The great labor that has been expended on the paleontology of the region of Cincinnati, where the Lower Silurian strata are at the surface over a large area, extending from southeastern Indiana and southwestern Ohio into Kentucky, has consisted very largely of the discovery and description of new species. Hall, Meek, Locke, Miller, Dyer, Nicholson, James (father and son), Mickleborough, Ulrich, Wetherby, Byrnes and others have added largely to the known fauna of these strata and have carried westward the definite stratigraphic limitations of these formations which were established in New York. From this region these fossiliferous strata pass out of sight with a westward and northwestward dip, rising again in Wisconsin and Minnesota on approaching the confines of the ancient land area now characterized by the older formations.

While all the American literature of the subject, and most of the European, has been at hand, and constantly consulted in the study represented by this volume, it has been thought desirable to note here more carefully only those geological works which appertain to the valley of the Mississippi, including Minnesota and the states adjoining, viz.: Wisconsin, Iowa and the northwestern portion of Illinois,† and the contiguous portions of Manitoba. These synoptical notes are arranged in chronological order.

---

*Palæontology of New York, vol. I, 1847. It should not be forgotten, however, that Mr. T. A. Conrad, between 1838 and 1843, studied the paleontology of New York assiduously and described many Lower Silurian forms.

§Palæontology of New York, vol. VIII, 1892.

†In the Tenth Annual Report of the Geological Survey of Indiana the reader will find a bibliography, by Mr. S. A. Miller, of the paleontology of the Cincinnati region up to the year 1879.

ANNOTATED CATALOGUE OF THE PALEONTOLOGY OF THE LOWER SILURIAN IN THE UPPER MISSISSIPPI VALLEY.

Sir John Franklin.

1823. *Narrative of a journey to the shores of the Polar sea in the years 1819, '20, '21 and '22,* by JOHN FRANKLIN, R. N., F. R. S., Commander of the expedition; with appendixes. Quarto, plates and maps, London, 1823.

In the appendix Dr. Richardson gives some general observations on the limestone seen at lake Winnipeg and further northward. From the numerous remains of orthoceratites he thinks this limestone may belong "to the formation under the new red sandstone" *i. e.*, to the "mountain limestone."

Note to page 506.—"Professor Jameson, having been requested to examine the specimens of limestone collected on the shores of lake Winnipeg, and in the Cumberland House district, obligingly sent the following note:

'The specimens of limestone received from you contain examples of the following fossil organic remains: Limestone with *encrinites*. The encrinites are in fragments.
Limestone with *Orthoceratites*.
Limestone with *Terebratulæ*.
Limestone with Caryophyllitæ.
Limestone with Lingulæ.

'These fossils would seem to intimate that the rock in which they are contained belongs to the mountain limestone formation, by many referred to the transition, by others to the oldest or deepest part of the secondary class of rocks.'"

Henry R. Schoolcraft.

1823. *Summary narrative of an exploratory expedition to the sources of the Mississippi river in 1820; resumed and completed, by the discovery of its origin in Itasca lake in 1832,* by HENRY R. SCHOOLCRAFT. Philadelphia, 1855. (First published in 1823).

The only allusions Schoolcraft makes to the age of the rocks embraced in this report are so vague and general that they are of no value. Once he refers to the falls of St. Anthony being "in the Silurian basin," and at another time he calls the limestone forming the falls "the same metalliferous limestone which for so great a length and in so striking a manner characterizes both banks of the Mississippi below St. Anthony falls." *Op. cit.*, p. 330. He evidently was inclined to consider the lead-bearing rocks about equivalent to the lead-bearing limestones of England, *i. e.*, the mountain limestone or Sub-Carboniferous, now known as the Mississippi limestone.

William H. Keating.

1823. *Narrative of an expedition to the source of St. Peter's river, lake Winnepeek, lake of the Woods, etc., performed in the year 1823, by order of the Hon. J. C. Calhoun, Secretary of War: under the command of Stephen H. Long, U. S. T. E.* Complied from the notes of Major Long, Messrs. Say, Keating and Calhoun, by WILLIAM H. KEATING. London, 1825. In two volumes; pp. 1–458 and 1–248, and appendix pp. 1–156.

A general description of the geology of the country from lake Michigan to the mouth of the Wisconsin river is given. Here the author finds two distinct magnesian limestone formations separated by a considerable thickness of fine grained friable sandstone. These three formations make up the rocks of this part of the route, He considers these strata as more recent than the Coal Measures, probably the equivalent of the limestone above the coal fields of Wheeling and Zanesville, W. Va., and after considerable discussion he places them as the American equivalents of the Lias of Europe; this conclusion is reached mainly from a consideration of the similarity of the lithology of the two limestone formations to the limestones of the Lias. In a detailed section at Ft. Snelling (pp. 319–320) he describes an upper limestone formation, which lies on a friable sandstone, which in turn is underlaid by another formation of limestone.* He consideres these strata as similar to those mentioned above as occurring in southern Wisconsin. At Ft. Snelling "the first stratum which is observed is about eight feet thick; it is formed of limestone, and presents a very distinct slaty structure. The texture of the rock is compact, its fracture splintery and uneven; organic remains abound in it. These are, as far as we saw, exclusively Producti; they lie in the rock as thick as possible; a small vacant space is generally observed between the inner and outer casts of the shell."

Sir John Franklin.

(Second Overland Journey.)

1825. *Narrative of a second expedition to the shores of the Polar sea*, by JOHN FRANKLIN, Capt. R. N., F. R. S., etc. London, 1829.

"Professor Jameson enumerates *Terebratulæ*, *Orthoceratites*, *Encrinites*, *Caryophyllitæ*, and *Lingulæ*, as the organic remains in the specimens brought home by captain Franklin on his first expedition. Mr. Stokes and Mr. James De Carle Sowerby have examined those which we procured on the last expedition, and found amongst them *terebratulites*, *spirifers*, *maclurites* and *corallines*.

"The *maclurites* belonging to the same species with specimens from lakes Erie and Huron, and also from Igloolik, are perhaps referrible to the Maclurea magna of Le Sueur.

"Mr. Sowerby determined a shell occurring in great abundance in the strata at Cumberland House, about one hundred and twenty miles to the westward of lake Winnipeg, to be the Pentamerus aylesfordii."

This is perhaps the species since described from that region by Whiteaves as Pentamerus decussatus.

G. W. Featherstonhaugh.

1835. *Report of a geological reconnoissance made in 1835, from the seat of Government, by way of Green bay and the Wisconsin territory, to the Coteau de Prairie, an elevated ridge dividing the Missouri from the St. Peter's river*, by G. W. FEATHERSTONHAUGH, U. S. Geologist. Senate Doc. 333; Washington, 1836, pp. 1–168.

The route taken was from Green bay along the Fox and Wisconsin rivers to the Mississippi, then up the latter stream to Fort Snelling and from there up the Minnesota to its head waters. The geology of the route is very rarely spoken of. The author considered the strata of the entire region, from Green bay west to the Cottonwood river and south to the mouth of the Des Moines, as made up of beds of blue and gray limestone underlaid by a friable sandstone. He refers both of these to the Carboniferous. In the description of Fort Snelling, he says:—

"The fort is built upon the bluff, which overlooks both the Mississippi and the St. Peter's, resting upon grayish buff-colored, fossiliferous beds of the Carboniferous limestone, containing zoophytes, many

*This lower limestone does not exist at Ft. Snelling; what Keating called the lower limestone is nothing but the detached fragments of the limestone from above the sandstone, which fragments now lie in the river bed many feet below their original position.

specimens of large orthocera, fragments of which measure a foot long and more than four inches wide. The faces of some of the rocks are covered with fuci, and in some producta form almost the body of the rock. These fossiliferous beds are separated from the great sandstone beds of the country, which here go far below the level of the river, by a thick stratum of eighteen feet of compact subcrystalline limestone without fossils. Below this stratum nothing but sandstone appears." (Pp. 135-136.) He thus corrects Keating's report (1823), in which it is said that a limestone formation underlies the sandstone at Fort Snelling. At St. Anthony falls "the immense slabs which have fallen from the limestone beds at the top are covered with producta, mixed with spirifers and cardia. * * * * * To a geologist, however, it is exceedingly interesting, finding here the uninterrupted continuation, for one thousand miles, of the Carboniferous limestone, with its characteristic fossils." (Pp. 136-137.)

David Dale Owen.

(Iowa, Wisconsin and Illinois.)

1839. *Report of a geological exploration of part of Iowa, Wisconsin and Illinois, made under the direction of the Secretary of the Treasury of the United States, in the autumn of the year 1839*, by DAVID DALE OWEN, M. D., principal agent to explore the mineral lands of the United States. 28th Congress, 1st Session, Senate document, 407, pp. 9-191, 1844. (Also 26th Congress, 1st Session, House of Representatives, document 239, pp. 9-161, 1845. The report was originally submitted for publication April 2nd, 1840, and was printed without the accompanying maps, charts, sections and other illustrations, June 4th, 1840. The foregoing editions were issued after the revision of the original, and the addition of some statistics and of all the accompanying illustrations.)

This report is confined almost exclusively to the lead region. The lead-bearing rock is embraced in the "Cliff limestone" which the author shows bears many points of similarity to the Carboniferous lead-bearing limestone of England. Notwithstanding this outward resemblance the organic remains require its assignment to a lower stratigraphic horizon. In the "Cliff limestone" Owen here includes a thickness of 500 feet of strata, extending from (and including) the Upper Silurian to the bottom of the Galena and Lower Silurian. He shows that this great member passes below the Coal Measures, instead of above them as thought by Keating, and is probably the equivalent of the Upper and perhaps of the Lower Silurian of Murchison, and of the Corniferous, Onondaga and Niagara limestones of New York, "and in part, perhaps, of the Champlain division." The fossils of the underlying Blue limestone he considers closely like those of the Caradoc formation of England, and of the Trenton limestone and shales of the New York system. This is the first suggestion of the Trenton limestone in the valley of the upper Mississippi, but it should be datedfrom the publication of his revised report,—1844.

"The most characteristic fossils of the cliff limestone of Iowa and Wisconsin are: (p. 25.)

"Casts (often siliceous) of several species of *terebratulæ*. Some of them, probably, of new species. These are chiefly confined to the upper beds. They are numerous and very perfect.

"Several species of *catenipora* (chain coral) in greater abundance, and in more perfect preservation, than I have ever seen them elsewhere; among them the *catenipora escharoides* of Lamarck; the *catenipora labyrinthica* of Goldfuss; and another species, not described by Goldfuss, nor elsewhere that I have seen—probably new. I name it the *catenipora verrucosa*. * * * * These *catenipora* are very characteristic of the upper beds of the cliff limestone. They do not occur in the rich lead-bearing strata.

"A *coscinopora* (the *sulcata?* of Goldfuss), the only coralline discovered in the middle and lower beds, and therefore characteristic of the true lead-bearing rocks.

"Several species of *calamopora*, *columnaria*, *tubipora*, *aulopora*, *sarcinula* (costata?), *astrea*, *cyathophylla*, and *caryophylla*. These are found with the chain coral in the upper beds.

"Several casts of spiral univalves; of a *cirrus* resembling the *perspectivus;* of an *ampullaria*, resembling the *canaliculata;* imperfect impressions of a long spiral univalve, resembling the genus *vivipara*—all taken from the walls of a lead-bearing fissure near Dubuque; a univalve of the genus *trochus* (found in the underlying blue limestone) and another, resembling a *delphinula*, found chiefly in the building rock.

"I also found both in the cliff rock and in the blue limestone (but chiefly in the latter, of which it is the characteristic fossil,) several species of *strophomena* of Goldfuss.

"Likewise, both in the cliff rock and in the blue limestone, several species of *orthoceratites*."

The report is accompanied by a geological map of the region explored and several sections, the most important of which is one from just below the mouth of Rock river northeast through the Blue mounds to the Wisconsin river. This section shows the Coal Measures above the Cliff limestone and separated from it by the shell stratum (*i. e.* the Devonian); immediately underlying the Cliff limestone is the blue fossiliferous limestone and below this are beds of red and white sandstone, which are followed by alternating strata of Lower Magnesian limestone and more red and white sandstone. The lead-bearing formation—Cliff limestone—is also called the Upper Magnesian limestone. The average dip of the strata is 9° in a southerly direction.

The report of Dr. Owen includes a report of Dr. John Locke in which carefully detailed sections at Dubuque, Prairie du Chien and from the Blue mounds to the Wisconsin river are given. Dr. Locke compares the lead-bearing rocks with the Cliff limestone of Ohio. He gives twelve points of agreement between the Cliff limestone of Ohio and the lead-bearing strata, the last of which is as follows: (p. 120)

"The fossil remains found in the lead region agree with those found in Ohio. Some of them are as follows:

"I. *Multilocular shells.*—Ammonitea and orthoceratites.

"II. *Crustaceans.*—Several species of calymene, asaphus, and isotelus. * * * *

"III. *Crinoideans.*— * * * *

"IV. *Mollusca.*—Spirifers, terebratulæ and productæ. A cast of several species of bivalves occurs. * * * * No fossil appears to be more characteristic of this formation than these casts; perhaps rather from their peculiar condition, than from the specific character of the fossil itself.

"V. *Zoophytes.*—Corallines are abundant in both regions; of cyathophylla, several species; of calamopora (Goldfuss), several species; of catenipora, at least three species are nearly equally abundant. The eschara (of Goldfuss) which is abundant on the Miami in Ohio, and which I once thought characteristic of this stratum, seems to be limited to particular localities. I did not see it in the lead region."

Dr. Locke seems to have been the first to parallelize the "Cliff limestone" of Ohio, a portion of the Upper Silurian, with the lead-bearing rocks. He makes special claim to this discovery in the Am. Jour. Sci., vol. xliii, p. 147 (1842). Although this idea was accepted by Owen in this report and by Hall later, as well as by others, it was found finally that the Cliff limestone of Ohio and Indiana did not embrace the lead-bearing horizon at all, but was separated from it by the Maquoketa shales.

Dr. Locke's section, plate No. XIX, extending from the south fork of the Little Maquoketa across the Mississippi to the Sinsinewa mound, represents a thickness of rocky strata amounting to 550 feet, and covers all the Lower Silurian, put by him into the "Cliff limestone;" although the Blue limestone is represented as somewhat below the water at Dubuque where the section crosses the river.

James Hall.

1842. *Notes upon the geology of the western states*, by JAMES HALL. Am. Journ. Sci., vol. XLII, p. 51, April, 1842. See also Association of Geologists and Naturalists, 1840-42, pp. 267-293, Boston, 1843.

This paper gives the generalized preliminary results of an extended tour made in 1841 for the purpose of ascertaining how far the grouping of the New York strata, published in the New York reports, was applicable in the western extension of the New York system. It shows a masterly comprehension of the geographic areas occupied by the principal parts of the lower Paleozoic as far west as the Mississippi river and as far north as the coal fields of Michigan. In treating of the Cliff limestone of Ohio, supposed to be the equivalent of the Niagara limestone of New York, he adopted the determinations of the first survey by Owen (1839) in its applicationn to the lead region and fell into the error of placing the lead-bearing dolomyte of Wisconsin and Iowa (the Galena of later reports) in the "Cliff limestone," and hence of making it a portion of the Niagara, here covering a thickness, according to measurements by Dr. John Locke, of five hundred and fifty feet. He, however, was of the opinion that some of the thin beds near the top of the Cliff limestone, as seen in Wisconsin and Iowa, should be assigned to the Lower Helderberg. He states that the Niagara in western New York is known to contain "everywhere sulphurets of lead and zinc." He formed the opinion that "the Ontario and Mohawk groups are both seen on the Mississippi above Dubuque," underlain by a mass of sandstone. That is, he was of the opinion that below the Galena (Niagara) the Hudson River and Trenton, as now known, existed. In this paper Prof. Hall indicated by the fossils which he named, that the "Blue limestone" at Cincinnati is to be considered the western representative of the Hudson River group of New York, which at that time was designated by him the "Ontario group." The inference which ought to have been drawn from this, viz., that the term Blue limestone could not be applied to the equivalent of the Trenton in the Mississippi valley, seems not to have been heeded, but that term has been perpetuated, even to the present time, at the lower horizon. Later, however, as will be seen, Prof. Hall applied the term "green and blue shales" to the Ontario group in the upper Mississippi valley.

F. De Castelnau.

1843. *Essai sur le système Silurien de l'Amérique septentrionale, par* F. DE CASTELNAU, Consul général des Etats Unis à Lima, Membre de plusieurs sociétés savantes. Avec vingt-sept planches, Paris, 1843, 56 pp. and one geological map.

This memoir was presented to the Academy of Sciences at the meeting of the 25th of August, 1842. A large number of fossils are figured. The region explored was chiefly that lying in the immediate vicinity of lakes Superior and Huron, and special attention was given to Drummond's island and other islands near it. On these islands M. De Castelnau found large amounts of white dolomyte containing some forms of *Huronia* and *Euomphalus*. This same formation of dolomyte—his "système magnésifère"—extends westward to the headwaters of the Missouri and is said to embrace the lead-bearing limestones of Wisconsin; it also covers a great extent of country to the east, especially around the St. Lawrence river and in New York state. There are 138 species of fossils described; these are principally from the lake region of the United States. He discusses at some length the existence of ambulatory appendages in the trilobites, drawing his conclusions from his examinations of specimens of *Calymene* on which he finds certain spots or scars which seem to indicate the places of attachment of branchial feet*. The author regards the "système magnésifère" as forming an upper member of Murchison's Silurian, or as perhaps constituting a separate formation just above the Silurian. The structure, age and formation of the great lake basins are also discussed.

LIST OF CASTELNAU'S FOSSILS, PREPARED BY CAPT. A. W. VOGDES.

Crustacea.

Asaphus micrurus *Green*, p. 18, Trenton, N. Y.
A. limulurus *Green*, p. 18, pl. IV, fig. 1, Lockport, N. Y.
A. cordieri, *n. sp.*, pl. IV, fig. 2, p. 18, Lockport, N. Y.
A. caudatus *Brong.*, p. 19, Trenton, N. Y.
A. edwardiis, *n. sp.*, p. 19, Trenton, N. Y.
A. murchisoni, pl. IV, fig. 3, Trenton, N. Y.
Homalonotus giganteus, *n. sp.*, pl. III, fig. 1, p. 20, Lockport, N. Y.
H. herculaneus, *n. sp.*, pl. IV, fig. 5, p. 20, Lockport, N. Y.
H. atlas, *n. sp.*, pl. IV, fig. 4, p. 20, Lockport, N. Y.
Arctinurus, *n. gen.*, p. 21.
Arctinurus boltoni *Bigsby*, pl. III. fig. 2, p. 21, Lockport, N. Y.
Calymene bufo *Green*, pl. II, figs. 1-4, p. 21, Capon près du Potomac, Va.
Odontocephalus, *Conrad*, p. 23.
Acantholoma, *idem*, p. 23, Clarksville, N. Y.
Aspidolites, *idem*, p. 24.
Dicranurus, *idem*, p. 24.

Cephalopoda.

Orthoceras hercules, *n. sp.*, p. 29, Ile. Drummond.
O. conicum, *idem*, pl. X, fig. 3, p. 29, Ile. Drummond.
On propose de substituer à ce nom déjà employé celui d'O. Castelnau.
O. filiformis, *idem.*, pl. X, fig. 2, p. 30, Ile Drummond.
Cyrtoceras markoei, *n. sp.*, pl. IX, fig. 3, p. 30, Montmorency falls.
Actinoceras richardsoni ? *Stokes*, pl. VII, figs. 1-2, Ile Manitouline (lac Huron);idem, pl. VIII, figs. 2a-b, p 30.
A. blainvillei, *n. sp.*, pl. V, fig. 1, p. 31, Ile Manitouline; *idem*, pl. VIII, fig. 1.
A. cordieri, *n. sp.*, pl. V, fig 2, p. 31, Ile Manitouline.
A. baudanti, *n. sp.*, pl. VI, fig. 2, p. 31, Ile Drummond.
A. beaumonti, *n. sp.*, pl. VI, fig. 1, p. 32, Ile Drummond.
A. lyonii? *Stokes*, pl. IX, fig. 4, p. 32, Lac des Bois.
A. dufresnoyi, *n. sp.*, pl. VIII, fig. 3, p. 32, Ile Drummond.
A.? deshayesii, pl. VIII, fig. 4, p. 32, Baie Verte.
Huronia obliqua, *n sp.*, pl. IX, fig. 9, p. 32, Ile Drummond.
H. stokesi, pl. IX, fig. 3, p. 33, Schoharie, N. Y.
Sidemina, *Castlenau*, p. 33.
Sidemina infundibuliforme *Caslln*, pl. X, fig. 1, p. 33, Ile Manitouline.
Nelimenia, *Castelnau.*
Nelimenia incognita, *n. sp.*, pl. X, fig. 4, p. 33, Montmorency falls.
Tentaculites irregularis, *n. sp.*, pl. X, fig. 5, p. 34, Trenton, N. Y.
T. regularis, *n. sp.*, pl. X, fig. 6, p. 34, Trenton, N. Y.
Goniatites canadensis, *n. sp.*, pl. XI, fig. 7, p. 34, Montmorency falls.

*Late literature on this subject seems to make no reference to this work of Castelnau's.

Heteropoda.

Bellerophon striatus? *Ferussac*, pl. XI, fig. 2, p. 34. Lac Erie.

Gasteropoda.

Euomphalus verneuli, *n. sp.*, pl. XI, fig. 1 a-b, p. 34, Lac Huron.
E.? minutissmus, *n. sp.*, pl. XI, fig. 9, p. 35, Trenton, N. Y.
Trochus huroniensis, *n. sp.*, p. 35, Riv. Ottowas.
Turritella schohariensis, *n. sp.*, pl. XI, fig. 8, p. 35, Schoharie, N. Y.
Pileopsis naticoides, *n. sp.*, pl. XI. fig. 3, p. 35, Scoharie, N. Y.
P. rotundata, *n. sp.*, pl. XI, fig. 4, p. 36, Schoharie, N. Y.
P. spiralis, *n. sp.*, pl. XI, fig. 5, p. 36, Schoharie, N. Y.
P. conoides, *n. sp.*, pl. XI, fig. 6, p. 36, Schoharie, N. Y.

Brachiopoda.

Orthis schohariensis, *n. sp.*, pl. XIV, fig. 5, p. 36, Schoharie, N. Y.
O. michelini? *Leveille*, p. 36, Schoharie, N. Y.
O. flabellulum *Murch.*, p. 37, St. Regis.
O. panderi?, p. 37, New York.
O. huronensis, *n. sp.*, pl. XIV, fig. 6, p. 37, Lac Huron.
O. conradi, *n. sp.*, pl. XV, fig. 4, p. 37, Schoharie, N. Y.
O. unguiformis, *n. sp.*, pl. XV, fig. 3, p. 37, Schoharie, N. Y.
O. plana *Pander*, pl. XIV, fig. 1, p. 38, Lac Huron.
O. curvata *Sheppard*, p. 38, Baie Verte.
O. alternans, *n. sp.*, pl. XIV, fig. 3, p. 38, Lac des Bois.
Pentamerus deshayesii, *n. sp.*, pl. XV, fig. 12, p. 38, Schoharie, N. Y.
P. beaumonti, *n. sp.*, pl. XIII, fig. 9, p. 38, Lac Erie.
Atrypa? nustella, *n. sp.*, pl. XIV, fig. 3, p. 39, Schoharie, N. Y.
A. galeatea *Dalm.*, pl. XIV, fig. 4, p. 39, Etat de New York.
Productus? sulcatus, *n. sp.*, pl. XIII, fig. 7, p. 39, Schoharie, N. Y.
Productus antiquatus *Sow.*, p. 39, Lac Huron.
Leptæna vicina *Casteln.*, pl. XIV, fig. 9, p. 39, Comté d'Ontario.
Terebratula valenciennei, *n. sp.*, pl. XIII, fig. 6, p. 39. Schoharie, N. Y.
T. mesogona, *Phill.*, pl. XIII, fig. 3, p. 40, Quebec.
T. stricklandi *Murch.*, p. 40, Catskill, N. Y.
T. imbricata, *idem*, p. 40, Lac Huron.
T. prisca *Schl.*, pl. XIII, fig. 8, p. 40, Schoharie, N. Y.
T. borealis *Schl.*, pl. XIV, fig. 14, p. 40, Grande baie Verte.
Cette espèce étant differente de la T. borealis *Schl.* on porpose de l'appeler T. turpis.
T. acuminatissima, pl. XIV, fig. 17, p. 40, Hudson, N. Y.
Spirifer inæquivalvis, *n. sp.*, pl. XIV, fig. 8, p. 40, Ile Drummond.
S. murchisoni *Casteln.*, pl. XII, figs. 1 and 2, p. 41, Schoharie, N. Y.
S. huronensis, *idem*, pl. XII, fig. 6, p. 40, Lac Huron.
S. troostii, *idem*, pl. XII, fig. 5, p. 41, Kentucky.
S. costalis, *n. sp.*, pl. XIV, fig. 7, p. 41, Schoharie, N. Y.
S. macropleurus, *idem*, pl. XIII, fig. 5, p. 41, Schoharie, N. Y.
S. fischeri, *idem*, pl. XIII, fig. 4, p. 42, Kentucky.
S. alatus, *idem*, pl. XII, fig. 4, p. 42, Schoharie, N. Y.
S. multicostatus, *idem*, pl. XII, fig. 3, p. 42, Schoharie, N. Y.
S. sheppardi, *idem*, pl. XIV, fig. 15, p 42, Nashville, Tenn.
S. sowerbyi, *idem*, pl. XIII, fig. 1, p. 43, Pennsylvania.

Conchifera.

Cardium? nautiloides *Casteln.* pl. XV, figs. 5-6, p. 43, Lac des Sénécas.
Bilobite, *DeKay*, pl. XIV, fig. 16, p. 43, Catskill, N. Y.
Amphidesma delafieldi *Casteln.* pl. XIV, fig. 10, p. 44, T. tert du Potomac?
Perna chactas, *idem*, pl. XIV, fig. 12, p. 44, idem.
Venus mohegan, *idem*, pl. XIV, fig. 11, p. 44, idem.

Polyparia.

Columnaria sulcata *Goldf.*, p. 44, New York.
C. troostii *Casteln.*, pl. XIX, fig. 2, p. 44, Kentucky.
C. multiradiata, *idem*, pl. XIX, fig. 1, p. 44, Ile Drummond.
C. mamillaris, *idem*, pl. XIX, fig. 3, p. 45, Bords du lac Huron.

C. alveolata *Goldf.*, p. 45, Drummond.
Catenipora labyrinthica *Goldf.*, pl. XVII, fig. 2, p. 45, Drummond et bords du lac Supérieur.
C. escharoides *Lam.*, pl. XVII, fig. 3, p. 45, Lac Huron.
C. michelini *Casteln.*, pl. XVII, fig. 1, p. 45, Ile Drummond.
Syringopora verticillata *Goldf.*, p. 45, Drummond Ile du Castor.
Astræa mamillaris *Fischer*, pl. XXIV, fig. 3, p. 45, River de l'Ohio.
Strombodes pentagonus *Goldf.*, p. 45, Lac Huron.
Calamopora fuvosa, *idem*, p. 46, Ile Manitouline.
C. minutissina *Casteln.*, pl. XIX, fig. 2, p. 46, Ile Drummond.
C. minuta, *idem*, p. 46, idem., bords du lac Erie.
C. radians, *idem*, pl. XVIII, fig. 1, p. 46, Buffalo, N. Y.
C. cellulata, *idem*, p. 46, Lac Huron.
C. basaltica *Goldf.*, pl. XVIII, fig. 3, p. 46, bords du lac Erie.
C. polymorpha, *idem* p. 46, Baie Verte.
C. gothlandica *Lam.*, p. 46, Buffalo, N. Y.
C. inflata *de Koninck*, p. 47, Baie Verte.
C. goldfussii *Casteln.*, p. 47, Lac Huron, Baie Verte.
C. fibrosa *Goldf.*. pl. XIX, fig. 4, p. 47, Trenton, N. Y.
C. verneuili *Casteln.*, pl. XXIII, fig. 2, p. 47, Quebec.
Cyathophyllum hexagonum *Goldf.*, p. 47, Lac Huron.
C. goliah, *Casteln.*, pl. XX, fig. 1, p. 47, Ile Drummond.
C. atlas, *idem*, pl. XX, fig. 2, p. 47, Ile Drummond.
C. goldfussi, pl. XXI, fig. 2. p. 47, Buffalo, N. Y.
C. plicatum? *Goldf.*, p. 48, Ile Makinau (Huron).
C. ceratites, *idem*, p. 48, Ile Drummond.
C. ammonis *Casteln.*, pl. XXI, fig. 1, p. 48, New York.
C. vicinum, *idem*, pl. XXII, fig. 6, p. 48, idem.
C. conicum, *idem*, pl. XXI, fig. 4, p. 48, Bords de l'Ohio.
C. plicatulum, *idem*, pl. XXII, fig. 4, p. 48, Ile Drummond.
C. dilatatum, *idem*, pl. XXI, fig. 3, p. 48, Lac Huron.
C. striatulum, pl. XXII, fig. 1, p. 48, Lac Huron and Erie.
C. michelini, *idem*, pl. XXII, fig. 3, p. 49, Ile Drummond.
C. arborescens, *idem*, pl. XXII, fig. 2, p. 49, Lac Huron.
C. orbygnyi, *idem*, pl. XXII, fig. 7, p. 49, Batavia, N. Y.
C. rollinii, *idem*, pl. XXII, fig. 5, p. 49, Ile Drummond.
C. distinctum, *idem*, pl. XXII, fig. 8, p. 49, Ile Manitoulines.
C. agglomeratum, *idem*, pl. XXI, fig. 5, p. 49, Idem.
Lithodendron irregulare *Phill.*, pl. XXIII, fig. 1, p. 49, Lac Huron.
Axinura, *Casteln.*, p. 49.
A. canadensis, *idem*, pl. XXIV, fig. 4, p. 49, Lac Sainte-Claire.
Gorgonia ripisteria, *Goldf.*, pl. XXIV, fig. 3, p. 50, Schoharie, N. Y.
G. anticorum *Casteln.*, pl. XXIV, fig. 1, p. 50, Lac Huron.
G. siluriana, *idem*, p. 50, idem.
Eschara scapellum *Murch.*, p. 50, Iles Manitoulines.

Crinoidea.

Crisonoma antiqua *Casteln.*, n. sp., et. gen., pl. XXV, fig. 1, p. 50, Genesee, N. Y.
Cariocrinites ornatus *Say*, pl. XXV, fig. 2, p. 51, Lockport, N. Y.
Pentremites florealis, *idem*, pl. XXV, fig. 3, p. 51, Kentucky and Alabama.
Encrinites, pl. XXV, figs. 4-11, Lac Huron and Lac des Senecas.
Apiocrinites rosaceus *Schl.*, pl. XXV, fig. 12, p. 51, Lac des Senecas.
Encrinites, pl. XXVI, figs. 1-4, p. 51, New York and Lac Huron.
Corps inconnus, pl. XXVII, figs. 1-7, Trenton and Lac Huron.

T. A. Conrad.

1843. *Observations on the lead-bearing limestone of Wisconsin, and descriptions of a new genus of trilobites and fifteen new Silurian fossils*, by T. A. CONRAD. Proc. Acad. Nat. Sci., Philadelphia, 1843, Vol 1, 1841-43.

The new genus is *Thaleops*, and the specific name given is *ovata*. It was from Mineral Point. Mr. Conrad unhesitatingly assigns the lead-bearing beds to the Trenton, viz:

"From the evidence it is clear that the limestone of Galena, Illinois, and of Mineral Point, Wis., in which the lead occurs, is certainly not of more recent date than the Pulaski and Lorraine shales of New York, and the Caradoc sandstone of Great Britain; but I believe it will prove to be an upper member of the Trenton limestone formation."

In the lead-bearing rock, "a buff, granular limestone," Mr. Conrad reported the following as having been identified:

Inachus pervetus Con.	Orthis testudinaria?
Pleurotomaria angulata Sow.	Delthyris—
Turritella —	Strophomena sericea

Cyathophyllum profundum Con.

The following are definitely located at Mineral Point, Wis.:

Crytoceras marginalis Con.	Orthis disparilis Con.
Orthoceras annellus Con.	Orthis perveta Con.
Phragmolites compressus Con.	Orthis tricenaria Con.
Turritella —	Orthis bellarugosa Con.
Pleurotomaria angulata Sow.	Orthis subequata Con.
Bellerophon bilobatus Sow.	Atrypa schlottheimi Von Buch.
Euomphalus triliratus Con.	Nuculites —
Inachus pervetus Con.	Nuculites —
Subulites elongata.	Delthyris —
Strophomena sericea Sow.	Ceraurus pleurexanthemus Green.
Strophomena deflecta Con.	Isotelus gigas DeKay.
Strophomena recta Con.	Thaleops ovata Con.
Orthis testudinaria?	Cytherina fabulites Con.

Several of the foregoing are new species, described here for the first time. Mr. Conrad should have the credit of first determining the age of these rocks correctly from adequate data. His studies were the basis of the statement of Mr. Nicollet made the same year. It is known that Mr. Nicollet had the aid and co-operation of Mr. Conrad.

J. N. Nicollet.

1843. *Report intended to illustrate a map of the hydrographical basin of the upper Mississippi river*, made by J. N. NICOLLET, Washington, 1843. 20th Congress, 2d Session; Senate doc. 237, pp. 1–170.

Very little of this report is devoted to geology. The rocks of the Undine region (valley of the Blue Earth river) and of the lower half of the Minnesota valley are considered to be the same as those at Fort Snelling—*i. e.*, a thick friable sandstone overlaid by limestone, sometimes magnesian and occasionally containing fossils (pp. 19–20). He considers these rocks as Silurian (p. 30) and gives approximately the outlines of the Silurian, or, as he terms it, the formation of St. Peter's (p. 71):—"The geological formation of St. Peter's continues to show itself in the river of the same name,* and goes on thinning out as far as *Waraju* river (the *rivière aux Liards* of the French) and there it disappears. Hence it passes to the head waters of the Mankato* river, crosses the southern part of the *Coteau des Prairies*, and finally loses itself in the Missouri, Sioux and Iowa rivers. * * * * To the east, starting from St. Anthony falls, it may conjecturally be stated to cross the St. Croix, make its appearance on *Manomin*, *Chippeway* and *Sapak* rivers, not far from the rapids and falls of these rivers, and then, passing through the

*The Minnesota river was formerly called the St. Peter.

*Now known as the Blue Earth.

upper portion of Wisconsin, reaches the state of Michigan." On p. 68 a section along the Mississippi from Fort Snelling to the falls of St. Anthony is given as follows:

1. "Fine grained unstratified sandstone." 2. "A compact sub-lamellar limestone of variable colors, as fawn, yellowish-buff, or grayish. It contains many fossils, but very irregularly distributed in the mass. This bed is from 8 to 12 feet thick, weathering into layers of from two inches to a foot thick." 3. "Drift."

A list of a few of the fossils found in the mineral region of Wisconsin (p. 168) is given and also a list of those found at Fort Snelling and the falls of St. Anthony (p. 169).

These lists are given below in full. In the determination of the fossils Nicollet was assisted by Mr. T. A. Conrad, and he gives his idea of the stratigrahic position of the fossil-bearing strata at Ft. Snelling in the following words:—

"I may remark here, that it will be seen that this list of fossils embraces a few species of the Trenton limestone, as described by the New York geologists; whence we might infer that the group of St. Peter's characterizes a rock of the same age as that which contains the lead at Galena, and which may probably be an upper portion of the Trenton limestone, newer than any part of that formation hitherto observed in the state of New York." (p. 70.)

This seems to be the first correct assignment of the rocks at the falls of St. Anthony to the horizon of the New York Trenton.

MINERAL REGION OF WISCONSIN TERRITORY—GALENA AND ITS VICINITY.

Blue limestone. (Trenton of Dr. Owen and Dr. Locke.)

Trilobites:—

Illænus, (new)
Asaphus, (new.)
Ceraurus pleurexanthemus, (Green.)
Portion of an Isotelus gigas.
Calymene spinifera, (Conrad.)

} Trenton limestone of New York, corresponding with the lower part of the Caradoc,——perhaps still lower.

Shells:—

Strophomena, (new.)
Strophomena sericea, (Sowerby.)
Strophomena alternata, (?) } Same of the Trenton limestone, New York.
Orthis alternata, (?) }
Orthis callactis.
Cypricardites, (new.)
Trochus lenticularis, (Sowerby.) Murch. Sil. Syst.
Pleurotomaria.
Bellerophon bilobatus.
Orthoceras. (one species, large.)

Cliff limestone. (Supposed by Drs. Owen and Locke to include the lead bearing rocks.)

Illænus, (new.) Same species as in the Trenton limestone.
Strophomena deltoidea.
Atrypa, (new species).
Lingula, (new). Same with a Trenton limestone species.
Euomphalus, (new).
Orthoceras; fragment, (undetermined).

Corals:

Cyathopyllum ceratites (?).
Turbinolopsis, (new).
Favosites, (new).
Portion of an Asterea.

ST. PETER'S* AND FALLS OF ST. ANTHONY.

Strophomena, allied to *S. alternata.*
Strophomena, (new species).
Orthis testudinaria? (Murch. Sil. Sys., pl. xx, fig. 10).

* Fort Snelling.

Orthis polygramma? (Murch. Sil. Sys., pl. XXI, fig. 4).
Orthis, (three new species).
Stenoscisma, resembling *Terebratula schottheimii*, (Dalman).
Atrypa, (new species).
Pleurotomaria, (new species—numerous).
Euomphalus, allied to *Maclurites magna*, (Des.)
Euomphalus, resembling *E. sculptus*, (Sowerby).
Phragmolites, same as the Trenton limestone, N. Y.
Phragmolites, (new species).
Bellerophon bilobatus.
Orthoceras, (two species, undetermined).
Crinoidal remains of peculiar forms; one resembling *Lipocrinites.*
Turbinolopsis bina? (Silur. Syst., pl. XVI bis, fig. 5).
Favosites lycoperdon, (Say). Trenton limestone fossil.
Favosites, (two new species).
Fucoides, (obscure).
Cyathophyllum ceratites?
Turritella.

G. W. Featherstonhaugh.

1847. *A Canoe Voyage up the Minnay Sotor, with an account of the lead and copper deposits of Wisconsin, etc.* G. W. FEATHERSTONHAUGH, two volumes, London. 1847. There is very little geology in these volumes. At Fort Snelling he "cursorily examined the limestone beds superincumbent upon the soft sandstone, in which were a great variety of fossils, such as *orthocera, bellerophon, fucoides, orthis*, and other fossils characteristic of some upper beds of some Silurian limestones." Vol. I, p. 258.

D. D. Owen.

1848. *Report of a geological reconnaissance of the Chippewa Land District of Wisconsin, and incidentally of a portion of the Kickapoo country, and of a part of Iowa and of the Minnesota Territory; made under instructions from the United States Treasury Department*, by DAVID DALE OWEN, M. D., U. S. Geologist for Wisconsin. Dated April 23, 1848. New Harmony, Ind.

This is one of the progress reports of the survey which subsequently was reported fully in 1852, and much of its contents and nearly all of its maps and other illustrations are included in the later volume. It also embraces a report by Dr. J. G. Norwood on the lower waters of the St. Louis valley, and on the country between Fond du lac and the falls of St. Anthony.

In an appendix are lists of fossils found in the formations at various points, viz., in the "lower fossiliferous limestone at St. Peter's and Fort Snelling, which are identical with those occuring in the blue limestone of the Ohio valley;" "near the Big Spring on the Upper Iowa river," and "in the limestones (F. 3) of Turkey river, near the agency and vicinity." These, however, are classified and further reported in the final report, noted below.

He does not mention definitely the probable age of the limestone at the falls of St. Anthony, but under the designations "Formation 3," which Shumard divides into For. 3*a*, For. 3*b* and For. 3*c*, and "St. Peter shell limestone," he states that the abundant organic remains embrace some species found in the inferior beds of the upper magnesian (*i. e.*, the Cliff) limestone of the Dubuque district, and some found in the Blue limestone of the Ohio valley, all being of Silurian type (p. 30).

Sir John Richardson.

1848. *Arctic searching expedition: a journal of a boat voyage through Rupert's land and the Arctic sea, in search of the discovery ships under command of Sir John Franklin, with an appendix on the physical geography of North America,* by SIR JOHN RICHARDSON, C. B., F. R. S. 8vo. 1852. Harper Brothers, New York.

Dr. Richardson in this journey obtained information which authorized him to refer the limestones on the western shores of lake Winnipeg to the Silurian, "chiefly birds eye limestone."

Foster and Whitney.

1850. *Report on the geology and topography of a portion of the Lake Superior land district in the state of Michigan,* by J. W. FOSTER and J. D. WHITNEY, U. S. Geologists; in two parts.—Pt. I, Copper lands; 31st Congress, 1st session, House doc. 69; Washington, 1850; pp. 1–224.

On pages 117 to 119 the "Compact, or Lower Magnesian Limestone" is described; all the clastics, above the Potsdam, found just west of Keweenaw bay are included under this head. A small number of fossils were collected and submitted to professor James Hall, who says: "The evidence from the whole together goes to prove that the rocks from which they were obtained belong to the older Silurian period." Concerning the fossils, all of which were imperfectly preserved, the author concludes:

"From all of the facts, these fossils may be regarded as belonging to the earlier types of organic life. From the limited scale on which these deposites are developed, and the imperfect character of the organic remains, it is impossible to fix their precise equivalents in the New York classification. The sandstones and limestones which we have described may be regarded as the equivalents of the Potsdam and Calciferous sandstones, the Chazy, Birdseye, and Black River limestones, and perhaps of the Trenton and even the Hudson River groups."

This rock appears in outcrop "west of Keweenaw bay," near the quarter-post between sections 13 and 14, township 51, range 35, also a little west of the line between sections 23 and 24, extending for a little more than a mile, forming a high cliff running south.

Foster and Whitney.

1851. *Report on the geology of the Lake Superior land district,* by J. W. FOSTER and J. D. WHITNEY, U. S. Geologists; Pt. II. The iron region, together with the general geology; Special session, March, 1851, Senate doc. 4; Washington, 1851; pp. 1-406.

This report is accompanied by several sections and a geological map of the shores of lake Superior and the upper peninsula of Michigan. The map shows an area of Trenton limestone (including Chazy, Birdseye and Black River limestones) along the west shore of Green bay. On the east shore of this bay are rocks of the Hudson River group, and from here these two formations (Trenton and Hudson River) extend in a narrow belt northeast and east through the centre of the peninsula to its eastern end, the latter group lying immediately south of the former. The Chazy, Birdseye, Black River and Trenton limestones, although of small thickness, are well defined and each shows its characteristic fossils similar to those of the same strata in New York. There are twenty-five fossils described and figured (nine for the first time); of these the following are from the last mentioned limestones and the Hudson River group:—

Phenopora multipora, n. sp.
Clathropora flabellata, n. sp.
Chætetes lycoperdon.
Schizocrinus nodosus ?
Echinosphærites ? n. sp.
Murchisonia major, n. sp.
Asaphas barrandi, n. sp.
Harpes escanabiæ, n. sp.
Phacops callicephalus.
Catenipora gracilis, n. sp.
Sarcinula ? obsoleta, n. sp.
Modiolopsis pholadiformis, n sp.
Modiolopsis modiolaris.
Ambonychia carinata.

Fossils listed from the Birdseye, Black River and Trenton limestones are given below :—

Plants.

Palæophycus —?
Buthotrephis succulens.
Phytopsis tubulosum.

Corals.

Chætetes lycoperdon.
Streptelasma corniculum.
— profunda.
Stictopora ramosa.
S. elegantula.
S. — n. sp.
Stictopora — n. sp.
Phenopora multipora, n. sp.
Escharopora recta.
Clathropora flabellata, n. sp.
Aulopora arachnoidea.
Graptolithus amplexicaulis.

Crinoidea.

Schizocrinus nodosus.
Homocrinus — ?
Echinosphærites — n. sp.
— nov. genus.

Brachiopoda.

Lingula æqualis.
Orthis testudinaria.
O. subæquata.
O. pectinella.
O. disparilis.
Leptæna alternata.
Leptæna filitexta.
L. sericea.
L. deltoidea.
L. tenuistriata.
Spirifer lynx.
Atrypa increbescens.
Atrypa recurvirostra.

Acephala.

Ambonychia obtusa.
Nucula levata.
Tellinomya dubia.
Edmondia ventricosa.

Gasteropoda.

Subulites elongata.
Murchisonia major.
M. bellicincta.
M. — n. sp.
M. angulata.
Pleurotomaria lenticularis.
Pleurotomaria umbilicata.
P. rotuloides.
P. subconica.
Bucania bidorsata.
Bellerophon bilobatus.
Cyrtolites compressus.
Carinaropsis — n. sp.

Cephalopoda.

Orthoceras multicameratum.
O. fusiforme.
Ormoceras tenuifilum.
Endoceras proteiforme.
Gonioceras anceps, (west of the limits of the district).

Crustacea.

Isotelus gigas.
Illænus crassicauda?
Calymene blumenbachii var. senaria.
Phacops callicephalus.
Ceraurus pleurexanthemus.
Asaphus extans.
A. barrandi, n. sp.
Harpes escanabiæ, n. sp.
Lichas trentonensis.
Cytherina fabulites.

Those from the Hudson River group are:—

Plants.

Buthotrephis subnodosa.

Corals.

Chætetes lycoperdon.
Favistella stellata.
Streptelasma — n. sp.
— ? nov. genus and sp.
Catenipora gracilis, n. sp.
Syringopora obsoleta, n. sp.

Crinoidea.

Columns of Heterocrinus and Glyptocrinus.

Brachiopoda.

Lingula quadrata.
Orthis testudinaria
O. occidentalis
O. subjugata.
Orthis subquadrata.
Leptæna alternata.
L. sericea.
Atrypa increbescens.

Acephala.

Ambonychia carinata.
Avicula demissa.
Modiolopsis modiolaris.
M. pholadiformis, n. sp.
Modiolopsis anadontoides.
Nucula — ?
Lyrodesma — ?
Cleidophorus planulatus.

Gasteropoda.

Murchisonia gracilis.
Bellerophon bilobatus.
Cyrtolites ornatus.

Cephalopoda.

Orthoceras lamellosum.
Ormoceras crebriseptum.

Crustacea.

Isotelus megistos.

In the classification of the formations (pp. 2-7) Messrs. Foster and Whitney distinctly separate the Galena limestone from the "Cliff or Upper Magnesian limestone," of which it had hitherto erroneously been supposed to be a part. But the interlying Blue shale (the Maquoketa) they suppose to be "associated with No. 3, or the Blue limestone and marls of the west," which at that time were regarded, without dissent, as the equivalent of the Trenton. It is plain therefore that although they distinctly recognized the Hudson River strata in Green bay, overlying the Galena beds, they could not satisfactorily adjust the "Blue shale" of Locke in the Mississippi valley, in the same position. The term Galena limestone is first met with in this report.

This separation was evidently due to the paleontological determinations of Prof. James Hall, who in Chapter IX details the geographic distribution of the Chazy, Birdseye and Black River formations, and names the fossils found by him in the lead-bearing rock, none of which could be assigned to the Upper Silurian. He remarks that if the Hudson River beds of the Green Bay region should finally be discovered in the Mississippi valley they must lie above the Galena limestone, but that he had been unable to trace them from one region to the other.

D. D. Owen.

1852. *Report of a geological survey of Wisconsin, Iowa and Minnesota; and incidentally of a portion of Nebraska territory, made under instructions from the United States treasury department*, by DAVID DALE OWEN, United States geologist, Philadelphia, 1852, 4to, numerous illustrations, maps and plates, pp. XXXVIII and 635.

Dr. Owen, in the preparation of his report (pp. 71–73), evidently included in formation 3 not only the Trenton, as seen at the falls of St. Anthony, but also rocks of the horizons of the Hudson River, the Galena and the Niagara limestones, thus not recognizing the Upper Silurian. This is apparent from the following remarks, p. 73:

"Many species found both by Dr. Shumard and myself, in the lower shell limestone of the Upper Mississippi are identical with forms occurring both in the substratum of gray limestone at Eagle Point in the Dubuque district—figured and described in my report of 1839—and in the blue limestone of the Ohio valley. Those of the upper division [For. 3, c], resemble rather the species found in the inferior beds of the Upper Magnesian limestone of that district. But all, so far as our examinations have yet extended, are of Lower Silurian type."

There is, therefore, some contradiction between the earlier and later portions of this magnificent report, and in the application of the characters (F. 3, *a*, *b* and *c*), by which he chose to designate the different parts of Formation III. It is evident, whether these terms describe this formation "high up on the Turkey river" (p. 73), or "on the heights at Fort Snelling," that the lettering of the parts, and the descriptions of the sections (see Sec. 2, R. at the falls of St. Anthony) are intended to be applicable to the same beds, although the thickness is supposed to be greatly reduced at the falls of St. Anthony. The general report passes from this immediately to the Devonian as it occurs on the Cedar and Lower Iowa rivers, in Iowa. At the falls of St. Anthony, however, Dr. Shumard's section, to which Dr. Owen refers, is as follows (Plate, Sec. 2, R.):

Upper Shell limestone, F.3, *c*. 6 feet,	St. Peter Shell limestone.
Non-fossiliferous bed, F.3, *b*, 5 feet,	
Lower Shell limestone, F.3, *a*, 23 feet,	

In the final discussion of the paleontological results as presented in the tables at the end of the volume, it becomes apparent that Dr. Owen had discovered that under the designation "Formation III," especially in Iowa, he had included some beds which actually contained an Upper Silurian fauna, and the following section is finally given, [see table, p. 624.]

Coralline and Upper Pentamerus beds, F. 3. *c*. Upper Silurian.
=Clinton and Niagara group of New York.
Lead-bearing beds of the Upper Magnesian limestone, F. 3. *b*.
=Utica slate and Hudson River group of New York. Lower Silurian.
Shell beds, F. 3, *a*=Trenton limestone of New York. Lower Silurian.

The term "St. Peter's Shell limestone" therefore is here made the equivalent not only of the shell beds described by Shumard at the mouth of the St. Peter's (Minnesota) river, but of all the Trenton beds, or "Blue limestone," up to the base of the lead-bearing beds, which at St. Paul carries the St. Peter shell limestone to near the summit of the hills, or about 90 feet higher than proposed by Shumard.

The strata covered by the scope of the present volume are arranged by Owen in the following scheme:

1. Formation 3 *b*. Lead-bearing beds of the Upper Magnesian limestone.
2. Formation 3 *a*. St. Peter's shell limestone.

The second of these was divided into three parts by Dr. B. F. Shumard under the following distinctions as seen at St. Paul and the falls of St. Anthony, in descending order:

1. Grayish buff-colored magnesian limestone, with numerous casts of fossils. Thickness not given.
2. Ash-colored argillaceous hydraulic limestone, sometimes with conchoidal fracture. No fossils observed. Thickness 5 feet.
3. Ash-colored limestone, clouded with blue, full of fossils. Contains about 65 per cent. carbonate of lime. Thickness, 15 feet.

In the appendix, Article III, p. 598, is a short discussion of the tables showing the distribution of the fossils collected by Dr. Owen's survey. The following thirty-seven "may be referred to species distributed through the Trenton limestone, Utica slate and Hudson River group of New York, as follows:

Chætetes lycoperdon.
Conularia trentonensis.
Ambonychia undata.
Ambonychia amygdalina.
Nucula levata.
Bellerophon bilobatus.
Pleurotomaria lenticularis.
Pleurotomaria subconica.
Pleurotomaria umbilicata.
Subulites elongata.
Murchisonia subfusiformis.
Murchisonia bellicincta.
Murchisonia tricarinata.
Cyrtoceras macrostomum.
Orthoceras vertebrata.
Orthoceras laqueatum.
Orthoceras junceum.
Leptæna planumbona.
Leptæna alternata.
Leptæna sericea.
Leptæna deltoidea.
Atrypa hemiplicata.
Atrypa modesta.
Atrypa capax.
Spirifer biforatus.
Orthis testudinaria.
Orthis tricenaria.
Lingula quadrata.
Echino-Encrinites anatiformis.
Heterocrinus heterodactylus.
Calymene senaria.
Isotelus gigas.
Illænus crassicauda.
Ceraurus pleurexanthemus.
Phacops callicephalus.
Lichas trentonensis.

"One species, Gonioceras anceps, is peculiar to the Black River limestone; one, the Orthoceras multicameratum, to the Birdseye limestone; and Maclurea magna, to the Chazy limestone."

In addition to the foregoing his tables also contain the following, referred to the "Shell beds" or Trenton limestone.

Asaphus iowensis.
Illænurus ovalis.
Bumastus barriensis.
Lituites undatus.
Lituites convolvans.
Cyrtolites ornatus.
Cyrtolites compressus.
Ambonychia orbicularis.
Orthis bellarugosa.
Orthis sinuata.
Orthis disparilis (?)
Orthis perveta.
Orthoceras undulostriatum.
Campulites arcuatus (?)
Endoceras proteiforme.
Endoceras subcentrale.
Trocholites ammonius.
Orthis subæquata.
Orthis subquadrata.
Orthis occidentalis (?)
Leptæna deflecta (?)
Leptæna recta.
Leptæna trilobata.
Selenoides iowensis.

The following are referred to the age of the Utica slate:

Asaphus iowensis.
Cyrtoceras conicum.
Campulites ventricosum.
Trocholites ammonius.
Maclurea magna.
Pleurotomaria lenticularis.
Murchisonia bellicincta.
Murchisonia abbreviata.
Murchisonia subfusiformis.
Murchisonia tricarinata.
Bellerophon bilobatus.
Ambonychia obtusa.
Spirifer lynx.
Spirifer lynx, var. biforatus.
Orthis testudinaria.
Leptæna alternata.
Leptæna sericea.
Atrypa hemiplicata.
Atrypa capax.
Lingula quadrata.

The following are referred to the age of the Hudson River group.

Calymene senaria.
Cyrtoceras macrostomum.
Orthoceras vertebrale.
Endoceras cuvieri.
Pleurotomaria subconica.
Pleurotomaria bilex.

The fossils of F. 3 are represented in Table II, IIa and IIb.

In the general table of stratigraphical and geographical distribution of fossils, Dr. Owen represents the lead-bearing beds (For. 3b) as the equivalent of the Utica slate and Hudson River group, and he indicates what fossils of these beds are found in the Utica slate and Hudson River in New York. This is a very meager showing, as might be anticipated from the fact that the true horizon of the Hudson River group is entirely above the lead-bearing horizon, and between it and his "Coralline and Pentamerus beds."

In another table, of the equivalency of the formations of the lead region with the New York system, not only does he express the same idea, but shows clearly that he regarded the Shell-bed (For. 3a) as the representative of the whole of the "Blue limestone" of Ohio, and also makes it embrace the Trenton and Black River limestones, the Birdseye and Chazy having no representative in the upper Mississippi valley.

It is singular that neither the survey of Foster and Whitney, whose parties visited the lead region and the falls of St. Anthony, nor that of D. D. Owen, whose central and most important area was that covered by the Lower Silurian, in the upper Mississippi valley, detected the Hudson River group in its true position, although they both made some quasi provision for it in their classification.

Edward Daniels.

1854. *First annual report of the Geological Survey of the state of Wisconsin*, by EDWARD DANIELS; Madison, 1854; pp. 1–84.

This report is devoted chiefly to the economic resources of the lead region. Two geological sections are given, one from Dubuque to the Blue mounds, and the other a vertical generalized section of the rocks of the lead region; the latter is as follows:

1. Drift; 20 feet.
2. Coralline beds of Dr. Owen; 300 feet.
3. Nucula shale; 15 feet.
4. Gray limestone—the lead-bearing rock; 250 feet.
5. Blue limestone; 40 feet.
6. Buff-colored limestone; 30 feet.
7. Sandstone; 60 feet.
8. Lower Magnesian limestone of Owen: 200 feet.

The Nucula shale of this section is the Blue shale of J. G. Percival. It is said to be thickest in the lead region and to gradually thin out toward the north and east. The fossils being all of diminutive size, he styles the shale a "fossil Lilliput," analogous to Hugh Miller's "age of dwarfs" among the fishes of the old red sandstone. He does not assign it to any place in the New York system.

The Blue limestone is considered as "undoubtedly the equivalent of the Blue limestone so abundantly developed at Cincinnati." The Buff limestone is below the Blue.

J. G. Pericival

1855. *Annual report on the Geological Survey of the state of Wisconsin.* By JAMES G. PERCIVAL; Madison, 1855; pp. 1–101.

The entire report is given to economic geology and the lead region is the only part of the state described. The series of rocks found here is as follows:

"1. The Mound strata, consisting of three distinct beds of limestone; the upper, middle and lower. 2. A bed of Blue shale, separating the Mound strata from the next lower limestone series. 3. The Upper Magnesian of Owen, also consisting of three distinct beds. 4. The Blue limestone, including the Blue and Buff limestones of Owen (1st Rep.,) also presenting three distinct beds. 5. The Upper Sandstone. 6. The Lower Magnesian of Owen. * * * * 7. The Lower Sandstone."

The Blue shale here individualized, being the "Nucula bed" of Daniels, became subsequently known as the Maquoketa shale. Percival calls attention to the small fossils, but seems to have no idea, as yet, of the equivalence of this bed with the Hudson River of New York. He gives it a distinct place in the lead region, viz., between the Mound limestone (the Coralline limestone of Owen) and the Upper Magnesian limestone. The term "Blue limestone" is here made to include the Blue and the Buff of Owen.

J. G. Percival.

1856. *Annual report of the Geological Survey of the state of Wisconsin.* By J. G. PERCIVAL; Madison, 1856; pp. 1-111.

This is a continuation of the descriptions of Dr. Percival's first report. He gives more details of the lithology of the several formations, spoken of in the other report, and the characteristics of the minor divisions of each. He mentions shells of the genus *Leptæna* as being characterastic of the "Blue limestone." Below the coralline beds of Dr. Owen he describes a blue shale "underlying the mound limestone, and thus immediately above the upper magnesian," (p. 14). This he describes at numerous points in the Mississippi valley, and affirms that it occurs in the eastern part of the state, describing it at several points on the narrow peninsula which forms the eastern side of Green bay. This seems to have been the first published identification of this shale with the Hudson River rocks of the east shore of Green bay.

James Hall.

1858. *Report of the Geological Survey of the state of Iowa, embracing the results of investigations made during portions of the years 1855-56, and 57.* By JAMES HALL and J. D. WHITNEY. Vol. I, parts 1 and 2 (in two volumes), 1858.

In giving a general review of the formations (Chapter III) Prof. Hall states that the "Trenton limestone with the subordinate beds of the Birdseye and Black River limestones, preserve, at several points above Dubuque, upon Turkey river and other places in Iowa, at Platteville and Mineral Point in Wisconsin, at the falls of St. Anthony and at St. Paul in Minnesota, in a greater or less degree, their distinctness of character and position." In a section at Pike's hill opposite the mouth of the Wisconsin river he includes the Trenton and Birdseye limestones between the Galena and the "magnesian beds below," giving them a total thickness of 75 feet. In other words, he excludes both Trenton and Birdseye from that stratum of the Lower Silurian which later became known as the Buff limestone, and which still later came to be considered exclusively as the Trenton. With these he also must necessarily have excluded the Black River limestone. In a section at Clayton (p. 56) he describes the Galena as alternating with the Trenton. The total thickness, between the St. Peter sandstone and the Galena, he found at Guttenburg to be about 100 feet, and in the same place he mentions Receptaculites over 50 feet below the base of the Galena lime stone. The same occurs at Elkader mills.

The Galena is estimated, at Elkader mills, as 130 or 140 feet thick, and at Dubuque as 200 or 250 feet thick. "From all the sections measured it is very certain that the Galena limestone gradually thins out to the north and northwest, and at the same time loses very much the characteristic features which distinguish it in the productive lead region." The uppermost beds at Elkader mills are said to be "black on fresh fracture, weathering to light gray or drab," an evenly bedded limestone with shaly partings.

The Hudson River group, which had been described by Percival in Wisconsin under the name of "Blue shale," was recognized by Hall in Iowa, occupying a slope usually without exposure of rock, situated between the Galena limestone and the magnesian limestone which forms the capping of numerous mounds in the northeastern part of Iowa. These beds were found to be characterized by great numbers of small orthoceratites and Nucula. The basal member is a black slate "not unlike the Utica slate," and contains two species of Lingula, one much larger than the other. The total thickness of these beds is not more than 60 feet. "The term 'Blue limestone' was originally applied in the Ohio geological reports to the shales and limestones of the Hudson River group as developed in the neighborhood of Cincinnati, and these were formerly supposed to be the continuation of the Trenton limestone of New York." The fossils described in Part II of this report are Devonian and Carboniferous.

J. D. Whitney.

1858. In the same volume as the last noted the chapter on "Chemistry and Economical Geology" is by professor J. D. Whitney. He reviews the geological succession in Iowa.

The term "Blue limestone" here is made the equivalent of the Trenton, including all the strata from the St. Peter to the Galena, and the Buff limestone is a subordinate member at the bottom, which for convenience of description could be distinguished "from the Blue limestone proper." The Buff varies from 15 feet to 20 feet in thickness, and the Blue proper from 70 feet to 80 feet. In the discussion of the stratigraphy and the chemical composition it is not plain whether the author speaks, generally, of the Blue limestone or of the "Blue limestone proper." The "glass rock" characters are common near the bottom. This is a nearly pure carbonate of lime, fine-grained, imperfectly crystalline, easily breaking into cuboidal blocks with a smooth, often conchoidal fracture. The passage from the Trenton to the Galena is by a series of alternations of purely calcareous and calcareo-magnesian layers.

The greatest thickness of the Galena is at Dubuque, 250 feet, and from that point it seems to thin out in all directions. This is a dolomyte, and resembles the Lower Magnesian limestone. Toward the top it becomes shaly, and gradually passes into the Hudson River shales. The central portion is massive, coarsely crystalline, with cavities that appear on weathering, with chert and other siliceous impurities, and the lower beds become less dolomitic, with alternations of shale and of Blue limestone. Receptaculites is confined to the Galena limestone, within the mineral district, but further north, as on Turkey and Upper Iowa rivers, it is abundantly scattered through the shaly beds of the Blue.

The Hudson River shales contain from one-tenth to one-fifth of their weight of carbonaceous matter, "The Hudson River shales, with the closely allied Hudson River slates, seem to have been deposited under conditions somewhat resembling those under which the true coal-bearing rocks were accumulated."

Henry D. Rogers.

1858. *The Geology of Pennsylvania, a government survey.* By HENRY DARWIN ROGERS. Vol. II, Philadelphia, 1858.

In the discussion of the history of the Matinal period (p. 784), the author makes a suggestion, carried out more fully by Mr. C. D. Walcott in 1879, that the Galena limestone occupies nearly the same stratigraphic position as the Utica slate of New York. He adds:

> "But whether it was produced in the same age with that deposit, or in that next before it, or, again, in that next after it, we are without the means, for the present at least, of ascertaining, since the black slate and it nowhere occur in the same districts, nor even approach each other by a wide geographical interval. * * * * * * The very marked transition between the Matinal argillaceous limestone [Trenton] and this lead-bearing rock, in regard to their organic remains, strongly intimates that some important physical change took place in the interval."

It is evident, from the last remark, that Prof. Rogers considered, at that date, the lead-bearing rock as a part of the Cliff limestone, as stated by Hall. This idea, however, had been corrected prior to the publication of the Pennsylvania report, largely through the agency of Prof. Hall, in the report of Foster and Whitney (1851), though perhaps not prior to the time at which Prof. Rogers wrote the above words. At any rate, as a matter of fact, there is no great contrast in their organic remains, between the Trenton limestone and the lead-bearing rock. The contrast which Prof. Rogers refers to as obtaining between the Matinal limestone and the Cliff (Niagara) to which the lead-bearing rock had been referred by Owen and Hall, as those formations are represented in New York and Pennsylvania, is that which is now well known at the top of the Galena.

Edward Daniels.

1858. *Annual Report of the Geological Survey of the Slate of Wisconsin, for the year ending Dec. 31, 1857.* By PROF. E. DANIELS, Madison, 1858. Pamphlet of 62 pages.

The author, in describing the iron ore at Iron ridge, Dodge county, reverts to the fact that he made the discovery of the "Blue shale" in 1851, and described it as "Nucula shale" in 1853. He evidently is in error when he states (p. 13) that this stratum had been "recognized by Prof. Hall in Foster and Whitney's report on the Lake Superior Land district as belonging to the Hudson River group," since it was only in the Green bay region, in the eastern part of the state, that Prof. Hall recognized the Hudson River formation, and there was then no known connection of the Blue shale of the Mississippi valley with the Hudson River strata seen in the region of Green bay. This connection was pointed out by Dr. Percival.

Henry Youle Hind.

1859. *Reports of progress: together with a preliminary and general report on the Assiniboine and Saskatchewan exploring expedition, made under instructions from the Provincial Secretary, Canada.* By HENRY YOULE HIND, M. A., Professor of Chemistry and Geology in the University of Trinity College. Toronto, 4to, with maps and plates, pp. 201, 1859.

This valuable report, which is too often ignored by later travelers in making their reports on the region, gives definite information concerning the paleontology of the rocks on the western side of lake Winnipeg, accompanied by detailed sections of the strata. "Nearly the whole length of the western coast of lake Winnipeg is composed of limestones, sandstones and shales of Silurian age." These are assigned to the Chazy, Birdseye, Trenton and Hudson River formations. The Chazy is a crumbling sandrock (the St. Peter sandstone of Owen). The Hudson River group is seen in cliffs 25 feet high at Stony Fort, on the Red river. He quotes the description of Owen who visited and reported on the Red River settlements in his final report on Iowa, Wisconsin and Minnesota, (p 181) in 1852. The fossils reported by Owen, from Lower Fort Garry are: Favosites basaltica, Coscinipora sulcata, hemispherical masses of Syringopora, Chætetes lycoperdon, a Conularia, a small, beautiful undetermined species of Pleurorhynchus, Ormoceras brongniarti, Pleurotomaria lenticularis (?), Leptæna alternata, Leptæna plano-convexa (?), Calymene senaria, and several specimens of the shield of Illænus crassicauda.

"Many of these are identically the same fossils which occur in the lower part of Formation 3 in Wisconsin and Iowa, in the Blue limestones of Indiana, Ohio, Kentucky and Tennessee, and also in the Lower Silurian of Europe."

In this report Mr. E. Billings, paleontologist of the Canadian survey, contributes a chapter on the paleozoic fossils, describing two new Silurian species, viz,, Modiolopsis parviuscula, and Orthoceras simpsoni. These and the other fossils named by him are considered sufficient to show that the beds containing them are probably about the age of the Chazy and Black River limestones.

James Hall.

1861. *Report of the Superintendent of the Geological Survey of Wisconsin, exhibiting the progress of the work*, Jan. 1, 1861. By JAMES HALL; Madison, 1861.

This report is devoted almost entirely to the description of fossils of which the following are from the Trenton, Galena and Hudson River:—

Receptaculites oweni Hall. "In the Galena limestone of Wisconsin, northern Illinois and the eastern part of Iowa this fossil is everywhere present and is the most marked and characteristic form in the rock."
Receptacutiles iowene Owen. Galena limestone.
Receplaculites fungosum Hall. Galena limestone.
Receptaculites globulare Hall. Galena limestone.
Graptolithus (Diplograptus) peosta Hall. Hudson River shales.
Dictyonema neenah Hall. Trenton limestone.
Buthograptus laxus, n. sp. Trenton limestone.
Tellinomya inflata, n. sp. Trenton limestone.
Tellinomya alta, n. sp. Trenton limestone.

Tellinomya ventricosa, n. sp. Trenton limestone.
Tellinomya ovata, n. sp. Trenton limestone.
Cypricardites rotunda, n. sp. Trenton (Buff) limestone.
Cypricardites niota, n. sp. Trenton (Buff) limestone.
Cypricardites rectirostra, n. sp. Trenton (Buff) limestone.
Modiolopsis planus, n. sp. Trenton (Buff) limestone.
Modiolopsis? superbus. n. sp. Trenton (Bluff) limestone.
Ambonychia lamellosa, n. sp. Trenton limestone.
Ambonychia planistriata, n. sp. Trenton limestone.
Ambonychia erecta, n. sp. Trenton limestone.
Ambonychia attenuata, n. sp. Trenton (Buff) limestone.
Pleurotomaria niota, n. sp. Trenton (Buff) limestone.
Pleurotomaria nasoni n. sp. Trenton (Buff) limestone.
Pleurotomaria semele, n. sp. Shales above Galena limestone.
Maclurea bigsbyi, n. sp. Trenton (Buff) limestone.
Ecculiomphalus undulatus, n. sp. Trenton (Buff) limestone.
Lituites undatus var., occidentalis n. sp. Trenton (Buff) limestone.
Lituites robertsoni, n. sp. Trenton (Buff) limestone.
Cyrtoceras whitneyi, n. sp. Shales above Galena limestone.
Cyrtoceras neleum, n. sp. Trenton (Buff) limestone.
Cyrtoceras engium, n. sp. Trenton (Buff) limestone.
Crytoceras loculosum, n. sp. Trenton limestone.
Onoceras abruptum, n. sp. Trenton limestone.
Onoceras plebeium, n. sp. Trenton (Buff) limestone.
Onoceras pandion, n. sp. Trenton (Buff) limestone.
Onoceras lycum, n. sp. Trenton (Buff) limestone.
Onoceras alceum, n. sp. Trenton (Buff) limestone.
Orthoceras gregarium, n. sp. Shales above Galena limestone.
Orthoceras planoconvexum, n. sp. Trenton (Buff) limestone.
Gonioceras occidentalis, n. sp. Trenton limestone.
Illænus taurus. n. sp. Trenton (Buff) limestone.
Calymene mammilata, n. sp. Shales above Galena limestone.

C. L. Anderson and Thomas Clark.

1861. *Report on Geology and a plan for a Geological Survey.* By ANDERSON and CLARK; addressed to the Legislature of Minnesota, Jan. 25, 1861. In this report Mr. Anderson follows Dr. Owen. denominating the limstones at St. Paul, and the falls of St. Anthony, "Shell or Blue limestone."

"Its distinguishing fossil is Leptæna, some fifteen species of which occur in it. Orthoceratites are exceedingly common, and the species numerous. Some of them are of enormous size, measuring nine or ten feet in length."

He remarks that the line distinguishing this from the "Upper Magnesian limestone" is difficult to find, and that Dr. Owen classed them together. We have seen, on the contrary, that Dr. Owen, in his final report, considered the Upper Magnesian limestone, or the the lead-bearing portion of it to which the the term was latterly confined, as the equivalent of the Utica slate and the Hudson River group, and that he parallelized the "Shell or Blue limestone" with the Trenton.

As to the Galena limestone, these authors are inclined to consider it almost if not entirely wanting in Minnesota, but suggest that it may exist in some of the high bluffs in the middle southern counties.

James Hall.

1862. *Report on the Geological Survey of the State of Wisconsin,* Vol. I, 4to, 1892. JAMES HALL and J. D. WHITNEY. By authority of the Legislature of Wisconsin.

Chapter IX is devoted to the paleontology of Wisconsin. After a short description of the conditions of preservation of fossils in the various formations, the chapter contains a catalogue of the paleozoic fossils of Wisconsin, including those described by Owen, Conrad, Hall, and others, from localities within the state, and those which had been identified with species described from other states, giving references to original descriptions and to other publications. This catalogue also includes the names of fossils identified in the state on authority of I. A. Lapham. Localities are generally not mentioned. Fossils are simply referred to their formation, and to the places where originally described.

There is a "note on the Hudson River group," and its use as a geological term, which recommends that the term be dropped, because of the discovery of characteristic Taconic fossils in very much of the area over which the rocks of this group had been supposed to extend in the Hudson valley, (pp. 443-445. See also foot note, p. 47.)*

Of the "Buff limestone" the section given (p. 34) at the falls of St. Anthony is quite inapplicable, and must have been referred to that locality by mistake. On p. 37 the same section is referred to the Blue limestone. This limestone in southwestern Wisconsin is not regarded as so nearly resembling the typical Trenton limestone, either in lithology or in fossil remains, as the overlying Blue limestone. Its thickness is about 20 feet. It is an impure dolomyte, but sometimes quite argillaceous.

The Blue limestone is thin-bedded, bluish-gray, sometimes almost entirely calcareous but usually with seams of argillaceous matter, and in some localities having a distinctly "slaty" structure. "In the northern part of the state, and the adjacent parts of Minnesota, this rock is sometimes more heavily bedded and compact, with layers separated by several inches of shaly matter.

Prof. Hall at the time considered the Buff limestone (*i. e.* the building-stone layers at Minneapolis) as the near parallel of the Birdseye and Black River limestones, remarking that the large orthoceratites, Gonioceras and Lituites mark in more eastern localities the horizon of the Black River limestone; and that these fossils in the west hold a position everywhere below the beds charged with the more characteristic fossils of the Trenton limestone (p. 36). The author illustrates lamellibranchs and gasteropods from the Buff and trolibites and brachiopods from the Blue.

The Galena is a compact, crystalline, heavy-bedded dolomyte with numerous cavities and veins in which sometimes is brown spar and sometimes sulphides of lead, zinc and iron, its greatest thickness being 250 feet. It was identified as far northeast as the Escanaba river in Michigan.

Receptaculites is its principal fossil, but there are several species. In the upper beds Lingula quadrata usually abounds, also large orthoceratites.

*"This recommendation, however, was subsequently withdrawn on the ground that the *idea* of the term Hudson River was not incorrect. It was a mistake to extend the term over rocks that were found to be of Taconic age, but that was a mistake of identification. The true Hudson River idea pertained to the uppermost horizon of the Lower Silurian, and as such it had a basis of stratigraphic as well as paleontologic fact which could not be affected by any error in the mere construction of a map. The same mistake was made by Dr. Emmons in the represented extension of his Taconic, as he included in it erroneously some localities of Lower Silurian rock. But his *idea* was a primordial one, and on the later correction of his map, his idea stands as intact as that of the Hudson River group. See Am. Assc. Adv. Sci. 1877, Nashville Meeting, pp. 259-265.

The "Green and Blue shales and limestones" with a thickness of 60 to 100 feet, are next above the Galena. They are supposed to be in a general way, the equivalent of the Blue limestone of the Ohio geological reports and of the Utica slate, the Frankfort slate, the Pulaski shales and sandstone and the Lorraine shales of the New York geological reports. So far as noticed this is the first reference of the "Blue shales and limestone" of Ohio to this horizon in the Northwest, although they had been stated to be of the age of the Hudson River group in 1842 by Prof. Hall. The Blue limestone of Ohio had hitherto been regarded, even by Hall, as suggested by Dr. Locke, as equivalent with the Trenton, and the term was transferred from Ohio to the Mississippi valley for that reason.* This series in New York had a thickness of 800 to 1,000 feet, but gradually diminishes westward. The characteristic organic remains are lamellibranchs, trilobites and bryozoans. The brachiopods are Strophomena, Orthis and Rhynchonella. Orthis occidentalis and Strophomena alternata occur in the upper beds in the southwestern part of the state and adjacent parts of Iowa. However, the most abundant and characteristic fossils of the upper beds in the southwestern part of the state are a small Nucula and a Clidophorus, along with a small Pleurotomaria and an Orthoceras. The fauna of these beds in the lead region is different from that of the same strata in the region of Green bay.

J. D. Whitney.

1862. *Report upon the Lead Region*, comprising chapters II, III, IV, V, and VI, of the "Report on the Geological Survey of Wisconsin, vol. i. 1862," last mentioned.

The term "Blue limestone" here is made to cover all the strata from the top of the St. Peter sandstone to the bottom of the Galena, comprising a vertical series of from 50 to 100 feet. The term "Buff limestone" is quite subordinate, being applied to a non-important "buff-colored stratum" designated by that term by Dr. Owen in the map accompanying his report of 1840, as revised and republished in 1844. This term, and the stratum to which it was applied, came to be known as the Buff limestone in all later reports. It has a thickness of about 25 feet, and is supposed to be the equivalent of the Chazy, Birdseye and Black River limestones of New York. Its characteristic fossils are large Orthocerata, Lituites undatus, Maclurea magna, Columnaria alveolata and several species of Murchisonia and Pleurotomaria.

The Blue limestone (supposed to be the New York Trenton limestone) is said to be a pure limestone, with abundant remains of animal life. The first ten feet above the Buff limestone, very compact, brittle, and breaking conchoidally, are known as the "glass rock," but in the eastern portion of the lead district this term is applied generally to any portion of the Blue limestone. The thickness of the Blue averages perhaps 50 feet.

The Galena is a crystalline dolomyte, 250 feet thick.

"Toward the north this formation gradually dies out, and soon disappears after crossing the water-shed. * * * * There are carbonaceous layers occasionally met with in the body of the Galena limestone which are not only so impregnated with organic matter as to take fire and burn with flame

*This reference of the Ohio Blue limestone to the Hudson River was later confirmed by the report of a committee of the Cincinnati Society of Natural History, published in the Journal of the Society, pp. 193-194, January, 1879. See also the tenth report of the Indiana Geological Survey, p. 23, 1879.

when heated, but which show distinct impressions of a vegetable character. * * * * That the same fossils which are characteristic of the Galena limestone in the lead region are found in the Blue, beyond the limits of our district, to the northwest, is a fact observed during the progress of the Iowa survey. It is evident that after crossing the Mississippi, and proceeding beyond Gutenberg in that direction, the Galena and the Blue limestones become more and more merged in each other, and less distinguishable either by paleontological or lithological characters."

In plate IV, giving a section of the rocks exposed in the lead region, the Galena and the Blue are together said to be the equivalent of the Trenton limestone of New York.

Mr. Whitney retains the term Hudson River group for the next overlying formation—the Green and Blue shales and limestones of Prof. Hall. It is given a thickness, in the lead region, from 70 to 100 feet. It is shaly, but holds some beds of dolomyte. The shale is sometimes carbonaceous in sufficient degree, perhaps, to make it, in the future, of economical value, and is marked by traces of graptolites.

James Hall.

1863. *Note on the geological range of the genus Receptaculites in American Paleozoic strata.* JAMES HALL. Sixteenth report of the New York State Cabinet, pp. 67-70, 1863.

Five species have been described from the Galena limestone, viz., oweni, iowensis, fungosus and obicularis, and one from the Trenton limestone, occidentalis (neptuni?), in New York.

F. B. Meek and A. H. Worthen.

1868. *Geological Survey of Illinois, Vol. III, Paleontology,* F. B. MEEK and A. H. WORTHEN, Springfield, 1868.

This volume embraces descriptions and figures of fossils from the Trenton, Galena and Hudson River formations, viz., from the Trenton one echinoderm, three lamellibranchs, one cephalopod and one crustacean; from the Galena, one pteropod, one zoophyte, one brachiopod, five lamellibranchs, five gasteropods, one cephalopod, and two crustaceans; from the Hudson River, six echinoderms, three brachiopods, one gasteropod and three pteropods.

C. A. White.

1870. *Report of the Geological Survey of Iowa.* CHARLES A. WHITE. Vol. I, Des Moines, 1870. On pages 174–182 the Trenton group, of the Lower Silurian, is treated. The Trenton limestone proper is made to include the strata between the St. Peter sandstone and the Galena limestone. Along the bluffs of the Mississippi its thickness is about eighty feet, but in Winnishiek county it increases to above two hundred feet.

The Galena diminishes in thickness from Dubuque northwesterly, from 250 feet to probably 100 feet on the northern state boundary, where it also has a greater westerly dip.

The name Maquoketa shales is given to the shales lying above the Galena limestone and separating it from the Niagara limestone. They are said to be characterized by peculiar faunal features, ("Orthoceras, Murchisonia, Pleurotomaria, Schizodus(?), Discina, Graptolithus, etc.,") sufficient to warrant their assignment to a very low horizon in the Cincinnati group.

J. H. Kloos.

1871. *Geologische Notizen aus Minnesota.* By J. H. KLOOS. Zeitschr. d. Deutschen geologischen Gesellschaft, Jahrg. 1871. (Translation in the Tenth Annual Report of the Minnesota Survey, 1881).

Geognostische und geographische Beobachtungen in Staate Minnesota. J. H KLOOS. Zeitschr. d. Gesell. f. Erdkunde zu Berlin, Bd. XII, 1877. (Translation in the Nineteenth Annual Report of the Minnesota Survey, 1890).

The foregoing are titles of papers based on observations and collections made by Mr. Kloos during a sojourn in Minnesota before the commencement of the present survey. Of the Lower Silurian strata at St. Paul he mentions, in the former, the following species: *Orthis tricenaria* Con. and *O. testudinaria* Dalm., *Leptæna sericea* Sow., *Murchisonia bicincta*, *Bellerophon bilobatus* Sw.; "all characteristic shells of the Trenton, and partly also of the Llandeilo flags of England." In higher layers he mentions the following: *Rhynchonella recurvirostra* H., and *R. increbescens* H., *Petraia corniculum* H., *Stenopora fibrosa* Goldf., *Calymene senaria* (*blumenbachii*), and *Ptilodictya* sp. "fossils which altogether have been assigned to the Trenton by Logan in Canada."

In the latter paper, besides the above, he mentions the following, at the same place: *Strophomena alternata* Con., (the "Producti" of W. H. Keating and others), *Ctenodonta nasuta* Hall, *Leperditia fabulites*, *Pleurotomaria lenticularis* Con., *Subulites elongata* Con., *Orthoceras junceum* Hall, *Buthotrephis succulens* Owen, *Palæophycus rugosus*, *Strophomena deltoidea* Con., and *Schizocrinus nodosus* Hall. He objects to Hall's statement that at this place the different members of the Trenton, as displayed in the eastern part of the United States, can be distinguished: "So far as Minnesota is concerned this must be wholly erroneous," * * * "The fossils taken together point to the level of the proper Trenton limestone, and some extend much higher, in the Hudson River group, though they are not found in the lower beds in the eastern states."

W. D. Hurlbut.

1871. *Geology of Southern Minnesota*, by W. D. HURLBUT, in *The Minnesota Teacher*, Jan., Feb., March, April, May, 1871. (Vol. IV).

Mr. Hurlbut was the first to direct public attention to the geology of the southern portion of the state, remote from the Mississippi valley. He based his observations upon a careful study of the stratigraphy of Owen. He stated that the Lower Silurian rocks form the surface over an area of about 6,000 square miles in the southern part of the state. He worked out their stratigraphy, specially along Root river and its branches, giving diagrams illustrating their position and thickness, but without the aid of fossils. The green shales overlying the Trenton (*i. e.* Buff limestone) he called Hudson River oil shales, and the alternating beds of shale and limestone (*i. e.* the transition from the Trenton to the Galena) still higher he regarded as Clinton. The Galena limestone he considered of Devonian age, probably Corniferous, although he here mentions Maclurea and "other

Silurian gasteropods," Receptaculites, Orthis, Lingula "and probably Discina," cyathophylloid corals, Tentaculites, Spirifers, trilobites, and Orthoceras.*

James Shaw.

1872. *Geological Survey of Illinois*, vol. v, Geology, by A. H. WORTHEN and JAMES SHAW. Springfield, 1873.

The preliminary chapter in this volume, on the "Geology of Northwestern Illinois," and several others describing several counties more specially, in that portion of the state, are by Mr. Shaw. These counties are contiguous to that part of Iowa and of Wisconsin which embrace the lead region of the Northwest, and have a bearing on the nature and extent of the Lower Silurian strata considered in this volume of the Minnesota survey.

The Hudson River shales, above Savanna, are said to have an exposed thickness of 80 feet, and to reach a total thickness of about 100 feet.

In the Galena the characteristic fossil is termed Receptaculites sulcata, the "sunflower coral."

Below the Galena "comes the Blue limestone, or Trenton limestone proper, of the earlier western geologists. It is now regarded as the middle division of the Trenton group, the Galena above and the Buff below both being regarded as members of the Trenton." The Blue limestone has a thickness from 45 to 60 feet, and the Buff generally about 20 feet.

A. H. Worthen and F. B. Meek.

1875. *Geological Survey of Illinois.* Vol. VI. Paleontology, Section II. Descriptions of Invertebrates, Springfield, 1875. A few species of Lower Silurian fossils are described in this volume. They are from Dixon, Mount Carroll, Savannah and Oswego, Illinois.

R. P. Whitfield

1877. *Preliminary descriptions of new species of fossils from the lower geological formations of Wisconsin*, by R. P. WHITFIELD. Ann. Rpt. Wisconsin Geol. Survey for 1877; Madison, 1878; pp. 50-89.

In this paper sixty-five new species are described. Those from the Trenton period,—twenty-four in number—are as follows:—

Trematopora annulifer, Hudson River shales. *Trematopora granulata*, Hudson River shales.
Fenestella granulosa, Hudson River shales. *Fistulipora solidissima*, Hudson River shales.
Fistulipora lens, Hudson River shales. *Chœteles fusiformis*, Hudson River shales.
Monticulipora rectangularis, Hudson River shales. *Multiculipora punctata*, Hudson River shales.
Monticulipora multituberculata, Hudson River shales. *Alveolites irregularis*, Hudson River shales.
Hemipronites americana, Galena. *Strophomena kingi*, Hudson River shales.
Rhynchonella perlamellosa Hudson River shales. *Cypricardites megambonus*, Buff limestone.
Metoptoma perovalis, Lower Blue limestone. *Trochonema beloitensis*, Buff limestone.
Clisospira occidentalis, Buff limestone. *Maclurea cuneata*, Galena.
Maclurea subrotunda, Galena. *Bucania (Tremanotus ?) buelli*, Upper Buff limesone.
Hyolithes baconi, hard bluish-buff layers. *Orthoceras (Actinoceras) beloitense*, Buff beds.
Bellerophon wisconsinensis, blue beds of Trenton limestone.
Gyroceras duplicostatum, Trenton limestone and bluish-buff beds.

These descriptions are republished in vol. IV of the final report of the Wisconsin survey, 1882 with illustrations.

Mr. Hurlbut, still resides at Rochester, Minn. The writer retains a vivid recollection of his cordial and generous welcome by Mr. Hurlbut when, in 1872, the present survey was inaugurated.

R. P. Whitfield.

1878. *Geology of Wisconsin.* Survey of 1873–1877. Vol. II, of the final report; Madison, 1878. T. C. CHAMBERLIN, chief geologist.

In this volume are numerous references to the preliminary identification of fossils by Prof. R. P. Whitfield, paleontologist of the survey. Of these the following refer to the Lower Silurian as defined by the Minnesota Survey.

Page 561 gives a list of Trenton fossils, without specification of their geographical localities; and after the discussion of the Cincinnati shales and limestones is given a full tabulation of the fossils of the Trenton period (p. 320), for which the identification of the species was by Whitfield. It appears, however, in Prof. Chamberlin's general chapter on the "Lower Silurian" and will be mentioned more fully under his name.

T. C. Chamberlin.

1878. *Geology of Wisconsin.* Survey of 1873–1877. Vol. II, T. C. CHAMBERLIN, chief geologist, Madison, 1878.

Part II of this volume, entitled "Geology of Eastern Wisconsin," is by Prof. Chamberlin. Of this, chapter VII is devoted to the Lower Silurian, which by the author is considered to include all the rocks of this district from the Archean formations to the Clinton in the Upper Silurian. The Trenton group is said to consist of three main divisions, viz., in ascending order, Trenton limestone, Galena limestone and the Cincinnati shales and limestone. The Trenton proper is given a thickness in southeastern Wisconsin of 120 feet, divided as follows:

Upper Blue beds, 15 feet.
Upper Buff beds, 55 feet.
Lower Blue beds, 25 feet.
Lower Buff beds, 25 feet.

It was found that the designations "Buff" and "Blue" of former reports had been used indiscriminately for either the upper or lower, and that the strata are all strongly dolomitic. It was learned that they cannot be separated on paleontological grounds. That which is above named Lower Buff is what has been known generally simply as Buff. The color which has given it its name is wholly a superficial character due to weathering, the interior of the rock being blue. The Buff beds, upper and lower, are less intermixed with argillaceous matter than the Blue beds, and for that reason are more readily changed in color. The Buff beds are particularly marked by the preponderance of lamellibranchs, gasteropods and cephalopods, and the Blue beds by corals, bryozoans and small brachiopods, especially the Orthidæ. Murchisonia gracilis occurs abundantly near the base of the Lower Blue, which also contains sometimes a notable amount of carbonaceous material.

"It appears from all the facts that there was an alternation of conditions in the depositing Trenton seas, and that when the conditions were such as to favor the formation of limestones simply, the life above characterized predominated, and that whenever the conditions changed so as to cause a deposit of shale interleaved with layers of limestone, the brachiopodous and coralline fauna prevailed. These subdivisions than signify rather physicial mutations of a more or less local nature than wide-spread changes in the life-character of the period." (P. 294.)

The Galena, with a thickness of about 160 feet, reposes on the Upper Blue beds, in southeastern Wisconsin. This is another dolomyte, but sometimes has siliceous and aluminous matter in considerable amount, some of its thin layers, or partings consisting of shale. It is in general heavy-bedded, irregular, coarse-textured, gray or buff, with frequent crystal-lined cavities, but toward the north becomes more shaly, and has a greenish or bluish color, with more fossils and sometimes a strongly graptolitic fauna.

The Cincinnati shales and limestones, next in ascending order, have an approximate average thickness of 200 feet. The clay shales and limestones prevail in the upper portion, and slaty and arenaceous shales in the lower. Yet in the northern part of the area limestone prevails in the upper part over the shales. The characteristic faunal feature is the prevalence of corals and bryozoans. Upwards of 30 species were collected from the shale thrown out of two shafts of no considerable depth. Brachiopods are next in abundance, Orthis and Strophomena predominating.

In recapitulation of the facts of thə Trenton period Prof. Chamberlain draws three conclusions respecting its paleontology, viz: (1) There are a considerable number of species that range throughout the whole Trenton period, including the Cincinnati epoch, and are therefore of no service in discriminating between its subdivisions; (2) There is another portion whose occurrence is chiefly confined to the strata of the Trenton epoch; and, (3) There are a few that are not authentically known to occur either above, or below the Galena, and may be regarded as characteristic of it. Of this number Receptaculites oweni and Murchisonia bellicincta or major, are the most constant and reliable. Lingula quadrata, although rare in other beds in eastern Wisconsin, does not appear to be strictly confined to the Galena. Fusispira ventricosa and F. elongata are perhaps to be added to this list.

The tables given by Prof. Chamberlin showing the stratigraphic distribution of species of the Trenton period distribute the species that had been identified in the following manner: In the Lower Buff, 53; Lower Blue, 57; Upper Buff, 69; Upper Blue. 25; the Trenton epoch, 195; Galena proper, 62; Galena modified, 88, and the Cincinnati, 66. Total in the Trenton period, 295.

R. D. Irving.

1878. In the same volume as the last Prof. R. D. Irving described the "Geology of Central Wisconsin." A portion of his chapter is devoted to the Trenton and Galena limestones, the latter occuring, however, in unimportant, isolated cappings. The Trenton, as described, embraces two parts, the Lower Buff (or "the Buff"), and the Lower Blue (or "Blue"). The former is generally a dolomitic limestone about 25 feet thick, the latter an argillaceous limestone with but little carbonate of magnesia, the interleaved calcareous dark shale sometimes containing black graptolite-like markings near the base. The thickness of the Blue is not given.

Moses Strong.

1878. In volume II of the final report of the late Wisconsin survey is a chapter by MOSES STRONG on the "Geology and Topography of the Lead Region." Under the term Trenton he embraces the Buff and Blue limestones, their total average thickness being about 50 feet. The Blue is divisible into two parts, viz., the "glass rock," in heavy layers, the lower half, and the other thin-bedded which sometimes graduates into the thin-bedded Galena above. At the separation of the Blue from the Galena, occurs almost invariably, a carbonaceous shale, having a thickness from a quarter of an inch to a foot or more. This is considered an unfailing guide to the bottom of the Galena. This shale has its greatest thickness in the vicinity of Shullsburg, where it is seven feet thick, the carbonaceous matter amounting to 43.60 p. c. Large quantities of lead, and more particularly of zinc, have been taken from the Blue and Buff limestones in southwestern Wisconsin.

The Galena limestone is a dolomyte and is the chief lead-bearing rock. It is regularly bedded and has a thickness of 200 feet or more. It is apt to weather with an irregular surface owing to cavities and softer spots. Its lower portion is interbedded with thin layers and irregular nodules of flint. The characteristic fossil of the formation is Receptaculites oweni, found indifferently in all parts. Next in frequency are Streptelasma corniculum and some species of Orthis. The most infrequent is Maclurea magna, which pertains to the middle beds. Lingula quadrata is quite frequent in the upper beds. Other and more infrequent fossils are Pleurotomaria lenticularis, Bellerophon bilobatus, Orthis biforata and occasional Orthocerata.

The Cincinnati, which rarely contains important layers of limestone, has a thickness of about 125 feet. The lower beds abound with shells of the Nucula fecunda, and the middle ones with Rhynchonella increbescens, Strophomena alternata and stems of Chætetes. The upper beds contain a few Orthocerata.

R. P. Whitfield.

1879. *Description of new species of fossils from the Paleozoic formations of Wisconsin*, by R. P. Whitfield; Ann. Rept. Wisconsin Geol. Survey for 1879; Madison, 1880; pp. 44-71.

Twenty six new species are described in this paper. The Trenton forms,—ten in number,—are as follows:

Trochonema beachi, Buff beds of lower Trenton.
Endoceras (Cameroceras) subannulatum, upper part of Buff limestone.
Cyrtoceras planidorsalum, lower part of Buff limestones.
Oncoceras mumiaforme, Lower Buff limestone.
Oncoceras brevicurvatum, upper part of Buff limestones.
Asaphus triangulatus, Blue limestone.
Fistulipora rugosa, Hudson River shales.
Streptorhynchus cardinale, Hudson River shales.
Strophomena wisconsinensis, Hudson River shales.
Rhynchonella neenah, Trenton, Galena and Hudson River.

These forms are illustrated in volume IV of the final report.

J. F. Whiteaves.

1879. *On some Silurian and Devonian fossils from Manitoba and the valleys of the Nelson and Churchill rivers*, J. F. Whiteaves, Geol. Sur. Can. 1879. Appendix 1, p. 45 C.

This is a preliminary paper, giving provisional identifications of Silurian fossils from various localities, viz: Banks of the Red river, in the Parish of St. Andrews; Limestone rapids, 100 miles up the Nelson river: First Birch brook, Nelson river; Second and third limestone rapids of the Nelson river; Junction of the Little and Churchill rivers; Fort Churchill, (loose); Stony Mountain.

C. D. Walcott.

1879. *Descriptions of new species of fossils from the Trenton limestone*, by C. D. Walcott; 29th report of the New York State Museum of Natural History; Albany, 1879; pp. 91-97. "Transmitted to the Legislature March 30, 1875."

The following species are noted from Wisconsin and Minnesota, all being new, and described without figures:

Conchopeltis minnesotensis, four miles below Medford, Cannon river, Minn. Trenton limestone.
Bathyurus longispinus, Trenton limestone. Plattsville, Wis.
Asaphus romingeri, Trenton limestone. Quinby's mill, Lafayette Co., Wis.
Asaphus wisconsensis, Trenton limestone, Mineral Point and Plattsville, Wis.

Descriptions of new species of fossils from the Chazy and Trenton limestones, by C. D. Walcott; 31st annual report of the New York State Museum of Natural History; Albany, 1879; pp. 68–71. "Transmitted to the Legislature April 17, 1878."

The following species are described, but not figured, from western localities:

Ceraurus rarus, Trenton limestone, Beloit, Wis.
Encrinurus trentonensis, Clifton, Grant Co., Wis., and two miles above Dunleith, Ill.
Encrinurus varicostatus, Trenton limestone, Mineral Point, Beloit and north of Janesville, Wis.
Dalmanites intermedius, Trenton limestone, two miles north of Dunleith, Ill.; Clifton, Grant Co., and Plattsville, Wis.
Illænus indeterminatus, Trenton limestone, Plattsville, Wis.
Asaphus homalonotoides, Trenton limestone, two miles north of Dunleith, Ill.

The Utica slate and related formations. Fossils of the Utica slate and Metamorphoses of Triarthrus becki. C. D. Walcott. 1879, Albany. Printed in advance of vol. x, of the Transactions of the Albany Institute. June, 1879.

The fossils described are from Oneida county, N. Y. In the discussion of the Utica slate the author reaches the conclusion that the Galena limestone is its northwestern representasive. The author gives a complete tabulation of the fossils occurring in the Utica slate, with references to the literature where described. This table also shows their extension into the Hudson River formation above and into the Trenton below. Another table shows the number of species that had been found respectively in the Utica slate and in the Galena, and the numerical range of the same into the Trenton and the Hudson River. This view of Mr. Walcott will be considered further in another place inasmuch as our studies do not tend toward the same result.*

*Compare, *The Age of the Galena Limestone*, N. H. Winchell, American Geologist, January, 1895.

R. P. Whitfield.

1880. *On the occurrence of true Lingula in the Trenton limestone,* by R. P. WHITFIELD; Amer. Jour. Sci., [3], XIX, pp. 472-475; June, 1880.

The author thinks that fossils of the genus *Lingula*, as represented by the living *L. anatina* Lamarck, occur in the older Paleozoic rocks. As proof of this he describes and figures a new species—*L. elderi*—from the Trenton limestone near Rochester, Minn. In this form the muscular scars and vascular lines are very strong and well preserved and they are found to be very similar to the same markings shown in the living species.

G. D. Swezey.

1882. *On some points in the geology of the region about Beloit,* by G. D. SWEZEY; Trans. Wisconsin Acad. Sci. Arts and Letters, vol. V, (1877–81); Madison, 1882; pp. 194-204

This paper is devoted to a description of the various strata of the Lower Silurian exposed at Beloit, Wis. No particular mention of the fauna of the different strata is made. The section given, is as follows:

Galena limestone.
Trenton limestone.
- Upper blue, 20 feet.
- Upper buff.
- Cherty, 19 feet.
- Upper fucoidal, 3 feet.
- Birdseye, 7 feet.
- Lower fucoidal, 3½ feet.
- Carpenter, 18½ feet.
- Lower blue, 18 feet.
- Lower buff, 22 feet.

St. Peter's sandstone.

R. P. Whitfield.

1882. *Geology of Wisconsin, vol. IV, part III, Paleontology,* by R. P. WHITFIELD, Madison, 1882.

In his preliminary remarks, professor Whitfield states:

"Throughout the Blue and Buff limestones of the formations in southern Wisconsin the gasteropods and cephalopods characterize the formation, almost to the exclusion of brachiopods, the few forms of the latter class which are common, being principally strophomenoid forms, and mostly of three species, Strophomena alternata and S. camerata Conrad, and S. incrassata Hall or one usually referred to that species. But by far the greater proportion of the organic remains of the beds consists of true mollusca, Lamellibranchiata, Gasteropoda and Cephalopoda. In the upper Blue beds of the group there are usually large numbers of Orthis, of two or three species, but they are mostly confined to the few feet constituting this bed, which occurs immediately below the Galena beds, and but few individuals of the species occur below. Among the lamellibranchiates the genera Cypricardites and Tellinomya are much the most common. A few other genera are represented, but by comparatively few species and individuals. The gasteropods are more numerous, but consist principally of the genera Maclurea, Ophileta, Raphistoma, Trochonema, Murchisonia, Pleurotomaria, Subulites, Bucania and Bellerophon."

Bryozoans specially characterize the Hudson River shales.

In the enumeration of species in the Lower Silurian the term Trenton limestone is made to include all the strata from the Galena to the top of the St. Peter sandstone, the terms Buff and Blue being ignored. But at the special localities, the fossils are said sometimes to have been obtained from the "buff limestone of the Trenton group," or "from the upper layers of the buff limestones of the Trenton group," or "buff limestones near the middle of the Trenton group," or "blue beds of the Trenton limestone below Carpenter's quarry" (at Beloit). Sometimes the description involves such combinations as "hard layers of the bluish-buff limestones of the Trenton group, below Carpenter's quarry," and again "Lower Buff limestone of the Trenton group below Carpenter's quarry," or "in the Buff limestone of the Trenton group at Carpenter's quarry." This variety of usage of the terms Buff and Blue is explainable by reference to the abstract already presented, of the report of Prof. Chamberlin in 1878. Prof. Whitfield describes and illustrates 36 species from the Trenton, being: lamellibranchs, 6; gasteropods, 16: pteropods, 1; cephalopods, 10; and crustaceans, 3.

The following species are said to more particularly characterize the Galena limestone: Receptaculites oweni Hall, Halysites catenulatus, Fischer, (two specimens from Rockton, Ill.) Lingulella iowensis Owen, Hemipronites americanus Whitf., Murchisonia major Hall, Fusispira ventricosa Hall, Fusispira elongata Hall, Maclurea cuneata Whitf., and Maclurea subrotunda Whitf.

The Hudson River species illustrated are, five species of Radiata (Chætetes, Alveolites and Monticulipora), eight species of Bryozoa, and ten of Brachiopoda.

The general list of species given in this volume by Prof. Whitfield is enlarged and reproduced in volume I, which was the last volume of the report to be published. It is condensed below, from vol. I.

CLASS.	1	2	H.R.	Gal.	Trent
PLANTÆ	......	3	1	3	7
PROTOZOA.—Petrospongia	......	1	......	1	1
Foraminifera	......	......	......	3	......
RADIATA.—Zoophyta	......	......	......	......	......
Alcyonaria (Graptolitidæ)	1	1	1	3	5
Zoantharia—tabulata	3	3	19	3	8
Zoantharia—rugosa	1	3	1	4	5
RADIATA—Echinodermata	......	......	......	......	......
Cystidia	......	......	......	4	......
Crinoidea	......	3	1	3	4
MOLLUSCA.—Molluscoidea	......	......	......	......	......
Bryozoa	2	5	17	5	8
Brachiopoda	12	23	30	29	43
MOLLUSCA.—Mollusca proper	......	......	......	......	......
Lamellibranchiata	.....	4	2	4	24
Gasteropoda	1	12	3	19	28
Heteropoda	......	......	......	1	6
Pteropoda	......	......	......	1	3
Cephalopoda	......	2	......	3	37
ARTICULATA.—Annelldæ	......	......	......	......	1
Crustacea:—					
Entomostraca	......	......	1	......	2
Trilobita	2	4	3	8	17
Total species	22	64	79	94	199

Total species identified with the Lower Silurian, 278.
COLUMN 1.—Species common to the Hudson River and the Galena, 22.
COLUMN 2.—Species common to the Galena and Trenton, 64.

Note. In each of these comparisons we may note the closeness of affinity by the ratio of the common species to the smaller one of the faunas compared, and in this way we find, for the column 1, that the common species are 28 per cent. of the smaller fauna, *i. e.*, of the total possible number; and for column 2, the much larger proportion of 68 per cent.

Such comparison of the Hudson River and Trenton shows 28 common species, a slightly larger number than comes in column 1, but the greater number of species in the Trenton than in the Galena accounts for this increase, while yet there is in this last comparison a less close affinity than in the first.

W. H. Pratt.

1883. *An artesian well at Moline* (Ill.), by W. H. PRATT, Proc. Davenport Academy of Natural Sciences, vol. III, p. 181. Read Nov. 25, 1881. This well gives the depth and thickness of the Maquoketa shales, showing a great increase toward the east from their typical locality. They are 395 feet below the surface, and 220 feet thick.

Jos. F. James.

1886. *Description of a new species of Gomphoceras, from the Trenton of Wisconsin,* by PROF. JOS. F. JAMES. Journal of the Cincinnati Society of Natural History; Jan., 1886.

Describes Gomphoceras powersi, from Beloit, Wis.

George M. Dawson

1886. *On certain borings in Manitoba and the Northwest Territory,* by GEORGE M. DAWSON. Trans. Roy. Soc. Canada, 1886, vol. IV.

In this paper certain shales passed through in the Rosenfeld deep well are regarded as belonging to the Maquoketa, amounting to 352 feet, and the underlying cream-colored limestone and red shale, amounting to 380 feet, are assigned to the Galena and the Trenton. No fossils were obtained. This interpretation of this well is quite different from that given by one of the writers in the thirteenth report of the Minnesota survey, pp. 40-46 (for 1884), of the salt well at Humbolt, Minn., situated about twenty-five miles toward the southeast. The Rosenfeld well section is also published, without comment, in the fourteenth report of the Minnesota survey, p. 15.

Samuel Calvin.

1888. *Notes on the formations passed through in boring the deep well at Washington, Iowa.,* by SAMUEL CALVIN; American Geologist, vol. I, p. 28; Jan., 1888.

At the depth of 702 feet the Hudson River shales were struck in this well, with a thickness of 91 feet They were immediately beneath a sandstone 170 feet thick which was referred to the Niagara period. The Galena was found at 803 feet, extending to 963 feet. This is a grayish limestone, but not a dolomyte. The Trenton, with bits of carbonaceous shale, and quite rich in bituminous matter, was encountered at the depth of 1020 feet, and extended to 1095 feet, with some arenaceous shale and sandstone near the bottom. At 1100 feet the St. Peter sandstone appeared.

J. F. Whiteaves.

1889. *Descriptions of eight new species of fossils from the Cambro-Silurian rocks of Manitoba,* by J. F. WHITEAVES, Trans. Royal Soc., Canada, 1889, vol. vii. Plates xii and xiii.

In this paper Dr. Whiteaves describes the following:

Maclurea manitobensis. Widely distributed.
Poterioceras nobile, East Selkirk and Lower Fort Garry.
Poterioceras apertum, Dog's Head, Winnipeg lake.
Oncoceras magnum. East Selkirk.
Oncoceras gibbosum, Swampy island, and Jack-Fish bay, etc.
Cyrtoceras manitobensis, Deer island, Big island, etc.
Trochoceras mc'charlesi, East Selkirk.
Aspidoceras insigne. Stony mountain.

"On purely paleontological evidence the highly fossiliferous deposits of Stony mountain were referred to the Hudson River formation by the present writer, in 1880,* and the fossils of the pale buff-colored limestones or dolomites of East Selkirk and Lower Fort Garry have long been supposed to show that these rocks are the equivalents of the Galena limestone or upper portion of the Trenton formation of Wisconsin and Iowa. On the same evidence the somewhat similarly colored and fossiliferous limestones of the islands and shores of lake Winnipeg appear to be of the same age as the Trenton limestone proper, or at any rate not older than the Birdseye and Black River group of eastern Canada and the state of New York. It is possible that the fossiliferous rocks on the shores and islands of lake Winnipeg may be a little lower down in the series than those at East Selkirk and Lower Fort Garry, but the whole of these deposits, apart from those at Stony mountain and elsewhere in Manitoba which can be somewhat confidently referred to the Hudson River group, probably represent only one well-defined horizon in the Cambro-Silurian system. However this may be, in the writer's judgment there is at present no satisfactory paleontological evidence for the existence of the Chazy formation or its equivalent in Manitoba," p. 83.

C. H. Gordon.

1889. *Notes on the Geology of Southeastern Iowa.* By C. H. GORDON, American Geologist, vol. IV, p. 237, Oct., 1889. The records of some deep wells are given, viz: At Keokuk the Maquoketa shale, struck at 800 feet, developed a thickness of 63 feet, and the Galena and Trenton combined a thickness of 140 feet. At Ottumwa the Maquoketa shales appeared at 955 feet and they apparently continued to the depth of 1045 feet, with the designations "lime and sandrock," given by the drillers, a thickness of 99 feet. The Galena and the Trenton can scarcely be recognized under the designations given. At Sigourney the Maquoketa has a thickness of 165 feet, and was struck at the depth of 1030 feet. The Galena and Trenton have a thickness, apparently, of 113 feet.

C. W. Hall.

1889. *The lithological characters of the Trenton limestone of Minneapolis and St. Paul, with a note on the borings of the West hotel artesian well.* By C. W. HALL. Bulletin of the Minnesota Academy of Natural Sciences, vol. III, p. 111, 1889.

The author gives the stratigraphic order in detail, and the chemical and petrographic characters.

Frank Leverett.

1889. *Studies in the Indiana Natural Gas Field.* By FRANK LEVERETT. American Geologist, vol. IV, pp. 6-21, July, 1889. This paper contains a valuable tabulation of the data of gas wells, both in Indiana and in Ohio, by which it is shown that the "lower shales," *i. e.*, the Cincinnati shales and limestones, extend unbroken, though with some variations of dip, and with diminishing thickness, toward the west from the Cincinnati anticlinal. From 1100 feet in Union and Madison counties, Ohio, their thickness is reduced to less than 400 feet in Cass and Carroll counties, Indiana. Mr. Leverett shows

*Geol. Sur. Can. Rep. Progr. 1878-79, p. 50 C.

also that the main trend of the Cincinnati anticlinal is northwestward, instead of northward past the west end of lake Erie.

Jos. F. James.

1890. *On the Maquoketa shales, and their correlation with the Cincinnati group of southwestern Ohio*, by JOSEPH F. JAMES, American Geologist, vol. v, p, 335, June, 1890.

After reference to previous literature Mr. James gives detailed sections at Graf, Iowa, covering 31 feet of the Maquoketa shales. He states that the top of the Galena is considerably eroded, showing an unconformity between it and the Maquoketa. He shows a continuation of the Cincinnati formation from southern Indiana to northwestern Illinois, by an examination of the records of gas wells through the state of Indiana, and by descriptions of outcrops published in the Illinois reports. He gives a list of Maquoketa fossils and a table showing their geographic distribution and their strong affinity with the fauna of the Cincinnati. With a reference to the identity of lithologic characters he concludes that the Maquoketa shales are an exact representation, except in being reduced in thickness, of the Cincinnati group of Ohio, and that the term Maquoketa ought be dropped from geological literature.

J. F. Whiteaves.

1891. *The Orthoceratidæ of the Trenton limestone of the Winnipeg basin*, by J. F. WHITEAVES. Trans. Roy. Soc., Canada, vol. IX, 1891. Sec. IV, p. 77. Seven plates.

This paper consists of a critical study and systematic list of the Trenton Orthoceratidæ of the Winnipeg region—that term being taken in a somewhat comprehensive sense to include all those highly fossiliferous deposits which immediately and conformably overlie the St. Peter sandstone and underlie the Hudson River formation. It names three species of Endoceras, of which End. crassisiphonatum is new; four of Orthoceras, of which O. semiplanatum, selkirkense and winnipegense are new; three of Actinoceras; one of Sactoceras, viz., canadense (new); one of Gonioceras, viz., lambii (new); and three of Poterioceras, of which P. gracile is new.

F. W. Sardeson.

1892. *Fossils from the St. Peter sandstone.* Read Feb. 3, 1891. *The Lower Silurian formations of Wisconsin and Minnesota compared.* Read Oct. 6, 1891. *The range and distribution of the Lower Silurian fauna of Minnesota, with descriptions of some new species.* Read Dec. 8, 1891.

The foregoing papers by Mr. F. W. Sardeson, were issued in a single brochure and distributed April 9, 1892, accompanied by plates IV, V and VI. They were read before the Minnesota Academy of Natural Sciences. The first announces an important discovery of lamellibranchs and gasteropods in the St. Peter sandstone at cuts along the Chicago, Burlington & Northern R. R., about five miles below St. Paul, about 50 feet below the Trenton. These are said to be remarkably like species found in the Trenton above, and thought to indicate that the St. Peter should be classed with the Lower Silurian.

The second paper compares, bed for bed, the different parts of the Lower Silurian in Minnesota with their supposed equivalents in Wisconsin, and divides the same in Minnesota as follows, naming some of the characteristic fossils of each.

The Cincinnati group comprises:

Wykoff beds, limestone	50	feet
Maquoketa beds, limestone and shale	20	"

The Galena embraces:

Maclurea bed, limestone	50	"
Lingulasma bed, limestone	20	"
Camarella bed, limestone	30	"
Orthisina bed, shale	20	"

In the Trenton are placed the following:

Zygospira bed, shale	8	"
Fucoid bed, shale	20	"
Stictopora bed, shale	30	"
Stictoporella bed, shale	10	"
Blue bed, limestone	12	"
Buff bed, limestone	15	"
Total	285	"

This substantially divides the strata covered by the investigations of this volume into three limestones separated by two epochs of shale. The Devonian is said to lie unconformably on the Wykoff limestone.

The third paper describes a number of new forms and presents a table showing the stratigraphic range of all the species found by the author in the Lower Silurian; the same subdivisions are used as above. These three papers constitute an important addition to the stratigraphic paleontology of the Minnesota Lower Silurian.

C. W. Hall and F. W. Sardeson.

1892. *Paleozoic formations of southeastern Minnesota,* by C. W. HALL and F. W. SARDESON. Bulletin of the Geological Society of America, vol. III, pp. 331-368, June 23, 1892.

This paper repeats the classification and the paleontological results expressed in the foregoing papers of Mr. Sardeson. It embraces also various structural and petrographical information relating to the Upper Cambrian and the Lower Silurian in Minnesota.

In speaking of the paleontological characters of the St. Peter sandstone some fossils lately found near St. Paul are named, which in the opinion of the authors show the Lower Silurian age of this sandstone. They are:

Murchisonia gracilis Hall.
Murchisonia perangulata Hall.
Two new species of Modiolopsis.
Undetermined species of Tellinomya.
Undetermined species of Endoceras.

THE REPORTS OF THE MINNESOTA SURVEY.

1872-1892. Several of the annual reports of the Minnesota survey have dealt with the strata and the fossils of the Lower Silurian, viz:

First report, 1872. The results of a general reconnoissance of the southern portion of the state are given in the first report; this statement includes detailed sections of the stratigraphy supposed to cover the whole of the Lower Silurian so far as known to exist in the state, with mention of the distribution of some of the fossils. The Hudson River was not identified.

Second report, 1873. Contains simply a section of the stratigraphy near Farmington, in Dakota county.

Third report, 1874. Gives a brief account of the "Silurian" in the northeast corner of Mower county.

Fourth report, 1875. Containing the geology of Fillmore, Olmsted and Dodge counties, deals largely with the Lower Silurian, especially in its effect on the topography in the eastern part of the county where the drift is thin or wanting.

Fifth report, 1876. Gives the geology of the Lower Silurian in Houston and Hennepin counties.

Sixth report, 1877. Contains observations on the Trenton at Wanamingo, in Goodhue county, and at St. Paul, in Ramsey county, also in Rice county.

Eighth report, 1879. Ten species of brachiopoda are here described, supposed to be new, from the rocks of the Lower Silurian in Minnesota.

Ninth report, 1880. Three new brachiopods are described in this report.

Twelfth report, 1883. Contains a description of a new trilobite, by A. W. Vogeles, assumed to have come from the Trenton, but shown by Prof. Clarke in part II of this volumeto have been derived from the middle Devonian.

Fourteenth report, 1885. This contains a "report on the Lower Silurian Bryozoa, with preliminary descriptions of some of the new species," embracing forty forms; also "remarks on the names Cheirocrinus and Calceocrinus, with descriptions of three new generic terms and one new species."

Fifteenth report, 1886. Three species of trilobites, two of them new, are here described from the Trenton limestone by Mr. A. F. Foerste.

Nineteenth report, 1890. "New Lower Silurian Lamellibranchiata, chiefly from Minnesota rocks." Contains descriptions of 28 new forms.

Volume 1. Final report, 1872-1882. In this volume are the final reports on the counties of Houston, Winona, Fillmore, Olmsted, Dodge, Steele and Rice, in all of which these formations occur, with maps of their surface distribution.

Volume II. Final Report, 1882-1885. Here are given the final reports, with county maps, on the geology of Goodhue, Dakota, Ramsey and Hennepin counties.

Bulletin No. 5. Natural Gas in Minnesota, 1889, N. H. WINCHELL. A record is given of the deep well sunk at Freeborn, in Freeborn county. Here the Galena limestone is given at 10 feet, being the first rock struck below the drift. The shales and underlying Trenton are given a thickness of 310 feet, which may be considered doubtful.

OTHER PUBLICATIONS BEARING ON MINNESOTA, BY MEMBERS OF THE MINNESOTA GEOLOGICAL CORPS, ON THE PALEONTOLOGY OF THE LOWER SILURIAN.

A correlation of the Lower Silurian horizons of Tennessee and of the Ohio and Mississippi valleys with those of New York and Canada. E. O. ULRICH, American Geologist, vol. I, pp. 100, 179, 303, 333, 1888; vol. II, p. 39, 1888.

On Sceptropora, a new genus of Bryozoa, with remarks on Helopora, Hall, *and other genera of that type.* E. O. ULRICH, American Geologist, vol. I, p. 228, 1888.

Preliminary description of new Lower Silurian sponges. E. O. ULRICH, American Geologist, vol. III, p. 233, 1889.

On Lingulasma, a new genus, and eight new species of Lingula and Trematis. E. O. ULRICH, American Geologist, vol. III, p. 377, 1889; vol. IV, p. 21, 1889.

Contributions to the micro-paleontology of the Cambro-Silurian rocks of Canada. Part II. E. O. ULRICH, Geological Survey of Canada, 1889.

New Lamellibranchiata. E. O. ULRICH, American Geologist, vol. V, p. 270, 1890; vol. VI, pp. 173, 382, 1890; vol. X, p. 96.

New Lower Silurian Ostracoda. E. O. ULRICH, American Geologist, vol. X, p. 263, 1892.

Preliminary descriptions of new Brachiopoda from the Trenton and Hudson River groups of Minnesota, by N. H. WINCHELL and CHARLES SCHUCHERT, American Geologist, vol. IX, p. 284, 1892. (Distributed April 1, 1892).

Two new Lower Silurian species of Lichas (subgenus Hoplolichas). E. O. ULRICH, American Geologist, vol. X, p. 271, 1892.

Geological Survey of Illinois. A. H. WORTHEN, director, vol. VIII. Geology and Paleontology, Text and Plates. Edited by JOSUA LINDAHL, July, 1892. *American paleozoic Sponges,* E. O. ULRICH, pp. 211-251; *Descriptions of Lower Silurian Sponges,* E. O. ULRICH, pp. 255-282; *Paleozoic Bryozoa,* E. O. ULRICH, pp. 285-688.

TABLE OF STRATIGRAPHIC DESIGNATIONS.

The following table shows approximately the stratigraphic positions of the various terms that have been applied to the different parts of the Lower Silurian in the upper Mississippi valley since 1820. The base of the Hudson River formation has been a well-known horizon, and since its first discovery it has not been changed. The base of the Galena limestone has been a well-known lithologic horizon, and for many years has been accepted as the base of the Galena formation. Owing however to the early enumeration of fossil species which were said to be characteristic of the Galena, in some of the shales and shaly limestones below the principal limestone, by the authors of the term Galena, it was soon found that the Galena formation, on those definitions, must be considered to embrace a portion of the underlying shales. Opinion fluctuated, however, as to the propriety of including these shales in the Galena, inasmuch as that would destroy the usefulness of the term as a convenient lithological base, and since there was as yet no way of deciding how

Table of Stratigraphic Designations Applied to the

Formations. (As now known.)				Special Designations Employed in this Volume.	Names used in the Minnesota Reports, 1872-1892.	F. W. Sardeson, 1892.	Joseph F. James, 1890.	R. P. Whitfield, 1882.	G. D. Swezey, 1882.	C. D. Walcott, 1879.	Moses Strong, 1878.	R. D. Irving, 1878.	T. C. Chamberlin, 1878.	James Shaw, 1872.	W. D. Hurlbut, 1871.	J. H. Kloos, 1871.	C. A. White, 1870.
Hudson River or Cincinnati.	Richmond.	Limestone.	Upper part.		Maquoketa = Hudson River Group.	? Wykoff.	Cincinnati.	Hudson River.		Hudson River.	Cincinnati.		Cincinnati.	Hudson River.			Maquoketa.
	Utica.	Shales.	Lower part.	Nucula beds.		Maquoketa.	Unconformity										
TRENTON.	Trenton.	Limestone.	Galena limestone.	Maclurea beds.	Galena.	Maclurea, 50 ft.	Galena.	Galena.	Galena.	Utica Slate.	Galena.		Galena.	Galena.	Devonian.		Galena.
				Fusispira bed.		Lingulasma, 20 ft.											
				Anastrophia and Upper Clitambonites beds		Camarella, 30 ft.											
		Shales.	Upper Galena Shales.	Nematopora bed.	Galena Shales.	Orthisina, 20 ft.				Trenton.	Blue. Carbonaceous Shale?			Blue Limestone=Trenton.	Clinton.		Trenton.
			Basal beds.	Clitambonites Prasopora insularis.													
	Black River.	Shales.	Upper Third.	Fucoid bed. Phylloporina horizon. Orthis pectinella beds. Bryozoa layers.	Upper Trenton.	Fucoid, 20 feet. Zygospira, 8 feet.		Upper Blue.	Upper Blue.				Upper Blue.		Hudson River oil shales.		
			Middle Third.	Ctenodonta bed. Rhinidictya beds.	Trenton Shales.	Stictopora, 30 feet.		Upper Buff.	Upper Buff.		Glass rock—Lower ½ of the Blue. Blue limestone.		Upper Buff.				
	Stone's River.		Lower Third.	Stictop'rella	Green Shales.	Stictoporella, 10 feet.		Lower Blue.	Lower Blue.			Lower Blue.	Lower Blue.		Green shales.		
		Limestone.	Shaly Limestone.	Vanuxemia bed.	Trenton. (Chazy?)	Blue.		Lower Buff.	Lower Buff.		Trenton.	Lower Buff.	Lower Buff.		Trenton.	Trenton.	
			Building Layers.			Buff.											

Lower Silurian in the Upper Mississippi Valley since 1823.

Black River. Birdseye. Chazy.	Glass rock.	Blue limestone. Trenton of New York.	Galena.	Hudson River.	J. D. Whitney, 1862.
Birdseye. Black River.	Blue limestone=Trenton of New York.		Galena.	Hudson River=Blue limestone of Ohio.	James Hall, 1862.
Shell and Blue limestone.			Galena.		Anderson and Clark, 1861.
Trenton.			Galena.		James Hall, 1861.
				Nucula shale.	Edward Daniels, 1858.
			Utica slate.		H. D. Rogers, 1858.
Buff.	Glass rock.	Blue limestone.	Galena.		J. D. Whitney, 1858.
Magnesian beds below 25 feet.	Birdseye, 75 ft.	Trenton. Receptaculites 50 feet below the base of the Galena.	Galena.	Utica and Hudson River.	James Hall, 1858.
Blue limestone.			Upper Magnesian.	Blue shale.	J. G. Percival, 1854.
Blue limestone.			Galena.	Nucula shale.	Edward Daniels, 1854.
St. Peter shell limestone=Blue limestone=Trenton.			Utica slate and Hudson River groups.		D. D. Owen, 1852.
			Galena.	Blue limestone. Trenton.	Foster and Whitney, 1851.
St. Peter shell limestone.	Fossiliferous limestone No. 3=Blue limestone of Ohio.				D. D. Owen, 1848,
Some Silurian limestone.					G. W. Featherstonhaugh, 1847.
St. Peter's=Trenton.			Trenton.		J. N. Nicollet. 1843.
			Upper member of the Trenton.		T. A. Conrad, 1843.
			Part of the Cliff limestone (Upper Magnesian). Lower Helderberg, and Niagara.		James Hall, 1842.
Buff colored stratum.	Blue limestone. Caradoc, Trenton (1844).		Part of the Cliff limestone (Upper Magnesian). *i. e.* Upper Silurian.		Locke and Owen, 1839.
			Gray limestone. Part of the Carboniferous.		G. W. Featherstonhaugh, 1836.
Lower Magnesian, St. Peter sandstone, and Upper Magnesian were all put in the Lias.					W. H. Keating, 1823.
Part of the Mountain limestone series, now the Mississippi series.					H. R. Schoolcraft, 1823.

much of the underlying shale should be thus included. When, however, it was found that the Galena limestone proper had no uniform base line, but that its basal portion became shale toward the north and that other shale beds began to be interbedded in the limestone at higher levels, it was apparent that in Minnesota there was nothing left of a lithological base line, and that the only criterion on which to establish the bottom of the Galena was a downward extension of its characteristic fossils, and an enumeration of the other associated and characteristic species. Thus it became apparent that in Minnesota about thirty feet only of the underlying shales might be put into the Galena formation. In Iowa there is reason to believe that a greater thickness of the underlying strata may thus be transferred to the Galena. Owing, however, to the gradual lithologic transition from shales to limestone, or *vice versa*—whether horizontally or perpendicularly—it is apparent, as already remarked that the characteristic fossils of the Galena and their associates will not be found to be distributed throughout the region in complete conformity with the limits here established and the query very naturally arises whether the distinction between the Galena and the Trenton is one which on any terms, whether lithological or paleontological, ought to be perpetuated. Our results certainly show so intimate a relation between them that they might with propriety be put into the same formation with a common designation.

It is barely necessary to call attention to other conclusions that spring from an inspection of this table and a comparison of it with the tabulation of fossil species given in the introduction to part II of this volume.

The suggestion of D. D. Owen in 1852 that the Galena can be parallelized with the Utica slate and Hudson River formations finds no support in our results, but those formations are necessarily at a higher horizon if they both occur in the Northwest.

The suggestion of H. D. Rogers, in 1858, that the Galena limestone is possibly the western representative of the Utica slate, more elaborated and adopted by C. D. Walcott in 1879, is not supported by our results.

The terms Buff and Blue, used to designate some portions of these formations (Trenton), under the erroneous idea that the strata to which they were applied were of the age of the Blue limestone of Ohio (Cincinnati group), have been the source of many mistakes; and as the strata are older than their supposed equivalents, these terms ought not to be further employed.

There are good reasons for believing that the Hudson River was separated from the Galena, or top of the Trenton, in the Northwest, by some physical convulsion which exterminated, or expelled, most of the species that preceded it. This is indicated not only by the rarity of the species that survived the change but by certain physical features that accompany the basal beds of the Hudson River. At Maquoketa, Iowa, Mr. James mentions some evidence of stratigraphic non-conformity at this horizon. From this horizon upward into the limestones of the Upper Silurian the transition is not more marked than from the Galena to the Hudson River.

In the introduction to part 2 the reader will find further discussion of the stratigraphic peculiarities and the distribution of the fossils of the Lower Silurian. and some comparitive tables indicating the relations of the Mississippi valley with the same rocks in New York and Canada and in the Cincinnati region.

Dates of publication of the chapters of this part of this volume.

The five chapters which are included in part I were published, in editions of one hundred copies each, and distributed on the dates given below.

Chapter I. Cretaceous Fossil Plants from Minnesota. Feb. 15, 1893.

Chapter II. The Microscopic Fauna of the Cretaceous in Minnesota, with additions from Nebraska and Illinois. Feb. 15, 1893.

Chapter III. Sponges, Graptolites and Corals from the Lower Silurian of Minnesota. June 6, 1893.

Chapter IV. On Lower Silurian Bryozoa of Minnesota. Jan. 15, 1893.

Chapter V. The Lower Silurian Brachiopoda of Minnesota. June 6, 1893.

ACKNOWLEDGMENTS.

The authors of part I of Volume III are under obligations to numerous geologists for advice and coöperation. Throughout the whole course of its preparation they have enjoyed the friendly aid and guidance of Mr. W. H. Scofield, late of Cannon Falls, whose familiarity with those formations in Goodhue and Olmsted counties has not only brought to light many fossil forms but has enabled the authors to study in the field their stratigraphy with greater fullness. Prof. James Hall generously allowed the use of advance proofs of his recent revision of the Brachiopoda (Paleontology of New York, vol. viii, part 1.) A year or more before the publication of that volume.

For various favors the authors also have to thank Mr. C. D. Walcott, C. E. Beecher, Prof. J. M. Clarke, Prof. A. Hyatt, J. F. Whiteaves of the Canadian Geological Survey, Capt. A. W. Vogdes, Prof. C. W. Hall and Mr. F. W. Sardeson. Throughout the volume will be found various acknowledgments for fossils and other aid furnished.

ERRATA.

FOR PART I, PAGES 1 TO 474.

P. 9. Add note on "2. *Sequoia winchelli* Lx." as follows: This species was found at Austin and is not known to occur near New Ulm.

P. 9. For "7. *Populus winchelli*, sp. nov," read 7. *Populites winchelli*, sp. nov.

P. 9. After "19. *Aralia radiata* Lx." dele "†" in the first column and insert it in the third.

P. 36. Tenth line from top, for "PLATE B" read PLATE D.

Plate D. Fourth line from bottom of explanation, for "ARBULINA" read ORBULINA.

P. 69. Under "ANOMALOSPONGIA" insert PLATE F, FIGS 13-15.

P. 85. Sixth line from top, for "Galena shales" read Trenton shales.

P. 92. First line in description of figure, for "Galena" read Trenton.

P. 106. Under "Family PTILODICTYONIDÆ" add *Escharopora* HALL.

P. 106. Under "Family RHINIDICTYONIDÆ" add *Trigonodictya* ULRICH.

P. 107. Under "Family BATOSTOMELLIDÆ" add *Eridotrypa* ULRICH.

P. 107. Under "Family DIPLOTRYPIDÆ" add *Stromatotrypa* ULRICH.

P. 107. Under "Family CERAMOPORIDÆ" add *Bythotrypa* ULRICH.

P. 110. Twenty-first line from bottom, for "*Dichtyotrypa*" read *Dichotrypa*.

P. 157. Thirteenth line from bottom, add PLATE VIII, FIGS. 4 and 5.

P. 171. Second line from top, for "FIGS. 1-12" read FIGS. 1-11.

P. 178. Eleventh line from top, for "ANTHROPORA" read ARTHROPORA.

P. 180. Under "Section *a*" insert *S. exigua* Ulrich, Trenton limestone, Canada.

P. 184. "STICTOPORELLA EXIGUA" should be described here; for description see explanation to plate XIII.

P. 185. Fourteenth line from bottom, for "*Clathopora*" read *Clathropora*.

P. 220. Eighteenth line from top, add Reappears in the upper part of the Galena shales.

P. 244. First and second lines from bottom, dele "and only * * * * * Lower Silurian," and add An examination of the types of this species proves it to be an *Aspidopora*. It should be added therefore to the species of that genus on page 255.

P. 255. See erratum for page 244.

P. 281. Fourteenth line from top, for "FIGS. 15" read FIGS. 13-15.

P. 321. Fifth line from top, for "*Stromatotrypa ovalis*" read *Stromatotrypa ovata*.

P. 339. Eleventh line from bottom, for "pl. L," read pl. I.

P. 375. Fourth line from top, for "pl. IV II," read pl. IV I.

Pp. 382 and 383. Substitute Parastrophia in all places for "Anastrophia."

P. 385. Insert *S. winchelli* Hall, Trenton between the eighth and ninth lines.

P. 391. Fourth line from top, for "pl. XI A" read pl. IX A.

P. 407. Seventeenth line from bottom, add PLATE XXXII, FIGS. 59 and 60.

P. 453. Fifteenth line from top, for "FIGS. 48 and 49" read FIGS. 48-50.

P. 455. Second line from top, for "FIGS. 49 and 52" read FIGS. 51-54.

P. 458. Second line from top, for "FIGS. 53 and 54" read FIGS. 55 and 56.

P. 471. Seventh line from bottom, after "HALLINA" add a note as follows: The genus *Hallina* is later known to be a young condition of *Zygospira*, of which it is a synonym. (See Proc. Biol. Soc. Washington, 1893.)

GEOLOGICAL AND NATURAL HISTORY SURVEY
OF MINNESOTA.

PALEONTOLOGY.

CHAPTER I.

CRETACEOUS FOSSIL PLANTS

FROM MINNESOTA.

BY LEO LESQUEREUX.

In looking over the long series of the groups of plants which have inhabited the earth at the divers periods of its evolution, none appear so remarkable, none excite so much of interest and stimulate so forcibly the mind to researches by problems of importance and magnitude, as that of the Middle Cretaceous known in North America as the flora of the Dakota group.

The geological area occupied by the formation, its thickness and the constitution of the rocks are well known.* Some portions of its flora have been already described by European and American authors in more or less complete memoirs which have put in evidence the great variety and luxuriance of its constituents. It seems, therefore, that the vegetation of that period should be satisfactorily known, from the fossil remains which have been determined until now, but, nevertheless, every new research in this field brings forth some facts which contribute to more evidently expose the peculiar character of the flora and its wonderful diversity.

Though the above assertion has been made already at different times, it is now suggested again, by the examination of some lots of specimens procured in Minnesota, representing a number of species, which, described below, give occasion to some remarks upon the origin, the distribution and the peculiar characters of the vegetation prevalent during the period of the Middle Cretaceous, generally known as the Cenomanian.

In the present stage of its progress, vegetable palæontology has discovered evident traces of land vegetation as far down as the Middle Silurian. The most ancient remains of land plants represent species of the three orders, composing the class of the Acrogens or cryptogamous vascular plants, viz: the *Equisetaceæ*, the *Filices* (or

*See for what relates to the geographical and stratigraphical distribution of the Dakota group: F. V. Hayden's reports of the United States Geological Survey of the Territories. "Vol. VI, Cretaceous Flora, pp. 13-25."

ferns) and the *Lycopodiaceæ*. It is very probable that, already at this old epoch some kind of phænogamous angiosperms, first representatives of the conifers and the *Cycadeæ* had their existence; for remains of *Cordaites* have been found in the Lower Devonian, especially in Canada. These *Cordaites*, like the ferns, the Lycopods and the *Equisetaceæ*, were plants of various size; either small, floating, bushy, or large trees. Their stems or trunks were composed of a woody cylinder, the wood being disposed in concentrical circles and perforated by pores like that of the conifers, and their fruits, of very diversified forms, had a great analogy to that of the *Cycadeæ*, of which they have been considered as the ancestors or prototypes. Hence it is probable that from its origin the land vegetation was characterized by the four essential elements which have composed it in the long series of ages and formations from the Silurian to the Cretaceous.

In the Upper Devonian already, numerous species of ferns, some of them tree ferns, the *Lycopodiaceæ* with their generic divisions, *Lepidodendron, Ulodendron, Knorria, Halonia, Lepidophloios, Sigillaria and Stigmaria;* the *Calamarieæ* as *Calamites, Asterophyllites, Annularia, Sphenophyllum* and the *Cordaiteæ*, as *Cordaites*, are present. Even trunks considered by some authors as referable to the *Araucarieæ*, a family of the conifers, have been found there in England as in America. Excepting this last kind, all the above genera are more abundantly represented in the Carboniferous, a number of their species passing higher, into the Permian. Here while the large *Lycopodiaceæ* and a number of species of ferns lose their predominance and gradually disappear, their place is taken by conifers of a peculiar type. *Valchia, Ulmannia*, and later in the Trias by *Volzia* and *Albertia*, all, like the *Araucarieæ*, of the order of the *Abietaceæ*. It is there also that the *Cordaiteæ* give place to tree *Cycadeæ*, which gradually become predominant together with the ferns and the conifers. In the Keuper, the *Calamarieæ* still represented by gigantic *Calamites*, become somewhat modified in their conformation, the articulations of their stems becoming like those of the genus *Equisetum*, surrounded by sheaths instead of whorls of separated narrow leaflets. But in the Lias, the *Calamarieæ* and the arborescent ferns become, like the *Lycopodiaceæ*, mostly reduced to herbaceous plants; and in the Oölyte, the Jurassic, the Wealden, even the Lower Cretaceous, the whole vegetation, though modified in its aspect and its forms, is still composed of acrogenous and gymnospermous plants with a few monocotyledons of as yet uncertain affinity.

Still in the Cretaceous, but near its base in Europe, the vegetable remains attest the persistence of that peculiar and uniform vegetation which has inhabited the land during such a long series of geological periods. For example, in the Vernsdorf schists of North Germany, which by their fauna and their geological stage are referable to the Urgonian or Lower Cretaceous, a group of plants has been discovered composed of 1 algoid, 3 ferns, 12 *Cycadeæ*, 5 conifers and 1 monocotyledon. The characters of these plants are like those of the plants of the Wealden and of the Jurassic. In Greenland, the Swedish expedition under the direction of Nordenskiöld also found at Korne, in strata which by their fauna are referable to about the same geological subdivision of the Lower Cretaceous as the Vernsdorf schists, a group of 88 species of plants representing 48 ferns, 1 *Marsilia*, 1 Lycopod, 3 species of *Equisetum*, 14 *Zamieæ*, 17 conifers, 5 monocotyledons with a few fragments of a leaf of a dicotyledonous species, a *Populus* which Heer, who has examined and determined the plants, has named *Populus primæva*. Here still we find precisely the same elements of vegetation as in the Wealden and the Jurassic, except that leaf of *Populus*.

It is from this point or from above the lower Urgonian subdivision that appear the earlier American Cretaceous strata, those of the Dakota group, immediately superposed, in the western states to the Permian magnesian limestone. Above this formation and up to the base of the Tertiary, one passes, in ascending through the four geological subdivisions fixed by Hayden and Meek, the Benton, the Niobrara, the Fort Pierre and the Fox Hill groups. The fauna of the Benton group is that of the Cenomanian of d'Orbigny; by its position the Dakota group is referable to the same subdivision, while its flora is that of the Middle Cretaceous of Greenland and of the Quader sandstone of Germany. Its geological stage is thus positively fixed as succeeding the Urgonian, where, as seen above, the types of the vegetation are still mostly Jurassic and without any trace of dicotyledons, except that *Populus* found by Heer among the 88 species of Korne. Now, the flora of the Dakota group is of a totally different character. As known at the present it has in more that 200 species of plants which have been determined, 1 *Equisetum*, 6 ferns, 6 *Cycadeæ*, 10 conifers, 3 monocotyledons and 175 dicotyledons, these being in the proportion of 81 per cent. while the other groups of plants, including the monocotyledons, remain relatively the same. The flora of Atane which has been discovered in Greenland in strata at a higher stage of the Cretaceous than that of Korne, and which is also referable to the Cenomanian by its fauna, has about the same elements in its composition. In 177 species described by Heer, it has 3 *Fungi* (*Hypoxyleæ* upon leaves of dicotyledons), 31 ferns, 1 *Marsilia*, 1 *Selaginella*, 1 *Equisetum*, 11 *Cycadeæ*, 24 conifers, 8 monocotyledons and 97 dicotyledons, or a proportion of 55 per cent. of dicotyledons. This group of plants has a greater number of ferns and conifers than that of the Dakota group, a difference evidently due to the influence of local atmospheric circumstances. In collections recently made of plants of the Dakota group, the number of species of *Cycadeæ* is greatly increased at some localities and most probably the conifers and the ferns may be found also more abundant at some others. The flora of Atane, and that of the Dakota group have a number of identical species.

As yet, no remains of fossil plants have been described from the American Cretaceous above the Dakota group. But in Greenland, at a higher stage than that of Atane and in strata considered as referable to the Lower Senonian, Upper Cretaceous, the same discoverers have found a group of plants still related to the Cenomanian by some identical species, and comprising in 118 species, 1 fungus, 19 ferns, 1 *Equisetum*, 17 conifers, 5 monocotyledons and 75 dicotyledons. In this flora the proportion of the dicotyledons is 63 per cent., and the general character of the vegetation is evidently the same. In continuing the researches above, in the subsequent formations, we would find the same kind of gradual change and the same proportion in the composition of the flora. Some of the types are modified in the character of the species, which either disappear or are constituted as new; but the general proportion in the constituents of the floras remains about the same. For example, at the base of the Tertiary, the flora of the Laramie group, Lower Eocene in character, has in its composition a proportion of 66 per cent. of dicotyledons. It has, moreover, a new element in the predominance of the palms, of which very few remains have been found in the Cretaceous. But above, in the Oligocene where the palms have become extremely rare, the proportion of the dicotyledons remains the same, as it is also in the Miocene, and in the flora of the present epoch, being merely modified by local influences, especially by variations of temperature.

Is it then possible to explain in some way the total change noticed in the characters of the vegetation of the earth in the middle of the Cretaceous? To show the difficulty of the solution of a problem like that of the appearance of the dicotyledons in the flora of that period, it is necessary to know something more about the characters of those primitive dicotyledons, as we find them in the Dakota group.

To admit, as do some authors, that the change has been produced by a gradual modification of some types, caused by external influences, one would suppose, in considering the large number of dicotyledons now known from the Middle Cretaceous, that it would be possible to find some traces of the successive degrees of modifications which, of course, can not have acted merely upon the leaves, or upon a single kind of organ, but upon all the parts of a plant. No species of the dicotyledonous series has as yet shown any such intermediate characters indicating by its inferiority a degree of transition; and thus, of all the species found in the strata of the Middle Cretaceous, it is not possible to consider any one as being of a lower degree of organization than another. And also, in the large number of vegetable remains of the lower division of plants, none have been found in the long series of ancient vegetables, whose characters would indicate a tendency to a transition to a a higher order. Some ferns of the Trias and the Lias, even of the Carboniferous, are by their outlines, like dicotyledonous leaves, but their nervation is always far different, and, moreover, as said above, the likeness of a leaf can not by itself indicate a relation in the characters of a plant, as in passing for example, from a fern to a dicotyledon the whole plant has to be modified, the structure of the stem, the wood, the flowers, fruits, etc. Evolutionists may trace the derivation of a species of mammals from one to another, but they can not look for such transitional forms between a saurian and a mammal; and it is a difference of this kind which exists between the dicotyledons and the lower series of vegetables predominant from the origin of the land plants to the Wealden.

But more. If the change had proceeded by slow degrees of modification of one species, the results would be, of course, a great uniformity or an affinity of parentage noticeable in the derived types. That is certainly not the case for the flora of the Dakota group, as it is known at the present time, has its dicotyledonous species referable to the three great divisions of the present dicotyledonous flora; the *Apetaleæ*, the *Gamopetaleæ* and the *Dialapetaleæ*. Of the first, it has the *Amentaceæ* with species of the genera *Myrica*, *Betula*, *Alnus;* the *Cupulifereæ* with *Fagus*, *Quercus*, *Salix*, *Populus*, *Platanus*, *Liquidambar;* the *Moreæ* with *Ficus;* the *Proteaceæ* with *Proteoides*, *Todea*, *Lomatia;* the *Lauraceæ* with *Laurus*, *Persea*, *Sassafras*, *Cinnamomum*, *Oreodaphne;* the *Aristolochieæ* with *Aristolochia*. Of the second, it has the species of *Diospyros* in the *Diospyrineæ* and of *Andromeda* in the *Ericaceæ*. Of the third, it has the *Araliaceæ* with a number of species of *Aralia*, and of *Hedera;* the *Ampelideæ* with *Cissus;* the *Polycarpeæ* with *Magnolia*, *Liriodendron*, *Liriophyllum*, *Anona* and a number of species of *Menispermaceæ;* the *Malvaceæ* with *Sterculia;* the *Tiliaceæ* with *Greviopsis;* the *Aceraceæ* with *Acerites*, and especially *Sapindus;* the *Frangulaceæ* with *Ilex*, *Palinurus*, *Rhamnus;* the *Terebinthineæ*, with *Juglans* and *Rhus;* the *Rosifloreæ* with a *Pyrus* and a *Prunus;* then species of the *Leguminoseæ* with a number of leaves assigned to genera whose affinity with plants of the present epoch is not distinctly marked. How is it possible to admit or even suppose that plants referable to such a number of genera distributed in divers families of the three essential subdivisions of the dicotyledons might have originated by gradual modifications of one or more species of the inferior classes of plants, to which, as remarked above, it has been impossible to find any kind of analogy, and this, too, during the time of transition between two consecutive periods, the Urgonian and the Cenomanian?

In considering the question of the correlation of the plants recognized in the succession of the floras since their origin, one forcibly arrives at the same conclusion, the impossibility of explaining by antecedents the characters of the vegetation of the Middle Cretaceous, or rather the presence of the dicotyledons as its essential element. From the beginning and in closely following the march of the vegetation, we find an evident degree of parentage between the groups which disappear and those which follow them. Thus the affiliation of the ferns of the Devonian to those of the Catskill group; then to those of the Subcarboniferous, is easily followed up into the Permian, and still, by gradual modification through the ages, to the present epoch. The great *Lycopodiaceæ,—Sigillaria, Lepidodendron, etc.*, gradually take a more marked place in the vegetation of the palæozoic times, have the highest degree of predominance in the Carboniferous, have their time of decline in the Permian, but continue to be represented up to the present epoch by plants of the same kind but of small size. The conifers also, which distinctly appear in the Permian by peculiar forms, gradually becoming more predominant, constitute the essential vegetation of the Jurassic, still remain in the present flora under somewhat modified forms. The *Cycadeæ*, apparently as old as the *Lycopodiaceæ*, follow the same march of development traversing the Carboniferous as an essential constituent of the vegetation, declining in the Permian and by modification of some of their characters passing to the *Cycadeæ* which then follow the same march as the conifers. There is, indeed, between the *Cordaiteæ* and the *Cycadeæ* a marked difference, but the mode of gradual transformation between plants which have such great analogy of characters may be easily conceived. After following the gradual variations of types through the palæozoic time one may follow them still from the Cretaceous and see them also continued upon the dicotyledons from their appearance through the cenozoic ages, to the present epoch. Hence all the groups of vegetables appear from their origin as linked together by a kind of putative affiliation; but nothing like that can be seen to foretell the appearance of the dicotyledons in the Middle Cretaceous; the parentage is derived from them in the hereafter, but none can be found in the past.

As we see it in the Dakota group, in the formation of Atane in Greenland, and also in the Middle Cretaceous of Europe, the Cenomanian flora appears in its distribution and in the general character of its groups, as a complex assemblage of vegetable types developed under the acting forces of a long series of ages. Though a number of species are found identical at the different localities, the groups are generally different in characters. For example, the four species of *Populus* of Greenland are of the section of the coriaceous poplars, and of these, none is found in the Dakota group. Of the seven species of *Quercus* described from Greenland, two are identified in the Cretaceous of Germany, none in the Dakota group, which has species of oaks of a different type. Of the *Laurineæ*, Greenland has seven; we have seventeen in the Dakota group; Europe has none, while species of *Credneria* are numerous in the Quader sandstone of Germany, and one only has been described from Greenland and one from the Dakota group. The same differences are observed in some of the other groups, while some present a remarkable degree of affinity. The same remark is applicable to the distribution of the plants upon the land surface of the formation in North America. Kansas, for example, has many species which have not been found in Nebraska or in Colorado, and vice versa. In the small number of species described here below from Minnesota, there are eight which have not been found elsewhere and are considered as new. The geographical distribution, as far as it is known at the present time, is really more complex and varied than it is in the vegetation of the present epoch. The vegetable remains are not found strewn over large surfaces of the land, as if they were derived from forests of wide extent, but over small isolated areas, more or less distant from each other, as if the leaves found there had fallen from groups of trees growing separate upon small islands or around wood swamps of small extent. And generally the plants of each area are of the same or of related species or represent only few species or genera, each locality having some plants proper to it. At one place the *Sassafras* abounds; at another the *Laurineæ*; still at another the *Liriodendron*, or species of another genus or family. Such a distribution does not agree with what it should be for plants derived by evolution of one or more species, as the plants of the same kind or varieties should, of course, remain together or follow the same range and direction in their distribution. It is worth remarking that as far as it can be observed neither the geological features nor the conditions of the atmosphere of the Middle Cretaceous have been subjected to great changes. The cataclysms caused by volcanic agency, and the gradual elevation of the chain of the Rocky mountains, have come after the Cretaceous. Nothing in the vegetation of that epoch indicates great and prolonged disturbances of the atmosphere. In the lower series of the vegetable scale, the ferns, the conifers and the *Cycadeæ* are of the same type and some of the same species, as in the Wealden, the Vernsdorf shale of the Lower Cretaceous, the schists of Korne, and those of the Cenomanian of Atane in Greenland. And from the time when the dicotyledonous plants appeared, or when we find them predominant, some of the types which may be called primitive, as it is not possible to refer them by derivation to some anterior ones, have continued in the different groups of floras through the Upper Cretaceous and the Tertiary to the present epoch, modified, indeed, but distinct enough to be recognized in many genera and species of the living flora of this country.

The small lot of specimens of Cretaceous fossil plants obtained in Minnesota by the state geologist Prof. N. H. Winchell, and described here below may serve as a confirmation of the above remarks.

The number of specimens, 55, represent no less than 28 species. Of these two only are of gymnospermous plants; all the other, dicotyledonous, are referable to eighteen genera pertaining to the three great subdivisions of the dicotyledons, the *Apetaleæ*, the *Gamopetaleæ*, and the *Dialapetaleæ*.

APETALEÆ.	GAMOPETALEÆ.	DIALAPETALEÆ.
Populus.	*Diospyros.*	*Aralia.*
Salix.	*Andromeda.*	*Cissus.*
Alnites.		*Credneria.*
Platanus.		*Magnolia.*
Ficus.		*Dewalquea.*
Laurus.		*Juglans.*
Cinnamomum.		*Sapindus.*
		Cratægus.
		Protophyllum.

The relation of the genus *Protophyllum*, represented by two species, though still uncertain, is most probably to *Credneria*, and therefore shall be admitted in the *Dialapetaleæ*.

The following table sufficiently shows the botanical and geographical distribution of the species.

	North side of the Cottonwood river near New Ulm.	Mankato, Minn.	Goodhue Co., Minn.	Kansas.	Nebraska.	Greenland.
Gymnospermeæ.						
1. *Pinus* species	†					
2. *Sequoia winchelli* Lx	†					
Apetaleæ.						
3. *Populites elegans* Lx	†				†	
4. *Populites cyclophyllus* Heer	†			†	†	
5. *Populites litigiosus* Heer	†			†	†	
6. *Populites lancastriensis* Lx	†				†	
7. *Populus winchelli*, sp. nov	†					
8. *Populus berggreni* Heer	†					†
9. *Salix proteifolia* Lx			†	†	†	
10. *Alnites crassus*, sp. nov	†					
11. *Platanus primæva* Lx		†				
12. *Ficus austiniana* sp. nov	†					
13. *Ficus* species			†			
14. *Laurus nebrascensis* Lx	†			†	†	
15. *Laurus plutonia* Heer		†		†		†
16. *Cinnamomum scheuchzeri* Heer	†			†	†	
Gamopetaleæ.						
17. *Diospyros pseudo-anceps*, sp. nov	†					
18. *Andromeda parlatori* Heer	†			†	†	†
Dialypetaleæ.						
19. *Aralia radiata* Lx	†					
20. *Cissus browniana*, sp. nov	†			†		
21. *Magnolia alternans* Heer	†			†	†	†
22. *Dewalquea primordialis*, sp. nov	†					
23. *Juglans debeyana* (H.) Lx	†			†	†	
24. *Cratægus atavina* Heer	†			.		†
25. *Sapindus morrisoni* Lx	†			†		†
26. *Leguminosites* species	†					
27. *Protophyllum crednerioides* Lx	†			†		
28. *Protophyllum integerrimum* Lx		†				

DESCRIPTION OF SPECIES OF CRETACEOUS FOSSIL PLANTS OF MINNESOTA.

1. PINUS *species.*

Leaf comparatively very long, narrow, linear, medial nerve broad; borders flat, irregularly very thinly striate lengthwise.

The fragment of a leaf 11 cm. long, $2\frac{1}{4}$ mm. broad, is as far as can be seen that of a simple leaf of a *Pinus*, much like *Pinus hayesiana* Heer, of the Tertiary of Greenland. The medial nerve is obsolete in some parts of the leaves, very distinct in others.

Hab. North side of the Big Cottonwood river near New Ulm.

Mus. Reg. No. 5160.

2. SEQUOIA WINCHELLI, *sp. nov.*

PLATE A, FIG. 1.

First An. Rep. Minn. Sur., p. 114. Final Rep., Vol. I, p. 354.

Branches slender; leaves linear-oblong, obtuse, gradually narrowed to a linear decurring base, disconnected from the branches, at least in the upper part; medial nerve thin, sometimes obsolete; surface transversely rugulose under the thin epidermis.

A beautiful species with slender pinnately divided branches; leaves and branchlets subdistichous and sub-opposite, half open; leaves 8 mm. long or a little less, $1\frac{1}{2}$ to 2 mm. broad at the middle, equally narrowed upward to an obtuse apex, and downward to a narrow linear prolongation, decurring upon the branches, but disconnected from them in the upper part or under the point of union to the leaves.

The only relative known to the species is *Sequoia brevifolia* Heer, abundantly found near the base of the Laramie group formation at Point of Rocks, Wyoming, and also in the Miocene of the Baltic in Germany. The leaves of the Cretaceous species are narrower, their base more distinctly decurrent and detached from the stems.

Hab. Austin, Minnesota.

Mus. Reg. No. 115.

POPULITES ELEGANS *Lesqx.*

PLATE A, FIG. 2; PLATE, B, FIG. 1.

*U. S. Geol. Report, F. V. Hayden, Vol. VI. Cret. Fl. p. 59, Pl. III, Fig. 3.**

Leaves broadly oval, obtuse, or nearly round, narrowed at base by an abrupt curve to a

---

*The quotations of this work are merely indicated here below as Cret. Fl.

long petiole; borders entire, undulate; nervation obscurely tripalmate; and craspedodrome primary lateral nerves emerging at a distance above the basal borders.

I have figured two fragments of this species, in order to show the real form of the leaves. In comparing the two figures it will be seen that in Pl. A, fig. 2, the primary lateral nerves are at a slightly greater distance above the basal border than in Pl. B, fig. 1, a fragment which has exactly the same characters as in the leaf in Cret. Fl. *loc. cit.* The leaves are generally large, about 9 cm. long and nearly as broad. The lateral nerves about parallel, at an angle of divergence of 40°, branch underneath, or sometimes dichotomously, the ultimate division becoming very thin, but running into the border as sub-craspedodrome, a character rarely remarked in the living species of *Populus.* It is for this reason that I have preserved for the leaves having this peculiar character the name of *Populites.*

The genus *Populus* was abundantly represented in the Cretaceous of North America. In his Phyllites de Nebraska, Heer has described one species. Prof. Newberry has three, also from Nebraska, in his Notes on the Extinct Floras. I have added to the number three in the Cret. Fl. from Kansas and Nebraska, and one described here below, or already 8 species. And still Heer has found four species in the specimens from the Cretaceous of Atane, Greenland, a formation which, by the number of its species identical with those of the Dakota group, is evidently of the same age. Even the first and only leaf of a dicotyledon found at Korne, a stage of the Cretaceous of Greenland lower than Atane, is that of a *Populus.* It is remarkable that all the species of Greenland have a camptodrome nervation.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. Nos. 5155 C, 5377.

POPULITES CYCLOPHYLLUS? *Heer.*

Proceed. of the Acad. of Nat. Sci. of Philadelphia, 1858, p. 266. Lesqx., Cret. Fl. p. 59, Pl. IV, f. 5; Pl. XXIV, f. 4.

Leaves round, entire, slightly undulate rounded or truncate to the petiole, texture rather thin; nervation pinnate; lower lateral nerves, emerging at the base of the leaves all craspedodrome, straight, simple, except the lowest pair branching underneath.

The species is still uncertain, as I remarked in the first description *l. c.* I have referred to it leaves answering to the description of Heer, but the author does not consider my reference as right. I have not seen any original specimen nor any figure of it. The specimens from Minnesota are mere fragments, not sufficient for a positive determination.

Hab. North side of the Big Cottonwood river, near New Ulm.
Mus. Reg. No. 5155.

POPULITES LITIGIOSUS *Heer.*

PLATE A. FIG. 3.

Populus litigiosa Heer, Phyll. du Neb., 7, p. 13, Pl. 1, f. 2. *Newb'y, Notes on Extinct Floras,* p 8. *Illustr.* Pl. III, f. 6; Pl. IV, f, 1.

Leaves round, very entire at base; lateral nerves opposite in the lower pairs, alternate in the upper, all distant; nervilles strong, curved, not dividing, the upper forking; marginal nerve none or thin and short.

Comparing the specimens from Minnesota with the figure in the "Phyll." *l. c.* the identity is easily ascertained, though the figure of Heer represents a mere fragment. The author does not mention in the description the presence of a marginal or basilar nerve which in some leaves, as in the one from Minnesota, is quite strong, while in others it is thin and sometimes even indistinct.

Hab. North side of the Big Cottonwood river, near New Ulm.
Mus. Reg. No. 5155.

POPULITES LANCASTRIENSIS *Lesqx.*

PLATE A. FIG 4.

Cret. Fl. p. 58, Pl. III, f. 1.

Leaves large, broadly cordate ovate, obtusely pointed; borders entire, slightly undulate; basilar nerves in five, the upper alternate or sub-opposite, somewhat flexuous, branching from above the middle, all sub-camptodrome; nervilles very thin, the lower undivided, the upper broken and branching.

The leaf is well preserved; the apex and the petiole, however, are destroyed; it is smaller than that in Cret. Fl. *l. c.*, and more like that of Newb'y, Illustr., Pl. 3, f. 7, named *Populus cordifolia*, but appears to be referable to the same species, though the basilar nerves are in three.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5155 D.

POPULITES WINCHELLI, *sp. nov.*

PLATE B. FIG. 2.

Leaf coriaceous, rhomboid-elliptical, borders regularly undulate-repand; nervation palmate-pinnatifid, obscurely craspedrome; medial nerve somewhat thick; basilar lateral nerves emerging a little above the top of the petiole, sparingly branching; secondaries thin, alternate, distant, parallel, simple.

A fine leaf, 7 cm. long without the petiole, which is broken 1 cm. below the base of the leaf, 5 cm. broad in the middle. Its form is the same as that of *P. repando-*

crenata Heer, in Fl. Tert. Helv., Pl. LXII, f. 6, being only smaller and narrower. It differs much, however, by its coriaceous texture, the secondaries equidistant, straight, and ending into the borders; their divergence being only 25°. The nervilles, at right angles to the veins, are flexuous, generally simple and percurrent. The leaf is also comparable to *P. gaudini* Heer, *l. c.*, Pl. LXIV, f. 2.

Hab. North side of Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5376.

Populus berggreni *Heer.*

PLATE B, FIG. 3.

Heer, Arct. Fl. III, p. 106, Pl. XXIX, f. 1-5; VI. Part 2, p. 63, Pl. XVII, f. 8a; Pl. XVIII, f. 1-4a, b, 9a, 10a; Pl. XIX, f. 1a; Pl. XL, f. 7a; Pl. XLI, f. 1; Pl. XLV, f. 12.

Leaves ovate, equally narrowed upward to a blunt apex and downward to the base, decurring into a long petiole destroyed in the leaf; very entire; lateral nerves thin, camptodrome.

In regard to the shape, the leaf is like that of Pl. XXIX, f. 5, *l. c.*, having however, the secondaries less arched, especially similar, for the cuneate base and the straight nervation, to Pl. XVIII, f. 3, and for the general form and size, to f. 1, of the same plate. This last has also on one side a marginal nerve following the border upward as high as the nerve above it and parallel to it. The leaf is broken quite near its base, and the petiole destroyed. I consider the identification of this leaf as right. It has a distant relation to *P. winchelli.*

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5383.

Alnites crassus, *sp. nov.*

PLATE B, FIG. 4.

Leaf coriaceous, thick, rough of surface, round-oval, obtuse, obliquely truncate at base, shallowy toothed from below the middle upward; nervation pinnate, strongly marked; lateral nerves thick, open, parallel, alternate, the lower ones much branched; craspedodrome.

The leaf, which has the facies of an *Alnus*, is $5\frac{1}{2}$ cm. long, 6 cm. broad with a petiole entire or fragmentary(?) 1 cm. long. It is unequilateral, somewhat inclined to one side, with 6 pairs of secondaries at an angle of divergence of 60° curving upward in traversing the lamina, the lowest joining the nerve at a short distance above the basal borders, much branching on the under side; the upper either dichotomous or branching near the borders, all entering the point of the teeth with their divisions, teeth short at right angles to the borders, separated by shallow sinuses nervilles distinct and percurrent.

The general character of the leaf is that of *A. kefersteini* and *A. nostratum* Ung. resembling some of the numerous forms of the species as figured by Heer, Fl. Tert. Helv., Pl. LXXI.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5368.

Platanus primæva? *Lesqx.*

Cret. Fl. p. 69, Pl. VII, f. 2.

A large leaf, more than 12 cm. long, 10 cm. broad in the middle. The base and the borders all around are destroyed. The nervation is that of a *Platanus* and the species would be identified with *P. primæva* Lesqx., *l. c.*, if the lateral nerves and the nervilles were not comparatively thinner. The identification with *P. heeri* Lesqx., or another allied species, is rendered impossible by the destruction of the lower part and of the borders of the leaf.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5155 S.

Ficus austiniana, *sp. nov.*

PLATE A, FIG. 5.

First Annual Report, Minn Sur., p. 114.

Leaves coriaceous, oblong, truncate or cordate at base, entire and undulate; nervation pinnate, camptodrome; lateral nerves at an open angle of divergence 60°, curving in areoles at a distance from the borders, branching above into strong nervilles anastomosing at right angles with the secondary nerves or their branches.

This beautiful species is represented by two fragmentary leaves, one larger (figured), broken at its upper part, recurved at base, the border being embedded into the stone, thus appearing truncate, though probably cordate. The second specimen is part of a much smaller leaf, showing only one side of the leaf less the point, with the nervation deeply marked and perfectly distinct. The nervation is of the same character as that of *Ficus protogea* Ett., Kreide Fl., v. Nieders, p. 15, Pl. II, f. 5; a species also represented by a mere fragment whose nervation is the only point of affinity observable.

Hab. North side of the Cottonwood river, in North Star Brown Co., and Austin, Mower Co., Minnesota.
Mus. Reg. Nos. 3808 and 5163.

Laurus plutonia? *Heer.*

PLATE A, FIG. 6; PLATE B, FIG 5.

Leaves sub-coriaceous, lanceolate, narrowed from the middle upward to a somewhat long, blunt-pointed acumen, downward to a short petiole, very entire; primary nerve com-

paratively thick, straight; secondaries numerous, alternate; slender, at an acute angle of divergence, parallel, except those of the lower pair, more oblique and prolonged reticulate in the intervals.

One of the leaves (Pl. A, f. 6), is 6 cm. long, nearly 2 cm. broad below the middle, with a petiole 6 mm. long; has the characters of the species as described by Heer, *l. c.*, from specimens of the Middle Cretaceous of Greenland.

The reticulation of the nervilles is obscure, the lateral veins being thin, and obsolete in the upper part, and thus the leaf appears at first like that of a *Salix*, but traces of the transverse nervilles are seen in the lower lateral veins, as marked upon the figure, quite as well as they would be observed upon the specimens from Atane, figured by Heer. The other leaf, which I refer to the same species (Pl. B f. 5), is longer and more linear, without any trace of nerves. It is remarkably similar to some of the figures of Heer, *l. c.*, especially to f. 2 of Pl. XIX, and f. 4 of Pl. XX, and as these figures have scarcely any nerves distinctly seen, the absence of secondaries may be merely casual. However, the reference is not conclusive, as none of the figured leaves of Heer have the upper part represented. Another species also of the Cretaceous of Greenland, *Myrica longa* Heer, Arct. Fl. VI, Part 2, p. 65, Pl. XVIII, f. 9 b; Pl. XXIX, f. 15–17; Pl. XXIII, f. 10, has the leaves about of the same form and size without any nerves, but these leaves are rather linear than lanceolate, and broadly obtuse at the apex. The relation is therefore less clearly marked than with *Laurus plutonia*.

Hab. North side of Big Cottonwood river, near New Ulm, Minnesota. *Mus. Reg.* No. 5157 C. The other is from Mankato. No. 5666 A.

Laurus nebrascensis *Lesqx.*

PLATE A. FIG. 7.

Cret. Fl. p. 74, Pl. X. f. 1, Pl. XXVIII, f. 14.

Leaves coriaceous, elliptical-oblong or narrowly lanceolate, obtusely pointed, tapering downward to a short, thick petiole; medial nerve thick, half round; lateral nerves at an acute angle of divergence, camptodrome.

The leaf is somewhat longer and narrower than the one *l. c.*, Pl. X, f. 1, but it is of the same size as that of Pl. XXVIII, f. 14. It is easily identified by the very thick medial nerve continuous to a short terete petiole. The species is not rare in the Dakota group, both in Nebraska and Kansas. Another species also frequently found in Kansas, and closely allied is *L. proteifolia* Lesqx., Cret. and Tert. Fl., Pl. III, f. 9

and 10. The leaves are broader, shorter and thicker ; the medial nerve only half as broad ; the secondaries close, numerous and distinct their whole length.

Hab. North side of Minnesota river, eight miles below New Ulm.
Mus. Reg. No. 3911.

Cinnamomum scheuchzeri? *Heer.*

Fl. Tert. Helv. II, p. 85, Pl. XCI, f. 4–22; Pl. XCII; Pl. XCIII, f. 1, 5. Lesqx. Cret., Fl., p. 83, Pl. XXX, f. 2, 3.

Leaves thick, coriaceous, polished on the upper surface, elliptical or oblong-lanceolate, pointed, narrowed by a curve to a short petiole, entire and slightly undulate, triple nerved from the base or from above it, medial nerve thick, lower lateral nerves ascending along the borders higher than the base of the lower secondary veins, which they join by anastomosing branches.

The description is that in Cret. Fl., made from better specimens than that which I refer to it from Minnesota, and which, broken on one side and partly covered on the other, is merely identified by its nervation. As in the specimen from Kansas, f. 3, *l. c.*, the lower lateral nerves join the medial one close to the base of the leaf, while in the European specimens, the point of connection is generally higher, and therefore, as the species is Tertiary for Europe, the specific reference of all the leaves of the same character, found in the Dakota group, is somewhat uncertain.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5155 T.

Andromeda parlatori *Heer.*

Phill. du Nebr., p. 18, Pl. 1, f. 5. Lesqx., Cret. Fl., p. 88, Pl. XXIII, f. 6–7; Pl. XXVIII, f. 15.

Leaves lanceolate, narrowed to the base, decurring to the short thick petiole, very entire, thickish; medial nerve thick, transversely striate, lateral nerves very thin, close, at an acute angle of divergence, camptodrome; areolation reticulate.

The species is not rare in North America and Greenland. The leaves are somewhat coriaceous, larger toward the base. The specimens are often fragmentary; that of Minnesota represents only the lower half of a leaf with the lateral nerves mostly obsolete.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5157 A.

Diospyros pseudo-anceps, *sp. nov.*

PL. B, FIG. 6.

Leaf subcoriaceous, elliptical-oval, cuneiform to the base, border very entire, medial nerve strong; secondaries irregular in distance, few, curving in traversing the lamina; nervilles irregular in direction except as thin branches of the secondaries anastomosing in festoons along the borders.

The leaf 4 cm. broad is apparently 7–8 cm. long, the upper part being destroyed. Comparing it with *Diospyros anceps* Heer, Fl. Tert. Helv. III, p. 12, Pl. CII, f. 17, it is scarcely possible to point out a difference marked enough to be considered as specific. The base of the leaf in the American specimen is merely slightly less rounded; the lateral nerves are as irregular in distance, those of the lowest pair close by each other, follow the borders in continuous series of bows formed by anastomose from the superior to a marginal inferior veinlet or to the borders; the nervilles are either at right angles to the secondaries and obsolete or passing from the medial nerve to join the secondaries at a distance, and in irregular or anormal direction. The leaf being fragmetary and the upper part destroyed, it is not possible to follow the characters in its upper part.

Hab. North of the Big Cottonwood river, near New Ulm, Minnesota.

Mus. Reg. No. 5372.

Cissus browniana, *sp. nov.*

PLATE A, FIG. 8.

Leaf oval, angularly undulate, obtuse at apex, the borders slightly turned down at base, penni nerve; primary nerve straight, half cylindrical, secondaries half open, sub-opposite, parallel, rigid, the lower pairs branching, the upper simple or branching; all the divisions craspedodrome; nervilles straight at right angles to the nerves.

The leaf is evidently petioled, the base being inclined downward as slightly decurring; but the pedicel is destroyed. Except the petiole, the leaf is fully preserved, 6 cm. long, 4½ broad. The lateral nerves, 6 pairs, are at an angle of 40°, the marginal vein is marked on one side only.

The species is comparable to *Cissus atlantica*, or *Cissus nimrodi* Ett., Bilin. Fl. III, p. 3 and 4, Pl. XL, f. 3–10, two species of the Tertiary, which differ from it by the leaves being smaller, more distinctly irregularly undulate-dentate, and short pointed. The nervation is of the same character.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota,

Mus. Reg. No. 5156.

Magnolia alternans *Heer.*

PLATE A, FIG. 9.

Heer, Phill. du Neb., p. 20, Pl. III, f. 2–4; Pl. IV, f. 1, 2. Lesqx., Cret. Fl., p. 92, Pl. XVIII, f. 4. Newby. Notes on Extinct Floras, p. 8, Illustr. Pl. V, f. 6.

Leaves subcoriaceous, elliptical, very entire, rounded at base in narrowing to the petiole; medial nerve deep and narrow; secondary nerves at an acute angle of divergence, curved in passing to the borders, camptodrome, separated by shorter, thinner veins.

The leaves are variable in size and form, generally narrower, even acutely narrowed at base, but also often rounded in the lower part. They are not rare in the whole extent of the Dakota group, also found in Greenland. They are easily known by their peculiar nervation, the secondary nerves being generally separated by thinner, shorter tertiary ones, which, however, are not always distinguishable. The leaves vary in size from 8 to 10 cm. long, and from 2½ to 5 cm. broad in the middle. The divergence of the lateral veins from the midrib is 35°–40°.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5155 B.

Dewalquea primordalis, *sp. nov.*

PLATE A, FIG. 10.

Leaflet coriaceous, oblanceolate or gradually narrowed from below the apex to the base, very entire; borders incurved; medial nerve thin, nearly equal its whole length; lateral nerves at unequal distance, very oblique, camptrodrome, the lower more or less curved, the upper nearly straight.

The genus *Dewalquea* was established by Saporta and Marion in Marnes Hersiennes of Gelinden, p. 55, for plants which the authors refer to the *Ranunculaceæ–Helleboreæ* with the following characters: "*Leaves coriaceous, petiolate, pedately or palmately divided in 3, 5, 7 leaflets, either dentate on the borders or entire, penni nerve, the secondary nerves more or less oblique, curving in areoles near the borders.*"

At first remains of species of this genus had been found only in the upper part of the Cretaceous, the Senonian. Heer has lately described two species from Patoot in Greenland, a formation somewhat more recent than that of the Dakota group, but where a number of species of this formation are still found.

The specimen from Minnesota represents only a leaflet or a lobe, but its characters indicate its connection to a palmately divided leaf. It has a marked relation to *D. gelindensis* Sap. and Mar., *l. c.* p. 61, Pl. IX, f. 3 b. Identity with this species could even be admitted if the lateral nerves were not at a slightly more acute angle of divergence in the American form, and also less curved in passing to the borders.

The leaflet is also related, though in a less degree, to *D. greenlandica* Heer, a species found at divers localities and stages of the Cretaceous of Greenland.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5158.

Juglans debeyana (*Heer*) *Lesqx.*

PLATE B, FIG. 7.

Populus debeyana Heer, *Phillites du Nebraska, p. 14, Pl. 1, f. 1. Newby., Ext. Fl., p. 17, Illustr. Pl. IV, f. 3. Juglans(?) debeyana Lx., Cret. Fl., p. 110, Pl. XXIII, f. 1–5.*

Leaves coriaceous, entire, ovate, obtuse or with a short obtuse point; rounded subcordate at the base or narrowed by a curve and slightly decurring to the petiole; medial nerve thick; secondaries numerous, open, camptodrome, generally separated by short tertiaries; areolation reticulate.

This species is not rare in the red sandstone of Kansas and Nebraska. Prof. Heer, who had seen a single large specimen with the surface somewhat effaced, referred it with doubt to the genus *Populus.* The nervation is indeed too different, and, as seen from a large number of specimens, some of which are figured, Cret. Fl. *l. c.*, the leaves, rarely large, cordate at base and long petioled, are more generally small or of various sizes, 4 to 12 cm. long. 3½ to 7 cm. broad, narrowed to the base and often inclined on one side like leaflets of compound leaves. For this reason I referred them to *Juglans.* The nervation is peculiar, the secondaries close, parallel at an angle of 50° to 60° are camptodrome abruptly curving and forming arches along, but not quite near the borders, separated by short tertiaries which, by anastomosing on both sides with secondaries and irregularly dividing in the middle, form a quadrangular very distinct reticulation more analogous to that of some species of *Juglans*, like *J. latifolia* Heer, Fl. Tert. Helv., III, p. 88, Pl. CXXIX, f. 3, 6, 9.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5373.

Sapindus morrisoni *Lesqx.*

PLATE A, FIGS. 11, 12.

Cret. and Tert. Fl., Pl. XVI, f. 1, 2.

Leaflets subcoriaceous, short petioled, lanceolate, acuminate, unequally narrowed in a curve to a short petiole and slightly decurring to it; lateral nerves alternate, close, parallel, curving in passing to the borders, camptodrome.

The leaves vary in width and are sometimes ovate, as in fig. 12, sometimes, also, nearly linear in the middle, as in fig. 11, but always unequal at the base.

This species, first found in the Dakota group of Colorado, has been lately sent from Kansas also. It is not rare in Greenland.

Hab. North side of Minnesota river, eight miles below New Ulm, Minnesota.
Mus. Reg. Nos. 3808, 3912.

CARTÆGUS ATAVINA *Heer.*

PLATE B. FIG. 8.

Arct. Fl., Vol. VII, p. 43, Pl. LXIV, f. 11.

Leaves ovate, deeply cut on the borders in large obtuse teeth ; secondary nerves branching craspedodrome.

The borders and the teeth of the leaf are destroyed, but the size, the shape of the leaves and the nervation, seem to fully authorize the reference to Heer's species. The leaf is coriaceous, the basal nerves opposite, attached above the basal border; the five pairs of secondaries, at the same angle of divergence of 60°, are parallel and inequidistant, and of the same character as seen in the figure of Heer, *l. c.*

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5379.

PROTOPHYLLUM CREDNERIOIDES ? *Lesqx.*

PLATE B, FIG 9.

Cret. and Tert. Fl., p. 90, Pl. II, f. 1-3.

Leaves coriaceous, usually small, nearly round, broadly cuneate, rounded or subtruncate at base with a long slender petiole, borders entire or more generally undulate, nervation obscurely trifid ; secondary nerves equidistant, at various angles of divergence more or less branching.

The leaf, which I refer with some doubt to this species, is only 4 cm. long and 3½ broad, with a petiole 2 cm. long. Its shape is nearly round. It differs essentially from the other leaves seen as yet of this species, in its less complex nervation, the two lower lateral nerves only being branched, and the lateral primaries being alternate. This difference may be due to the small size of the leaf, which has, notwithstanding, the essential characters of the genus, the shape, the craspedodrome nervation, and the long petiole.

Hab. North side of the Big Cottonwood river, near New Ulm, Minnesota.
Mus. Reg. No. 5380.

Protophyllum integerrimum, *sp. nov.*

PLATE B, FIGS. 10, 11.

Leaves membranaceous, of medium size, round or broadly oval in outline, rounded at base and apex, nervation palmatifid; craspedodrome; lower lateral nerves two pairs, very open, nearly at right angle to the broad midrib, the upper five pairs oblique and parallel, all opposite and branching underneath, except the lowest.

This fine species has distinctly the characters of the genus, but is remarkable for its very entire borders, nearly smooth surface and the secondaries all opposite. This opposition of the secondaries is more or less remarked in the leaves of *Protophyllum*, as in *P. quadratum* and *P. multinerve* Lesqx., Cret. Fl., Pl. XVIII and XIX. But there is generally some deviation from the rule in the lowest nerves, while in other species the opposition of all the nerves is perfect. The angle of divergence of the nerves is gradually more acute from the base upward; in these leaves, from the 3 pairs of secondaries upward, the angle of divergence is the same, 40°.

Hab. Mankato, Minnesota.
Mus. Reg. No. 5666, 1 C.

Besides the specimens described above, there are, in fragments more or less uncertainly determinable the following species worth mentioning:

6060. Mankato: nothing determinable.
6061. *Salix proteifolia* Lx. Part of base. A species very variable and common in the Dakota group of Kansas, Nebraska, etc.
6062. *Leguminosites* with nervation totally obsolete; not determinable.
6063. *Diospyros?* Fragment of undeterminable leaf: no nervation distinct: same as 6068, and perhaps as 5372 of Big Cottonwood river.
6064. Basilar part of a leaf of *Aralia radiata?* Lx., as far as can be seen, the lobes being destroyed.
6065. Fragment of *Ficus?*
6066. Same as 6062.
6067. Poor fragment; possibly same as 6068.
6068. *Diospyros.* Species not determinable; nervation obsolete.
6069. Three specimens with very small fragments of dicotyledonous leaves; not determinable.

SPECIMENS FROM MANKATO.

5666, 1A. *Platanus primæva* Lx., in fragments of leaves like those of Kansas.
5666, 1B. Fragment of a small oval, dentate? leaf, probably a *Ficus;* not determinable.
5666, 1C. *Protophyllum integerrimum*, sp. nov. Counterpart of 5666. (?)
5666, 2. *Protophyllum integerrimum*, sp. nov. Figured.
5666, 3. Fragments of rootlets and branches; nothing determinable.
5666, 4. Fragments of a small leaf like 5666, 1B.
5666, 5*a*. *Laurus plutonia* Heer. Figured.
5666 5*b*. *Protophyllum integerrimum* Lx. Fragments figured.
5666, 6. Rootlets and a dicotyledonous fragment; all undeterminable.
5666, 7. *Protophyllum integerrimum* Lx. =1C. Large leaf.
5666, 8. *Protophyllum integerrimum.* Only a small fragment.
5666, 9. *Protophyllum integerrimum*, base of leaf.
5666, 10, 11. Small undeterminable fragments.

LIST OF THE CRETACEOUS PLANTS KNOWN TO OCCUR IN MINNESOTA.

The page references refer to this volume. The numbers refer to registration in the University museum.

I. Near New Ulm, Redwood county.

Pinus species? P. 10. No. 5160.
Pinus quenstedti Heer. No. 5384(A).
Sequoia species? No. 5382(A).
Alnites crassus Lesqx. P. 13.
Salix proteifolia Lesqx. Minn. Geol. Sur.; 12th Ann. Report, p. 12. Nos. 3912 and 5157(C).
Populus berggreni Heer. P. 13. No. 5383.
Populites elegans Lesqx. P. 10. Nos. 5155(C) and 5377.
Populites cyclophyllus (?) Heer P. 11. Nos. 5155(G), 5155(K) and 5155(P).
Populites litigiosus Heer. P. 12. Nos. 5155(A), 5375, 5381 and 5382(B).
Populites lancastriensis Lesqx. P. 12. Nos. 5155(D) and 5369.
Populites winchelli Lesqx. P. 12. Nos. 5374 and 5376.
Platanus primæva(?) Lesqx. P. 14. Nos. 5155(Q), 5155(S) and 5373.
Ficus species? No. 5386.
Ficus austiniana Lesqx. P. 14. Nos. 3808 and 5163.
Ficus? halliana Lesqx. Hayden Survey, Vol. VI, Lesquereux, Cret. Flora, p. 68.
Laurus species? Minn. Geol. Sur.; 12th Ann. Report, p. 12. No. 5158.
Laurus plutonia(?) Heer. P. 14. Nos. 5157(C), 5389 and 5390.
Laurus nebrascensis Lesqx. P. 15. No. 3911.
Cinnamomum scheuchzeri(?) Heer. P. 16. Nos. 5155(I) and 5155 (T).
Diospyros pseudo-anceps Lesqx. P. 17. No. 5372.
Andromeda parlatori Heer. P. 16. Nos. 5157(A) and 5387.
Bumelia marcouana (Heer) Lesqx. Hayden Survey, Vol. VI, p. 90.
Cissus browniana Lesqx. P. 17. Nos. 5156, 5370 and 5371.
Magnolia alternans Heer. P. 18. Nos. 5155(B), 5155(H) and 5157(B).
Liriodendron mecki Heer. Hayden Survey, Vol. VI, p. 93.
Dewalquea primordialis Lesqx. P. 18. Nos. 5158 and 5388.
Juglans debeyana (Heer) Lesqx. P. 19. Nos. 5373 and 5378.
Cratægus atavina Heer. P. 20. No. 5379.
Sapindus morrisoni Lesqx. P. 19. Nos. 3888 and 3912.
Protophyllum crednerioides Lesqx. P. 20. Nos. 5155(F) and 5380.
Phyllites vanonæ Heer. Hayden Survey, Vol. VIII, p. 113.

II. Goodhue township, Goodhue county.

Salix proteifolia Lesqx. No. 6061.
Ficus species? No. 6065.
Diospyros species? Nos. 6063 and 6068.
Aralia radiata Lesqx? No. 6064.
Leguminosites species? No. 6062.

III. Near Mankato.

Platanus primæva Lesqx. P. 14. No. 5666 1A.
Laurus plutonia Heer. P. 14. Nos. 5666(A) and 5666(5*a*).
Protophyllum integerrimum Lesqx. P. 21. Nos. 5666(C), 5666(C1), 5666(2), 5666(7), 5666(8) and 5666(9).

IV. Austin, Mower county.

Sequoia winchelli Lesqx. P. 10. No. 115 or No. 5393.

V. Locality not Known.

Ficus laurophylla Lesqx. Hayden Survey, Vol. VIII, p. 50.
Laurophyllum reticulatum Lesqx. Hayden Survey, Vol. VI, p. 76.

PLATE A.


1
11
8
2
10
9
6
5
7
3
12
4

PLATE B.

11
10
1
6
9
7
3
5
2
8
4

CHAPTER II

THE MICROSCOPICAL FAUNA

OF THE

CRETACEOUS IN MINNESOTA, WITH ADDITIONS

FROM NEBRASKA AND ILLINOIS

(FORAMINIFERA, RADIOLARIA, COCCOLITHS, RHABDOLITHS).

BY ANTHONY WOODWARD AND BENJAMIN W. THOMAS.

I. METHODS OF MICROSCOPIC PREPARATION.

The microscope of a few years ago, if compared with that now in use, was of but little practical value, and was regarded more as an amusing toy than as an instrument of absolute necessity in scientific investigation. The geologist and the botanist were apparently satisfied with their pocket lenses, and the physician had but little use for even these. Careful students, however, were getting occasional glimpses of fields just beyond their power of satisfactory resolution. These a somewhat more powerful combination of lenses would, to some extent, resolve, but would at the same time show that there were much larger and more interesting ones yet beyond their reach. Scientists and physicians at once called for objectives of higher powers, and for improved appliances, and manufacturing opticians of Europe and America have promptly and satisfactorily responded to the demand. Excellent instruments can now be secured at prices within the reach of every student.

Geologists have long been familiar with fossil remains of pre-historic life, so abundant in most of the geological formations, but it is of comparatively recent date that improved microscopes have shown them that of these vast deposits there is hardly a cubic inch that does not contain the wreckage of an earlier world that teemed with animal and vegetable life, and from which can now be studied its history, climate, etc. These revelations are not infrequently of great commercial value as well as of scientific interest. One of which, while not quite germane to the subject under consideration, we will mention as an illustration. When the "lake tunnel", which supplies the city of Chicago with water from lake Michigan, was in process of construction, in 1865–1867, large numbers of minute and nearly translucent amber-colored discs, $\frac{1}{85}$ to $\frac{1}{250}$ of an inch in diameter were discovered by two members of the Chicago Academy of Sciences, in the clay through which it was being driven, at a depth of about 86 feet below the surface. These discs were unknown to paleontologists, to several of whom they were submitted. Careful and repeated examinations showed that the whole mass of the boulder clay underlying the vicinity of Chicago was loaded with these discs, and also that the many fragments of shale and shale boulders in the clay were largely composed of them. This last discovery rendered it more than probable that the discs in the clay were derived from the shale, large formations of which must at some period of the world's history have been broken up and scattered through it.(1) The shale when lighted by a lamp or candle burned freely with a smoky flame and strong petroleum odor. Our next light was from a paper by Sir William Dawson, published in the *American Journal of Science* in 1871, in which he stated that similar "microscopic orbicular bodies" had been referred to by Sir W. E. Logan, in a report in 1863, as occurring in the "Upper Erian shale" at Kettle point, lake Huron, and to which he (Sir William) gave the name *Sporangites huronensis*(2), the two principal species of which are now known as *Protosalvinia huronensis* Dawson, and *P. chicagoensis* Thomas. Prof. Edward Orton, state geologist of Ohio, in a report on "Petroleum and Natural Gas"(3), after referring to the great fishes, &c., as described by Newberry, and other fossils of the oil and gas producing shales of Ohio, says: "But the forms already named are of small account so far as quantity is concerned when compared with certain microscopic fossils, that are of little doubt of vegetable origin, and which are accumulated in large amount throughout the black beds of the entire shale formation, and apparently give origin to an important extent to the bituminous character of the beds. * * * They were first discovered by B. W. Thomas, a Chicago microscopist, in the water supply clay and shale at Chicago".(4) * * * "The thickness of the series of shale now under consideration is, in Crawford county, about 450 feet, in Loraine county about 950 feet, at Cleveland 1,350; while in Tuscarawas county the drill reached 1,860 feet, and in the Ohio valley at Wellsville, 2,600 feet in shale without reaching bottom." On pages 413 and 414 of the same work, under heading of "Ohio Shale as a Source of Oil and Gas", Prof. Orton says that "they contain much more oil

---

(1) Bulletin, Chicago Academy of Sciences, No. 4.
(2) Bulletin, Chicago Academy of Sciences, No. 9.
(3) Geological Survey of Ohio, Vol. 6, 1888.
(4) As stated above, they were first discovered by Sir W. E. Logan, but he gave them no further notice.

than any other strata with which they are associated, the great sandstone reservoirs not excepted; and careful estimates based on chemical investigations show that if the shale series is counted at the low average of 1,000 feet in thickness for its entire area (it is over 400 miles long and 10 to 30 miles wide), it would yield over ten million [10,000,000] barrels of oil to the square mile." While this oil must largely be separated from the shale by distillation, which is now being done at the rate of some 20 gallons to the ton, these estimates are truly bewildering.

Most of the material used in these investigations was sent to us by Prof. N. H. Winchell, state geologist of Minnesota, and was of almost every kind and variety that a geologist would naturally collect for microscopical study, and they required almost as many different methods of treatment to free from them their microscopical organisms in proper condition for examination under the lens, as there were samples of material. While we cannot, of course, give all of the various experiments necessary to ascertain the chemical character of the material and of its organic contents, before deciding whether its reduction, so as to preserve its fossils in their best condition for examination, would require the use of rain water, nitric or other acids, soda, caustic potash, &c., we will give a few general directions that may be of some assistance to beginners.

One of the first essentials is that all glassware, pipettes, &c., designed for this use be absolutely clean, and that only river or rain water, recently filtered, be used; otherwise you will probably find on your slides many beautiful organisms that do *not* belong to the substance under examination.

Clay. In preparing most of the samples of clay, we would put about one ounce of the material, and the same amount of common washing soda, into a druggist's two-quart clear-glass packing-bottle, not over ¼ filled with water, and let it remain 12 to 24 hours, frequently shaking the bottle so as to thoroughly break up the clay. Now fill the bottle with water, and after 25 minutes carefully pour off the upper ¾ of it. Again fill with water, and in 25 minutes decant as before; repeating this at 25 minute intervals until the upper ¾ of the water in the bottle, after a 25 minute rest, will be nearly clear. A large amount of the fine sand, clay and the soda, has by this process been washed away, and the action of the soda has broken up the clay and removed most of the adhering material from the fossils. Now mount a few microscope slides from the residuary sand, etc., at the bottom of the bottle, by taking up with a pipette (a piece of small glass tubing makes the best pipette) a small amount of the material; scatter very thinly over the middle of the slides; dry them thoroughly over an alcohol lamp, or in some better way, and, while hot, cover the dry material with a few drops of Canada balsam, keeping the slide quite warm until the balsam will be hard when cold. As these "trial slides" are seldom of any value, it is not necessary to use cover glasses if the balsam is hardened, as above directed. A careful examination of these slides under the microscope with a good $\frac{1}{4}$ or $\frac{1}{2}$ inch objective will decide as to the value of the material under observation, and if it proves to be only sand, pour it all out, wash the bottle, and again try the same process with another sample of clay. But if the slides show a few good fossils, the next step is to separate them as much as possible from the mass of sand, etc., with which they are associated. In this as in the first washing, specific gravity will do most of the work. Pour off most of the water and put the shells, sand, etc., into a 4 oz. beaker (or glass tumbler), wash out the bottle, fill the beaker about $\frac{3}{4}$ full of water, and after it has rested ten minutes, pour $\frac{3}{4}$ off the top through a glass funnel into the bottle, repeating this 5 or 6 times. As in the first washing, mount and examine a few slides from the material at the bottom of the bottle, mounting and preserving slides, if found to be of value. If nothing of value is found, pour out the contents of the bottle, and fill up again as before from the beaker, after five minutes rest repeating these washings and examinations at shorter resting intervals of say three, two, and one minute, or less, until nothing but the coarsest sand remains in the beaker. In that there may be a few good specimens of *Polycystina*. Each layer of the clay, as deposited by its specific gravity, has now been examined, and most of the fossils are contained in some one or possibly two of them. Nineteen-twentieths of the original sample of clay have been washed away, and in the selected one-twentieth that remains there may be one fair fossil to one hundred grains of sand.

Shale. The fossil contents of most of the softer shales can be secured by breaking up the specimen with a pair of strong pliers, crushing the shale while under water and edgewise of its laminæ. This will free many of the fossils without breaking them ; then boil the firmer parts of it for a few minutes (or longer if the material requires) in a rather strong solution of washing soda, and wash and separate the fossils from the fine shale, sand, etc., by repeated decantations, as directed in the treatment of clay.

Chalk. Foraminifera, coccoliths, rhabdoliths, with an occasional radiolarian (*Polycystina*), of which the "farmer's chalk", or soft limestone, is largely composed, can be freed from the rock by washing off the surface of a clean piece of it with a rather stiff brush while under the surface of the water in a bowl or basin. The water will soon become as white as milk. The specific gravity of the Foraminifera and Radiolaria will promptly carry them to the bottom, and they can partly be separated from the sand, etc., by repeated washings, decantations, etc., as directed in the treatment of clay ; but unless great care be taken in this washing, the coccoliths and rhabdoliths, which largely give to the water its milky appearance, will be lost. They are very fine and very light, and some of them will remain suspended in a 4 oz. beaker of water for several hours. They can be separated from the other material by repeated washings and decantations, so as to make almost pure mountings, but the resting time between decantings must be from one-half to three-quarters of an hour.

II. FORAMINIFERA.

This paper is the result of the preparation and microscopical examinations of several hundreds of slides of material from the boulder clays, hard and soft Cretaceous shales, rotten or chalky limestone, etc., from various parts of Minnesota, many samples of which were collected, as already stated, by Prof. N. H. Winchell, state geologist of Minnesota; from boulder clay and fragments of shale, kindly sent by Prof. G. D. Swezey, Doan College, Nebraska, and from our own collections in Illinois and Wisconsin. Much of the material examined abounded in fossil remains of Foraminifera, radiolarians, coccoliths, rhabdoliths, fresh-water Diatomaceæ, sponge spicules, and other microscopical organisms; but by far the most numerous and interesting were the calcareous casts or shells of Foraminifera, a minute marine animal of the sub-kingdom Protozoa, class Rhizopoda.

These fossils in the clays are evidently derived from the Cretaceous formations which have been broken up and their contents scattered through the boulder clays presumably in the direction of the glacial currents. In many localities in Minnesota and Nebraska, and on the upper Missouri and Niobrara rivers, the Cretaceous formations are yet in place, and some of the chalk rocks are almost wholly composed of these organisms. The "Eolian sand" of the Smoky Hill river, near Lindsborg, Kansas where the river has cut its way through the Cretaceous rocks, is very rich in many species of well preserved Foraminifera, and it is probably the presence of vast numbers of these minute marine shells in the sand that gives to it its peculiar quality. The same genera and species of Foraminifera that constitute so considerable a part of some of these Cretaceous rocks, and that are so abundant in some of the boulder clays, are now living in vast numbers in the Atlantic, Mediterranean and other oceanic waters. They constitute an important ingredient of the "chalk cliffs" of England and the building stone of the city of Paris, France, is largely composed of them. The "Nummulites", or "Coin-stones" of which the pyramids of Egypt are built are principally Foraminifera.

Fairly well preserved casts or shells of Foraminifera were more or less abundant in most of the specimens from Minnesota and Nebraska, and a few good forms of

Foraminifera and Radiolaria were secured from Illinois boulder clay. Much time and labor were given to the examination of material that did not add to the interest or value of our collection.

Samples of inter-glacial peat, from Blue Earth county, Minnesota, were well filled with more than 100 species of fresh water Diatomaceæ, but did not yield Foraminifera, while the boulder clay both above and below the layer of peat afforded good specimens of them.

Of Foraminifera we have noted the following genera and number of species in the material submitted to us for examination: *Trochammina*, 1 sp.; *Textularia*, 4 sp.; *Spiroplecta*, 1 sp.; *Gaudryina*, 1 sp.; *Verneuilina*, 1 sp.; *Bulimina*, 2 sp.; *Pleurostomella*, 1 sp.; *Bolivina*, 1 sp.; *Lagena*, 3 sp.; *Polymorphina*, 1 sp.; *Nodosaria*, 1 sp.: *Uvigerina*, 2 sp.; *Globigerina*, 4 sp.; *Orbulina*, 1 sp.; *Anomalina*, 1 sp; *Pulvinulina*, 2 sp.; *Operculina*, 2 sp.; *Nonionia*, 1 sp. Total, 18 genera and 30 species, most of which are figured, and the original descriptions are given as nearly as possible.

Sub-Kingdom PROTOZOA.
Class RHIZOPODA.

FORAMINIFERA.

LITUOLIDÆ.

Sub-Family TROCHAMMINÆ.

TROCHAMMINA, Parker and Jones.

TROCHAMMINA INFLATA *Montagu, sp.*

PLATE D, FIG. 31.

Nautilus inflatus MONTAGU, 1808. Test. Brit., Suppl., p. 81, pl. xviii, fig. 3.
Rotalina inflata WILLIAMSON, 1858. Rec. For. Gt. Brit., p. 50, pl. iv, figs. 93, 94.
Rotalina (Trochammina) inflata PARKER and JONES, 1859 .Ann. and Mag. Nat. Hist. ser. 3, vol. iv, p. 347, Figure, F.
Trochammina inflata CARPENTER, 1862. Introd. Foram., p. 141, pl. xi, fig. 5.
Trochammina squamata var. *inflata* PARKER and JONES, 1862. Introd. Foram., Appendix, p. 310.
Trochammina inflata BRADY, 1865. Nat. Hist. Trans, Northd. and Durham, vol. i, p. 95.
Trochammina inflata(?) TATE and BLAKE, 1876. Yorkshire Lias, p. 452 pl. xvii, fig. 18.
Trochammina inflata BRADY 1884. Report on Foram., H. M. S. Challenger, Zool., vol. ix, p. 338, pl. xli, fig. 4.

"Test free; trochoid or convex, depressed. rotaliform; consisting of about three convolutions, the outermost of which is formed of five or six very ventricose segments with deeply excavated septal lines. Inferior face somewhat concave, with sunken umbilicus; peripheral margin lobulated. Aperture small, arched; situate on the inferior side of the final segment, close to the previous convolution, a little within the periphery. Color pale brown, the small primary segments much darker than the rest. Diameter $\frac{1}{35}$ inch (0.7 mm)." BRADY, *loc. cit.*

Locality. Northeast Minn.(?). South Chicago, Ill.

TEXTULARIDÆ.

Sub-Family TEXTULARINÆ.

TEXTULARIA. Defrance.

TEXTULARIA GLOBULOSA *Ehrenberg.*

PLATE C, FIGS. 1-6.

Textularia globulosa EHRENBERG. Abhand. Akad. Berlin. (1838) 1839, pl. iv.
Textularia globulosa Id., Ibid., (1841) pp. 291, 438.
Textularia globulosa HITCHCOCK, 1843. Trans. Asso. Geol. and Nat., 1840-1842, p. 357, pl. xv, figs. 1, 3, 4, 5, 7.
Textularia americana BAILEY, 1841. Amer. Jour Sci., vol. xli, p. 401, figs. 1, 2.
Textularia globulosa MEEK, 1864. Smithsonian Inst. Check List, Cretaceous and Jurassic Fossils, p. 1.
Textularia americana Id., Ibid., p. 1.
Textularia missouriensis Id., Ibid., p. 1.
Textularia globulosa DAWSON, 1874. Can. Nat., vol. vii, p. 253, fig. a.
Textularia globulosa SCHARDT, 1884. Etudes Geol. Sur. le Pays—D'Enhaut. Bull. Soc. Vaud., vol. xx, p. 74.
Textularia globulosa BALKWILL and WRIGHT, 1885. Trans. Roy. Irish Acad., p. 323.
Textularia globulosa WOODWARD and THOMAS, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Surv. Minn., p. 166, pl. iii, figs. 1-5.

"*T. globulosa*, testula microscopica superficie lævi, in adulta longiore quam lata, articulis globosis." EHRENBERG. (1838, Abhand. Akad. Berlin, p. 135.)

T. globulosa, microcsopic test with a smooth surface, adult forms longer than wide, with spherical or globular chambers.

Locality. Meeker county, Little Fork river, Minn. Saline county, Neb. South Chicago, Ills.

Textularia globulosa is very abundant in the Minnesota clay and chalky limestone, and common in Nebraska, the specimens from that material being very fine. In the south Chicago material they are quite common and well preserved.

Dr. G. M. Dawson, in his paper on the Foraminifera of the Cretaceous rocks of Manitoba, gives the following description of *T. globulosa :* "A stout form with globose chambers rapidly increasing in size at each addition, and sometimes even as broad as long. The primordial chamber, and those next to it, are often bent away several degrees from the axis of symmetry of the larger part of the shell. The surfaces of the chambers are marked with extremely minute diagonal interrupted ridges or wrinkles."† This description is far superior to that of Ehrenberg. The species has also been found in Dakota, and in the "Eolian sand" from the Smoky Hill river, near Lindsborg, Kansas.

Textularia americana Ehrenberg. This species forms a very large part of the mass of the chalk rocks of the upper Missouri and Niobrara rivers. It is found in a light cream colored Cretaceous marl on the upper Mississippi, called there "prairie chalk"; has been examined by Prof. Bailey, and figured, but not described, in the *Amer. Journ. Sci., xli. p. 401, 1841.**

---

*Amer. Jour. Sci. 1841.
†Canadian Naturalist, vii, 1874.

Textularia agglutinans *d'Orbigny.*

PLATE C, FIGS. 7, 8.

Textularia agglutinans d'Orbigny, 1839. Foram. Cuba, p. 144, pl. i, figs. 17, 18, 32–34.
Textilaria agglutinans Seguenza, 1862. Atti dell' Accad. Gioenia, vol xviii, ser. 2, p. 112. pl. ii, fig. 4.
Plecanium sturi Karrer, 1864. Sitzungsb. d. k. Ak. Wiss. Wien, vol. I, p. 704, pl. i, fig. 1.
Textularia agglutinans Parker and Jones, 1865. Phil. Trans., vol. clv, p. 369, pl. xv, fig. 21.
Plecanium agglutinans Reuss, 1869. Sitzungsb. d. k. Ak. Wiss. Wien, vol. lix, p. 452, pl. i, figs. 1. 2.
Textularia agglutinans Moebius, 1880. Foram. von Mauritius, p. 93, pl. ix, figs. 1–8.
Textularia agglutinans Brady, 1884. Report Foram. H. M. S. Challenger. Zool., vol. ix, p. 363, pl. xliii, figs. 1–3, vars. figs. 4, 12.
Textularia agglutinans Woodward and Thomas, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Sur. Minn., p. 167, pl. iii, figs. 6. 7.

"*T. agglutinans.* Testa elongato-conica, rugoso-agglutinate, alba, lateraliter convexiuscula; postice cuneata; loculis largis, ultimis convexis; apertura semi-lunari." D'Orbigny. (Foram. Cuba, p. 144).

Test elongate, conical, rugose, agglutinous (from grains of sand), white, laterally convex, posteriorly cuneate, segments large, the last convex, aperture semi-lunate.

Locality. Meeker county and Little Fork river, near Rainy lake, northeastern Minn.: South Chicago, Ill. This species is not common in either locality. It has also been found in the Eocene shell sand at Jackson and Red Bluff, Mississippi.

Textularia turris *d'Orbigny.*

PLATE C, FIGS. 9. 10.

Textularia turris d'Orbigny, 1840. Mem. Soc. Geol. France, vol. iv, p. 46, pl. iv, figs. 27, 28.
Textularia turris Parker and Jones, 1863. Ann. and Mag. Nat. Hist., ser. 3, vol. xi, p. 97.
Textularia turris Brady, 1884. Report on Foram., H. M. S. Challenger, Zool., vol. ix, p. 366, pl. xliv, figs. 4, 5.
Textularia turris Woodward and Thomas, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Surv. Minn., pp. 167, 168, pl. iii, fig. 8.

"*Textularia turris* is round in transverse section, elongate and tapering. It differs from *Textularia trochus* chiefly in its greater proportionate length and its rougher exterior, as well as in its frequent irregularity of contour." Brady, *loc. cit.*

Locality. Meeker county, Minn.; Saline county, Neb.; South Chicago, Ill. Very rare in all these localities.

Textularia carinata *d'Orbigny.*

PLATE C, FIG. 11.

Textularia carinata d'Orbigny, 1826. Ann. Sci. Nat., vol. vii, p. 263, No. 23.
Textularia carinata Id., 1846. Foram. Foss. Vien., p. 247, pl. xiv, figs. 32-34.
Textularia lacera Reuss, 1851. Zeitschr. d. deutsch. Geol. Gesell., vol. iii, p. 84, pl. vi, figs. 52, 53.
Textularia attenuata Id., Ibid., p. 84, pl. vi, fig. 54.
Textilaria carinata and *Textilaria carinata* var. *attenuata* Reuss, 1870. Sitzungsb. d. k. Ak. Wiss. Wien, vol. lxii, p. 489, No. 1. Schlicht. 1870. Foram. Pietzpuhl., pl. xxxiii, figs. 1–4, 8, 9.
Textilaria carinata Hantken, 1875. Mitth. Jahrb. d. k. ung. geol. Anst., vol. iv, p. 66, p. vii, fig. 8.
Textularia carinata Brady, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 360, pl. xlii, figs. 15, 16.

"Testâ cuneiformi, lingulatâ, convexiusculâ, punctatâ, anticè dilatatâ, truncatâ, posticè obtusè acuminatâ, lateraliter carinatâ, acutâ, lamellosâ; loculis angustatis, obliquis, arcuatis, marginatis."

Shell cuneiform, lingulate, convex, punctate, anteriorly dilate, truncate, posteriorly obtuse acuminate, laterally carinate, acute, lamellose, foramina narrow, oblique, arcuate, marginate.

Locality. Saline county, Nebraska.

SPIROPLECTA, Ehrenberg.

Spiroplecta a ericana *Ehrenberg.*

PLATE C, FIGS. 12, 13, 14.

Spiroplecta americana Ehren., 1854. Mikrogeolgie, pl. xxxii, I, figs. 13, 14 : II, fig 25.
Spiroplecta americana Brady, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 376, pl. xlv, fig. 24 a, b.
Spiroplecta americana Woodward and Thomas, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Survey Minn., p. 168, pl. iii, fig. 9.

"The test is usually much compressed, and widens rapidly towards the distal end; the lateral edges are thin and slightly lobulated, the chambers somewhat inflated, and the septal lines correspondingly depressed on the exterior; the walls are thin and smooth." Brady, *loc. cit.*

Locality. Meeker county, Minn.; Saline county, Neb.; South Chicago, Ill. This species does not seem to be very widely distributed; only two specimens found, one in Minnesota, and the other in Nebraska. The specimens figured by Ehrenberg were from the Cretaceous beds of Missouri and Mississippi.* We believe that in the fossil state it has only been found in North America.

GAUDRYINA, d'Orbigny.

Gaudryina pupoides *d'Orbigny.*

PLATE C, FIGS. 15, 16.

Gaudryina pupoides d'Orbigny, 1840. Mem. Soc. Geol. France, vol. iv, p. 44, pl. iv, figs. 22–24
Gaudryina pupoides Id., 1846. Foram. Foss. Vien., p. 197, pl. xxi, figs. 34–36.
Gaudryina subglabra Gümbel, 1868. Abh. d. k. bayer. Akad. Wiss., II, cl., vol. x, p. 602, pl. i, fig. 4.
Gaudryina pupoides Brady, 1884. Report on Foram. H. M. S. Challenger, Zool., vol ix, p. 378, pl. xlvi, figs. 1–4.
Gaudryina pupoides Woodward and Thomas, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Surv. Minn., p. 168, pl. iii, fig. 10.

"*Guadryina pupoides* is an easily recognized species. Its dimorphous mode of growth is generally very apparent, and its variability is limited to such features as the number of segments, the relative length and breadth of the test, and the degree of lateral compression. In recent shells the walls are thin and calcareous, smooth externally, and almost invariably of a greyish hue; fossil specimens sometimes exhibit a slightly rough exterior. In form and position the aperture resembles that of the typical *Textulariæ*, but it is often surrounded by a raised lip or border." Brady, *loc. cit.*

Locality. Meeker county and Little Fork river, near Rainy lake, Minnesota, and Saline county, Nebraska. Moderately abundant in these localities.

---

*Brady, Report on the Foraminifera, H. M. S. Challenger, p. 376.

VERNEUILINA, d'Orbigny.

VERNEULINA PYGMÆA *Egger. sp.*

PLATE C. FIGS. 17, 18.

Bulimina pygmæa EGGER, 1857. Neues Jahrb. für Min., p. 284, pl. xii, figs. 10, 11.
Verneuilina pygmæa PARKER and JONES, 1863. Ann. and Mag. Nat. Hist., ser. 3, vol, xi, pp. 92, 98.
Textilaria triseriata TERQUEM, 1882. Mem. Soc. Geol. France, ser. 3, vol. ii, Mem. III, p. 145, pl. xv. fig. 10.
Verneuilina pygmæa BRADY, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 385, pl, xlvii, figs. 4–7.

V. pygmæa, "testa minima globulosa lævigata, antice dilatata; aufractibus 3; loculis globosis. Longitudo $\frac{1}{5}$ millim." EGGER. (1857. Neues Jahrb. für Min., p. 284.)

Verneuilina pygmæa, shell very small, globose, smooth, dilated in front, with three whorls, chambers globose. Length $\frac{1}{5}$ mm.

Locality. Quite rare in the boulder clay at South Chicago and Saline county, Nebraska. (Common in the European Tertiary.) We have not noted it in Minnesota material.

Sub-Family BULIMINÆ.

BULIMINA.

BULIMINA AFFINIS *d'Orbigny.*

PLATE C, FIG. 19.

Bulimina affinis d'ORBIGNY, 1839. Foram. Cuba, p. 105, pl. ii, figs. 25, 26.
Bulimina ovulum REUSS, 1850. Haidinger's Naturw. Abhandl., vol. iv, p. 38. pl. iv, fig. 9.
Bulimina affinis BRADY, 1884. Report on Foram. H. M. S. Challenger, Zool., vol, ix, p. 400, p. l, fig. 14.

B. affinis. "Testâ, oblongo-ovata, lævigata, alba, postice subacuminata; spira brevi, anfractibus quatuor subplanis; loculis convexiusculis per quamque spiram trinis. Apertura virgulari. Dimensiones. Longueur totale $\frac{1}{2}$ mill." D'ORBIGNY. (Foraminifera of Cuba, 1839, p 105, pl. II, figs. 25, 26.)

B. affinis. Shell oblong-ovate, smooth, white, posteriorly subacuminate; short spire, four subplanulate whorls with three somewhat convex chambers in each spire. Aperture tubular. Dimensions, total length, $\frac{1}{2}$ mm.

Locality. Saline county, Nebraska.

BULIMINA PUPOIDES *d'Orbigny.*

PLATE C, FIGS. 20-24.

Bulimina pupoides d'ORBIGNY, 1846. Foram. Foss. Vien., p. 185, pl. xi, figs. 11, 12.
Bulimina pupoides WILLIAMSON, 1858. Rec. Foram. Gt. Br., p. 62, pl. v, figs. 124, 125.
Bulimina presli, var. *pupoides* PARKER and JONES, 1862. Introd. Foram., Appendix, p. 311.
Bulimina pupoides TERRIGI, 1880. Atti dell' Accad. Pont. ann. xxxiii, p. 193, pl. ii, figs. 30-34.
Bulimina pupoides BRADY, 1884. Report on Foram. H. M. S. Challenger. Zool., vol. ix, pp. 400, 401, pl. l, fig. 15, a, b.
Bulimina pupoides WOODWARD and THOMAS, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Surv. Minn., p. 159, pl. iii, fig. 11.

Bulimina pupoides. Shell oblong; obtuse, especially at the inferior lateral surface; composed of numerous segments, arranged in an indistinct spiral, and exhibiting a tendency to form three oblique vertical rows; segments remarkably ventricose and prominent; the anterior one usually more oblong than the rest, from its anterior part not being embraced, as all the preceding ones, by the next segment. Septal plane convex; semilunar. Septal orifice single, placed near the umbilical border of the septal plane, and usually characterized by a curious obliquity at its inner part, owing to the two lips of the orifice not meeting at their umbilical extremites, but passing one behind the other. Texture hyaline; transparent; when examined after being mounted in Canada balsam, through a high power, it is seen to be perforated by innumerable minute foramina. WILLIAMSON, (Recent Foraminifera Gt. Brit., p. 62.)

Locality. Meeker county, Minnesota; Saline county, Nebraska; South Chicago, Illinois. Of the material examined containing this species, in that from Minnesota it was quite rare; from Nebraska very common, and in that from Illinois, rare. It has also been found in the Post-tertiary of Canada.

PLEUROSTOMELLA, Reuss.

PLEUROSTOMELLA SUBNODOSA *Reuss.*

PLATE C, FIG. 25.

Nodosaria nodosa (*pars.*) REUSS, 1845. Verstein. Bohm. Kreid., pt. 1, p. 28, pl. xiii, fig. 22 (*fide* Reuss).
Dentalina subnodosa (*pars.*), Id. 1850. Haidinger's Naturw. Abhandl., vol. iv, p. 24. plate i, fig. 9 (*fide* Reuss).
Pleurostomella subnodosa, Id. 1860. Sitzungsb. d. k. Ak. Wiss. Wien, vol. xl, p. 204, pl. viii, fig. 2, a, b.
Pleurostomella subnodosa MARSSON, 1878. Mittheil. Naturw. Vereine Neu-Vorpom. u. Rügen, Jahrg. x, p. 133.
Pleurostomella subnodosa BRADY, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 412, figs. 12, 13.

"*D. subnodosa* (T. I. f. 9), elongata, subrecta; loculis fere regulariter increscentibus, parum convexis, ultimo maximo, convexo, breviter acuto; primo minimo obtusum-sculo; apertura nuda. Long.=1.15 mm." REUSS. (Haidinger's Naturw. Abhandl., vol. iv, p, 24, pl. i, fig. 9.)

Test elongated, nearly straight; chambers quite regularly increasing, slightly convex, the last one the largest, convex, shortly acute; the first chamber smallest, rather obtuse; aperture naked.

Locality. Saline county, Nebraska; South Chicago, Illinois.

BOLIVINA, d'Orbigny.

BOLIVINA DILATATA *Reuss,*

PLATE C, FIG. 26.

Bolivina dilatata REUSS, 1849. Denkschr. d. k. Akad. Wiss. Wien, vol. i, p. 381, pl. xlviii, fig. 15.
Bolivina dilatata TERRIGI, 1880. Atti dell' Accad. Pont., ann. xxxiii, p. 197, pl. ii, fig. 42.
Bolivina dilatata BRADY, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 418, pl. lii, figs. 20, 21.

Bolivina dilatata. "Testa cuneata, superne dilatata, infra acuta, compressa, punctata, margine acutangula. Loculi numerosi angusti; recti, parum obliqui; apertura simplex. Long.=0.3—0.4 mm." REUSS. (Denkschr. d. k. Akad. Wiss. Wien, vol. i, p. 381.

A more general description is given in German, of which the following is a translation:

B. dilatata, shell, narrow-cuneiform, broad above, acuminated below, but in the middle relatively stout, thinning out gradually toward the sharp margins, punctate on the surface. The "chambers" are numerous (11 to 12 on each side), lower, not curved, only a little oblique, scarcely rounded.

Locality. Saline county, Nebraska.

BOLIVINA PUNCTATA *d'Orbigny.*

PLATE C, FIGS. 27, 28.

Bolivina punctata d'ORBIGNY, 1839. Foram. Amer. Merid., p. 61, pl., viii, figs. 10—12.
Bolivina antiqua, Id., 1846. Foram. Foss. Vien., p. 240, pl. xiv, figs. 11-13.
Grammostomum polystigma EHRENBERG, 1854. Mikrogeologie, pl. xix, fig. 84.
Grammostomum caloglossa EHRENBERG, Ibid., pl. xxv, figs. 17, 18.
Bolivina punctata BRADY, 1864. Trans. Linn. Soc. Lond., vol. xxiv, p. 468, pl. xlviii. fig. 9, a, b.
Bulimina presli var. (*Bolivina*) *punctata* PARKER and JONES, 1865. Phil. Trans., vol. clv, p. 376, pl. xviii, fig. 74.
Bolivina elongata HANTKEN, 1875. Mittheil. Jahrb. d. k. ung. geol. Anstalt, vol. iv, p. 65, pl. vii, fig. 14.
Bolivina antiqua TERRIGI, 1880. Atti dell' Acad. Pont., ann. xxxiii, p. 196, pl. ii, fig. 40.
Bolivina punctata MOEBIUS, 1880. Foram. von Mauritius, p. 94, pl. 9, figs. 9, 10.
Bolivina punctata BRADY, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 417, pl. lii, figs. 18, 19.
Bolivina punctata WOODWARD and THOMAS, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Sur. Minn., p. 169, pl. iii, fig. 12.

B. punctata. "Testa elongata, compressa, conica, antice obtusa, postice acuminatea, alba, punctata, lateraliter subcarinata; loculis numerosis, obliquis, undulatis, ultimo obtuso; apertura simplici." D'ORBIGNY. (Foram. Amer. Merid., p. 63.

Test elongated, compressed, conical, obtuse anteriorly, acuminated posteriorly. white, punctate, sub-carinate on sides, with numerous oblique undulate segments, the last obtuse, aperture simple.

Locality. Meeker county, Minnesota: Saline county, Nebraska, and South Chicago, Illinois. Quite rare in all these localities.

LAGENIDÆ.

Sub-Family LAGENINÆ.

LAGENA, Walker and Boys.

LAGENA ASPERA *Reuss.*

PLATE D, FIG. 1.

Lagena aspera REUSS, 1861. Sitzungsb. d. k. Akad. Wiss. Wien., vol. xliv, p. 305, pl. i, fig. 5.
Lagena aspera REUSS, 1863. Ibid., vol. xlvi, p. 335, pl. vi, fig. 81.
Lagena parkeriana (?) BRADY, 1876. Monogr. Carb. and Perm. Foram., p. 120, pl. viii, figs. 1-5.
Lagena aspera SIDDALL, 1878. Proc. Chester Soc. Nat. Sci., pt. 2, p. 48.
Lagena aspera BRADY, 1884. Report on Foram. H. M. S. Challenger, Zool., vol ix, p. 457, pl. lvii, figs. 6–12.

L. aspera. "Fast kugelig, oben sich wenig verschmälernd und zu keinem schnabel zuspitzend. Die schalenoberfläche is mit ziemlich gedrängt stehenden, ungleichen, unregelmässig eckigen Höckerchen bedeckt. Sehr selten." REUSS. (Sitzb. d. mathem-naturw. cl, xliv, p. 305.)

Lagena aspera REUSS. Quite spherical, above narrowed somewhat, but forming no beak. The surface is covered with moderately crowded, unequal, irregular, angular tubercles.

Locality. Saline county, Nebraska. Has been found in the Eocene limestone, Alabama river, Monroe county, below Claiborne, Alabama.

LAGENA HISPIDA *Reuss.*

PLATE D, FIG. 2.

"*Sphærulæ hispidæ*" SOLDANI, 1798. Testaceographia, vol. ii, p. 53, pl. xvii, v, x.
Oolina salentina(?) COSTA, 1856. Atti dell' Accad. Pont., vol. vii, p. 118, pl. xi, figs. 13, 14.
Lagena hispida REUSS, 1858. Zeitschr. d. deutsch. geol. Gesellsch., vol. x, p. 434.
Lagena hispida REUSS, 1863. Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 335, pl. vi, figs. 77–79.
Lagena jeffreysii BRADY, 1866. Report Brit. Assoc. Trans. Sec., p. 70.
Lagena hispida JONES, PARKER and BRADY, 1866. Monogr. Foram. Crag, p. 30, No. 15.
Lagena hispida BRADY, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. lix, p. 459, pl. lvii, figs. 1–4; pl. lix, figs. 2-5.

L. hispida und *concinna* Reuss, in Zeitschr. d. deutsch. geol. Ges., pag. 434 (nomen), 1858.

"Der gewölbte Theil des Gehäuses ist in seiner Gestalt sehr veränderlich, bald beinahe kugelig, bald eiförmig oder selbst schmal und lang-elliptisch, beinahe walzenförmig. Nach oben zieht er sich zu einem dünnen röhrigen Schnabel zusammen, der die halbe Länge des Gehäuses einnimmt. Die Oberfläche ist mit regellos gestellten, aber gedrängten kürzeren und längeren, dickeren und dünneren, unregelmässig gestalteten Stachelhöckerchen bedeckt. An manchen Exemplaren, besonders den schmal-elliptischen, werden sie sehr klein und schrumpfen zu kurzen Höckerchen zuzammen. REUSS. (Sitzb. d. mathem-naturw. cl., xlvi, p. 335.)

The arched part of the shell is very variable in form, sometimes nearly circular, almost egg-shaped or even narrow and long-elliptic, very near cylindriform. Towards the top it is drawn out into a thin tubular beak, which embraces half the length of the shell. The surface is covered with irregularly disposed, but crowded shorter and longer, thicker and thinner, variously shaped thorny tubercles. In some examples, especially the narrow-elliptical ones, the tubercles are very small and contracted into short monticules.

Locality. Northeastern Minnesota.

Lagena favosa-punctata *Brady.*

PLATE B, FIGS. 3-6.

Lagena favosa-punctata Brady, 1881. Quart. Journ. Mic. Soc., vol. xxi, n. s., p. 62.
Lagena favosa-punctata Brady, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 473, pl. lviii, fig. 35; pl. lix, figs. 3, 4: pl. lxi, fig. 2.
Lagena favosa-punctata Woodward and Thomas, 1885. Thirteenth Annual Report, Geol. Nat. Surv. Minn., p. 170, pl. iv, figs. 32, 33, 34, 38.

"Test ecto- or ento-solenian, shape variable; surface areolated or reticulated, with a conspicuous orifice or perforation in the middle of each area or depression. Length $\frac{1}{75}$th inch (0.34 mm.) or less." Brady, *loc. cit.*

Locality. Meeker county, Minnesota. Found only in the material from Minnesota.

NODOSARINÆ.

NODOSARIA, Lamarck.

Nodosaria (D) communis *d'Orbigny.*

PLATE D, FIGS. 7, 8.

Nautilus rectus Montag, 1803. Test. Britann., p. 197; supplem. p. 82, t. 19, figs. 4-7.
Nautilus subarcuatus Montag, 1803. Test. Britann., p. 198, t. 6, fig. 5.
Nodosaria (Dentalina) communis d'Orbigny, 1826. Ann. Sci. Nat., vol. vii, p. 254, No. 35.
Dentalina carinata d'Orbigny, 1826. Ann. Sci. Nat., vol. vii, p. 255, No. 39.
Nodosaria lævigata Nilsson, 1827. Petrificata Suecana, p. 8, vol. ix, fig. 2.
Dentalina lorneiana d'Orbigny, 1831. Foram. Craie bl. Paris; Mem. Soc. Geol. France, vol. vi, p. 14, pl. i, figs. 8, 9.
Dentalina nodosa d'Orbigny, 1839. Foram. Craie bl. Paris; Mem. Soc. Geol. France (2) vol. iv, p. 14, pl. i, figs. 6, 7.
Dentalina gracilis, Id., Ibid., vol. vi, p. 14, pl. i, fig. 5.
Dentalina communis, Id., Ibid., (1840) p. 13, pl. 1, fig. 4.
Nodosaria radicularis Münst., Rom., 1838. Nord. tert. Meeressand; Leonh. u. Bronn's, Jhrb., 1838, p. 382, pl. 3, fig. 3.
Nodosaria linearis Röm., 1842. Vert. nordd. Kreidegeb., p. 95, pl. xv, fig. 5.
Nodosaria nodosa Reuss, 1845. Bohm. Kreide 1, p. 28, pl. xiii, fig. 22.
Nodosaria gracilis, Id., Ibid., p. 27, pl. viii, fig. 6.
Nodosaria lorneiana, Id., Ibid., p. 27, pl. viii, fig. 5.
Nodosaria communis, Id., Ibid., p. 28, pl. xii, fig. 21.
Nodosaria legumen, Id., Ibid., p. 28, pl. xiii, figs. 23, 24.

Dentalina inornata d'ORBIGNY, 1846. For. Foss.Vien., p. 44, pl. i, figs. 50, 51.
Dentalina badensis, Id., Ibid., p. 44, figs. 48, 49.
Dentalina brevis, Id., Ibid., p. 48, pl. ii, figs, 9, 10.
Dentalina elegans, Id., Ibid., p. 45, pl. i, figs. 52–56.
Dentalina scripta, Id., Ibid., p. 51, pl. ii, figs. 21–23.
Dentalina punctata, Id., Ibid., p. 49, pl. ii, figs. 14, 15.
Dentalina verneuilli, Id., Ibid., p. 48, pl. ii, figs. 7, 8.
Dentalina pauperata, Id., Ibid., p. 46, pl. i, figs. 57, 58.
Dentalina boneana, Id., Ibid., p. 47, pl. ii, figs. 4–6.
Dentalina consobrina, Id., Ibid., p. 46, pl. ii, figs. 1–3.
Dentalina inermis CZJZEK, 1847. Haidinger's Naturw. Abhandl., vol. ii, p. 139, pl. xii, figs. 3–7.
Dentalina ferstliana, Id., Ibid., p. 140, pl. xii, figs. 10–13.
Dentalina cingulata, Id., Ibid., p. 139, pl. xii, figs. 8, 9.
Marginul contraria, Id., Ibid., p. 140, pl. xii, figs. 17–20.
Dentalina chrysalina CORN., 1848. Norw. Foss. Micros. Cret.; Mem. Soc. Geol. France,(2) vol. iii, p. 251, pl. 1, fig. 21.
Dentalina intermedia, Id., Ibid., p. 251, pl. i, fig. 20.
Dentalina antenna, Id., Ibid., p. 250, pl. i, fig. 19.
Dentalina gracilis ALTH., 1849. Umgeb. Lemb.; Haid. Nat. Abh., 3, 2, p. 269, pl. xiii, fig. 27.
Dentalina mutabilis BAILEY, 1850. Examin. of Soundings; Smithson. Contrib. to Knowledge, vol. ii, art. 3, pl. x, fig. 7.
Dentalina annulata REUSS, 1850. Kreide Lemberg; Haid. Nat. Abh., 4, 1, p. 26, pl. i, fig. 13.
Dentalina acus, Id., Ibid., p. 27, pl. i, fig. 15.
Marginul elongata, Id., Ibid., p. 28, pl. i, fig. 17.
Marginul apiculata, Id., Ibid., p. 28, pl. i, fig. 18.
Dentalina obtusata REUSS, 1851. Tert. Sch. Oberschlesien; Zeitschr. deutsch. geol. Ges., p. 151, pl. viii, fig. i.
Dentalina emaciata REUSS, 1851. Sept. Thon von Berlin; Zeitschr. deutsch. geol. Ges., 3, p. 63, pl. iii, fig. 9.
Dentalina acuticauda REUSS, 1851. Ibid., p. 62, pl. iii, fig. 8.
Dentalina nitens COSTA, 1854. Pal. d. Reg. Nap., 2. p. 165, pl. xii, fig. 26.
Marginul torulosa COSTA, 1854. Pal. d. Reg. Nap., 2, p. 185, pl. xii, fig. 15.
Dentalina prælonga COSTA, 1854. Pal. d. Reg. Nap., 2, p. 163, pl. xii, fig. 21.
Dentalina nodosa, Id., Ibid., p. 164, pl. xii, fig. 8.
Dentalina badenensis, Id., Ibid., p. 174, pl. xvi, fig. 23.
Marginul inversa, Id., Ibid., p. 139, pl. xii, fig. 16.
Dentalina megalopolitana REUSS, 1855. Kreidegeb. Mecklenburg; Zeitschr. deutsch. geol. Ges., vol. vii, p. 267, pl. viii, fig. 10.
Dentalina tenuicollis, Id., Ibid., p. 267, pl. viii, fig. 11.
Dentalina plebeja, Id., Ibid., p. 267, pl. viii, fig. 9.
Dentalina verneuilli BORNEMAN, 1855. Sept. Thon. Hermsdorf; Zeitschr. deutsch. geol. Ges., vol. vii. p. 324, pl. xiii, fig. 8.
Dentalina consobrina, Id., Ibid., p. 323, pl. xiii, figs. 1–4.
Dentalina pauperata, Id., Ibid., p. 324, pl. xiii, fig. 7.
Marginul tenuis, Id., Ibid., p. 326, pl. xiii, fig. 14.
Dentalina adunca COSTA, 1855. Foram. Marna Blu. Vaticano; Mem. Nap., vol. ii, p. 117, pl. i, fig. 1.
Dentalina nepos, Id., Ibid., p. 117, pl. i, fig. 2.
Dentalina haidingeri NEUGEB., 1856. Foram. Stichosteg. Ob. Lapug.; Wien Ak. Dkschr. 12. 2, p. 85, pl. iii, fig. 12.
Dentalina perversa, Id., Ibid., p. 80, pl. ii, fig. 8.
Dentalina reussi, Id., Ibid., p. 85, pl. iii, figs. 6–7, 17.
Dentalina perscripta EGGER, 1857. Miocän. Ortenburg; Leonh. u. Bronn's Jahrbuch, 1857, p. 307, pl. xv, figs. 30, 31.
Dentalina acuminata REUSS, 1859. Westphäl. Kreide; Wien, Ak. Sitz.-Ber., vol. 40, p. 181, pl. i, fig. 7.
Dentalina tenuicaudata, Id., Ibid., p. 182, pl. ii, fig. 3.
Dentalina commutata, Id., Ibid., p. 183, pl. ii, fig. 4.
Dentalina pugiunculus, Id., Ibid., p, 183, pl. iii, fig. 9.
Dentalina communis PARKER and JONES, 1860. Foram. Chellast.: Quart. Journ. Geol. Soc., vol. xvi, p. 453, pl. xix, fig. 25.
Dentalina pauperata, Id., Ibid., p. 453, pl. xix, fig. 22.
Dentalina colligata REUSS, 1861. Grünsand von New Jersey; Wien. Ak. Sitz.-Ber., 1, 44, p. 334, pl. vii, fig. 4.
Dentalina linearis REUSS, 1862. Nordd. Hils u. Gault; Wien. Ak. Sitz.-Ber., 1, 46, p. 42, pl. ii, fig. 15.

Dentalina deflexa, Id., Ibid., p. 43, pl. ii, fig. 19.
Nodosoria nuda, Id., Ibid., p. 38, pl. ii, figs. 8, 9.
Dentalina fasciata SEQUENZA, 1862. Rhizopod. d. Catania; Acad. Gioenia Atti,(2) vol. xviii, p. 12, pl. i, fig. 1.
Dentalina indifferens REUSS, 1863. Sept. Thon Offenbach; Wien. Ak. Sitz.-Ber., 1, 48, p. 44, pl. ii, figs. 15, 16.
Dentalina communis PARKER and JONES, 1865. North Atlantic and Arctic Oceans; Phil. Trans., p. 342, pl. xiii, fig. 10.
Dentalina consobrina PARKER and JONES, 1865. North Atlantic and Arctic Ocean; Phil. Trans., p. 342, pl. xvi, fig. 3.
Dentalina æqualis KARRER, 1865. Foram Grünsandstein N. Zeeland; Novara Reise, geol. Theil, 1, 2, p. 74, pl. xvi, fig. 1.
Dentalina inornata REUSS, 1865. Sept. Thon Offenbach; Wien. Ak. Sitz.-Ber., 1, 48, p. 45, pl. ii, fig. 18.
Nodosaria vermiculum REUSS, 1865. Foram. deutsch. Sept. Thon; Wien. Ak. Dksehr., 1, 25, 1, p. 133, pl. ii, figs. 14, 15.
Nodosaria approximata, Id., Ibid., pl. ii, fig. 22.
Dentalina communis sub-var. *pauperata* PARKER and JONES, 1866. Crag. Foram.: Pal. Soc., vol. xix, p. 58, pl. i, figs. 13, 20.
Nodosaria neugeboreni SCHWAGER, 1869. Novara-Exped., geol. Theil, vol. ii, p. 232, pl. vi, fig. 67.
Nodosaria gracilescens, Id., Ibid., p. 234, pl. vi, fig. 70.
Nodosaria pupiformis KARRER, 1867. Foram. Fauna Osterreich; Wien. Ak. Sitz.-Ber., 1. 55, p. 354, pl. i, fig. 5.
Dentalina aherculea GÜMBEL, 1868. Nordalp. Eocan; Abh. k. Bayr. Ak., 1, 10, 2, p. 621, pl. i, fig. 34.
Dentalina linearis, Id., Ibid., p. 622, pl. i, fig. 36.
Dentalina glandulifera, Id., Ibid., p. 622, pl. i, fig. 37.
Dentalina fusiformis, Id., Ibid., pl. 621, pl. i, fig. 35.
Dentalina korynephora GÜMBEL, 1869. Foram. St. Cassin u. Raibl. Sch.; Oster. geol. Reichsanst., Jharb. xix, p. 176, pl. v, fig. 1.
Dentalina transmontana, Id., Ibid., p. 177, pl. v, fig. 17.
Dentalina inorta TERQUEM, 1870. Foram. du Syst. Oolith., 3 ieme Mem., p. 262, pl. xxvii, figs. 26-34.
Nodosaria peracuta REUSS, 1873. Geinitz, Elthalgeb. Sachsen, 2, p. 86, pl. ii, fig. 21.
Nodosaria annulata, Id., Ibid., p. 85, pl. ii, figs. 19, 20.
Dentalina budensis HANTKEN, 1875. Mittheil. Jahrb. d. k. ung. geol. Anstalt, vol. iv, p. 34, pl. xiii, figs. 7, 12.
Dentalina boneana HANTKEN, 1875. Foram. lav. Szab. Sch.; Mittheil. Jahrb. d. k. ung. geol. Anstalt, p. 34, pl. xii, figs. 11, 19.
Dentalina communis BRADY, 1876. Carbonif., and Perm. Foram.; Pal. Soc., vol. xxx, p, 127, pl. x, figs. 17, 18.
Nodosaria clava KARRER, 1878. Foram. Luzon; Bolet. Comis. Mapa Geol. del España, 7, 2, p. 16, pl. E, fig. 11.
Nodosaria communis GOES, 1882. Reticularian Rhizopoda of the Caribbean Sea; K. S. Vet. Akad. Hand., vol. xix, p. 26, pl. i, figs. 11-16.
Nodosaria legumen, Id., Ibid., p. 34, pl. ii, figs. 20-31.
Nodosaria (D) communis BRADY, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 504, pl. lxii, figs. 19-22.

"*N. (D.) communis*, testa elongata, arcuata, lævigata; postice acuminatâ, caudata; loculis numerosis, obliquis, ultimo supra convexo, acuminato, primo convexo; suturis subcomplantis; aperturâ minimâ, radiata." D'ORBIGNY. (1840, Mém. Soc. Géol. de France, vol. iv, p. 13.)

N. (D.) communis, shell elongated, arched, smooth; posteriorly acuminate, caudate; numerous chambers, oblique, last very convex, acuminate, first convex; sutures subcomplanate; very small aperture radiate.

Locality. Saline county, Nebraska.

This species seems to be very rare in the western Cretaceous; in the material examined we found only one perfect specimen and two fragments. It is very abundant and well preserved in the Cretaceous of New Jersey, at Timber creek and Mullica hill.

UVIGERINA, d'Orbigny.

Uvigerina asperula *Czjzek.*

PLATE D, FIG. 10.

Uvigerina asperula Czjzek, 1847. Haidinger's Naturw. Abhandl., vol. ii, p. 146, pl. xiii, figs. 14, 15.
Uvigerina orbigniana, Id., Ibid., p. 147, pl. xiii, figs. 16, 17.
Uvigerina gracilis Reuss, 1851. Zeitschr. d. deutsch. geol. Gesellsch., vol. iii, p. 77, pl. v, fig. 39.
Uvigerina gracilis Bornemann, 1865. Ibid., vol. vii, p. 343, No. 1.
Uvigerina hispida Schwager, 1866. Novara-Exped., geol. Theil, vol. ii, p. 249, pl. vii, fig. 95.
Uvigerina asperula Seguenza, 1880. Atti Accad. dei Lincei, ser. 3, vol. vi, pp. 146, 226, 307.
Uvigerina asperula Brady, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 578, pl. lxxv, figs. 6–8.

"U. testa oblonga, antice et postice acuminata, asperula et longitudinaliter costulata; loculis convexis, globulosis, inæqualibus; apertura fistulosa, marginata. Diam. ½ mill. Long. 1¼ mill." Czjzek. (Haidinger's Naturw. Abhandl., vol. ii, p. 146)

Shell oblong, anteriorly and posteriorly acuminate, longitudinally ribbed, spinulose undulate, chambers convex, globose, unequal, aperture tubular, margined.

Locality. Saline county, Nebraska. Very rare.

Uvigerina canariensis *d'Orbigny.*

PLATE D, FIG. 9.

"*Testæ pineiformes minusculæ*" Soldani, 1798. Testaceographia, vol. ii, p. 18, pl. iv, figs. E, F, G, H.
Uvigerina nodosa var B. d'Orbigny, 1826. Ann. Sci. Nat., vol. vii, p. 269, No. 3.
Uvigerina canariensis, Id., 1839. Foram. Canaries, p. 138, pl. i, figs. 25–27.
Uvigerina urnula d'Orbigny, 1846. Foram. Foss. Vien., p. 189, pl. xi, figs. 21, 22.
Uvigerina irregularis Brady, 1865. Nat. Hist. Trans. Northd. and Durham, vol. i, p. 100, pl. xii, fig. 5.
Uvigerina proboscidea Schwager, 1866. Novara-Exped., geol. Theil, vol. ii, p. 250, pl. vii, fig. 96.
Uvigerina farinosa Hantken, 1875. Mittheil. Jahrb. d. k. ung. geol. Anstalt, vol. iv, p. 62, pl. vii, fig. 6.
Uvigerina canariensis Brady, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 573, pl. lxxiv, figs. 1–3.
Uvigerina canariensis Woodward and Thomas, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Surv. Minn., p. 171, pl. iv, fig. 37.

"U. testa oblongo-conica, punctata, albida; spira conica, anfractibus quinis minime convexis; loculis convexis per quamque spiram trinis; apertura rotunda; siphone brevi." D'Orbigny. (Foraminifera Canaries, p. 138.)

Test oblong conical, punctate, whitish with a conical spire of five whorls slightly convex, segments convex, three to each whorl of the spire, aperture round, siphon short.

Locality. Meeker county, Minnesota; Saline county, Nebraska. Very rare in Minnesota and Nebraska. Has also been found in the borings from an artesian well at Atlantic City, New Jersey.

GLOBIGERINIDÆ.

GLOBIGERINA, d'Orbigny.

GLOBIGERINA BULLOIDES *d'Orbigny.*

PLATE D, FIGS. 11-17.

"*Polymorpha Tuberosa et Globulifera*" SOLDANI, 1791. Testaceographia, vol. i, pt. 2, p. 117, pl. cxxiii, figs. II, I, O, P.
Testæ tuberosæ, etc., Id., 1798. Ibid., vol. ii, p. 20, pl. vi, figs. dd, ee.
Globigerina bulloides d'ORBIGNY, 1826. Ann Sci. Nat., vol. vii, p. 277, No. 1, Modèles, No. 17 (young) and No. 76.
Globigerina bulloides, Id., 1839. Foram. Amér. Merid., p. 37.
Globigerina bulloides, Id., 1839. Foram. Canaries, p. 132, pl. ii, figs. 1-3, 28.
Globigerina hirsuta, Id., Ibid., p. 133, pl. ii, figs. 4-6.
Globigerina siphonifera, Id., 1839. Foram. Cuba, p. 95, pl. iv, figs. 15-18.
Globigerina bulloides, Id., 1846. Foram. Foss. Vien., p. 163, pl. ix, figs. 4-6.
Globigerina concinna REUSS, 1849. Denkschr. d. k. Akad., Wiss. Wien., vol. i, p. 373, pl. xlvii, fig. 8.
Globigerina diplostoma, Id., Ibid., p. 373, pl. xlvii, figs. 9, 10.
Globigerina depressa EHRENBERG, 1854. Mikrogeologie, pl. xix, fig. 92.
Globigerina foveolata (pars.), Id., Ibid., pl. xxii, fig. 74.
Globigerina cretæ EHRENBERG, 1854. Mikrogeologie, pl. xxvi, fig. 44; pl. xxx, fig. 38.
Globigerina stellata, Id., Ibid., pl. xxvi, fig. 45.
Globigerina ternata EHRENBERG, 1854. Mikrogeologie, pl. xxxv B, figs. 5, 6.
Planulina porotetras, Id., 1854. Ibid., pl. xx, II, fig. 16.
Planulina pertusa, Id., Ibid., pl. xxii, fig. 75.
Planulina stigma, Id., Ibid., pl. xxv, fig. 29.
Rotalia rudis, Id., Ibid., pl. xxiv, figs. 35, 36.
Rotalia leptospira, Id., Ibid., pl. xxiv, fig. 39.
Rotalia senaria (pars.), Id., Ibid., pl. xxiv, fig. 40.
Ptygostomum orphei, Id., Ibid., pl. xxxv B, figs. 1, 2.
Phanerostomum atlanticum, Id., Ibid., pl. xxxv B, figs. 3, 4.
Globigerina bulloides KÜBLER and ZWINGLI, 1866. Neujahrsblatt, v. d. Bürgerbib. in Winterthur, pt. 2, p. 22, pl. iii, figs. 30, 31.
Globigerina taminensis, Id., Ibid., p. 24, pl. iii, fig. 26.
Globigerina bulloides GÜMBEL, 1868. Abh. d. k. bayer. Akad. d. Wiss., II, cl. vol. x, p. 661, pl. ii, figs. 106 a, b.
Globigerina alpigena (?), Id., Ibid., p. 661, pl. ii, fig. 107.
Globigerina cocæna, Id., Ibid., p. 662, pl. ii, fig. 109.
Planulina mauryana EHRENBERG, 1873. Abhandl. d. k. Akad. Wiss. Berlin (1872), p. 388, pl. iii, fig. 1.
Planulina globigerina, Id., Ibid., p. 388, pl. iii, fig, 3.
Planulina megalopentas, Id., Ibid., p. 388, pl. iv, fig. 7.
Pylodexia platyletras, Id., Ibid., p. 388, pl. iii, fig. 14.
Aristerospira omphalotetras, Id., Ibid., p. 388, pl. iii. fig. 15.
Globigerina detrita TERQUEM, 1875. Anim. sur la Plage de Dunkerque. fasc. i, p. 31, pl. iv, fig. 4, a-c.
Globigerina bulloides TERQUEM, 1875. Anim. sur la Plage de Dunkerque, fasc. i, p. 31, pl. iv, fig. 5, a-b.
Globigerina bulloides HILGARD and HOPKINS, 1878. Rec. of the Alluvial Basin of the Miss. river, pp. 13, 42, pl. ii, figs. 70, 71, 72.
Globigerina bulloides BRADY 1879. Quart. Journ. Micr. Soc., vol. xix, n. s., p. 71.
Globigerina bulloides BRADY, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 593, pl. lxxix, figs. 3-7.
Globigerina bulloides ANDREÆ, 1884. Beitrag zur Kenntniss des Elsasser Tertiars, II Theil, pl. ix, figs. 1, 2.
Globigerina bulloides WOODWARD and THOMAS, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Surv. Minn., p. 172, pl. iii, fig. 13.

"Test spiral. subtrochoid; superior face convex, inferior more or less convex but with deeply sunken umbilicus, periphery rounded, lobulated; adult specimens composed of about seven globose segments, of which four form the outer convolution; the apertures of the individual chambers opening independently into the umbilical vestibule. Diameter sometimes $\frac{1}{40}$th inch (0.63 mm.) but oftener much less." BRADY *loc. cit.*

Locality. Meeker county, Minnesota; Saline county, Nebraska; South Chicago, Illinois. Common in Nebraska: not quite so common in Minnesota; rare in South Chicago. The most common of all our living forms, and may be found anywhere along our seacoast, also as a fossil in the "Eolian sand" from the Smoky Hill river, near Lindsborg, Kansas.

GLOBIGERINA CRETACEA *d'Orbigny.*

PLATE D, FIGS. 18, 19.

Globigerina cretacea d'ORBIGNY, 1840. Mem. Soc. Geol. France, vol. iv, p. 34, pl. iii, figs. 12–14.
Globigerina faveolota (pars) EHRENBERG, 1854. Mikrogeologie, pl. xxiv, fig. 49.
Globigerina libani EHRENBERG, Ibid., pl. xxv, fig. 30.
Planulina pachyderma, Id., Ibid., pl. xxv, fig. 31.
Rotalia pertusa, Id., Ibid., pl. xxiv, fig. 41.
Rotalia aspera, Id., Ibid., pl. xxvii, figs. 57, 58: pl. xxviii, fig. 42; pl. xxxi, fig. 44.
Rotalia globulosa, Id., Ibid., pl. xxvii, fig. 60; pl. xxviii, figs. 40, 41; pl. xxxi, figs. 40, 41, 43.
Rotalia densa, Id., Ibid., pl. xxvii, fig. 62.
Rotalia quaterna, Id., Ibid., pl. xxvii, fig. 53; pl. xxviii, fig. 34.
Rotalia rosa, Id., Ibid., pl. xxvii, fig. 54.
Rotalia pachyomphala, Id., Ibid., pl. xxvii, fig. 55.
Rotalia tracheotetras, Id., Ibid., pl. xxvii. fig. 35.
Rotalia perforata, Id., Ibid., pl. xxviii, fig. 36; pl. xxix, fig. 2.
Rotalia protacmœa, Id., Ibid., pl. xxviii, fig. 37.
Rotalia laxa, Id., Ibid., pl. xxviii, fig. 38; pl. xxix, fig. 1; pl. xxxi, fig. 42.
Rotalia centralis, Id., Ibid., pl. xxviii, fig. 39.
Globigerina cretacea BRADY, 1879. Quart. Journ. Micr. Soc., vol. xix, n. s., p. 285.
Globigerina cretacea BRADY, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p. 596, pl. lxxxii, fossil specimens, fig. 11, a–c.
Globigerina cretacea WODWARD and THOMAS, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Surv. Minn., p. 171, pl. iii, figs. 14–16: iv, fig. 19.

"Test rotaliform, much compressed; superior face flattened or only slightly convex, inferior side depressed towards the centre and excavated at the umbilicus, periphery obtuse and lobulated; composed of about three tolerably distinct convolutions, the outermost consisting of from five to seven segments; segments relatively small, subglobular; apertures opening into an umbilical vestibule. Diameter $\frac{1}{50}$th inch (0.5 mm.)" BRADY *loc. cit.*

Locality. Meeker county, Minnesota: Saline county, Nebraska: South Chicago, Illinois, and Little Fork river, near Rainy lake, Minnesota. It is found very abundant in the Boulder clay of Minnesota, but the specimens are quite fragmentary, while those in the Nebraska and Illinois clays are more numerous and in a much better state of preservation. Dr. G. M. Dawson, in 1874, found it in the Cretaceous clays from Manitoba.

Globigerina marginata *Reuss.*

PLATE D, FIGS. 20, 21.

Rosalina marginata Reuss, 1845. Verstein. bohm. Kreid., pt. i, p. 36, pl. xiii, fig. 47.
Rosalina marginata Jones, 1853. Ann. and Mag. Nat. Hist., ser. 2, vol. xii, p. 241, pl. ix, fig. 7.
Rosalina marginata Reuss, 1854. Denkschr. d. k. Akad. Wiss. Wien, vol. vii, p. 69, pl, xxvi, fig. 1.
Discorbina marginata, Id., 1854. Sitzungsb. d. k. Akad. Wiss. Wien, vol. vii, p. 12, No. 2.
Globigerina marginata Parker and Jones, 1865. Phil. Trans., vol. clv, p. 367.
Rotalia marginata Gümbel, 1870. Sitzungsb. d. k. bayer. Akad. Wiss., vol. ii, pp. 283, 287.
Globigerina marginata Reuss, 1874. Das Elbethalgebirge in Sachsen, 2ter Theil, p. 112, No. 2.
Globigerina marginata Brady, 1879. Quart. Journ. Micr. Soc., vol. xix, n. s., p. 74.
Globigerina marginata Brady, 1884. Report on Foram. H. M. S. Challenger, Zool., vol. ix, p 597, wood cut, fig. 17.
Globigerina marginata Woodward and Thomas, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Surv. Minn., p. 174, pl. iv. figs. 20-22.

"Test rotaliform, much compressed; superior face convex, inferior face also convex, but with a sunken umbilical recess, peripheral edge thin or subcarinate; segments numerous, five or six in the last convolution, the outer margin of each segment exhibiting a well-marked narrow border; apertures opening into the umbilical vestibule. Surface of living specimens beset with spines. Diameter $\frac{1}{50}$th to $\frac{1}{25}$th inch (0.5 to 1 mm.)" Brady *loc. cit.*

Locality. Meeker county and Northeastern Minnesota; Little Fork river, Saline county, Nebraska; South Chicago, Illinois. This species in Minnesota is quite well represented, and in good state of preservation, while in Nebraska they are common but fragmentary. We are in some doubt about this species, it resembles so closely in some respects *G. linnæana*, while in others *Pulvinulina menardii*; but we feel quite satisfied to favor *G. marginata* Reuss.

Globigerina sacculifera *H. B. Brady.*

PLATE D, FIG. 22.

Globigerina helicina Carpenter, 1862. Introd. Foram., pl. xii, fig. 11.
Globigerina sacculifera Brady, 1877. Geol. Mag., dec. II, vol. iv, p. 535.
Globigerina sacculifera Brady, 1879. Quart. Journ. Micr. Soc., vol. xix, n. s., p. 73.
Globigerina sacculifera Brady, 1884. Report Foram. H. M. S. Challenger, Zool., vol. ix, p. 604, pl. lxxx, figs. 11-17; pl. lxxxii, fig. 4.

"Test oblong, compressed, rotaliform; segments few, usually five to seven in number, of which four generally compose the final convolution; earlier chambers small and subglobular; the ultimate segment, and sometimes also the penultimate, elongated radially and more or less pointed at the peripheral extremity. Aperture variable, consisting of a single large opening at the inferior umbilical margin of the terminal segment, and one or sometimes several round orifices in the sutural depressions of the superior face. Pelagic specimens spinous externally. Longer diameter $\frac{1}{25}$th inch (1 mm.) more or less." Brady *loc. cit.*

Locality. Northeastern Minnesota. We found but one specimen in the boulder clays, but it closely resembled, in so many respects, those figured by Carpenter and Brady, that we are quite satisfied that it is the same species.

ORBULINA, d'Orbigny.

ORBULINA UNIVERSA *d'Orbigny.*

PLATE D. FIGS. 23-27.

"*Polymorpha sphærulæ vitreæ,*" SOLDANI, 1791. Testaceographia, vol. i, pt. 2, p. 116, pl. cxix, figs. I–N.
Orbulina universa d' ORBIGNY, 1839. Foram. Cuba, p. 3, pl. i, fig 1.
Orbulina universa, Id., 1839. Foram. Canaries, p. 122, pl. i, fig. 1.
Miliola (*Monocystis*) *arcella* EHRENBERG, 1854. Mikrogeologie, pl. xxx, fig. 1.
Miliola sphærula, Id., Ibid., pl. xxxi, fig. 1, a, b, c.
Orbulina granulata var. *atra* COSTA, 1856. Atti dell' Accad. Pont., vol. vii, p. 116, pl. xi, fig. 2.
Orbulina granulata var. *areolata*, Id., Ibid., p. 117, pl. xi, fig. 4.
Orbulina universa, Id., Ibid., p. 114, pl. xi, fig. 5.
Orbulina universa WILLIAMSON, 1858. Rec. Foram. Gt. Br., p. 2, pl. 1, fig. 4.
Orbulina universa POURTALES, 1858. Amer. Jour. Sci., ser. 2, vol. xxvi, p. 96.
Orbulina universa BRADY, 1859. Quart. Journ. Micr. Soc., vol. xix, n. s., p. 75.
Orbulina punctata TERQUEM, 1862. Foram. du Lias, 2ieme mem., p, 432, pl. v, fig. 5.
Globigerina (*Orbulina*) *universa* OWEN, 1867. Journal Linn. Soc. Lond., vol. ix, Zool., p. 149, pl. v, fig. 1.
Globigerina (*Orbulina*) *continens*, Id., Ibid., figs. 3, 4.
Globigerina (*Orbulina*) *acerosa*, Id., Ibid., fig. 2.
Orbulina universa STOHR, 1876. Boll. R. Com. Geol. D' Ital., p. 463.
Orbulina universa SCHWAGER, 1877. Boll. R. Com. Geol. D' Ital., p. 20, pl. fig. 45.
Orbulina universa HILGARD and HOPKINS, 1878. Rec. of the Alluvial Basin of the Mississippi river, pp. 13, 39, pl. ii, fig. 73.
Orbulina universa SCHACKO, 1883. Wiegmann's Archiv fur Natur., Jahrg. xlix, p. 428, pl. xiii, fig. 1.
Orbulina universa SCHLUMBERGER, 1884. C. R. vol. xcviii, pp. 1002-1004, figs. 1, 2.
Orbulina universa BRADY, 1884. Report on Foram., H. M. S. Challenger, Zool., vol. ix., p. 608, pls. lxxviii: lxxxi, figs. 8–26; pl. lxxxii, fig. 1–3.
Orbulina universa WOODWARD and THOMAS, 1885. Thirteenth Annual Report, Geol. Nat. Hist. Surv. Minn., pp. 174, 175, pl. iv, figs. 25–31.

Generic character. Shell free, regular, spherical, hollow; perforated by innumerable very minute foramina, visible only under a high magnifying power; septal orifice single, small, situate at some point on the periphery of the shell; without any marginal projection; often invisible.

Specific character. "Spherical; parietes minutely granular, of a pale grayish-yellow hue. Texture finely arenaceous.* Septal aperture small, normally round, but usually irregular, and sometimes entirely closed up by the inspissated gelatinous sarcode, so as to be invisible. Diam. $\frac{1}{50}$–$\frac{1}{80}$ inch."**

Locality. Meeker county, Minnesota; Saline county, Nebraska; Calumet, South Chicago, Illinois. In Minnesota it is common, in Nebraska and South Chicago rare. This species was found in the Post-pliocene by Prof. Eugene W. Hilgard and Dr. F. V. Hopkins, in their "investigation of the microscopic character of the strata of dark-colored, brown or blue clays occurring in the borings of the blue 'delta clay' which is found almost everywhere in the delta coast region of Louisiana and Mississippi."† It is a very common species.

---

*We find by further examination, that the texture is not finely arenaceous, as stated in the description, but calcareous and similar in every respect to its closely allied species *Globigerina bulloides*.
**Williamson's Recent Foraminifera G. B., 1857.
†Reclamation of the Alluvial Basin of the Mississippi River, p. 12, 1878.

Sub-Family ROTALINÆ.

ANOMALINA, d'Orbigny.

ANOMALINA AMMONOIDES *Reuss, sp.*

PLATE D. FIGS. 28, 29.

Rosalina ammonoides REUSS, 1845. Verstein. Bohm. Kreid., pt. 1, p. 36, pl. xii, fig. 66; pl. viii, fig. 53.
Rosalina ammonoides, Id., 1850. Haidinger's Naturw. Abhandl., vol. iv, p. 36, pl. iv, fig. 2.
Nonionina bathyomphala. Id., 1862. Sitzungsb. d. k. Ak. Wiss. Wien, vol. xlvi, p. 95, pl. xiii, fig. 1, a, b.
Rosalina weinkauffii, Id., 1863. Ibid., vol. xlviii, p. 68, pl. viii, fig. 97.
Rosalina maorica STACHE, 1864. Novara-Exped., geol. Theil, vol. i, p. 282, pl. xxiv, fig. 32.
Rosalina orbiculus, Id., Ibid., p. 285, pl. xxiv, fig. 34.
Planorbulina ammonoides PARKER and JONES, 1865. Phil. Trans., vol. clv, p. 379.
Discorbina ammonoides REUSS, 1865. Sitzungsb. d. k. Ak. Wiss. Wien, vol. lii, p. 456, No. 5.
Rotalia capitata GÜMBEL, 1868. Abhandl. d. k. bayer. Akad. Wiss., II, cl. vol. x, p. 653, pl. ii, fig. 92.
Rotalia ammonoides, Id,, 1870. Sitzungsb. d. k. bayer. Akad. Wiss., p. 283.
Planorbulina (*Anomalina*) *ammonoides* JONES and PARKER, 1872. Quart. Journ. Geol. Soc., vol. xxviii, p. 106; table, p. 109.
Planorbulina ammonoides REUSS, 1874. Das Elbthalgebirge in Sachsen, 2ter Theil, p. 114, pl. xxiii, fig. 9.
Anomalina ammonoides BRADY, 1884. Report on Foram., H. M. S. Challenger, Zool., vol. ix, pp. 672, 673, pl. xciv, figs. 2, 3.

"The shell is generally much compressed, and nearly equally convex on the two sides; the peripheral edge is round, and the aperture is placed almost symmetrically in the median line. Some specimens are depressed at both umbilici, others are umbonate at one or both; sometimes the earlier convolutions are visible to a nearly equal extent on both faces. The coarse perforation of the shell wall is usually more conspicuous on the inferior than on the superior face." BRADY *loc. cit.*

Locality. Saline county, Nebraska, and South Chicago, Illinois.

Anomalina ammonoides is a very common Cretaceous foraminifer in Europe: in America we believe this is the first time it has been noticed.

PULVINULINA, Parker and Jones.

PULVINULINA HAUERI *d'Orbigny, sp.*

PLATE E, FIG. 34.

Rotalina hauerii d'ORBIGNY, 1846. Foram. Foss. Vien., p. 151, pl. vii, figs. 22–24.
Pulvinulina hauerii PARKER and JONES, 1865. Phil. Trans., vol. clv, p. 393.
Pulvinulina budensis HANTKEN, 1875. Mittheil. Jahrb. d. k. ung. geol. Anstalt, vol. iv, pl. ix, fig. 5. (*Pulvinulina brongniarti*, at p. 78).
Pulvinulina hauerii BRADY, 1884. Report on Foram., H. M. S. Challenger, Zool., vol. ix, p. 690, pl. cvi, figs. vi, vii.

"*P. hauerii.* Testa ovata-convexâ lævigatâ, subtus convexâ, umbilicatâ; spirâ convexiusculâ; anfractibus tribus externê rotundatis; loculis convexo. Diam. ⅛ mill." D'ORBIGNY. (Foram. Foss. Vien., p. 151, pl. vii, figs. 22-24.)

P. hauerii. Shell ovate-convex, smooth, convex below, umbilicate; spire somewhat convex, three whorls externally rounded, chambers convex. Diam. ⅛ mill.

Locality. Little Fork river near Rainy lake, Northeastern Minnesota.

Pulvinulina menardii *d'Orbigny, sp.*

PLATE E, FIG. 33.

Rotalia menardii d'Orbigny, 1826. Ann. Sci. Nat., vol. vii, p. 273, No 26; Modèle No. 10.
Rotalina cultrata d'Orbigny, 1839. Foram. Cuba, p. 76, pl. v, figs. 7–9.
Rotalia canariensis d'Orbigny, 1844. Foram. Canaries, p. 130, pl. i, figs. 34–36.
?*Rotalina spinimargo* Reuss, 1849. Neue Foram. Osten. tert. Beck.; Wien. Ak. Dkschr. 1. 1. p. 371, pl. 47, fig. 1.
Rotalina cultrata Bailey, 1851. Smithsonian Contrib., vol. ii, art. 3, p. 11, figs. 14–16.
Planulina incurvata, Ehrenberg, 1854. Mikrogeologie, pl. xxvi, fig. 42.
Planulina membranacea, Id., Ibid., pl. xxvi, fig. 43.
Pulvinulina repanda var. *menardii* Parker and Jones, 1865. Phil. Trans., vol. clv, p. 394, pl. xvi, figs. 35–37.
Pulvinulina repanda var. *menardii* subvar *pauperata*, Id., Ibid., p. 395, pl. xvi, figs. 50, 51.
Rotalia paupercula Stache, 1865. Tert. Merg. Whaingar. Hafen; Novara Reise, geol. Theil, I, 2, p. 277, pl. xxiv, fig. 27.
Discorbina saccharina, Schwager, 1866. Novara-Exped., geol. Theil. vol. ii, p. 257, pl. vii, fig 106.
Pulvinulina menardii Owen, 1867. Journ. Linn. Soc. Lond., vol. ix, Zool., p. 148, pl. v, fig. 16.
Rosalina asterites Gümbel, 1868. Abhandl. d. k. bayer. Akad. Wiss., II, cl. vol. x, p. 658, pl. ii, fig. 101, a–c.
Pulvinulina erinacea Karr., 1868. Mioc. Fauna Kostej; Wien, Sitz-Ber. I, 58, p. 187, pl. v, fig. 6.
?*Truncatulina budensis* Hantken, 1875. Foram. Clav. Szab. Sch., p. 75, pl. viii, fig. 6.
Pulvinulina menardii var. *cultrata* Van den Broeck, 1876. Ann. Soc. Belg. Micr., vol. ii, p. 141, pl. iii, figs. 13, 15.
Pulvinulina menardii Brady, 1879. Quart. Journ, Micr. Soc., vol. xix, n. s., p. 80.
Pulvinulina menardii Goes, 1882. Kongl. Sven.-Vet. Akad. Handl., vol. xix, p. 112, pl. viii, figs. 289–295.
Pulvinulina menardii Brady, 1884. Report on Foram., H. M. S. Challenger, Zool., vol. ix, p. 690, pl. ciii, figs. 1, 2.

Testa ovali, depressissima, punctata, carinata, cultrata, supra subcomplanata, subtus convexinscula; spira subplana, anfractibus duobus limbatis; loculis sex ovatis, contectis, supra limbatis.

Shell oval, very depressed, punctate, carinate, sickle shaped, above subcomplanate, below somewhat convex; spire subplanate, with two whorls limbate; foramina six, ovate, context, above limbate.

Locality. Saline county, Nebraska.

NUMMULINIDÆ.

Sub-Family NUMMULITINÆ.

OPERCULINA, d'Orbigny.

Operculina complanata *Defrance, sp.*

PLATE E, FIGS. 5, 37, 39.

"*Operculum minimum*," Plancus, 1739. Conch. Min., p. 18, pl. iii, fig. 1, A, B, C.
Lenticulites complanata Defrance, 1822. Dict. Sci. Nat., vol. xxv, p. 453.
Lenticulites complanata Basterot, 1825. Mem. Geol. Env. Bordeaux, pt. i, p. 18.
Operculina complanata d'Orbigny, 1826. Ann. Sci. Nat., vol. vii, p. 281, pl. xiv, figs. 7–10, Modèle No. 80.
Operculina ammonea Leymerie, 1846. Mem. Soc. Geol. France, ser. 2, vol. i, p. 359, pl. xiii, fig. 11, a, b.

Operculina complanata RÜTIMÉYER, 1850. Schweizer Nummuliten-terrain, p. 108, pl. iv, fig. 56.
Operculina arabica CARTER, 1853. Journ. Bombay Br. R. Asiatic Soc., vol. iv, p. 437, pl. xviii.
Operculina hardiei d'ARCHAIC and HAIME, 1853. Descr. Anim. Foss., du groupe nummulitique d l'Inde, p. 346, pl. xxxv, fig. 6, a, b, c.
Operculina complanata PARKER and JONES, 1861. Ann. and Mag. Nat. Hist., ser. 3, vol. viii, p. 229.
Operculina studeri KAUFMANN, 1867. Geol. Beschreib. des Pilatus, p. 151, pl. ix, figs. 1, 2.
Operculina marginata, Id., Ibid., p. 152, pl. ix, fig. 4.
Operculina complanata SCHWAGER, 1877. Boll. R. com. Geol. D'Ital., p. 17, pl. fig. 22.
Operculina complanata MOEBIUS, 1880. Foram. von Mauritius, p. 104.
Operculina complanata BRADY, 1884. Report on Foram., H. M. S. Challenger, Zool., vol. ix, p. 743, pl. cxii, figs. 3, 4, 5, 8.
Operculina complanata WOODWARD and THOMAS, 1885. Thirteenth Annual Report, Geol. and Nat. Hist. Surv. Minn., p. 175, pl. iv, fig. 35.

Lenticulites planulata LAMK., Ann. du Mus. d'Hist. Nat. "Coquille lenticulaire, lisse et ressemblant à une petite nummulite à centre un peu convexe des deux cotés, à cloisons courbes et bombées dans le sens de l'accroissement de la coquille : elle est lisse, et l'on voit extérieurement la forme des cloisons. Largeur, deux lignes : épaisseur une demi-ligne."

L. planulata. Shell lenticular, smooth and resembling a little nummulite, with centre somewhat convex on both sides, partitions curved, swelled in the direction of growth of the shell, smooth, and the form of the partitions can be seen on the exterior. Width 2 lines, thickness ½ line.

L. complanata DEF. "Cette espèce a beaucoup de rapports avec la précédente : mais il est aisé de la distinguer par son grand aplatissement. On l'a trouvée à Anvers, près de Pontoise, à Dax, à Loignan près de Bordeaux, à Boutonnet près de Montpellier, et en Italie dans les couches qui paroissent appartenir au calcaire coquillier grossier."

L. complanata DEF. This species very much resembles the preceding, but is easily distinguished by its great flatness. Found at Antwerp near Pontoise, Dax, Loignan near Bordeaux, Boutonnet near Montpellier, and in Italy in the Calcaire grossier beds (which appear to belong to the Middle Eocene).

Locality. Meeker county and northeastern Minnesota; South Chicago, Illinois.

OPERCULINA COMPLANATA var. GRANULOSA *Leymerie.*

PLATE E, FIG. 38.

Amphistegina fleuriausi d'ORBIGNY, 1826. Ann. Sci. Nat., vol. vii, p. 304, No. 7 (name only), fide Reuss.
Operculina granulosa, LEYMERIE, 1846. Mem. Soc. Geol, France, ser. 2, vol. i, p. 359, pl xiii, fig. 12, a, b.
Amphistegina fleuriausi REUSS, 1861. Sitzungsb. d. k. Ak. Wiss. Wien, vol. xliv, p. 308, pl. i, figs. 10, 12.
Operculina irregularis REUSS, 1864. Denkschr. d. k. Acad. Wiss. Wien, vol. xxiii, p. 10, pl. i figs. 17, 18.
Operculina granulata GÜMBEL, 1868. Abhandl. d. k. bayer. Akad. d. Wiss., II, cl. vol. x, p. 663, pl. ii, fig. 111, a, b.
Operculina var. *granulosa* BRADY, 1884. Report on Foram., H. M. S Challenger, Zool., vol. ix, p. 743, pl. cxii, figs. 6, 7, 9, 10.
Operculina complanata var. *granulosa* WOODWARD and THOMAS, 1885. Thirteenth Annual Report, Geol. and Nat. Hist. Surv. Minn., p. 175, pl. iv, fig. 36.

Operculina granulosa. B, 12, a, b, c. "Cette petite operculine, que l'on trouve dans les mêmes gisements que la précédente, nous parait devoir en être séparée. Elle est constamment plus petite ; ses cloisons, qui se montrent enformant un léger relief à la surface du test infiniment mince qui renferme les spires, sont ici proportionnellement plus serrées. Cette espèce très plate se compose de 3 à 4 tours de spire. Elle porte à sa surface, de chaque coté, un certain nombre de fines granulations qui se trouvent irrégulièrement distribuées sur les petites cotes en relief qui correspondent aux cloisons interieures. Ces points saillants, rares sur les derniers tours, se trouvent agglomérés au centre chez beaucoup d'individus. Diamètre, 4 à 5 millim."

Operculina granulosa. B, 12 a, b, c. This little *Operculina*, which is found in the same layers as the preceding (*O. ammonea*), appears to us worthy of separation. It is uniformly smaller ; its partitions, which form a slight relief upon the surface of the very thin shell which encloses the whorls, are proportionally more approximate. This species is very flat, and is made up of 3 or 4 spirals. It carries on its surface on each side, a number of fine granulations, which are found irregularly distributed upon the little elevations which correspond to the interior partitions. These projecting points, scarce upon the last whorls, are found crowded towards the centre in many individuals. Diameter 4 to 5 mm.

As there seems to be some doubt and difference of opinion in regard to the species and variety, we will give in addition to the above description the generic diagnosis of H. B. Brady.

"The test of the typical *Operculina* is a thin complanate disk, composed of three or four broad convolutions symmetrically arranged and equally visible on both faces. The central portion of the disk is usually somewhat thicker than the outer whorls, and not unfrequently almost umbonate ; the earlier convolutions are more or less embracing, the later whorls evolute. The segments are usually very numerous, of gradually increasing size, and typically very short in the direction of growth, as compared with their width radially ; they are for the most part produced on a uniform plan, but near the finish are often irregular, both as to shape and size (Pl. cxii, figs. 3, 4 and 6, Rept. Foram. Challenger). The exterior is sometimes smooth, but, more frequently, either the sutures or the surface of the chambers, or both, are ornamented with exogenous granules, papillæ or tubercles, which, as a rule, are more strongly developed near the centre than on the later whorls ; and in the small northern variety of the genus, the septal lines and periphery are distinctly limbate. The general aperture is a straight or slightly curved fissure at the inner margin of the final segment, close to the periphery of the previous convolution ; but the test has frequently also a number of secondary orifices, in the form of small circular pores on the face of the terminal segment. The septa are double, and the skeleton is furnished with a system of canals the general features of which are analogous to that of *Nummulites*."

Locality. Meeker county, Minnesota. Specimens of this variety have been identified in the Eocene at Jackson, Mississippi.

Sub-Family 2. POLYSTOMELLINÆ.

NONIONINA, d'Orbigny.

Nonionina scapha *Fichtel* and *Moll. Sp.*

PLATE E. FIGS. 35. 36

Nautilus scapha Fichtel and Moll, 1803. Test. Micr., p. 105, pl. xix, figs. d–f.
Nonionina sloani d'Orbigny, 1839. Foram. Cuba, p. 68, pl. vi, fig. 18.
Nonionina scapha Parker and Jones, 1860. Ann. and Mag. Nat. Hist., ser. 3, vol. v, p. 102, No. 4.
Nonionina boneana Reuss, 1863. Bull. Acad. Roy. Belg., ser. 2, vol. xv, p. 156, pl. iii, figs. 47, 48.
Nonionina scapha Brady, 1865. Nat. Hist. Trans., Northd. and Durham, vol. i, p. 106, pl. xii, figs. 10, a, b.
Polystomella crispa var. (*Nonionina*) *scapha* Parker and Jones, 1865. Phil. Trans., vol. clv, p. 404, pl. xiv, figs. 37, 38; pl. xvii, figs. 55, 56.
Nonionina scapha Brady, 1884. Report on Foram., H. M. S. Challenger, Zool., vol. ix, p. 730, pl. cix, figs. 14, 15 and 16?

"Testa spiralis involuta subovalis, utrinque *umbilico* impresso parvo, lateribus mediocriter convexis (minus quam in præcedente Non. faba, sed magis quam in sequente N. crepidula); *dorso* obtuso; articulis duodecim conspicuis, subelevatis, lævibus; *dissepimentis* antrorsum mediocriter convexis, non omnibus ex centro radiantibus, sed tribus ultimis parum extravagantibus; *plano orali* oblongo—subcordato convexo; *orificio* (in specimine obvio unico partim detrito) præsumtive, uti in aliis similibus, lineari parabolice arcuato."

Shell spiral, involute, suboval, slightly umbilicate on both sides, sides moderately convex (less than in the preceding *N. faba*, but more than in the following *N. crepidula*), back obtuse; with twelve conspicuous chambers; subelevate, smooth; partitions moderately convex anteriorly, not all radiating from the centre, the last three a little eccentric; the plane of aperture oblong, subcordate, convex; aperture (in specimen figured somewhat worn away) probably as in similar species, linear parabolic arcuate.

The following description will make the above more comprehensible.

"The test of *Nonionina scapha* is of elongate oval contour, and more or less compressed, the peculiar form being due to the rapid increase in size of the later segments. This increase is not merely in the length of the chambers, but also in their thickness. The peripheral edge of the later portion of the test is obtuse or rounded, and the exposed septal face of the final segment varies from oval to more or less cordate." Brady, *loc. cit.*

Locality. South Chicago, Illinois.

III. COCCOLITHS and RHABDOLITHS.

PLATE E, FIGS. 1, 2.

The nearest representative of the typical chalk of England and continental Europe with which we are familiar, is found where the Cretaceous rocks are exposed along the Upper Missouri and Niobrara rivers. It there forms bold bluffs for many miles, and the name "Chalk" is very properly applied to it, from the fact that, like the chalks of Europe, it is largely composed of Foraminifera and coccoliths, to which, in these formations, is added the more recently discovered rhabdolith. It has long been known that European chalk was largely composed of Foraminifera, but it is only of late years and with improved microscopes that attention has been called to these minute calcareous objects now known as "coccoliths", and yet more recently that the "rhabdoliths" have been noticed. Ehrenberg first recognized coccoliths associated with Foraminifera, as forming an important constituent of chalk, and called them "morpholites of chalk." The name by which they are now known was given them by Prof. Huxley in 1858, who found them to be characteristic of many deep-sea sediments. Dr. Wallich called them coccospheres. They have been carefully studied by Sorby, Häckel, Schmidt and many others, but none of them seem to know their true nature or to be able to place them in any appropriate group.

Of rhabdoliths, Dr Geo. M. Dawson, in his valuable paper, "Foraminifera, Coccoliths and Rhabdoliths from the Cretaceous of Manitoba" (*Canadian Naturalist*, April, 1874), writes as follows: "Rhabdoliths were first discovered by Dr. O. Schmidt in 1872 (*Ann. and Mag. Nat. Hist.*, 1872), in the Adriatic sea, in association with coccoliths, with which they appear to be closely allied in structure and mode of increase. I do not know that they have heretofore been found in the fossil state. In samples of Cretaceous limestone from Manitoba and Nebraska both coccoliths and rhabdoliths are abundant, and constitute indeed a considerable proportion of the substance of the rock. The rhabdoliths agree closely with those figured by Dr. Schmidt, and pass through nearly the same set of forms as those there represented. The coccoliths agree with those figured in the same place exactly, and also with those found in the English chalk and recent seas. They are in a remarkably good state of preservation. The average diameter of the larger among them is about .003 millimeter, which agrees very nearly with those found in other places. Dr. Gümbel has discovered coccoliths in limestones of many ages, and they appear, though so minute even in comparison with Foraminifera, to have played no unimportant part in the fixation of calcareous matter and the building up of the crust of the earth."

Coccoliths and rhabdoliths, associated with Foraminifera, abounded in most of the soft Cretaceous limestone from New Ulm, Minnesota, and some of the chalk rock was mostly composed of them, and was almost entirely free from sand.

REFERENCES.

1858. *Huxley, T. H.* Deep-sea Soundings in the North Atlantic Ocean, between Ireland and Newfoundland, made in H. M. S. Cyclops, Lieutenant Commander Joseph Dayman, in June and July, 1857.

1861. *Sorby, H. C.* On the Organic Origin of the so-called "Crystalloids" of the Chalk. Ann. and Mag. Nat. Hist., ser. 3, viii, pp. 193—200, wood cuts.

1861. *Wallich, G. C.* Remarks on some novel Phases of Organic Life, and on the Boring Powers of minute Annelids, at great Depths in the Sea. Ann. and Mag. Nat. Hist., ser. 3, viii, pp. 52–58, 3 wood cuts.

1862. *Wallich, G. C.* Further Observations on some novel Phases of Organic Life at great Depths in the Sea. Ann. and Mag. Nat. Hist., ser. 3, ix, pp. 30, 31.

1863. *Wallich, G. C.* Further Observations on Amœba villosa and other indigenous Rhizopods. Ann. and Mag. Nat. Hist., ser. 3, xi, p. 445.

1868. *Huxley, T. H.* On some Organisms living at Great Depths in the North Atlantic Ocean. Quart. Journ. Mic. Soc., 1868, pp. 203–212.

1869. *Thomson, W.* On the Depths of the Sea. Ann. and Mag. Nat. Hist., ser. 4, iv, pp. 112–124.

1870. *Gümbel, C. W.* Vorlaufige Mittheilungen uber Tiefseeschlamm. Neues Jahrbuch fur Min., 1870, pp. 753–767.

1870. *Schmidt, O.* Über Coccolithen und Rhabdolithen. Sitzungsb. der kais. Akad. d. W. math. naturw. lxii, Bd. Abth. 1 of I, II.

1872. *Schmidt, O.* On Coccoliths and Rhabdoliths. Ann. and Mag. Nat. Hist., ser. 4, x, pp. 359–370, pls. xvi, xvii.

Translation by W. S. Dallas, F. L. S.

1873. *Gümbel, C. W.* Coccolithen im Eocanmergel, fehlen dem Tiefseeschlamm der bayerischen Alpen; Untersuchung dichter Kalksteine: Arten der Oolith-Bildung. Neues Jahrbuch fur Min , 1873, pp. 299–304.

1873. *Thomson, C. W.* The Depths of the Sea, pp. 412–415, figs. 63, 64.

1874. *Dawson, G. M.* Note on the Occurrence of Foraminifera, Coccoliths, etc., in the Cretaceous Rocks of Manitoba. Can. Nat., vii, pp. 252–257.

1875. *Dawson, G. M.* Report on the Geology and Resources of the region in the vicinity of the Forty-ninth Parallel, from the Lake of the Woods to the Rocky Mountains, p. 80.

Cretaceous and Tertiary Rocks of the vicinity of the Forty-ninth Parallel—Pembina Escarpment to Wood Mountain, in which he says the finer part of the softer portions of the rock is composed almost entirely of the extremely minute bodies which are included under the general name, *Coccoliths* and *Rhabdoliths*. These are now known to belong to minute pelagic vegetable organisms.

1875. *Wallich, G. C.* On the true nature of the so-called "Bathybius," and its alleged function in the Nutrition of the Protozoa. Ann. and Mag. Nat. Hist., pp. 122–339.

1888. *Agassiz, A.* Three Cruises of the Blake, I. Bull. Mus. Comp. Zool. xiv, p. 209.

IV. RADIOLARIA, Etc.

Radiolaria, *Muller.*

PLATE E, FIGS. 3-9.

An order of Rhizopoda which possess a siliceous test, or siliceous spicules, a central capsule, and peculiar yellow or brownish-yellow cells. Among the Radiolaria are great numbers of minute and beautiful organisms when living, and in some formations in their fossil state. They are widely diffused, and have been discovered in nearly every ocean and sea. Ehrenberg found them at Cuxhaven and in dredgings from the Antarctic seas. Bailey describes them from the Atlantic, Muller from the Mediterranean, Häeckel from the Adriatic, Wallich from the Indian ocean, and Carpenter and others from deep-sea soundings of the North Atlantic. The siliceous shells of the *Polycystina* (one of the families of the Radiolaria to which most of our specimens belong) accumulated in thick deposits during the latest geological periods, and myriads of their exquisite microscopical forms are found in many of the strata of Sicily, Greece, Bermuda, Barbadoes, New Zealand, California, and Virginia, and are now noted in the Cretaceous of Minnesota, Nebraska and Illinois. While somewhat abundant in some of the material, which yielded a few good specimens, they were mostly so fragmentary that we will not attempt to describe or identify them, but have figured a few specimens. They occurred most abundantly in the Nebraska clay, but the best preserved forms were from a soft dark-brown shale from near Rainy lake, northeastern Minnesota, and a few fairly preserved specimens were secured from Calumet (Illinois) clay.

Porifera.

PLATE E, FIGS. 17-29.

Sponge spicules, mostly fragmentary, were quite frequent in some of the samples of material from Minnesota and Nebraska, but the spiculation of the sponge varies so greatly in the same species and even in the same collection, that we will not venture to place them, but have figured a few specimens on plate E, figs. 17–29, of which 24–27 are probably of fresh water and the others of marine origin.

Echinodermata.

PLATE E, FIGS. 30-32.

Many fragments of spines or plates, probably of Echinodermata, well known marine animals, were found in some of the specimens of clay from Nebraska, specimens of which we have figured in plate E, figs. 30–32.

Miscellaneous.

The well-defined organisms shown on plate E, figs. 10–16, we do not recognize. Fig. 15 is apparently a fish's tooth.

In the Chicago clay there are some very curious arenaceous cases, looking as if at some time they had covered very minute rootlets, or other organisms, which had decomposed, leaving these cases, which closely resemble rhizocarps of the genus *Aschemonella*, as figured by H. B. Brady.

LIST OF THE MICROSCOPIC ORGANISMS FOUND IN THE CRETACEOUS FROM MINNESOTA, NEBRASKA AND ILLINOIS, SHOWING THEIR DISTRIBUTION.

FORAMINIFERA.	Meeker county, Minnesota.	Little Fork river near Rainy lake, northeastern Minn.	Saline county, Nebraska.	South Chicago, Illinois.	New Ulm, Minnesota.
Trochammina inflata Montagu, sp.		* ?		*	
Textularia agglutinans d'Orbigny	*	*		*	
" carinata d'Orbigny			*		
" globulosa Ehrenberg	*	*	*	*	
" turris d'Orbigny	*		*	*	
Spiroplecta americana Ehrenberg	*		*	*	
Gaudryina pupoides d'Orbigny	*	*	*		
Verneuilina pygmæa Egger, sp			*	*	
Bulimina affinis d'Orbigny			*		
" pupoides d'Orbigny	*		*	*	
Pleurostomella subnodosa Reuss			*	*	
Bolivina dilatata Reuss			*		
" punctata d'Orbigny	*		*	*	
Lagena aspera Reuss			*		
" hispida Reuss		*			
" favosa-punctata Brady	*				
Nodosaria (D.) communis d'Orbigny			*		
Uvigerina asperula Czjzek			*		
" canariensis d'Orbigny	*		*		
Globigerina bulloides d'Orbigny	*		*	*	
" cretacea d'Orbigny	*	*	*	*	
" marginata Reuss	*	*	*	*	
" sacculifera Brady		*			
Orbulina universa d'Orbigny	*		*	*	
Anomalina ammonoides Reuss, sp			*	*	
Pulvinulina haueri d'Orbigny, sp.		*			
" menardii d'Orbigny			*		
Operculina complanata Defrance, sp	*	*		*	
" " var. granulosa Leymerie	*				
Nonionina scapha Fichtel and Moll, sp				*	
COCCOLITHS					*
RHABDOLITHS					*
RADIOLARIA		*	*	*	
SPONGE SPICULES	*		*		
SPATANGUS SPINES			*		

OTHER CRETACEOUS FOSSILS IN MINNESOTA.

In the course of the survey in different parts of the state fossils from the Cretaceous have been found, sometimes obtained from beds in outcrop, and sometimes from the drift. In order that this volume may contain all that is known of the fauna of the Cretaceous, so far as referable to the state, these scattered data are presented herewith.

Mr. J. H. Kloos reported the existence of the Cretaceous in the Sauk valley in 1872,* where it was described as lying on the Archean granites, but separated from them by a layer of kaolin. Fossils found near Richmond were identified for him by Mr. F. B. Meek. They consisted of casts of *Inoceramus problematicus*, impressions apparently of *Ammonites percarinatus*, scales of cycloid fishes, and a small shark's tooth allied to *Corax* or *Galeus*. *Scaphites larviformis*, or some nearly allied form, was also recognized by some drawings sent Mr. Meek. These fossils were thought to be indicative of the Fort Benton group. Kloos also reported *Baculites* from Nobles county, and states thatthe highest beds of the Cretaceous series probably exist in the southern part of the state.

Cretaceous outcrops are described in the first and second annual reports, but no fossils, except such as are mentioned in the report of Dr. Lesquereux (foregoing), were named.

In 1873, Rev. E. Alden presented the survey with some Cretaceous materials obtained in sinking a well near Marshall, in Lyon county, at 36 feet below the surface. Along with some shale and lignite were the fossils *Nucula cancellata* M. and H., and *Placenticeras placenta* Dekay (*sp*), museum register numbers 2279 and 2282, indicating the Fort Pierre or Fox Hills group. These were said to have been obtained in a bed of "fossiliferous clay."

In 1880, Mr. Warren Upham collected specimens of Cretaceous fossils on the west bank of the Mississippi river, "40 rods southeast of the mouth of the Main Two rivers," in Morrison county, which he identified (see vol. ii, final report, p. 602) as *Margaritana*, very nearly allied to *M. nebrascensis* M. and H., "from which it differs in having no considerable depression or corrugation on the sides," a *Unio*, probably *U. danæ* M. and H., and *Unio subspatutatus* M. and H. Associated with these is a seam of lignite, and a bed of clay resembling bauxite. He also reports a perfect tooth of *Otodus appendiculatus* Ag., found on a sand-bar of Two rivers about a quarter of a mile above its mouth.

In 1878, Mr. C. L. Herrick found some Cretaceous limestone fragments, and rounded limestone pebbles at lake Minnetonka in the drift. These contain fragments of the bones, plates, scales and teeth of fish, and impressions of some mollusks resembling *Ostrea congesta* Con., and of a small shell that appears to be *Neæra ventricosa* M. and H. These are museum register Nos. 5138 and 5144. The limestone apparently is from the Niobrara, but *Neæra* is not known from this horizon, but from the Fox Hills group.

In 1884, Mr. S. F. Alberger, of Mankato, was using a siliceous Cretaceous conglomerate to supply silica to clay which he employed for fire-brick.† In the coarser screenings were found numerous rounded. fragments of corals and brachiopods. Favositoids, cyathophylloids and masses of amorphous chert were most numerous. A well preserved *Heliolites* points to the existence of the Niagara as a formation able to supply such gravel to the waters of the Cretaceous ocean in that vicinity. This fact goes with others, mentioned in this volume, to indicate that the Niagara of Iowa probably was connected once with that of Manitoba.

Prof. A. F. Bechdolt has found from time to time, Cretaceous fossils in the vicinity of Mankato, viz. a fish-tooth in the sand of the alluvium of Le Sueur river, a vertebra of a fish, distinctly osseous, from ferruginous sand and gravel thrown out of a ditch dug for city water. This vertebra is biconcave and an inch and a half in length and an inch across the ends. The sides are buttressed as if with remnants of processes. He also reports the finding in a bank of clay formerly used for pottery, on Glenwood av., Mankato, of a number of pieces of shaly limestone with Inoceramus very plainly marked upon them.

In 1888, some Cretaceous fossils were found by the writer in an unorganized township in Redwood county (T. 111, 38). These had been thrown out from excavations for cellars, or in digging wells. They are museum register Nos. 6742–45. The first is *Scaphites nodosus* var. *quadrangularis* M. and H., the second *Inoceramus cripsii* var. *barabini* Norton, the third is *Lucina occidentalis* Morton *sp.*, and the fourth *Viviparus raynoldsanus* M. and H. The first three are Fort Pierre species and the last is known as a species of the Fort Union group.

---

*A Cretaceous basin in the Sauk valley, Minnesota. J. H. Kloos, Am Jour. Sci. (3), III, 17; 1872.
This locality and all the phenomena were described by Mr. Kloos subsequently at greater length in Zeit. d. Ges. f. Erd. zu Berlin, Bd. xii, 1877, of which a translation was published in the 19th annual report of the Minnesota survey.

†Thirteenth Annual Report, p. 144.

In 1887, Mr. H. V. Winchell discovered Cretaceous shales and lignites on the Little Fork, and on the Bowstring (or Big Fork) river,* but besides the foraminifers already described by Messrs. Woodward and Thomas, no fossil was identified specifically. Mr. Winchell mentions "cycloid fish scales and other fossiliferous remains."

As to the eastward extension of the Cretaceous sea in Minnesota, there is much reason to suppose that it covered the whole state. In the first annual report of the Minnesota survey† attention was called to certain lignites and green clays and shales which exist in the Grand Traverse region in the Lower Peninsula of Michigan, which Mr. A. D. White, of the Michigan survey of 1860, did not regard as belonging to the drift deposits with which they had usually been classed. In 1872, soon after the writer entered upon the Minnesota survey, information was sent to him by Prof. Frank H. Bradley, of a memorandum by Mr. Thomas Daniels, C. E., made in 1865, purporting to describe a "half-mile outcrop of 'Eocene' fossiliferous beds on the Nemacogin river in Wisconsin, about half way from St. Paul to Superior city, and perhaps thirty miles east of a straight line connecting those places." This memorandum was sent, at his request, to the late Prof. R. D. Irving; but, aside from a brief reference to it in the American Journal of Science‡ there has been no published note of Cretaceous at that point in Wisconsin. In reviewing the clays of the state of Minnesota for brick-making, in 1880,§ an alliance was shown to exist between the alkaline blue clays, referable to the Cretaceous ingredient in them, making on burning, a cream-colored brick, and the blue drift-clays of the vicinity of Milwaukee which also make cream-colored brick; and this alliance was thought to point to the former existence of a Cretaceous area in the region north from Milwaukee whence the same Cretaceous ingredient could have been supplied to the Milwaukee drift clays. At Chicago, Dr. Edmund Andrews has shown that the water derived from the till, on analysis, contains a greater "saline" ingredient than water from recent clays or from the surface. There is no Devonian or Silurian shale or clay that is known to be so charged with alkaline elements as the Cretaceous beds of the west to which this effect can be attributed. Quite recently Mr. B. W. Thomas has found, as stated by Messrs. Woodward and Thomas in this volume (page 28), the same species of Foraminifera, in limited numbers, in the boulder-clay at Chicago, as are distributed in the boulder-clays throughout Minnesota, and which are referable directly to the Cretaceous. Lastly, in studying the iron ores of the state of Minnesota, in 1889 and 1890, certain analogies were noticed‖ between the Cretaceous iron ores of Minnesota and certain limonitic ores of Wisconsin, allying them all together, and pointing to a common origin, thus extending the waters of the Cretaceous ocean over a large area in central Wisconsin.

Notwithstanding all these indications (which are given for what they may be worth) there is not yet any known locality, between Minnesota and the Grand Traverse region of Michigan, where any actual outcrop of such strata is known.

---

*Sixteenth Annual Report, pp. 403, 431, 434.
†Op. cit. pp. 110-11, 1872.
‡Op. cit. vol. x, [3], 307.
§Preliminary report on the Building stones, etc., of Minnesota, 1880, in the Eighth Annual Report.
‖The Iron Ores of Minnesota. Bulletin No. vi 1891, p. 151.

PLATE C.

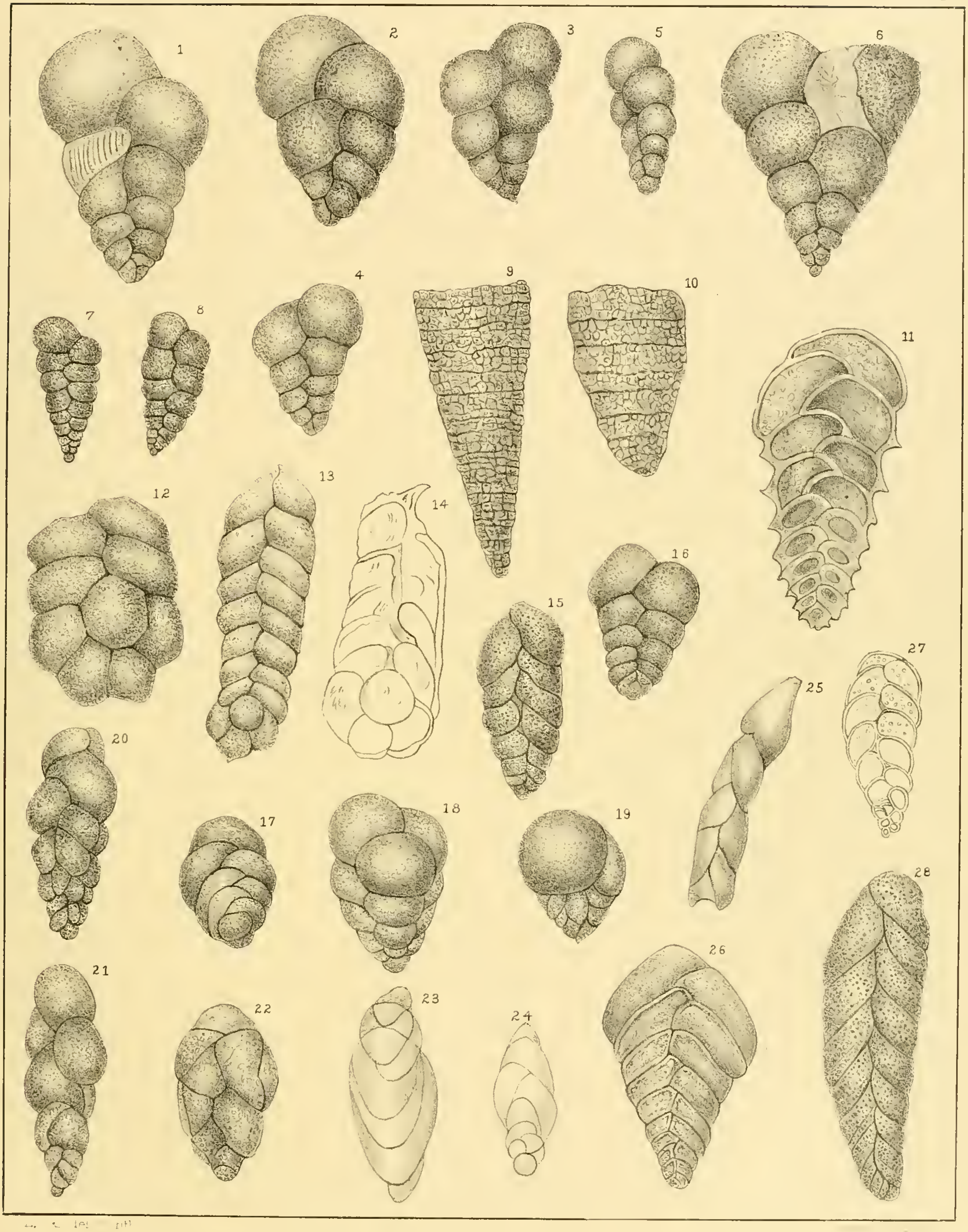
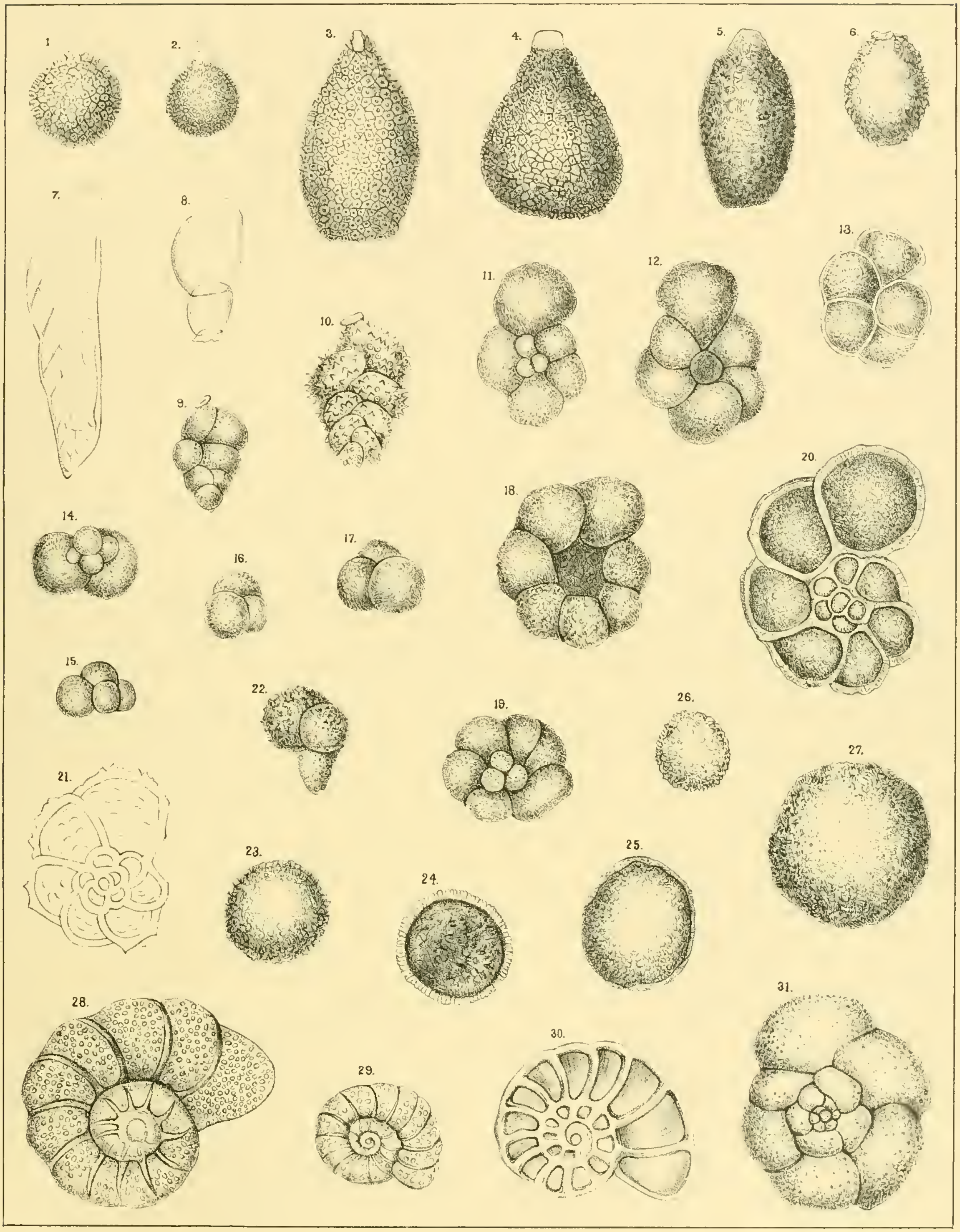

1
2
3
5
6
4
7
8
9
10
11
12
13
14
16
15
27
25
20
17
18
19
28
26
21
22
23
24

PLATE D.

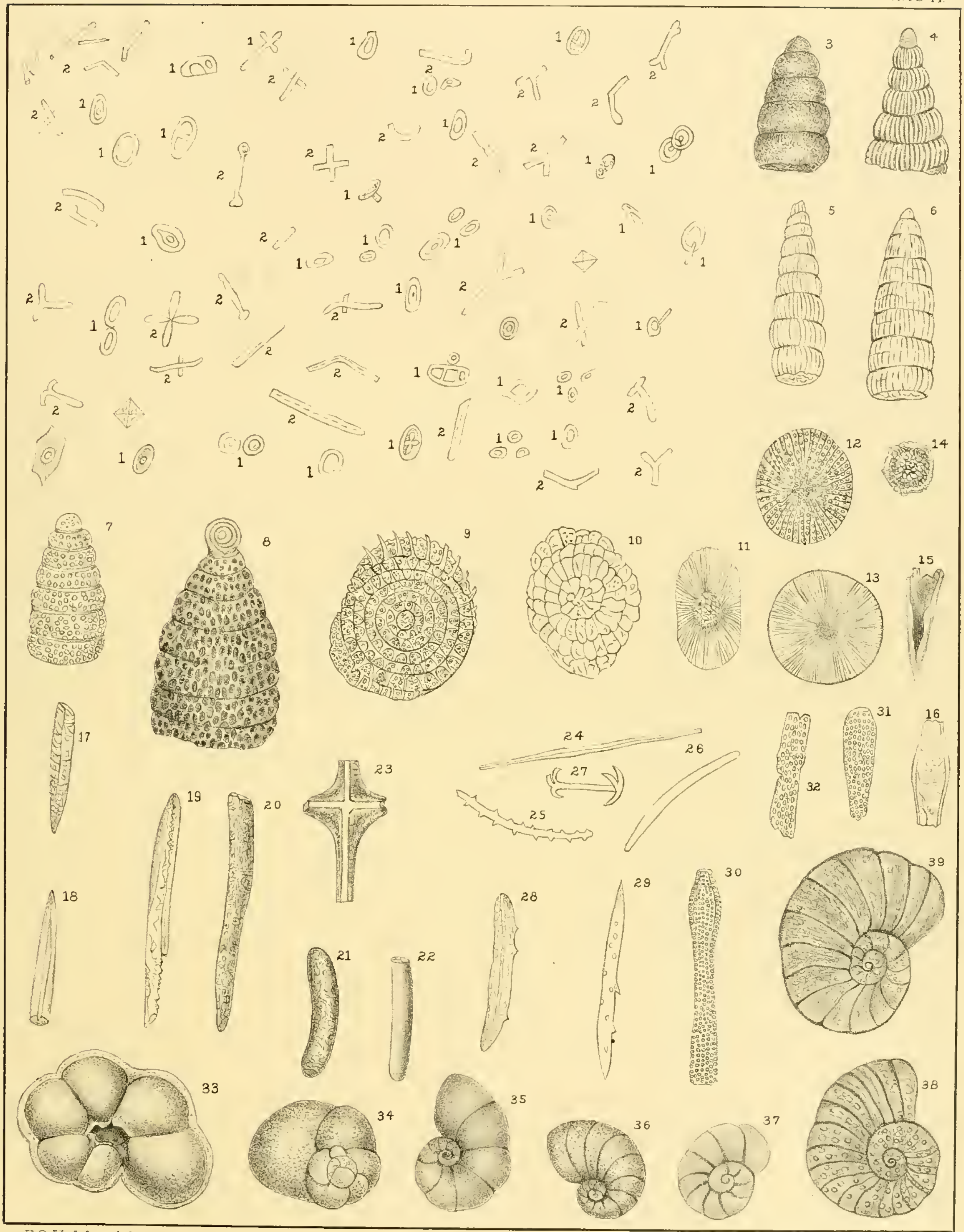
	Page.
Fig. 1. Lagena aspera Reuss. Nebraska	35
Fig. 2. Lagena hispida Reuss	35
Figs. 3 to 6. Lagena favoso-punctata Brady	36
Figs. 7 and 8. Nodosaria communis d'Orbigny. Nebraska	36
Fig. 9. Uvigerina canariensis d'Orbigny	39
Fig. 10. Uvigerina asperula Czjzek. Nebraska	39
Figs. 11 to 17. Globigerina bulloides d'Orbigny	40
13 to 17. Specimens from Nebraska.	
Figs. 18 and 19. Globigerina cretacea d'Orbigny	41
Figs. 20 and 21. Globigerina marginata Reuss	42
Fig. 22. Globigerina sacculifera Brady	42
Figs. 23 to 27. Arbulina universa d'Orbigny	43
Figs. 28 and 29. Anomalina ammonoides Reuss	14
Fig. 30. Anomalina ammonoides (sp.?) Reuss	44
Fig. 31. Trochammina inflata Montagu, sp?	28



Del DWT Lith E C U

THE HENDERSON ACHERT-KREBS LITH CO CINCINNATI

PLATE E.



E.O.U. del. et lith

MACBRAIR LITH

PLATE F.

		Page.
Figs. 1 to 4.	RECEPTACULITES OWENI Hall	57
1.	The upper or inner surface of a large fragment. Mineola, Minnesota.	
2.	A portion of the under surface of a specimen in which the head plates are surmounted by a knob-like projection. Twelve miles south of Cannon Falls, Minn.	
3.	A small portion of a large specimen in which are shown twelve radiating canals in each depression left by the spicular head plates.	
4.	Another portion of the same specimen in which the casts of the radiating canals are removed, leaving the clay fillings between the head plates serrated. Galena shales near Fountain, Minn. Minnesota Geological Survey collection.	
Figs. 5 and 6.	ISCHADITES IOWENSIS Owen, sp	64
	View of the under surface and profile of the same specimen, a natural cast of the spaces left between the vertical rays of the spicules. Galena, Wasioja, Dodge county, Minn. Minnesota Geological Survey collection.	
Figs. 7 to 10.	ISCHADITES KŒNIGII Murchison	61
7.	"The base of *Ischadites kœnigii* Murchison, enlarged three times, showing the eight diamond-shaped spicular plates of the nucleus and the plates succeeding them, each having a clearly marked central spot, indicating the center of the spicule." (After Hinde.)	
8.	"A portion of the lateral surface of a specimen, enlarged four times, showing the extension of one of the horizontal rays of each spicule, from beneath the distal angle of the correspoding-summit plate, over the summit plate of the spicule in front of it. In the center of the figure are the modified summit-plates developed at the intercalation of a fresh row of spicules." (After Hinde.)	
9 and 10.	"Portion of the lateral areas of two specimens, in which the surface summit-plates have disappeared, showing the four horizontal rays of independent spicules. The rays are often incomplete, and they frequently overlap each other. Enlarged three times." (After Hinde.)	
Figs. 11 and 12.	LEPIDOLITES DICKHAUTI Ulrich*	67
11.	Surface of a specimen × 10, showing the imbricating character of the head plates.	
12.	View of the inner side of the integument of another specimen, × 10. Lower part of the Cincinnati group, Covington, Ky. Collection of E. O. Ulrich.	
Figs. 13 to 15.	ANOMALOSPONGIA RETICULATA Ulrich	69
13.	A compressed-conical fragment of the natural size.	
14.	Surface of a well preserved fragment × 18, showing the character and arrangement of the spicules.	
15.	Diagrammatic view of one of the spicules × 18. Cincinnati group, Covington, Ky. Collection of E. O. Ulrich.	
Figs. 16 to 18.	RAUFFELLA FILOSA Ulrich	75
16.	View of an average specimen of the natural size.	
17 and 18.	Small parts of the surface of two specimens × 4, showing variable appearance of the spicular network. Middle third of the Trenton shales, St. Paul, and Minneapolis. Collection of E. O. Ulrich.	
Figs. 19 and 20.	RAUFFELLA PALMIPES Ulrich	76
19.	Small specimen with the radial leaves mostly broken away; natural size. Middle third of the Trenton shales, Minneapolis. Geological Survey collection.	
20.	Surface (×9) of a well preserved specimen in the collection of E. O. Ulrich. Shows the hirsute appearance of the external spicule layer.	
Figs. 21 to 23.	SOLENOPERA COMPACTA Billings	80
21.	A figure of a small mass. Trenton shales near Cannon Falls, Minn. Minnesota Geological Survey collection.	
22 and 23.	A longitudinal and transverse section × about 50. (After Nicholson.)	

*The drawings for figures 11 to 20 are by Mr. Ulrich.

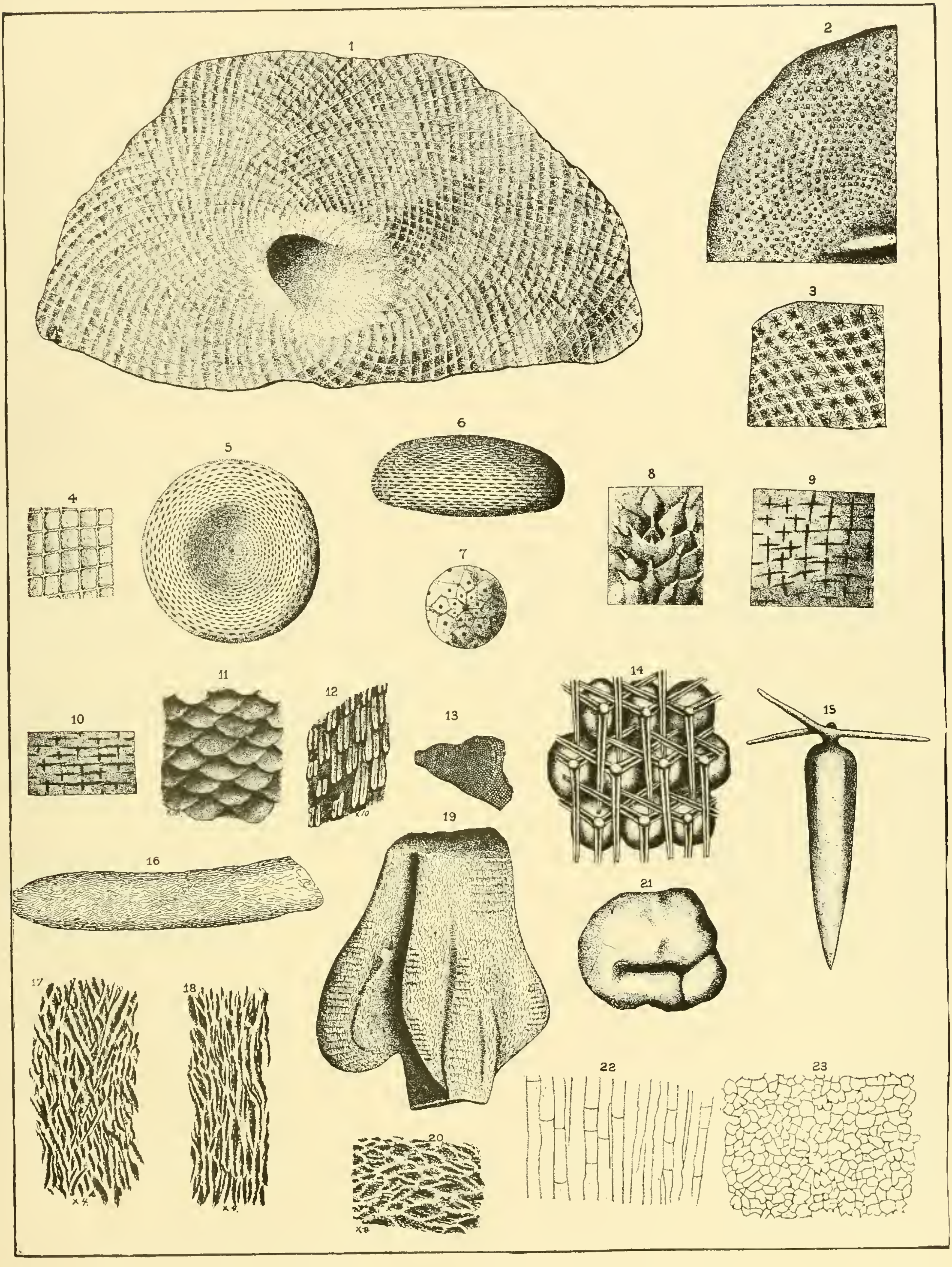

1
2
3
4
5
6
7
8
9
10
11
12
x10
13
14
15
16
17
x4
18
19
20
x8
21
22
23

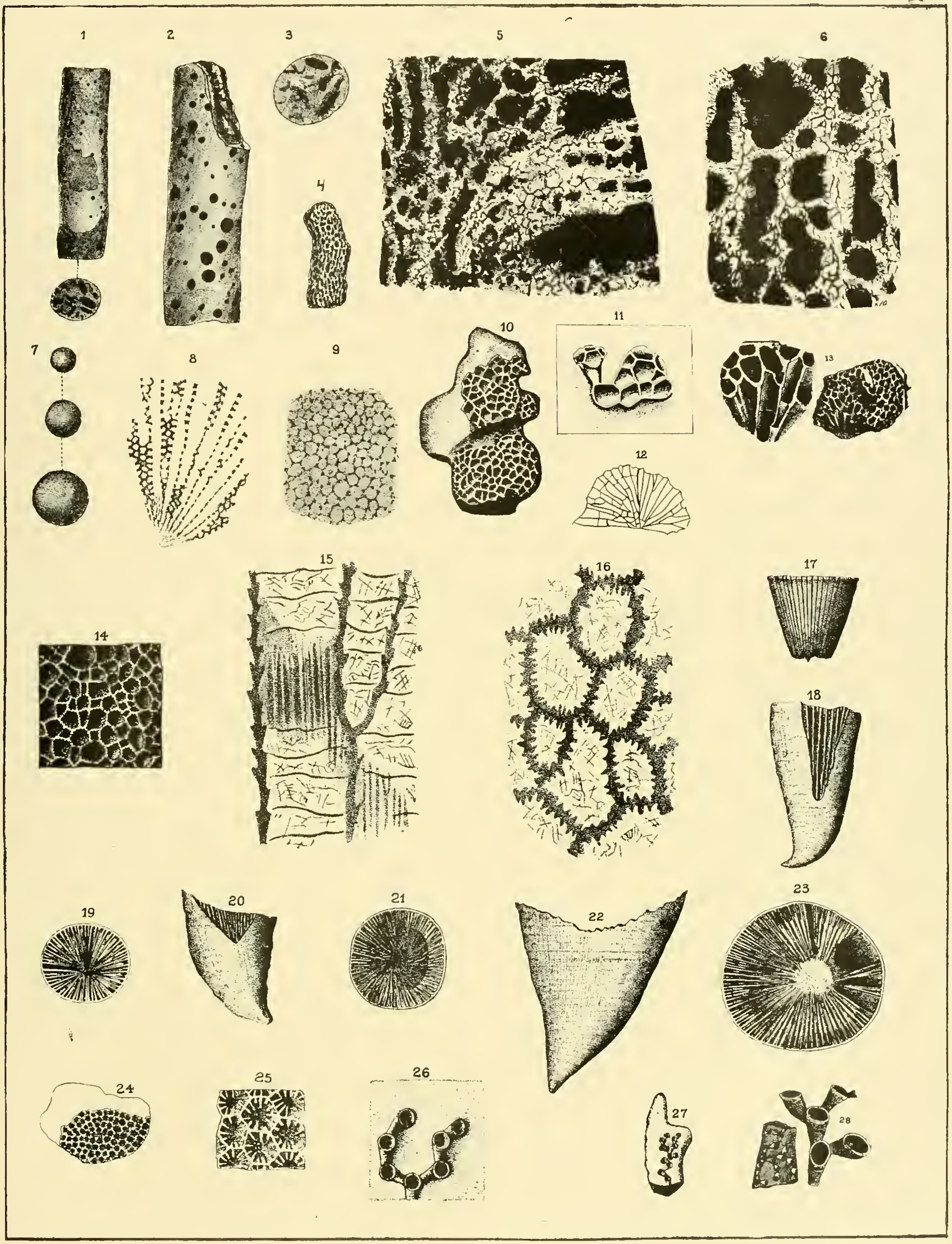
PLATE G.

		Page.
Figs. 1 to 3.	Cylindrocœlia minnesotensis Ulrich*..	78
1.	A small specimen, covered in part by a bryozoan; natural size. Also end view of same, showing numerous unequal canals.	
2 and 3.	A large fragment having canals of unusual size: and an end view of the same; natural size. Upper part of the middle third of the Trenton shales, St. Paul, Minn. Collection of E. O. Ulrich.	
Figs. 4 to 6.	Heterospongia subramosa? Ulrich..	79
4.	A fragment of the natural size, doubtfully referred to this species. Hudson River group, Spring Valley, Minn. Collection of E. O. Ulrich.	
5 and 6.	Vertical and tangential sections, × 10, of a typical specimen from Cincinnati, O.	
Figs. 7 to 9.	Hindia parva Ulrich	79
7.	Three specimens of this species, showing extremes in size so far observed.	
8 and 9.	Vertical and tangential sections × 10. Upper third of the Trenton shales and Galena shales, Goodhue and Fillmore counties, Minn. Collection of E. O. Ulrich.	
Figs. 10 to 13.	Lichenaria typa, gen. et. sp. nov.	83
10.	A large colony of this species growing upon a fragment of *Callopora incontroversa* Ulrich, × 2.	
11.	A small colony in which one of the buds has grown in a manner suggesting *Aulopora*, × 5.	
12.	A longitudinal section through a large colony. Trenton shales, Minneapolis, Minn. University of Minnesota collection.	
13.	A small free mass of this species, of the natural size, and a portion of the same × 3. The latter shows at *a*, and in the space to the right, a pore passing from the parent tube into the base of the buds. This fact is important in this that it indicates a relationship of *Lichenaria* with the *Auloporidæ*, rather than with *Columnaria*, where we have placed the genus provisionally. Middle third of the Treuton shales, St. Paul, Minn. Collection of E. O. Ulrich.	
Figs. 14 to 16.	Columnaria (?) halli Nicholson...	85
14.	A portion of the surface, to show the septal ridges. Trenton shales, St. Charles, Minn. Minnesota Geological Survey collection.	
15.	Part of a vertical section, enlarged five times, showing the tabulæ. (After Nicholson.)	
16.	Part of a transverse section, showing the amalgamation of the walls of the corallites and the marginal septa. (After Nicholson.)	
Figs. 17 to 19.	Streptelasma profundum Owen	88
17.	View of a natural cast of the visceral cavity, the usual mode of occurrence in the Trenton limestone, Minneapolis, Minn.	
18.	An entire specimen in which a portion has been broken away to show the great depth of the body cavity.	
19.	View of the visceral cavity, showing the three fossulæ and the counter septum. Base of the Upper Buff limestone, Mineral Point, Wisconsin. Minnesota Geological Survey collection.	
Figs. 20 and 21.	Streptelasma corniculum Hall	90
20.	An exterior view of a specimen broken so as to show the depth of the visceral cavity.	
21.	View of the visceral cavity to show the twisted nature of the septa. Galena shales, St. Paul, Minn. Minnesota Geological Survey collection.	
Figs. 22 and 23.	Streptelasma rusticum Billings	93
22.	The exterior of an imperfect specimen.	
23.	View of the visceral cavity, showing a distinct pseudocolumella. Hudson River group, Granger, Minn. Minnesota Geological Survey collection.	
Figs. 24 and 25.	Protaræa vetusta Hall, sp..	94
24.	A colony of this species growing on a fragment of a strophomenoid shell.	
25.	A portion of same, enlarged five times, showing the septal ridges. Hudson River group, Spring Valley, Minn. Minnesota Geological Survey collection.	
Figs. 26 to 28.	Aulopora (?) trentonensis, n. sp...	95
27.	A view of a colony of this species; natural size.	
26.	A portion of same enlarged three times.	
28.	An unusually well preserved specimen growing upon *Batostoma winchelli* Ulrich, of the natural size and a portion × 3.5. Middle third of the Trenton shales, Minneapolis, Minn. Collection of E. O. Ulrich.	

* The drawings for figures 1 to 9 are by Mr. Ulrich.

(Sponges and Corals)

Plate G



CHAPTER III.

SPONGES, GRAPTOLITES AND CORALS

FROM THE

LOWER SILURIAN OF MINNESOTA.

BY N. H. WINCHELL AND C. SCHUCHERT.

Sub-kingdom PORIFERA.

Order HEXACTINELLIDÆ, Schmidt.

Sub-order LYSSAKINA, Zittel.

Family RECEPTACULITIDÆ, Roemer.*

Dr. Hinde advances the theory that the sixth or summit ray of ordinary hexactinellid sponges has in the *Receptaculitidæ* been modified so as to form characteristic head-plates. He says (*loc. cit.*, p. 830), "In no other hexactinellid sponge, so far as I am aware, are there any spicules with similarly constituted head-plates; in many, however, no sixth or summit ray is developed, but in some of the abnormal spicules of the Carboniferous sponge, *Hyalostelia smithii*† Young and Young, sp., the sixth ray is in the form of a rounded knob. We have only to consider that the sixth ray in the spicules of the *Receptaculitidæ*, instead of being contracted to a knob merely, as in the Carboniferous sponge, has been developed in a horizontal direction, and by additions to its margins, has assumed the regular rhomboidal or hexagonal

*The above systematic position of the *Receptaculitidæ* is that of Dr. George Jennings Hinde. Students desiring to learn more of the detailed structure of these species and their affinities to other hexactinellid sponges are referred to Dr. Hinde's admirable monograph "On the Structure and Affinities of the Family of the Receptaculitidæ, including therein the Genera Ischadites, Murchison (Tetragonis, Eichwald); Sphærospongia, Pengelly: Acanthoconia, gen. nov., and Receptaculites, Defrance," Quar. Jour. Geol. Soc. London, Vol. XL, pp. 795-848.

In Nicholson and Lydekker's "Manual of Palæontology", Appendix to Vol. II, p. 1563, we learn that the *Receptaculitidæ* have recently formed the subject of an important investigation by Herr Rauff (Zeitschr. d. deutschen geol. Gesellschaft, bd.xl). This contribution we are unable to consult. Since, however, Herr Rauff has concluded that "the *Receptaculitidæ* are not *siliceous* organisms, but that the skeleton was originally *calcareous*, and the *siliceous* examples are the result of silification," Dr. Nicholson is of the opinion that the family "cannot be referred to the Hexactinellid Sponges," and that "its systematic position is still entirely uncertain."

†See Cat. Foss. Sponges, British Museum, pl. 32, fig. 1.

figure by which it is adapted to fit in with the adjoining spicular plates to form an exterior layer to the organism. Strong confirmatory evidence of the theory that the summit plates of the spicules are modifications of the sixth ray in the ordinary hexactinellid spicule, is afforded by the small blunted knob which projects in the center of these summit plates in the best preserved examples of *Sphærospongia*, and traces of which are also present in *Acanthoconia*. In these forms we find the commencement of the sixth or summit ray in the small central knob, from which, as a centre, the plate is developed horizontally by successive marginal additions."

A new species of *Receptaculites*, seen in the collection of Mr. E. O. Ulrich, from the Lower Silurian near Knoxville, Tennessee, has the vertical ray of the spicules with two constrictions, one immediately below the head-plates, and the other near the center of their length.

RECEPTACULITES, Defrance.

PLATE F, FIGS. 1-4.

1827. *Receptaculites*, DEFRANCE. Dictionnaire des Sciences Naturelles, t. 45, p. 5, atlas, pl. 68.
1859. *Receptaculites*, SALTER. Canadian Organic Remains, dec. i, p. 43.
1860. *Receptaculites*, EICHWALD. Lethæa Rossica, p. 427.
1863. *Receptaculites*, HALL. Sixteenth Rep. N. Y. State Cab. Nat. Hist., p. 68.
1865. *Receptaculites*, (partim) BILLINGS. Palæozoic Fossils, vol. i, p. 378.
1865. *Receptaculites*, (partim) BILLINGS. Canadian Naturalist and Geologist, sec. ser., vol. ii, p. 184.
1868. *Receptaculites*, DAMES. Zeitschr. der deutschen geol. Gesellschaft, bd. xx, p. 483.
1875. *Receptaculites*, GÜMBEL. Abhandl. der k. bayer. Akad. der Wissensch. bd. xii, p. 170.
1876. *Receptaculites*, ZITTEL. Handbuch der Palæontologie, pp. 83. 727.
1880. *Receptaculites*, ROMER. Lethæa Palæozoica, p. 285.
1884. *Receptaculites*, HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 821.
1885. *Receptaculites*, JAMES. Jour. Cincinnati Soc. Nat. Hist. vol. viii, p. 163.
1889. *Receptaculites*, NICHOLSON. Manual of Palæontology, vol. i, p. 170, figs. 61a-61d ; vol. ii, p. 1563.
1891. *Receptaculites*, JAMES. Jour. Cincinnati Soc. Nat. Hist., vol. xiv, p. 60.

Description.—"Cup or platter shaped bodies of considerable size, with walls of definitely arranged spicules. The outer surface is formed by the rhomboidal head-plates of the spicules; beneath these are the horizontal rays and robust subcylindrical vertical rays, which are connected with an inner layer or perforated plate. Communication with the exterior was carried on between the margins of the summit-plates of the spicules on the outer surface, and through the cylindrical canals of the inner surface layer, or, according to Gümbel, through intermarginal canals." (Hinde, *loc. cit.*)

According to Nicholson, Rauff concludes that "the *Receptaculitidæ* are spherical or pyriform bodies, with a central closed cavity, the supposed basin-shaped examples being only fragments of the base." *Receptaculites oweni* Hall, is a platter-shaped species attaining a great diameter ; is widely distributed, and of common occurrence in the Galena formation throughout the Northwest. In Minnesota, the diameter of this species is from four to twelve inches, and nearly every specimen obtained preserves the nucleus. Fragments are rare, but when secured prove to be portions not far removed from the nucleus. If *R. oweni* were originally a spherical or pyriform body, we should expect to find fragments of the upper portion, and these could be readily determined by the impression left by the head-plates. Such parts have not been discovered in the Northwest. Further, it is stated that "the genus *Ischadites* agrees essentially with *Receptaculites* in structure, but its skeletal elements are more slender." We fail to find an internal integument in *Ischadites*, or the lateral extension of the vertical rays in the "gastral" cavity; they have been observed as terminating freely, and pointed at their extremities, in specimens of *Ischadites iowensis*, but apparently end bluntly in *Lepidolites*. It may be that the lateral extension of the vertical rays of the spicules forming the upper integument in *R. occidentalis* and *R. oweni* served the same purpose as the large number of plates discovered by Herr Rauff, closing the heretofore supposed apical opening in *Ischadites*, *i. e.* for the regulation of the water currents. These lateral extensions of the vertical rays of the upper surface in *R. oweni* are traversed by from ten to twelve horizontal canals.

RECEPTACULITES OWENI *Hall.*

PLATE F, FIGS. 1-4.

1844. *Coscinopora sulcata* OWEN (non Goldfuss). Geological Report of Iowa, Wisconsin, and Illinois, p. 40, pl. 7, fig. 5.
1861. *Receptaculites oweni* HALL. Report of the Superintendent of the Geological Survey of Wisconsin, p. 13.
1862. *Receptaculites oweni* HALL. Geological Report of Wisconsin, p. 46, fig. 2, and p. 429.
1868. *Receptaculites oweni* MEEK and WORTHEN. Geological Survey of Illinois, vol. iii, p. 302, pl. 2, fig. 3.
1882. *Receptaculites oweni* WHITFIELD. Geology of Wisconsin, vol. iv, p. 239, pl. 10, fig. 7.
1883. *Receptaculites oweni* HALL. Twelfth Rep. State Geologist of Indiana, p. 243, pl. 1, fig. 1.
1884. *Receptaculites occidentalis* (partim) HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 842.

Original description.—"Body consisting of a broad expanded disc, from four to twelve inches [even twenty inches] in width, and from one quarter to half an inch [sometimes 20 mm.] in thickness (rarely a little thicker). Surface undulating with an abrupt funnel-shaped depression in the center of the upper side [with a small conical projection on the under side], from which the cell rows [head-plates of the spicules] radiate in curved lines.

"The thickness in the center is not more than one-eighth of an inch, and at a distance of three or four inches from the center is less than half an inch: cells [vertical rays of the spicules] cylindrical in the middle and contracted both above and below [from 1 to 3 mm. in diameter], the walls of the cavities often showing transverse striæ, which appear like the remains of septa [since these cavities are casts of the outer side of the vertical rays of the spicules they are not septa]. The distance of the cells [circular perforations of the matrix once occupied by the vertical rays of the spicules] from each other is variable, those near the center being closer together, though, in receding from the center, there are at intervals intercalated rows of cells, which take the same direction, and give the cells a closer arrangement towards the margin than in the intermediate space before the intercalation of the additional rows. The apertures [impression of head-plates] both above and below are essentially rhomboidal [from 3 to 5 mm. in width]; but in well preserved surfaces there are remains of rays, which, however, are rarely observed: and I have not seen them on opposite sides of the same specimen."

A small specimen of this species from Goodhue county, Minnesota, has the lower surface preserved as crystalline calcite, while all other portions of the sponge are missing. The outline of the plates cannot be determined, but their arrangement is well indicated by a series of knobs arranged in quincunx. These were regarded at first as having been produced by the wearing away of the softer matrix surrounding the crystalline calcite, usually filling the interior of the vertical rays of the spicules in Minnesota specimens. Upon grinding the specimen transversely to the surface, it was discovered that the vertical rays of the spicules are not present, and that only the lower or outer surface of the sponge is preserved. We therefore conclude that each head-plate in this specimen had originally a central knob similar to those figured by Dr. Hinde in *Sphærospongia tessellata* Phillips, sp.* In the latter these knobs are comparatively smaller than in *Receptaculites oweni* Hall.

The upper or inner layer is never preserved entirely in Minnesota specimens of *R. oweni*, and we shall therefore give Dr. Hinde's description of this integument as it occurs in *R. occidentalis* Salter, a closely related species: "The vertical rays in this species of *Receptaculites* continue cylindrical to near their basal extremities, and then abruptly expand into horizontal plates. These plates have four straight sides, but at each of the corners there is a semicircular or semi-elliptical vertical hollow.† Each plate appears also to be traversed by four horizontal canals, which radiate from the center, where they are in connection with the canal of the vertical ray. * * * These plates are intimately united together so as to form a continuous inner or upper layer. The delimitations of the separate plates in this layer are not always preserved; in many specimens they appear to have been completely obliterated, and the layer resembles a continuous plate with numerous cylindrical or elliptical canals which penetrate through it at right angles" (*loc. cit.* p. 825). In many specimens from Minnesota, the horizontal canals of the upper or inner layer

*Loc. cit. pl. 37, fig. 1b.

†Herr Rauff states, that these vertical hollows or pores did not originally exist in the "gastral" wall, but are the result of fossilization (Nicholson "Manual of Palæontology, vol. ii, p. 1564).

are indicated by furrows left between the casts now filling the original spaces. Between the four principal canals, which seem to have communicated with four circular hollows, one situated at each angle of the rhombic spaces, are two other canals, and these also seem to have had openings in the upper surface. In other words, each plate had originally twelve small semicircular hollows communicating with twelve horizontal canals joining in the center with the vertical ray. Where the filling of the spaces between the canals is not preserved, tubercles can be seen distinctly situated at each angle of the rhombic depressions, with two, and occasionally only one pustule between them. Along their edges the plates are separated from adjoining ones by distinct walls. These walls are not a portion of the skeleton, but are foreign matter which has accumulated between the plates, and has more or less disturbed their natural position.

This species is known throughout the Northwest as the "sunflower coral," "lead fossil," or *Receptaculites oweni* Hall. The specimens from Minnesota are from limestone and calcareous mud-stones, and rarely occur as hollow casts, but commonly as impressions of the skeleton. The vertical rays are filled usually with crystalline calcite.

Dr. Hinde, in treating of *R. occidentalis* Salter, and *R. oweni* Hall, says: "The examples from Illinois and other western states are usually of somewhat greater diameter than those from the same horizon in Canada, but from a comparison of specimens from these different places I am unable to detect any differences which would justify regarding them as distinct species. Their external aspect is, however, strikingly dissimilar owing to their different states of fossilization" (*loc. cit.* p. 843). On account of the greater size attained by *R. oweni*, and the plates of the inner surface having twelve canals instead of four, as in *R. occidentalis*, a central knob on each head-plate of the spicules on the outer surface of the former, should be sufficient to distinguish this species.

Formation and locality.—Throughout the Galena of Minnesota, Wisconsin, Iowa and Illinois. Some of the more prominent localities are: six miles south of Cannon Falls, Kenyon, Mineola, Fountain, near Marion, Wasioja, and Stewartsville, Minnesota; Decorah and Dubuque, Iowa; Green Bay, Wisconsin; Galena and Dixon, Illinois.

Collectors.—Miss Cora E. Goode, W. H. Scofield, and the writers

Mus. Reg. Nos. 3375, 4944, 6758, 7251, 7714-7721.

SYNOPSIS OF AMERICAN SPECIES OF RECEPTACULITES.

R. ARCTICUS *Etheridge.*

1878. *Receptaculites arcticus* ETHERIDGE. Quart. Jour. Geol. Soc. London, vol xxiv, p. 576.
1882. *Receptaculites arcticus* JONES. Catalogue Foss. Foram. British Museum, p. 3.
1884. *Receptaculites arcticus* HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 845.

Formation and locality.—Lower Silurian: Cape Louis Napoleon and Cape Frazer, Arctic regions.

R. CALCIFERUS *Billings.*

1865. *Receptaculites calciferus* BILLINGS. Palæozoic Fossils, vol. i, p. 359, fig. 346; p. 384, fig. 358.
1865. *Receptaculites calciferus* BILLINGS. Canadian Naturalist and Geologist, sec. ser. vol. ii, p. 190, fig. 6.
1884. *Receptaculites calciferus* HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 845.

This is the oldest known species of the genus.

Formation and locality.—Calciferous formation ; Mingan islands, Lower St. Lawrence.

R. MAMMILLARIS *Walcott.*

1884. *Receptaculites mammillaris* WALCOTT. Monograph U. S. Geological Survey, vol. viii, p. 65, pl. 11, fig. 11.

This species is smaller than *R. occidentalis* Salter, and has the outer margin elevated, producing a broad, deep depression in the upper portion.

Formation and locality.—Upper part of the Pogonip group=Chazy group of New York ; Eureka and White Pine districts, Nevada.

R. ELONGATUS *Walcott.*

1884. *Receptaculites elongatus* WALCOTT. Monograph U. S. Geological Survey, vol. viii, p. 66.

A cylindro-conical species, with a very deep depression on the upper side. The largest head-plates of the spicules are 1 mm. in width by five-sixths of 1 mm. in length.

Formation and locality.—Upper part of the Pogonip group=Chazy group of New York ; Eureka district, and in the Pahranagat range, Nevada.

R. ELLIPTICUS *Walcott.*

1884. *Receptaculites ellipticus* WALCOTT. Monograph U. S. Geological Survey, vol. viii, p. 67, pl. 11, fig. 12.

Seems to differ from *R. elongatus* in having larger spicular head-plates. The curved form and elliptical transverse section may be due to accidental causes.

Formation and locality.—Upper part of the Pogonip group=Chazy group of New York ; Eureka district, Nevada.

R. OCCIDENTALIS *Salter.*

?1847. *Receptaculites neptuni* HALL (non Defrance). Palæontology of New York, vol. i, p. 68, pl. 24, figs. 3a–3d.
?1855. *Receptaculites neptuni* EMMONS. American Geology, pt. ii, p. 230, pl. 14, fig. 1.
1859. *Receptaculites occidentalis* SALTER. Canadian Organic Remains, dec. i, p. 45, pl. 10, figs. 1–7.
1863. *Receptaculites occidentalis* BILLINGS. Geology of Canada, p. 937.
1865. *Receptaculites occidentalis* BILLINGS. Palæozoic Fossils, vol. i, p. 381, figs. 354–356.
1865. *Receptaculites occidentalis* BILLINGS. Canadian Naturalist and Geologist, sec. ser., vol. ii, p. 187, figs. 2–4.
1884. *Receptaculites occidentalis* HINDE. Quar. Jour. Geol. Soc. London, vol. xl, p. 842, pl. 37, figs. 3a–3m.

Very similar to *R. oweni*, but it differs in having a greater number of canals in the plates of the upper or inner surface; also in the head-plates of the outer or under surface having prominent central knobs.

Formation and locality.—Trenton limestone; Pauquette Rapids, Ottawa river, Canada; two miles south of High Bridge, Kentucky; and ? Carlisle, Pennsylvania.

R. INFUNDIBULIFORMIS *Eaton, sp.*

1832. *Coscinopora infundibuliformis* EATON. Geological Text Book.
1863. *Receptaculites infundibuliformis* HALL. Sixteenth Rep. N. Y. State Cab. Nat. Hist., p. 67.
1883. *Receptaculites infundibuliformis* HALL. Second Ann. Rep. N. Y. State Geologist, pl. 23, fig. 10.
?1883. *Receptaculites monticulatus* HALL. Ibidem, pl. 23, figs. 3–9, 11.
1887. *Receptaculites infundibuliformis* HALL. Palæontology of New York, vol. vi, p. 290, pl. 24, figs. 3–11.

A large disk-shaped species much like *R. occidentalis*. The specimens to which the name *R. monticulatus* has been given are now regarded by Prof. Hall as the young of this species and should be compared with *Cerionites dactylioides* Owen, sp.,* of the Niagara group.

Formation and Locality.—Lower Helderberg group; Helderberg Mts., New York.

*Geol. Surv. Illinois, vol. iii, p. 345, pl. 5, figs. 2a–2c; 1868.

R. BURSIFORMIS *Hall.*

1863. *Receptaculites catoni* HALL. Sixteenth Rep. N. Y. State Cab. Nat. Hist., pp. 68, 226 (not defined).
1883. *Receptaculites bursiformis* HALL. Second Ann. Rep. N. Y. State Geologist, pl. 23, figs. 12-14.
1887. *Ischadites bursiformis* HALL. Palæontology of New York, vol. vi, p. 291, pl. 24, figs. 12-14.
Much like *R. infundibuliformis* in shape, but with larger head-plates of the spicules than in that species.

Formation and locality.—Schoharie grit; Albany and Schoharie counties, New York.

R.? SACCULUS *Hall.*

1879. *Receptaculites sacculus* HALL. Transactions Albany Institute, vol. x.
1882. *Receptaculites sacculus* HALL. Eleventh Rep. State Geologist of Indiana, p. 222, pl. 1, fig. 5.
Probably this fossil does not belong to the *Receptaculitidæ*. Its nature cannot be determined from the description and figure given.

Formation and Locality.—Niagara group; Waldron, Indiana.

R.? INSULARIS *Billings.*

1866. *Receptaculites ? insularis* BILLINGS. Catalogue Silurian Foss. Anticosti, p. 29.
1884. *Receptaculites ? insularis* HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 846.
"Probably belongs to a quite distinct group" (Hinde).

Formation and Locality.—Anticosti group; Anticosti.

R.? ELEGANTULUS *Billings.*

1865. *Receptaculites ? elegantulus* BILLINGS Palæozoic Fossils, vol. i, p. 360, fig. 347.
1884. *Receptaculites ? elegantulus* HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 846.
This does not belong to the *Receptaculitidæ*.

Formation and Locality.—Calciferous formation; Mingan islands, Lower St. Lawrence.

R.? DEVONICUS *Whitfield.*

1882. *Receptaculites devonicus* WHITFIELD. Annals New York Acad. Sci., vol. ii, p. 198.
1890. *Receptaculites devonicus* WHITFIELD. Ibidem, vol. x, p. 519, pl. vi, fig. 10.
Probably an *Ischadites.*

Formation and locality.—Corniferous of Ohio.

ISCHADITES, *Murchison emende Hinde.*

PLATE F, FIGS. 5-10.

1839. *Ischadites*, MURCHISON. Siluria, p. 697.
1842. *Tetragonis*, EICHWALD. Urwelt Russlands, hft. ii, p. 81.
1852. *Selenoides*, OWEN. Geological Survey of Wisconsin, Iowa, and Minnesota, p. 586.
1859. *Dictyocrinus*, HALL. Palæontology of New York, vol. iii, p. 135.
1865. *Receptaculites*, (partim), BILLINGS. Palæozoic Fossils, vol. i, p. 378.
1884. *Ischadites*, HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 810.

The following description is somewhat condensed from Dr. Hinde's detailed diagnosis of this genus (*loc. cit.* p. 811): "Outer form variable. The prevalent forms are ovate or biconvex; depressed conical; subspherical and pyriform. Base either obtusely conical, flattened or concave. Summit usually obtusely conical; rarely with a small central elevation. A small circular perforation is present in the center of the summit which opens into the originally hollow cavity of the body. [According to Herr Rauff, this opening is closed by a large and variable number of plates.]

"The structure consists of spicules of various dimensions, regularly arranged in vertical and oblique rows, and held in position by the interlocking of their summit-plates and horizontal rays. Head-plates of the spicules delicate structures with smooth, flattened outer surfaces, thickest in the central portion where they connect with the horizontal rays, and gradually diminishing towards the margins, which are very thin. They have a generally rhomboidal outline, but in some parts of the specimen two of the sides of the rhomboids are not uniformly straight, but have a slight curve, which gives the plates the form of a sector of a circle. Another modification is frequently, if not invariably, present in the spicular-plates of the basal portion, which have their angles, or those directed away from the basal nucleus, either truncate or with a slight notch, from which one of the horizontal rays projects and extends nearly to the center of the plate immediately in front. The plates forming the basal nucleus are also more elongated than any others. The plates near the nucleus, as well as those of the nucleus itself, are relatively small, but they quickly increase in size towards the zonal area, where they attain their greatest dimensions (2 to 4 mm.); they then gradually diminish in size towards the summit, and the smallest plates surrounding the summit-aperture are scarcely distinguishable without a lens, measuring from .25 to .4 mm. in width, or about one-tenth of the diameter of the zonal plates.

"Head-plates arranged in regular spiral curves which, starting in opposite directions from the basal nucleus and extending to the summit, give to the surface the exact appearance of the engine-turned case of a watch. Each rhomboidal plate is so arranged that one of its angles points to the basal nucleus, and its opposite angle to the summit of the specimen, whilst the other angles are lateral, so that the distal angle of one plate is in contact with the proximal angle of the plate immediately in front of it. Thus vertical lines extending from the base to summit would pass through the proximal and distal angles of the plates, whilst concentric lines would pass through the lateral angles. At the nucleus, or center of the base, there is a series of eight minute spicules with diamond-shaped head-plates, which are so arranged as to form a star-shaped figure, the distal angles of each plate representing one of the rays of the star, and a line connecting the lateral angles would trace a small circle, with the proximal angles of the plates for its center.

"As a rule the margins of the plates appear to fit closely and evenly to each other, but in some cases the upper or front margins seem to be slightly elevated as if they imbricated over the lower or hind margins of the spicular plates immediately in front, and left a small intermediate space now filled with the matrix. That the plates, or at least those of the lower portion of the organism, did not fit so closely as to exclude the passage of water from the exterior to the interior cavity of the organism, is shown by the fact that one of the horizontal spicular rays projects from underneath the distant angle of each of the plates and extends over the outer surface of the plate in front, thus clearly preventing a close-fitting union at the margins, and, further, the ridges, which characterize the outer surface of the casts of specimens, are produced by the infilling of the matrix in the interspaces between the margins of the plates.

"These summit- or head-plates appear to have been connected by a somewhat narrow neck to the horizontal rays of the spicules at the central point of junction with these and the vertical rays, as the horizontal rays appear to be independent except at their central junction. As a rule, the head-plates are seldom preserved *in situ*.

"The surface of the fossil immediately beneath the rhomboidal spicular plates is divided into minute oblong rectangular areas by vertical and concentric lines. These lines are formed by the apposition of the horizontal spicular arms or rays. The spicules, in addition to the head-plate, consist of five rays; four extended in a horizontal direction, at right angles to each other, whilst the fifth extends from the junction of the four with the summit-plate towards the interior of the organism, and thus at right angles to the horizontal rays. The spicular rays are circular in transverse section, thickest at their central point of junction with each other and the head-plate, and they gradually taper to bluntly-pointed extremities [In *Ischadites iowensis* they are needle-shaped]. Canals present in the interior of the rays. The vertical or entering ray appears to be the longest, the lateral rays are subequal, whilst the distal ray, or that pointing to the summit of the specimen, seems to be longer than the opposite or proximal ray.

"The four horizontal rays are so arranged that each ray extends towards one of the angles of the head-plate of the spicule. Thus one ray, the proximal, points to the basal nucleus, and its opposite, the distal, to the summit. This distal ray in the basal portion of the organism frequently projects beyond the margin of the spicular head, and overlies the head-plate of the spicule immediately in front or above it.

"The vertical rays of the spicules, which extend at right angles to the summit-plates and the horizontal rays, are only seen when the interior of the specimens is exposed by fracture or by section. They appear as delicate, gradually tapering shafts, the extremities of which are pointed, and reach about half way to the center of the interior cavity, where they terminate freely. An interior plate or integument corresponding to that in *Receptaculites* has not been observed.

"The genus *Ischadites* itself has, by several writers, been regarded as identical with *Receptaculites*, but though similar in its main structural features to this latter genus, it is sufficiently characterized by its conical or ovate form, inclosing a central cavity, with a small summit aperture, and by the absence of an inner layer. From *Sphærospongia*, Pengelly, it is distinguished by the rhomboidal form of the spicular plates, and the development of vertical spicular rays; and from *Acanthochonia* by its conical ovate form and central cavity."

Dictyocrinus was at first doubtfully placed among the Crinoidea. Later, however Prof. Hall referred the type species to *Receptaculites* and then to *Ischadites*.

ISCHADITES IOWENSIS *Owen, sp.*

PLATE F, FIGS. 5, 6.

1844. *Orbitolites reticulata* OWEN. Geological Report, Iowa, Wisconsin, and Illinois, pl. 18, fig. 7.
1852. *Selenoides iowensis* OWEN. Geological Survey of Wisconsin, Iowa, and Minnesota, p. 587, pl. 2B, fig. 13.
1861. *Receptaculites Selenoides iowene* HALL. Report of the Superintendent of the Geological Survey of Wisconsin, p. 14.
1861. *Receptaculites fungosum* HALL. Ibidem, p. 15.
1861. *Receptaculites globulare* HALL. Ibidem, p. 16.
1865. *Receptaculites iowensis* BILLINGS. Palæozoic Fossils, vol. i, p. 385, fig. 364.
1865. *Receptaculites iowensis* BILLINGS. Canadian Naturalist and Geologist, sec. ser., vol. ii, p. 191, fig. 11.
?1868. *Receptaculites globularis* MEEK and WORTHEN. Geological Survey of Illinois, vol. iii, p. 301, pl. 2, figs. 2a, 2b.
1868. *Receptaculites*, sp? MEEK and WORTHEN. Ibidem, p. 301, pl. 2, figs. 1a, 1b.
1884. *Ischadites kœnigii* (partim) HINDE. Quar. Jour. Geol. Soc. London, vol. xl, p. 836.

Original description.—"One side flatly dome-shaped, the other ring-shaped, enclosing an umbilicus or central depression. Small rhomboidal cells opening on the surface in curved rows, intersecting in arches; the cells gradually increasing in size from the inner margin to the periphery." (Owen, 1852.)

Sponge depressed sub-globose, globose or sub-turbinate; base more or less concave. Greatest width near the base, which varies in diameter from 18 mm. to 70 mm.; hight of the largest and most sub-turbinate form, 35 mm.; the usual size met with is about 50 mm. in diameter, with a hight of 20 mm. Summit aperture observed in two examples; one 9 mm., the other 14 mm. in width. This aperture was probably closed by a number of small plates. Head-plates of the spicules not preserved. Spaces formerly occupied by them arranged in spiral curves starting in opposite directions from the nucleus, and extending to the summit. They enlarge as they recede from the nucleus to the zonal region, thence become narrower and more elongated transversely, closely compacted, and constantly diminishing in size towards the summit. The proximal and distal rays of the horizontal rays are usually absent, while the preserved lateral rays give the surface in the upper portion of the internal cast a distinct series of encircling lines. Near the periphery, traces have been observed of one of the horizontal rays of a spicule extending beyond the distal angle of its summit-plate over that of the one immediately in front. Vertical rays of spicules subcylindrical, about 15 mm. in length.

The above synonomy and *Receptaculites ohioensis* Hall and Whitfield, *R. subturbinatus* Hall, and *R. jonesi* Billings, Dr. Hinde regards as embracing but a single species, *Ischadites kœnigii* Murchison. *R. ohioensis* and *R. subturbinatus* are from the Niagara group of Ohio and Indiana; the first differs in the comparatively large head-plates and in its strongly convex base, while the latter has much larger head plates on the sides than *Ischadites iowensis*. *R. jonesi* agrees with *Ischadites iowensis* in form but as it is from a later geological horizon, we prefer to retain the species, particularly since we have no examples for comparison. *Ischadites iowensis* is constantly more or less strongly concave, never conical, and but rarely flattened on its under side. It attains a larger size and has comparatively smaller head-plates than *I. kœnigii*. Since these features are constant in *I. iowensis*, we deem it sufficient ground to retain this species as distinct from that form.

All the specimens of *I. iowensis* from Minnesota, seen by the writers, are depressed sub-globose, never sub-turbinate. *I. fungosus* Hall might be recognized as a good variety, were it not that both forms have been found lying with the umbilicated side downwards within a foot of each other, in the side of a cliff at Decorah, Iowa.

Formation and locality.—Galena formation of Iowa, Wisconsin, and Minnesota. In Minnesota, this species is usually obtained from the lower portion of the Galena; some localities are six and twelve miles south of Cannon Falls in Goodhue county, and Wasioja, Dodge county. Mr. F. W. Sardeson informs the writers that he obtained this species in the Hudson River or Cincinnati group, near Spring Valley, Minnesota.

Mus. Reg. Nos. 5839, 6760, 7250.

SYNOPSIS OF AMERICAN SPECIES OF ISCHADITES.

I. CYATHIFORMIS *Hall.*

1847. —— *cyathiformis* HALL. Palæontology of New York, vol. i, p. 72, pl. 25, fig. 6a-6c.
Closely related to *I. iowensis.*

Formation and locality.—Trenton limestone; Carlisle, Pennsylvania.

I. CIRCULARIS *Emmons.*

1885. *Receptaculites circularis* EMMONS. American Geology, pt. ii, p. 230, fig. 82.
1891. *Receptaculites circularis* JAMES. Jour. Cincinnati Soc. Nat. Hist., vol. xiv, p. 63.
This species may be identical with *I. Iowensis*, but the spicular head plates seem to be larger.

Formation and locality.—Loraine shales; New York.

I. JONESI *Billings.*

1865. *Receptaculites jonesi* BILLINGS. Palæozoic Fossils, vol. i, p. 389, fig. 365.
1865. *Receptaculites jonesi* BILLINGS. Canadian Naturalist and Geologist, sec. ser. vol. ii, p. 191, fig. 12.
1884. *Ischadites kœnigii* (partim) HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 836.
See remarks on this species under *I. iowensis.*

Formation and locality.—Lower Helderberg group; Cape Gaspé.

I. SQUAMIFER *Hall.*

1859. *Dictyocrinus squamifer* HALL. Palæontology of New York, vol. iii, p. 135, pl. 7A, figs. 11, 13.
1883. *Receptaculites squamifer* HALL. Second Ann. Rep. N. Y. State Geologist, pl. 23, figs. 1, 2.
1887. *Ischadites squamifer* HALL. Palæontology of New York, vol. vi, p. 291, pl. 24, figs. 1, 2.

Formation and locality.—Lower Helderberg; Schoharie, New York.

I. TESSELLATUS *Winchell* and *Marcy.*

1861. *Receptaculites infundibulum* HALL.* Report of the Superintendent of the Geological Survey of Wisconsin, p. 16.
1866. *Ischadites tessellatus* WINCHELL and MARCY. Memoirs Boston Soc. Nat. Hist., vol. i, p. 85, pl. 2, fig. 3.
1867. *Ischadites tessellatus* HALL. Twentieth Rep. N. Y. State Cab. Nat. Hist., pp. 390, 395.
1870. *Receptaculites formosus* MEEK and WORTHEN. Proc. Acad. Nat. Sci. Philadelphia, sec. ser vol xiv, p. 22.
1875. *Receptaculites formosus* MEEK and WORTHEN. Geological Survey of Illinois, vol. iv, p. 500, pl. 24, fig. 1.
1875. *Ischadites tessellatus* GÜMBEL. Abhandl. der. k. bayer. Akad. der Wissensch., bd. xii, p. 40.
1884. *Ischadites tessellatus* HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 839.

The pear-shaped form and the large spicular head-plates readily separate this from all other American species of the genus, except *I. canadensis* Billings, which will probably prove to be a synonym.

Formation and locality.—Niagara limestone; near Chicago, Illinois, and Racine, Wisconsin.

I. CANADENSIS *Billings.*

1863. *Ischadites canadensis* BILLINGS. Geology of Canada, p. 309, fig. 313, and p. 327 (not described).
1865. *Receptaculites canadensis* BILLINGS. Palæozoic Fossils, vol. i, p. 384, fig. 362 (not described).
1865. *Receptaculites canadensis* BILLINGS. Canadian Naturalist and Geologist, sec. ser. vol. ii, p. 191, fig. 10.
1880. *Receptaculites canadensis* ROMER. Lethæa Palæozoica, p. 289.
1884. *Receptaculites ? canadensis* HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 844.

Probably identical with *I. tessellatus*, in which case this name will have precedence, provided, however, that a figure without a description is regarded as sufficient for establishing a species.

Formation and locality.—Niagara limestone; township of Esquesing, Ontario, Canada.

I. SUBTURBINATUS *Hall.*

1863. *Receptaculites subturbinatus* HALL. Transactions Albany Institute, vol. iv, p. 224.
1879. *Receptaculites subturbinatus* HALL. Twenty-eighth Rep. N. Y. State Mus. Nat. Hist., p. 103, pl. 3, figs. 1–3.
1882. *Receptaculites subturbinatus* HALL. Eleventh Rep. State Geologist of Indiana, p. 221, pl. 2, figs. 1–3.
1884. *Ischadites kœnigii* (partim) HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 836.

This species is regarded as a synonym of *I. kœnigii* by Hinde (*op. cit.*).

Formation and locality.—Niagara group; Waldron, Indiana.

I. HEMISPHERICUS *Hall.*

1861. *Receptaculites hemisphericum* HALL. Report of the Superintendent of the Geological Survey of Wisconsin, p. 16.
1875. *Receptaculites ohioensis* HALL and WHITFIELD. Palæontology of Ohio, vol. ii, p. 123, pl. 6, fig. 1.
1882. *Receptaculites hemisphericum* WHITFIELD. Geology of Wisconsin, vol. iv, p. 269, pl. 13, fig. 4.
1884. *Ischadites kœnigii* (partim) HINDE. Quart. Jour. Geol. Soc. London, vol. xl, p. 836.

This is also regarded as a synonym of *I. kœnigii* by Dr. Hinde.

Formation and locality.—Niagara limestone; Racine and Waukesha, Wisconsin, and Yellow Springs, Ohio.

*Since this species was accompanied by a poor description, and without figures, we prefer to use the name *I. tessellatus* for it. Dr Hinde (*op. cit.* p. 839) says regarding *R. infundibulum*, "in the absence of figures, mere verbal description, like Hall's, of the fossils of this group is quite insufficient for the recognition of species, more particularly when the character of the fossil is so little understood by the author that he regards the base of the fossil as its summit, and *vice versa*." Meek and Worthen (Geol. Survey of Illinois, vol. iii, p. 302) also say that they were unable to identify "several allied forms already named and described from these rocks, and not yet figured."

LEPIDOLITES, Ulrich.*

PLATE F, FIGS. 11, 12.

1879. *Lepidolites*, ULRICH. Jour. Cincinnati Soc. Nat. Hist., vol. ii, p. 20.
1885. *Ischadites*, JAMES. Ibidem, vol. viii, p. 163.
1891. *Receptaculites*, JAMES. Ibidem, vol. xiv, p. 60.

Lepidolites is closely related to *Ischadites*, but possesses a few features that will not allow it at present to be regarded as synonymous with the latter. The spicular head-plates in *Ischadites* Dr. Hinde (*op. cit.* p. 812) describes as follows: "As a rule the margins of the plates appear to fit closely and evenly to each other so as not to leave any interspace between their edges, but in some cases the upper or front margins seem to be slightly elevated as if they imbricated over the lower or hind margins of the spicular plates immediately in front, and left a small intermediate space, now filled with the matrix." The head-plates in *Lepidolites* are very thin, strongly imbricating and wavy along their edges. While these sponges are more or less distorted, this overlapping character of the plates cannot be ascribed to pressure. Again, in *Ischadites* the head-plates increase in diameter from the nucleus to the zonal region, and then decrease in size towards the summit, but in *Lepidolites*, they gradually become larger from the center of the base to the upper portion of the sponge. The vertical or fifth ray of the spicules in *Lepidolites* is very short and terminates bluntly, while in *Ischadites* it is long and slender, gradually tapering and terminating in a point. This ray (the fifth) does not project free into the cavity, but lies flat and directed downward, with neighboring ones side by side, so that the result of the arrangement is an imbrication comparable with narrow shingles.

L. DICKHAUTI *Ulrich.*

1879. *Lepidolites dickhauti* ULRICH. Jour. Cincinnati Soc. Nat. Hist., vol. ii, p. 21, pl. 7, figs. 17–17b.
1879. *Lepidolites elongatus* ULRICH. Ibidem, p. 22, pl. 7, fig. 16.
1885. *Ischadites dickhauti* JAMES. Jour. Cincinnati Soc. Nat. Hist., vol. viii, p. 165.
1891. *Receptaculites dickhauti* JAMES. Ibidem, vol. xiv, p. 63.

Mr. Ulrich agrees that the name *L. elongatus* is superfluous.

Formation and locality.—Cincinnati group; Covington, Kentucky.

CERIONITES, Meek and Worthen.

1868. *Cerionites*, MEEK and WORTHEN. Geological Survey of Illinois, vol. iii, p. 346.
Type *Lunulites? dactylioides* OWEN.

C. DACTYLIOIDES *Owen, sp.*

1844. *Lunulites ?dactioloides* OWEN. Geological Report Iowa, Wisconsin and Illinois, p. 69, pl. 13, fig. 4.
1868. *Cerionites* (*Pasceolus?*) *dactylioides* MEEK and WORTHEN. Geological Survey of Illinois, vol. iii, p. 346, pl. 5, fig. 2.
1884. *Cerionites dactyloides* WHITFIELD. Geology of Wisconsin, vol. iv, p. 267, pl. 13, figs. 1–3.

Formation and locality.—Niagara limestone: Carroll county, Illinois, and Waukesha, Wisconsin.

---

*We are indebted to Mr. Ulrich for the opportunity of studying his type material.

Pasceolus Billings (Geological Survey of Canada; Report of Progress for 1857, p. 342), may belong to the *Receptaculitidæ*, but we are unable to give a definite opinion regarding its systematic position.

ANOMALOSPONGIA, nov. nom.

ON THE STRUCTURE AND SYSTEMATIC POSITION OF "ANOMALOIDES," AND A PROPOSAL TO CHANGE THE NAME TO ANOMALOSPONGIA.

BY E. O. ULRICH.

The name *Anomaloides reticulatus* was proposed by me in 1878 in my first contribution to paleontologic science (Jour. Cin. Soc. Nat. Hist., vol. i, p. 92). Viewed as a first effort, some of the errors contained in that paper may be excused, especially since none of them are very bad, and the worst not entirely my fault, as I hope to show in a paper to be published soon. One error, that in the construction of the name *Anomaloides*, was pointed out by Mr. S. A. Miller (North Amer. Geol. and Pal., p. 224, 1889). I acknowledge the justice of his criticism, and although similarly constructed names are allowed to stand, I think it best, now that the nature of the fossil is determined, to change the name. I propose therefore to use *Anomalospongia* instead. The new name retains the principal part of the original designation, and the ending *spongia* denominates the class to which the fossil belongs. Nor is *Anomalospongia* at all inappropriate, for the specimens now so named are, as will appear later on, still to be regarded as anomalous.

The original specimens, 35 in number, were all fragments, some large, most of them small, and all found within a space a few feet square in the middle beds of the Cincinnati group at Covington, Kentucky. Further search at the same spot resulted in a few more fragments, all of them small, and, like many of the originals, considerably obscured by the adhering clayey matrix. For ten years these specimens remained in my cabinet without further examination, I having been under the impression that their structure had been determined as far as the specimens at hand would admit. At last, after the possibility of other affinities than with Echinodermata was suggested, a re-examination was determined upon. This time I began with the fragments that in my original study were cast aside because of the obscuring matrix. Having some experience in cleaning fossils in that condition I succeeded in freeing several fragments of their clayey investment. The result was most gratifying, since the cleaned surface showed unquestionably a layer of overlapping spicule rays, proving the fossil to belong to the Spongida and not to the Echinodermata.

Naturally enough, my first supposition was that these horizontal rays would prove four in number, as in *Receptaculites* and related genera, and it was not till I began to study the enlarged drawing of the surface (here reproduced in fig. 14, on plate F), which I drew at once under the camera lucida. This figure is not diagrammatical, but represents the parts just as they appeared to me in the microscope. As shown in figure 14, we have only three instead of four horizontal rays—a troublesome fact, because it obliges us in the present state of our knowledge to refer *Anomalospongia* to the *incertæ sedes* among the sponges. Had four horizontal rays been present we might have overlooked certain other peculiarities and placed the genus with the *Receptaculitidæ*, but that can scarcely be recommended now, since it would necessitate too great an expansion of the characters of that family.

Before entering upon a discussion of the relations of the genus to the *Receptaculitidæ* and other organisms, I shall offer the following diagnosis of the genus and remarks upon the only known species :

ANOMALOSPONGIA, n. gen.

Proposed instead of *Anomaloides*, Ulrich, 1878, Journal Cincinnati Society of Natural History, vol. i, p. 92.

Sponge hollow, ? obconical, that being the shape of the most complete of the fragmentary specimens at hand ; the walls consisting of definitely arranged spicular elements. Spicules four-rayed, with a small, knob-like summit, probably to be regarded as an undeveloped fifth ray ; one of them (the vertical) thick and strong, subcylindrical or club-shaped, its inner extremity pointed, the outer rounded, and produced centrally into a neck-like prolongation from which three very delicate rays spread horizontally. Vertical rays arranged so as to be perpendicular to the surface and each in contact, yet not organically united, with six of its neighbors ; leaving, usually, a small interstice at the angles of junction, and the pointed inner extremity free. Horizontal rays thin, long, tapering toward their extremities, interwoven and overlapping each other three or four times : each divided longitudinally by a strongly impressed groove, causing them to appear double ; open meshes between these rays normally of triangular shape. Communication between the interior and exterior carried on, apparently, through the small interstices left between the adjoining vertical rays.

The complete form of *Anomaloides reticulatus* or, as it should now be called, *Anomalospongia reticulata*, is doubtful. It may have been conical, as suggested in the above description, with the base pointed and top open. But it is also possible that it was, as I believed originally, perhaps triradiate, with a central opening, as in *Brachiospongia.* Neither view is supported by positive evidence, so that for the present it seems best to leave that point entirely open.

Two of the specimens are depressed-conical in form, one about 50 mm. in length, the other only 22 mm. The larger is 20 mm. wide at the large end, its margins nearly parallel in the upper half and converging rapidly in the lower half. The extreme end may have been closed and pointed, but as both specimens are defective here, it would not be safe to assume that it was. Indeed, it is perhaps just as likely that a small opening existed in the extremity. The smaller specimen is very nearly a duplicate of the lower half of the larger.

The relative length and disposition of the three horizontal rays are probably specific peculiarities, hence are mentioned in the generic diagnosis merely in a general way. In *A. reticulata* they have a definite form and arrangement, in part, very likely controlled by the arrangement of the vertical rays. The latter form straight or curved transverse and diagonally intersecting rows, generally very regular, and when the horizontal rays are removed by attrition (seemingly a common occurrence) they appear as sub-hexagonal rounded knobs, in most cases with ten or eleven in 5 mm. transversely. In three fragments, otherwise apparently identical with the others, the parts are smaller, and in these there are thirteen in that space. Their length, and consequently the thickness of the sponge, is commonly about 2.7 mm., but varies between the observed extremes of 2.0 and 3.4 mm.

Since working out the nature of the fossil and its spicular elements, I can detect more or less clear evidences of the horizontal rays on most of the specimens.* In many the exposed rounded end of the vertical ray preserves a triradiate impression of the horizontal rays. In others the rays themselves are preserved but so much pressed that their extension beyond the impressed boundary line between the vertical rays is not to be made out. In the best preserved fragments, however, their entire extent, overlapping, and general construction, is shown in as clear a manner as can be hoped for in such delicate structures. From the last specimens, a small portion of the surface of one of which is represented by fig. 14, it appears that one of the horizontal rays is a trifle longer than the other two rays. It is also the one most prominent and oftenest seen, and *overlaps* except near its extremity. This may be called the longitudinal ray, since it lies parallel with the length of the conical specimens, while the two others are oblique. When the surface is partly obscured by adhering matrix, the first ray alone is likely to be seen clearly. Viewed through

*These remains of the horizontal rays were noticed by me in the 1878 work on the species, but their nature was misinterpreted because of my erroneous belief that the affinities of the fossils were to be sought for among the Echinodermata. Hence the statement in the original description that there is "a minute pit on the top for the articulation of two very fine and small spines."

a glass of low power, especially in a side light, the surface of such specimens appears to be striated longitudinally. But when the surface is perfectly clean the oblique rays are to be seen dipping under the longitudinal rays.

We now come to the consideration of one of the most peculiar features of *Anomalospongia*, namely, the duplex character of the horizontal rays. Each is in fact divided into two subcylindrical equal parts by a sharply impressed central groove, extending from the central node to their distal extremities. It is not possible that these grooves (there is one on both the upper and lower sides of the rays) can have resulted from pressure, because the condition is too uniform. And I have detected no sign whatever of fractures that would necessarily have resulted from pressure. Nor can I see how a cylindrical ray with a large axial canal, such as we would be obliged to assume in that case, could be compressed so as to become equally grooved on both the upper and lower sides. No, after viewing the matter from all sides, I see no other way than to accept the evidence as presented by the specimens. After that I believe we are warranted in assuming (1) that the duplex character is a peculiar form of bifurcation, (2) that the axial canal is small and (3) dividing at the node, ran independently up each half of the ray. A diagrammatic representation of the parts is given in the accompanying cut (fig. 1).

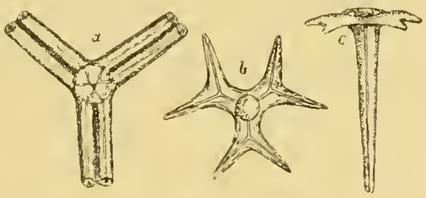


Fig. 1. *a*, diagrammatic representation of the inner part of the horizontal rays of a spicule of *Anomalospongia reticulata*, showing the supposed bifurcation of the rays and axial canals. *b* and *c*, highly magnified top and side views of a surface spicule of a recent lithistid sponge. (*Corallistes microtuberculatus* Schmidt.)

The sponge was probably originally siliceous, but the specimens as now preserved are crystalline calcite.

As regards the systematic position of *Anomalospongia* the *Receptaculitidæ* are deserving of first consideration; not so much because of a closeness of relationship as that "*Anomaloides*" has been referred to that family, indeed, a certain author has been indiscreet enough to place that name among the synonyms of *Receptaculites!*

The first essential of the *Receptaculitidæ* are the rhomboidal or hexagonal summit plates, which have been regarded by Hinde (see quotation ante p. 55) perhaps correctly, as modified spicule rays.

In *Anomalospongia* the abortive fifth ray is reduced precisely as in some hexactinellid sponges, to a mere knob, and therefore compares no nearer with the summit plates of the *Receptaculitidæ* than does the knob-like sixth ray sometimes seen in *Hyalostelia smithii* Young and Young, sp., and but little better than in the numerous sponges in which the summit ray is wanting entirely. On the whole it compares best with the condition commonly presented by the surface spicules of lithistid sponges. (See fig. 1*b* and *c*.)

The next point to be compared is the horizontal rays. A fundamental difference is at once evident in this, that in the *Receptaculitidæ* there are four of them arranged at right angles so as to form quadrangular interspaces; while in *Anomalospongia* there are only three, with the interspaces triangular. In the *Receptaculitidæ*, too, the horizontal rays overlap not at all or only sparingly, and when they do the overlapping extremities lie side by side and parallel with each other, and not, as in *Anomalospongia*, *over* each other. In the latter the crossing and interweaving of the rays is a marked feature, and not even approximated by the conditions prevailing in the *Receptaculitidæ*. As regards their duplex character in *Anomalospongia* it suffices to say that nothing of the kind is known in any of the *Receptaculitidæ*.

The vertical or entering ray of *Anomalospongia* is on the whole very similar to that ray in *Receptaculites*, but even more like that in *Ischadites*, and, if true relationship exists between them, it is here that we find it expressed with much greater obviousness than in any other feature held in common by them. Still, even here some important differences are apparent. In *Ischadites*, which as said presents the greatest resemblance to *Anomalospongia*, and therefore alone need be compared, the vertical rays are entirely separate from each other, and project freely into the central cavity, the continuity of the wall being formed in part by contact between the horizontal rays, but mainly by the overlapping summit plates. In *A. reticulata*, on the contrary, each vertical ray is in contact, normally, with six of its neighbors, so that the task of maintaining the shape of the sponge, was performed chiefly by this part of the spicules.

Other points of difference are noticed in the uniform size and in the arrangement of the spicular elements of *Anomalospongia* when compared with the true *Receptaculitidæ*.* In the latter they are small at the nucleus and increase gradually in size to the periphery; with the arrangement in regular curved intersecting lines closely simulating a common style of engraving on watch cases. In *Anomalospongia*, however, the pieces are of nearly the same size on all parts, and the arrangement that merely which would result from placing equal hexagonal pieces in contact with each other on all sides.

A feature in which *Anomalospongia* agrees with *Receptaculites*, but not more so than with other very different sponges (*Geodia clavata* Hinde), is the peculiar neck-like

*Not applicable to *Sphærospongia*, Pengelly, which it seems to me has little claim to association in the same family with *Receptaculites*.

constriction of the vertical ray immediately beneath the horizontal rays. This is relatively greater in *Anomalospongia* than in any other form known to me.

To resume: we have among the differences (1) the total absence of summit plates, (2) three instead of four horizontal spicular rays, (3) the duplex character, and (4) the interweaving of the horizontal rays, (5) the contact between the club-shaped vertical rays, and (6) the uniform size and different arrangement of the spicules. Opposed to these we have as points of agreement, (1) the form and comparatively large size of the vertical or entering ray, (2) its arrangement in the sponge-wall perpendicular to the surface, and (3) the possession of relatively small horizontal rays.

This concise statement of the points of likeness and of difference is I believe sufficient to show that *Anomalospongia* cannot be placed in the same family with *Receptaculites*. Still, I am satisfied that real relationship, however remote, exists between them. As I now view the matter it seems advisable to introduce a new order for the reception of the *Receptaculitidæ*, *Anomalospongia*, and also *Amphispongia*, Salter; the relations between the last two seeming to be, as I will endeavor to show presently, closer than might be suspected from a casual comparison.

The new order would be strictly paleozoic, and, excepting a few forms that survived into the Devonian and possibly later, would be essentially Silurian. It would therefore comprise only early types that, in common with nearly every class of animals represented in paleozoic times, may be called comprehensive because they combine characters which in more recent times became separately developed and diagnostic of now widely different groups of genera and families. Perhaps the most striking diversity in these respects, shown by the forms in question, is the difference in the number of horizontal rays pertaining on the one hand to the *Receptaculitidæ* with four, and on the other to *Anomalospongia* with three.

In the number and disposition of their rays the spicules of *Anomalospongia* remind us of true *Tetractinellidæ*. They also resemble, perhaps even more, the trifid surface spicules ("Gabel-Anker") of many lithistid sponges. The horizontal rays in the latter often are bifurcate close to the centre, so that even the duplex character of these rays in *Anomalospongia* is in a measure simulated. (See fig. 1*b* and *c*.) I am not prepared to decide definitely that these resemblances are or are not indicative of relationship. It seemed desirable, however, to mention the facts, since they illustrate the sense of the preceding paragraph.

As already indicated, it is my belief that the uncertain *Amphispongia* is related to *Anomalospongia*—indeed, that the two might well be united in one family. That genus was proposed by Salter* for certain free, compressed, elongate-elliptical masses, rounded at both ends, and rarely more than 50 mm. long by 18 mm. wide, which

*Mem. Geol. Sur. Gt. Britain, 32, Scotland, p. 135, 1861.

occur in Silurian strata near Edinburg, Scotland.* From Hinde's description and remarks on the only known species, *A. oblonga* Salter, (Catal. Foss. Sponges, Brit. Mus., p. 154, 1883) we learn that the lower half of the sponge is composed of "closely approximated, straight, elongated, conical spicules, about 3 mm. in length, and from .75 to 1 mm. in width, arranged so that their rounded summits form the outer surface of the sponge, whilst their obtuse points reach to its central axis." The upper part of the sponge is said to consist of small cruciform and five- (possibly six-) rayed spicules, and of very minute filiform mon-axial spicules, while "in one specimen there are indications of an exterior surface-layer of filiform spicules regularly arranged in the direction of the length of the sponge." The spicules seem in no case to have been organically attached to one another, nor are canals present, but a narrow tubular cloacal cavity was detected in the lower part of a few specimens.

Salter regarded the spicules as triradiate, and Hinde admits that when not detached from the mass "only casts of three rays are exposed." The surface of the upper part, as figured by Hinde (*op. cit.*) resembles part of the surface of casts of species of *Ischadites* so closely that it is a matter of surprise that so keen an observer as Dr. Hinde failed to make a note of it in his memorable work on the *Receptaculitidæ.*

The supposed surface-layer, with its longitudinally arranged filiform spicules, causes me to think it possible that the horizontal rays in *A. oblonga* may really be, as in *Anomalospongia*, three in number, with the longitudinal ray the strongest. At any rate it would be well to re-examine *Amphispongia oblonga* in the new light furnished by *Anomalospongia reticulata.* The club-shaped spicules of the lower part of the sponge are too much like the vertical ray of the spicules of *Anomalospongia* to be without significance entirely. My impression is that the lower spicules of *Amphispongia* are not really mon-axial, but will be found to have head rays similar to if not precisely like those of *Anomalospongia.* Further, is it not possible that the same kind of entering rays (only smaller, perhaps,) occur in the upper part of the sponge as well, being covered there by the matrix which may intervene at a constriction just beneath the horizontal rays, and thus present to view the casts of the latter only? Again, it is possible that the so-called "upper part" of *A. oblonga* may really owe its comparative smoothness to the development of a dermal layer consisting of small cruciform and filiform spicules. But this is only speculation. What is wanted are facts showing the true condition of things in *Amphispongia*, and I hope some of our British paleontologists will favor us with a full account of them. In the meantime we can use only the close approximation and the shape and size of the spicules of the lower part in showing the relationship which I am satisfied will sooner or later be proven to exist between the two genera.

*The specimens are moulds in shaly rock merely, the sponge spicules themselves having been dissolved completely away.

Family DICTYOSPONGIDÆ, HALL.

RAUFFELLA, Ulrich.

PLATE F. FIGS. 16-20.

1889. *Rauffella*, ULRICH. American Geologist, vol. iii, p. 235.

Original description.—"Sponges free (?) forming hollow cylindrical stems, or radially arranged leaves. Wall exceedingly thin, composed of two distinct layers of spicule-tissue. Inner layer minutely porous, the pores irregularly distributed, of unequal size, the larger ones rounded, the smaller ones much more numerous and mostly of irregularly angular outline : spicular tissue separating pores thin, the nature of its elements undetermined. Outer layer consisting of a network of large spicules, apparently of a curiously modified hexactinellid type. Usually they appear as irregularly coalescing thread-like striæ lining the surface in a longitudinal direction, with more slender connecting filaments traversing the narrow intervening spaces at more or less acute angles, leaving acutely elliptical depressed spaces. At other times the striæ cross each other diagonally, producing an appearance not much unlike that of the ordinary arrangement of the spicules in the *Dictyospongidæ*.

"Type *R. filosa* Ulrich."

RAUFFELLA FILOSA *Ulrich.*

PLATE F, FIGS. 16-18.

1889. *Rauffella filosa* ULRICH. American Geologist, vol. iii, p. 237, figs. 1, 2, 4.

Original description.—"Sponge forming a straight or slightly curved hollow cylindrical stem, 10 to 15 mm. in diameter. The largest fragment seen is 90 mm. in length. One of the ends (whether the upper or lower one, has not been determined) is rounded off somewhat like the tip of a finger. The other, probably, was open. Sponge wall less than 0.5 mm. in thickness. Outer surface generally appearing to the naked eye as strongly striated longitudinally. Under a good pocket lens numerous connecting filaments are noticeable forming with the stronger threads an irregular, narrow-meshed net-work. Nearly every specimen, however, exhibits on limited portions of the surface a comparatively regular arrangement of the spicular tissue in diagonally intersecting lines. Here the hexactinellid character of the spicules is determined, there being, apparently, four rays spread horizontally and one extending downward into the inner tissue, while the sixth is not developed. The spicules are joined together by a union of the horizontal rays of each with those of four other spicules in such a manner that a network with rhomboidal meshes is formed. Similar but smaller spicules are developed in the interspaces. This regular arrangement of the spicules is but rarely met with, the surface appearing, as already stated, usually to be striated in a longitudinal direction mainly. On an average eleven of the striæ occur in 5 mm. transversely.

"Inner layer of sponge tissue exceedingly thin and minutely porous. Its structure has not been determined, the finer details having been obliterated during the process of fossilization.

"This sponge cannot be confounded with any other fossil known to me from Cambrian or Silurian rocks, its finger-like form and the strong thread-like striations of the surface giving it a very characteristic and easily recognized aspect."

Formation and locality.—Common in the Trenton shales at Minneapolis, St. Paul, Oxford Mills, Fountain, Preston, and near Marion, Minnesota; Decorah, Iowa. ?In the Galena shales, six miles south of Cannon Falls, Minnesota.

Collectors.—Miss Cora E. Goode, E. O. Ulrich, C. L. Herrick, J. C. Kassube, W. H. Scofield, and the writers.

Mus. Reg. Nos. 712, 713, 3491, 4946, 5020, 7702-4, 7707, 7708.

RAUFFELLA PALMIPES *Ulrich.*

PLATE F. FGS. 19, 20.

1889. *Rauffella palmipes* ULRICH. American Geologist, vol. iii, p. 238, fig. 3 on p. 236.

Original description.—"Sponges rather large, originally probably of inverted pear-shaped outline, consisting of five bi- or tri-furcating compressed lobes springing from a short stem, united at the center and arranged in a radial manner. In the fossil state they present varied forms corresponding with the degree and direction of the compression they have suffered. This is much less than might be expected of so frail an organism, and I can account for the comparatively good preservation of the shape only by supposing the lower extremity of the stem to have been open, thus permitting the material that made up the strata (mud, fragments of shells, bryozoa, etc.) to enter freely into the internal cavity. Generally, the cavity is entirely filled with material of the same nature as the surrounding matrix. In a few cases free communication must have been interrupted causing a lobe to remain empty and now to appear much more compressed than usual. On account of the friable nature of the shales in which they are found, most of the specimens are mere fragments. Still, after a careful search, the author succeeded in securing three nearly complete examples. Two of these are compressed obliquely with the stem on one side, and look very much like the webbed foot of a bird. The specific name was suggested by this fancied resemblance. The third is compressed vertically and shows the radial arrangement and bifurcation of the compressed lobes very satisfactorily. As near as can be determined, the original dimensions of a specimen of medium size were about as follows: hight, 90 mm.; greatest width, 80 mm.; diameter of stem 15 mm.; thickness of lobe, 8 mm.; thickness of walls of sponge, 0.5 mm., or less.

"The spicules of the inner layer, owing to alteration and replacement by calcite, have not been determined. A thin section, however, shows that it was minutely porous, the tissue separating the pores thin, and the pores of variable size, the larger ones of rounded form, the smaller ones more or less angular. The surface, as in *R. filosa*, is striated, only the striæ are much finer and more irregular. The appearance of the surface is to be described as hirsute rather than filose."

Formation and locality.—From the Trenton shales at Minneapolis and St. Paul, Minnesota.

Collector.—Mr. E. O. Ulrich.

Mus. Reg. No. 8225.

Order CALCISPONGIÆ,* Blainville.

Family PHARETRONES, Zittel.

CYLINDROCŒLIA, Ulrich.

1889. *Cylindrocœlia*, Ulrich. American Geologist, vol. iii, p. 245.
1891. *Cylindrocœlia*, James. Jour. Cincinnati Soc. Nat. Hist., vol. xiv, p. 56.

Original description.—"Sponges free, cylindrical, or nearly so, with the lower end tapering rapidly to a point, or truncate. A central cloaca extends throughout at least the subcylindrical portion. It is of tubular or very elongate conical form, widening gradually upwards. Walls thick, traversed by irregularly disposed radiating canals. Very few of these penetrate the thin and compact dermal layer which covers both the inner and outer surfaces. When the dermal layer is worn away their sub-circular mouths appear. Skeleton, apparently very finely porous. The specimens are too much altered to admit of determining its elemental component.

"Type, *C. endoceroidea* Ulrich.

"Sponges of this genus are liable to confusion with slightly tapering forms of *Orthoceras* and *Endoceras*. The absence of septa and presence of canals should, of course, distinguish them at once."

*The systematic position of these sponges is that of Mr. Ulrich, Geol. Survey of Illinois, vol. viii, p. 239, 1890.

Cylindrocœlia minnesotensis *Ulrich.*

PLATE G. FIGS. 1-3.

1889. *Cylindrocœlia minnesotensis* Ulrich. American Geologist, vol. iii, p. 248.

Original description.—"This species differs from the preceding ones [*C. endoceroidea, C. covingtonensis*] in being almost perfectly cylinderical (*i. e.* allowing for a slight amount of compression apparent in all the specimens), the average taper in a length of 40 mm. being rarely more than 1 mm. Most of the fragments vary in diameter between 10 and 15 mm., but it is sometimes a mm. more or less. Basal extremity not satisfactorily shown in any of the specimens; apparently truncate. The cloaca must have been narrow since it, like the internal portion of the canal system, has in every case been entirely obliterated by the crystallization of the calcite of which the specimens are composed. The surface is smooth and may, according as the dermal layer remained or had been removed at the time of fossilization, exhibit very few or comparatively abundant canal apertures—more irregularly distributed, however, and not nearly so numerous as in the other species. The canals are rounded and vary in diameter from less than 1 to 2.5 mm."

Formation and locality.—Rare in the Trenton shales at Minneapolis, St. Paul, and Fountain, Minnesota. Occurring also at the base of the Galena shales, six miles south of Cannon Falls, Minnesota.

Collectors.—E. O. Ulrich and W. H. Scofield.

Mus. Reg. No. 7709.

HETEROSPONGIA, Ulrich.

1889. *Heterospongia*, Ulrich. American Geologist, vol. iii, p. 239.
1891. *Heterospongia*, James. Jour. Cincinnati Soc. Nat. Hist., vol. xiv, p. 71.

Original description.—"Sponges consisting of sublobate or irregularly divided compressed branches. Entire surface exhibiting the mouths of branching and more or less tortuous canals, which begin near the center, where they are nearly vertical, and proceed toward all portions of the surface in a curved direction. A limited number of oscula, distinguished from the ordinary canals by being larger and surrounded by radiating channels, occasionally present.

"Sponge skeleton between the canals of variable thickness, sometimes appearing nearly solid, at other times composed of loosely interwoven spicule fibers. None of the specimens show the spicules in a satisfactory manner. From the traces seen it would appear that they are mostly very small and of the three-rayed type.

"Type, *H. subramosa* Ulrich."

Heterospongia subramosa ? *Ulrich.*

PLATE G, FIGS. 4-6.

1889. *Heterospongia subramosa* Ulrich. American Geologist, vol. iii, p. 240, fig. 6 on p. 236.
1891. *Heterospongia subramosa* James. Jour. Cincinnani Soc. Nat. Hist., vol. xiv, p. 71.

Original description.—"Sponge subramose, occasionally palmate; branches more or less flattened, from 9 to 13 mm. thick and 11 to 30 mm. wide. The largest specimen seen is 65 mm. high and 45 mm. wide. Surface generally even, exhibiting the rather irregularly distributed canal apertures. These are generally of very unequal sizes, though on limited portions of the surface, both their distribution and size may be fairly regular. The average diameter of an aperture is nearly 0.7 mm., with about 5 in 5 mm. The width of the interspaces between the canal mouths is equally variable, the extremes being 0.2 and 1.2 mm. The sponge skeleton is composed of more or less loosely interwoven spicule-fibres, but in the usual state of preservation in the inter-canal spaces appear quite solid and structureless. In none of the specimens are the spicules sufficiently well preserved to make their determination a matter beyond dispute."

Formation and locality.—Rare in the Hudson River group at Spring Valley, Minnesota. Common in the same formation in Marion and Lincoln counties, Kentucky.

Collector.—E. O. Ulrich. Type in Mr. Ulrich's collection.

Order LITHISTIDÆ, Schmidt.

? Family TETRACLADINA, Zittel.

HINDIA, Duncan.

1879. *Hindia*, Duncan. Annals and Mag. Nat. Hist., fifth ser. vol. iv, p. 84.
1883. *Hindia*, Hinde. Catalogue Fossil Sponges, British Museum, p. 57.
1886. *Hindia*, Rauff. Sitzungsb. der Niederrh. Gesell. zu Bonn: Sitzung vom 10 Martz.
1887. *Hindia*, Hinde. Annals and Mag. Nat. Hist., fifth ser. vol. xix, p. 67.
1890. *Hindia*, Ulrich. Geol. Survey Illinois, vol. viii, p. 226.
1891. *Hindia*, James. Jour. Cincinnati Soc. Nat. Hist., vol. xiv, p. 56.

Hindia parva *Ulrich.*

PLATE G, FIGS. 7-9.

1889. *Hindia parva* Ulrich. American Geologist, vol. iii, p. 244.
1889. *Microspongia parva* Miller. North American Geology and Palæontology, p. 161.
1891. *Microspongia gregaria* (partim) James. Jour. Cincinnati Soc. Nat. Hist., vol. xiv, p. 54.

Original description.—"Sponges free, globular in form, with an even rounded surface. Specimens vary between 5 and 10 mm. in diameter, but in a large proportion of the specimens seen, the diameter varies but little from 7 or 8 mm.

"The radiating canals are a little smaller than in the common *H. spheroidalis* Duncan, of the Niagara, being as a rule not over 0.27 mm. in diameter. *H. inæqualis* Ulrich, from the lower or sponge beds of the Trenton limestone at Dixon, Illinois, is larger and has, as its name may indicate, radiating canals of very unequal size."

The specimens of this species occurring in the Galena of Kentucky, Tennessee, Wisconsin, and Minnesota, the localities from which Mr. Ulrich obtained his material, should not at present be regarded as belonging to *Microspongia gregaria* Miller and Dyer. The latter is not shown to be identical with *Hindia*, and, as the Galena specimens undoubtedly belong to the last named genus, there is no evidence that *H. parva* is synonymous with *Microspongia gregaria*. The varieties of *Hindia parva* found at Cincinnati and Middletown, Ohio, of which Mr. Ulrich writes *op. cit.*, p. 243), may be the same as Miller and Dyer's species, but this the writers cannot prove, as they have no material from Ohio for comparison.

Formation and locality.—Rare in the Trenton shales at Minneapolis, Minnesota. Not uncommon in the Galena of Goodhue county, Minnesota, and Oshkosh, Wisconsin. Also from a similar horizon at Danville and Frankfort, Kentucky, and south of Nashville, Tennessee.

Collectors—W. H. Scofield, E. O. Ulrich and C. Schuchert.

Mus. Reg. No. 7711.

? Class HYDROZOA.

? Sub-Class HYDROIDA.

SOLENOPORA, Dybowski.

Solenopora compacta *Billings.*

PLATE F, FIGS. 21-23.

1862. *Stromatopora compacta* Billings. Palæozoic Fossils, vol. i, pp. 55, 210.
? 1877. *Tetradium peachii* Nicholson and Etheridge. Annals and Magazine of Natural History, ser. iv, vol. xx, p. 166.
? 1877. *Solenopora spongioides* Dybowski. Die Chætetiden der ostbaltischen Silur Formation, p. 124, pl. 2.
1879. *Solenopora(?) compacta* Dawson. Quart. Jour. Geological Society, London, vol. xxxv, p. 53.
1883. *Tetradium peachii, var. canadense* Foord. Contribution Micro-Pal. Silurian Rocks of Canada, p. 24.
1885. *Solenopora compacta* Nicholson and Etheridge. Geological Mag., dec. iii, vol. ii, p. 529.
1888. *Solenopora compacta* Nicholson. Ibidem, vol. v, p. 15.
1889. *Solenopora compacta* Nicholson. Manual of Palæontology, vol. i, p. 201, figs. 83a-83d.

Original description.—"This species forms small sub-globular masses, from 1 to 2 inches in diameter. The concentric lamellæ are thin and closely packed together, there being in some specimens from 6 to 12 layers in the thickness of 2 lines."

The internal structure is described by Dr. Nicholson as follows: "Composed of radiating capillary tubes, arranged in concentric strata. The tubes vary from

$\frac{1}{12}$ to $\frac{1}{20}$ mm. in size, and are in direct contact throughout, no interstitial tissue of any kind being developed. The tubes are irregular in form, with thin, often undulated walls, which are not pierced by any apertures or pores, but are often crossed by more or fewer transverse partitions or "tabulæ." Very commonly the tubes exhibit more or fewer inwardly directed partitions, which extend to a greater or less distance into the cavity of the tube, and are the result of the cleavage or 'fission' of the tubes."

Formation and locality.—Rare in the Trenton shales near Cannon Falls, Minnesota; Frankfort, Kentucky and Nashville, Tennessee. In the Black River group at Pauquette Rapids on the Ottawa river, and island of Montreal, Canada. In division L, Newfoundland. Dr. Nicholson says it has also been found in Great Britain and Russia.

Mus. Reg. No. 8055.

Sub-Kingdom CŒLENTERATA.

Class HYDROZOA.

Sub-class GRAPTOLITOIDEA.

Family DIPLOGRAPTIDÆ, Lapworth.

DIPLOGRAPTUS PRISTIS? (*Hisinger*) *Hall.*

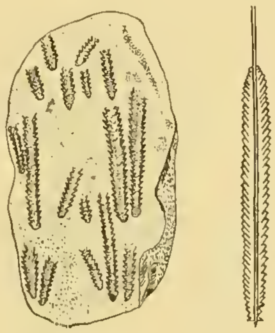


FIG. 2.

1837. *Prinotus pristis* HISINGER. Lethæa Suecica, p. 114, pl. 35, fig. 5.
1847. *Graptolithus pristis* HALL. Palæontology of New York, vol. i, p. 265, pl. 72, figs. 1a–1s.
1863. *Graptolithus pristis* BILLINGS. Geology of Canada, p. 200, fig. 195.
1865. *Graptolithus* (*Diptograptus*) *pristis* HALL. Canadian Organic Remains, dec. ii, p. 15, fig. 3b: p. 109, figs. 21, 30.
1867. *Graptolithus* (*Diplograptus*) *pristis* HALL. Twentieth Rep. N. Y. State Cab. Nat. Hist., pp, 182, 205, figs. 22, 32.
1875. *Diplograptus pristis* NICHOLSON. Palæontology of the Province of Ontario, p. 38.

Prof. Hall gives Hisinger's description of this species as follows: "Linear, straight, scarcely a line broad, compressed; rachis central, capillary; both sides with broad acute teeth" (*op. cit.* 1847).

Formation and locality.—Very common in the lower portion of the Hudson River group, in a small quarry two miles west of Granger, Minnesota. It also occurs in the Utica slate and Hudson River group at Baker's Falls, Utica, Trenton, Loraine, Turin, and elsewhere in New York; Whitby and Collingwood, Ontario; ? Cincinnati, Ohio, and Graf, Iowa.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. Nos. 7755, 7756, 7758.

DIPLOGRAPTUS PUTILLUS *Hall.*

FIG. 3.

1865. *Graptolithus* (*Diplograptus*) *putillus* HALL. Canadian Organic Remains, dec. ii, p. 44, pl. A, figs. 10–12,

1867. *Graptolithus* (*Diplograptus*) *putillus* HALL. Twentieth Rep. N. Y. State Cab. Nat. Hist., pl. 2, figs. 10–12.

Formation and locality.—Hudson River group, near Granger and near Spring Valley, Minnesota; Graf. Iowa.
Collectors.—W. H. Scofield and the writers.
Mus. Reg. Nos. 302, 4097, 7758, 7760.

CLIMACOGRAPTUS TYPICALIS *Hall.*

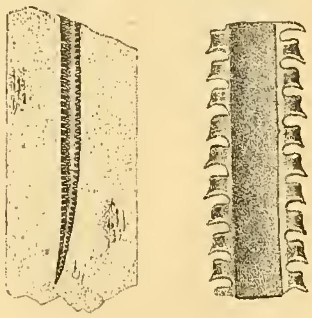


FIG. 4.

1865. *Climacograptus typicalis* HALL. Canadian Organic Remains, dec. ii, pl. A, figs. 1-9.

1867. *Climacograptus typicalis* HALL. Twentieth Rep. N. Y. State Cab. Nat. Hist., pl. 2, figs. 1-9.

Formation and locality.—In the Galena limestone at Mantorville, and Weisbach's dam near Spring Valley, Minnesota; ?Wisconsin. Cincinnati group at Cincinnati, Ohio; Hudson River group, New York.
Collectors.—W. H. Scofield and the writers.
Mus. Reg. Nos. 294, 295, 390, 7759.

Class ACTINOZOA.*

Order ZOANTHARIA.

Sub-order MADREPORARIA.

Section MADREPORARIA APOROSA.

Family ASTRÆIDÆ.

LICHENARIA TYPA, *gen. et. sp. nov.*†

PLATE G, FIGS. 10-13.

Corallum growing in small, irregular, hemispheric colonies, not exceeding 20 mm in diameter, attached by its entire under side to species of monticuliporoids. Addition of new corallites takes place, either interstitially or along the periphery, from underneath the marginal individuals. Walls of the corallites thin, imperforate. Corallites polygonal, inconstant, small but variable, the average adult size about 1 mm. or a little less in diameter, but in the largest specimens may vary from that size to 1.75 mm. in diameter. Tabulæ always few, perhaps occasionally wanting; when present they are horizontal and complete. Septa not developed; rarely two or three very faint longitudinal lines can be observed on each face of the calyx.

We know of no compound massive coral in Lower Silurian rocks with which this species need be compared. All have more or less strongly developed septa excepting *Lyopora favosa* Nicholson and Etheridge, jun.‡ In that species the septa are "rudimentary, often wanting in individual calices, varying in number from two or three up to ten or twelve or more, always abortive, and represented only by rough and blunt ridges on the interior of the wall." (Nicholson, *op. cit.*, p. 190.) *Lyopora favosa* differs however from *Lichenaria typa* in its very much thickened walls and in the mode of growth of the colony which was "rooted at its base to some foreign body, and the diverging corallites seem to have opened over the whole of the free surface, no traces of an epitheca having come under my observation." (Nicholson, *op. cit.*, p. 190.) Species of *Columnaria* are distinguished from *Lichenaria typa* by their well developed alternately large and small septa, which extend nearly to the centre of the corallites in the type species. *Columnaria incerta* Billings§ is

---

*The classification here given for the corals is that of Dr. Nicholson; "Manual of Palæontology, vol. i, pp. 240-345, 1889.
†*Lichenaria* from *leichen*, tree-moss, and *aria*, the latter portion of *Columnaria*, its most likely relative.
‡Mono. Sil. Foss. Girvan, p. 26, pl. 2, figs. 1-1e, 1878. Nicholson. Pal. Tab. Corals, p. 190, pl. 8, figs. 3, 3a; pl. 9, figs. 2, 2a. 1879.
§Canadian Nat. and Geol. vol. iv, p. 428, figs. 1, 2, 1859.

a species probably without septa, but the corallites are described as "slender cylindrical tubes which may be in contact or separate", and "the aspect of the species is remarkably like that of *Syringopora*."

Small colonies of *Lichenaria typa* look much like a mass of *Conchicolites flexuosus* Hall, as figured by Prof. Hall (Pal. New York, vol. vii, pl. cxv, fig. 19). The apertures of the latter are also polygonal in outline, but beyond this the two species are totally unlike.

A very small colony of this species, figured on plate G, fig. 11, has given off a single corallite in a manner which is characteristic of *Aulopora? trentonensis*, *n. sp.* This corallite has developed three other buds, which have elevated the calyx of the parent, as in *Aulopora*. Where there are no young corallites infringing upon it, the wall is circular in outline, with three distinct angles along the side from which the buds have originated. The polygonal outline of the cells of compound corals is probably due to lateral crowding of the corallites. In nearly every case observed by us, when the cells are round in outline, they stand out free from the colony.*

Formation and locality.—Not rare in the Trenton shales near Minneapolis, Minnesota. Mr. Ulrich writes us that he has specimens which "undoubtedly belong to this genus and probably are specifically the same as *typa*, from the Black River limestone at Pauquette Rapids, Canada."

Collectors.—E. O. Ulrich and C. Schuchert.

Lichenaria minor, *n. sp.* (*Ulrich.*)

Fig. 5.

Fig. 5. *Lichenaria minor* Ulrich, Trenton shales, near Cannon Falls, Minnesota. *a*, an example of this species, growing as usual upon a ramose bryozoan ; *b*, small portion of same with the corallites opening more direct than usual, x3.

Corallum attached parasitically to foreign bodies (chiefly ramose bryozoa) over which it forms irregular patches 1 mm. or a little more in thickness. Corallites comparatively small, of unequal size, irregularly distributed, their apertures rounded or subangular and more or less oblique ; the largest nearly 1 mm. in diameter, the average adult size about 0.7 mm., while many are smaller, presumably younger, ranging in size between 0.2 and 0.5 mm. Septal striæ apparently wanting. Here and there a faintly raised line may be detected on the inner side of the imperforate walls, but they are too irregular in their disposition and number to be called septa.

*"The majority of compound corals included in the *Favositidæ* are composed of polygonal prismatic cells or corallites in juxtaposition. When, however, these cells become free, their form is cylindrical. The polygonal form of closely arranged cells is therefore explained as the natural result of crowding"; Dr. C. E. Beecher, "Symmetrical cell development in the *Favositidæ*" (Trans. Connecticut Academy, vol. viii, p. 215, 1891).

This species is readily distinguished from the preceding form (*L. typa* Winchell and Schuchert) by its thinner corallum, smaller and more unequal corallites, and the obliquity of their apertures. The last is a strongly marked feature of the species, especially near the margins of the corallum. *L. typa* also occupies a lower horizon in the shales.

Formation and locality.--Galena shales, near Cannon Falls, Minnesota. The type specimen is in the collection of Mr. Ulrich.

COLUMNARIA (?) HALLI *Nicholson.*

PLATE G, FIGS. 14-16.

1832. *Columnaria alveolata* EATON (non GOLDFUSS). Geological Text Book, p. 131, pl. 4.
1842. *Columnaria* EMMONS. Geology of New York; Rep. Second District, p. 276, fig. 2.
1847. *Columnaria alveolata* HALL (non GOLDFUSS). Palæontology of New York, vol. i, p. 47, pl. 12, figs. 1a-1c.
1857. *Columnaria alveolata* BILLINGS. Canadian Naturalist and Geologist, vol. i, p, 124, figs. 9, 10.
1863. *Columnaria alveolata* BILLINGS. Geology of Canada, p. 139, fig. 70, and pp. 938, 954.
1875. *Columnaria alveolata* NICHOLSON. Palæontology of the Province of Ontario, pp. 8, 24.
1876. *Columnaria alveolata* ROMINGER. Fossil Corals of Michigan, p. 89, pl. 34, figs. 1, 2, 4.
1879. *Columnaria (?) halli* NICHOLSON. Palæozoic Tabulate Corals, p. 200, fig. 29, pl. 10, figs. 3, 3a.

Description.—"Corallum forming large massive colonies which vary from a few inches to several feet in diameter, and which are composed of variously-sized polygonal corallites, in close contact with one another throughout their entire length. The walls of the corallites are not excessively thickened, and they are so completely amalgamated in contiguous tubes that even under the microscope the original lines of demarcation between the tubes can be made out with difficulty or not at all. The large tubes are usually from two to three lines in diameter, though occasionally considerably more than this ; and the smaller corallites are of all sizes. Septa marginal, in the form of obtuse longitudinal ridges which vary in number from twenty to forty, do not extend to any distance into the visceral chambers, and are not divisible into an alternating longer or short series. Tabulæ strong, horizontal and complete, about half a line apart or sometimes closer. Mural pores not recognized with certainty."

"I am disposed to doubt very strongly if the present form can be referred to *Columnaria* at all, and whether it is not truly a perforate coral congeneric with *Nyctopora*, Nicholson." (Nicholson, *op. cit.*, p. 200.)

Columnaria alveolata Goldfuss (not Hall) and *Favistella stellata* Hall, are synonymous according to Milne-Edwards and Haime, and Nicholson. The latter writer says: "It is quite certain, however, that the Trenton limestone coral just alluded to [*C. alveolata* of American palæontologists] is *not* the form described originally by Goldfuss, and carefully figured by him under the name of *Columnaria alveolata* (Petref. Germ., pl. xxiv, fig. 7). On the contrary, the latter is almost certainly identical with the coral subsequently described by Hall under the name *Favistella stellata*. This is rendered the more certain by the fact that the specimens of *Columnaria alveolata* described by Goldfuss are said to come from the shores of Seneca Lake, in the state of New York, where the Lower Silurian rocks do not occur in place; so that they must have been derived from a traveled boulder. This also would harmonize with the assertion of Edwards and Haime, that *Columnaria alveolata* (Gold.) and *Favistella stellata* (Hall) are one and the same coral.

"Whilst fully believing that these two corals, as described by their original discoverers, are identical, it nevertheless remains certain that the corals now recognized universally in America as *Columnaria alveolata* and *Favistella stellata* are entirely distinct from one another, specifically if not generically. * * * * * If the strict law of priority, with its utmost rigor, is to be carried out, then the name of *Favistella stellata* must be abandoned; the coral now known by this name must be called *Columnaria alveolata* (Goldfuss), and the coral to which this latter title has been generally applied will have to be baptized by some quite new name." (Nicholson, *op. cit.*, p. 23, 1875).

In 1879, Prof. Nicholson proposed for this coral the name *Columnaria ? halli*. He writes, "I have come to the conclusion, after full consideration, that the best course to adopt with regard to this species, is to give it a distinct and specific name." (*op. cit.*, p. 201, 1879.)

The colonies of *C.* (*?*) *halli* occurring in Minnesota are usually small masses from an inch (25 mm.) to four and one-half inches (11.5 cm.) in diameter. In the Black River group of New York, this species often attains a large size. "There is a specimen (a portion only of an entire mass) in the state collection [New York] weighing about 1,500 pounds; the whole mass probably weighed 2,000 or 3,000 pounds." (Hall, *op. cit.*)

Formation and locality.—Rare near the base of the Trenton shales at Cannon Falls, Preston and St. Charles, Minnesota. In the "Upper Buff beds" of the Trenton, in Wisconsin, and at Rockton, Illinois. Common in the Black River group at Chazy, Watertown, and elsewhere in New York; Belleville, Peterboro, Collingwood, Ontario, Canada. In the Trenton at Dixon, Illinois; High Bridge, Kentucky, and Central Tennessee (Ulrich).

Collectors.—W. H. Scofield and the writers.

Mus. Reg. Nos. 5546, 7726, 7734.

Section MADREPORARIA RUGOSA.

Family STREPTELASMIDÆ, Nicholson.*

STREPTELASMA, Hall.

1847. *Streptoplasma*, HALL. Palæontology of New York, vol. i, p. 17.
1847. *Streptelasma*, HALL. Ibidem, corrections, p. 339.
1857. *Streptelasma*, BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 122.
1875. *Streptelasma*, NICHOLSON. Palæontology of Ohio, vol. ii, p. 21.
1889. *Streptelasma*, NICHOLSON. Manual of Palæontology, vol. i, pp. 247, fig. 127B; 278, 279, fig. 156 A, B; 280, fig. 157; 297, fig. 178 A, B.

Corallum simple, turbinate or conical, probably always slightly attached. Outer wall more or less thick, produced by the lateral thickening and fusing of the outer ends of the septa one with another. Septa numerous, prominent, alternately large and small, sometimes dentated along their edges, divided into four groups by three fossulæ and a more or less prominent counter septum, sometimes straight, slightly bent or strongly twisted and obscuring the fossulæ in the center of the calyx. Cardinal septum short or long dividing the most prominent or dorsal fossula centrally, which is situated on the convex side of the corallum ; alar septa short, situated in the lateral fossulæ ; counter septum sometimes very prominent. "The lower part of the visceral chamber is more or less extensively filled up with stereoplasma, and the upper part of the same is crossed by irregular tabulæ, dissepiments being also developed in moderate numbers. The center of the visceral chamber is [sometimes] occupied by a large, irregularly reticulated or trabecular pseudocolumella, with which the inner ends of the long septa are directly connected, and which is highly characteristic of the genus." (Nicholson, *op. cit.*, p. 298, 1889.)

Type, *S. expansa* Hall. Species usually adopted as the type, *S. corniculum* Hall.

A line of development can be traced clearly in *S. profundum*, *S. corniculum* and *S. rusticum*. The first species makes its appearance in the Birdseye and Black River groups, is generally straight in its growth with a deep visceral cavity and has regular septa. This form passes into a larger and more or less strongly curved corallum, *S. corniculum* of the Trenton and Galena groups, the visceral cavity is less deep, being more strongly filled up with stereoplasma, and has a greater number of septa which in approaching the center become twisted obscuring the lateral fossulæ and there forms a small pseudocolumella. In *S. rusticum* of the Hudson River group, the corallum attains to two or three times the length of *S. profundum*, while the septa are as a rule even more numerous and more strongly twisted, with a larger pseudocolumella than in *S. corniculum*, the entire lower portion of the coral is filled up with stereoplasma.

*Manual of Plæontology, vol. i, p. 297.

STREPTELASMA PROFUNDUM (*Conrad ms.*) *Owen.*

PLATE G, FIGS. 17-19.

1844. *Cyathophyllum profundum* OWEN. Geological Exploration of Iowa, Wisconsin and Illinois, pl. 16. fig. 5.
1847. *Streptoplasma profunda* HALL. Palæontology of New York, vol. i, p. 49.
1847. *Streptelasma profunda* HALL. Ibidem, pl. 12, figs. 4a-4d.
1857. *Streptelasma profunda* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 123, figs. 7, 8.

Original description.—"Obliquely turbinate, often slightly curved near the base, expanding above more or less abruptly; cell profoundly deep, extending nearly to the base of the coral; margin of the cup reflexed; surface scarcely marked by transverse rugæ; lamellæ from 36 to 60, strong, nearly equal on the margin, but distinctly alternating in length within; no transverse dissepiments or celluliferous structure."

Billings probably was the first to point out that the three primary septa of *Streptelasma* are plainly indicated on the outside of the corallum from which the other septa branch. He says: "The mode of growth of these corals [*S. corniculum* and *S. profundum*] appears to have been as follows: At first they consisted of a mere point attached to the rock, when the cup commenced to form there were only four partitions or lamellæ; as it increased others were added, three of the original ones continuing to grow, and the fourth being undeveloped. In good empty specimens of *S. profunda* the three large primary lamellæ are very conspicuous above the others on the inside of the cup, and on the outside their position is marked by three upright seams extending from the top to the bottom, and from each side of which the newer lamellæ may be seen branching away."

In the Canadian specimens of this species the corallum "is very little or not at all curved," and the same is true of Minnesota individuals occuring in the Trenton limestone and the lower portion of the shales immediately above. In Wisconsin, however, where it is quite abundant near the base of the "Upper Buff" beds in well preserved specimens, the curvature is more often as great as in *S. corniculum* Hall. The point of attachment in these is often well shown, but is generally smaller than in that species.

S. profundum can be readily separated from *S. corniculum* by its profoundly deep visceral cavity, smaller number of distinct crenulated septa which are never twisted in approaching the center and in the more sharply defined lateral fossulæ and greater development of the four primary septa. Billings gives the number of large and small septa in adult Canadian examples as about seventy-four, and this likewise is true for Minnesota specimens, while those from Wisconsin vary between 60 and 72. The greater variation mentioned by Hall, "lamellæ from 36 to 60," is probably due to young examples, which always have a smaller number of septa than adult specimens.

Formation and locality.—Abundant as natural casts of the visceral cavity near the top of the Trenton limestone at Minneapolis, St. Paul and Cannon Falls, Minnesota. In the Trenton shales it is common at Minneapolis, St. Paul, Cannon Falls, Fountain, near Caledonia, and Preston, Minnesota; Decorah, Iowa. Very common near the base of the "Upper Buff" beds of the Trenton in siliceous specimens at Mineral Point, Beloit and Janesville, Wisconsin; and as natural casts at Rockton, Illinois. In the Trenton limestone at Dixon, Illinois; "Glade limestone" of Tennessee. In the Birdseye limestone at Manheim and East-Canada creek, NewYork; Canada; and in Mercer county, Kentucky. In the Black River group at Watertown and Chazy, New York; Isle la Motte; and Canada

Collectors.—W. H. Scofield, H. V. Winchell, C. L. Herrick, E. O. Ulrich and the writers.

Mus. Reg. Nos. 433, 664, 710, 3487-3489, 4038, 4057, 5053, 5079, 5305, 6751, 6774, 6781, 6808, 7737-7743, 7912, 7986.

STREPTELASMA (?) PARASITICUM, *n. sp.* (*Ulrich*).

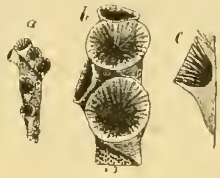


FIG. 6.

Fig. 6. *Streptelasma ? parasiticum* Ulrich, Trenton shales, St. Paul, Minnesota. *a*, View of the type specimen of this species, natural size; *b*, several of the corallites on the opposite side of the specimen, x3; *c*, sectional view of one of the corallites, to show depth of calyx.

Corallum small, parasitically attached to bryozoa, consisting of a variable number of conical cups growing in series one from the other in a manner suggesting *Aulopora;* each about 3.5 mm. long, and 2 mm. wide across the open calyx. The specimen which I regard as the type of the species, consists of ten corallites that have grown in a spiral manner over the two sides and one end of a fragment of *Rhinidictya mutabilis* Ulrich, about 12 mm. long. Of these the largest has a diameter of 3 mm., and the smallest only 1.5 mm. Where there is sufficient room for their unimpeded development the calices are circular and quite oblique, but at the upper end of the specimen, where they are more crowded, they are nearly direct and of shapes depending upon the degree in which they impinge upon each other. Outer surface marked with more or less distinct vertical ribs and fine but sharp encircling striæ. Calices very deep, the corallites seeming to consist in great part of a mere shell, exhibiting on the inner side from thirty to thirty-six, faintly denticulate, septal ridges. One half of the number are exceedingly delicate and might be overlooked.

I found it impossible to remove all the matrix from the calices, so I cannot say positively how the septa unite at the bottom. Fig. 3*b* shows all that could be made out.

The generic position of this fossil is rather doubtful, yet it seems to me within the possibilities that it may be proven to be merely the young of some species of *Streptelasma* like the associated *S. profundum.* Still, the probability of such a finding is so remote that I cannot hesitate to describe it as new, and as a matured form. Against these being young corallites I would urge (1) their nearly equal size, and (2) their crowded habit of growth. They could not have grown to larger size except by becoming detached from the supporting body, which is a supposition so unlikely that it is not to be entertained for a moment.

Where the calices are in contact the appearance is decidedly suggestive of *Columnaria*, and, while I doubt it, this resemblance may really indicate true relationship. For the present it seems to me the species may well be arranged as above under *Streptelasma* near *S. profundum*. There it can remain till we learn more of its characters, or until the genus *Streptelasma* is redefined and strictly characterized. And right here I wish to say that no genus of paleozoic corals is less understood and more in need of revision than *Streptelasma*. As now used it is made to include some very diverse types.

Formation and locality.—Rare in the middle division of the Trenton shales at St. Paul, Minnesota. Another specimen, consisting of six corallites, of the same or a closely related species, was collected by me from the Trenton limestone at Minneapolis. Now in my collection.

STREPTELASMA CORNICULUM *Hall.*

PLATE G, FIGS. 20, 21.

1847. *Streptoplasma corniculum* HALL. Palæontology of New York, vol. i, p. 69.
1847. *Streptelasma corniculum* HALL. Ibidem, pl. 25, figs. 1a–1e.
1847. *Streptoplasma crassa* HALL. Ibidem, p. 70.
1847. *Streptelasma crassa* HALL. Ibidem, pl. 25, figs. 2a–2c.
1847. *Streptoplasma multilamellosa* HALL. Ibidem, p. 70.
1847. *Streptelasma multilamellosa* HALL. Ibidem, pl. 25, figs. 3a–3c.
1847. *Streptoplasma parvula* HALL. Ibidem, p. 71.
1847. *Streptelasma parvula* HALL. Ibidem, pl. 25, figs. 4a–4c.
1857. *Streptelasma corniculum* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 122, figs. 3 and 4, on p. 121.
1863. *Petraia corniculum* BILLINGS. Geology of Canada, p. 156, fig. 118, and p. 938.
1875. *Streptelasma corniculum* NICHOLSON. Palæontology of Ontario, p. 12, (p. 26 partim).

Original description.—"Turbinate, curved near the base, which terminates in an acute point, somewhat rapidly expanding above; cup profound; lamellæ about sixty; surface marked by strong longitudinal lines indicating the lamellæ, which are crossed by fine concentric wrinkled lines.

"Length varying from three-fourths to one and a half inches."

Corallum conical, more or less curved, greatest length observed 45 mm., with a diameter of 27 mm.; slightly attached. Exterior exhibiting longitudinal lines corresponding with the larger septa within, those on the dorsal side converging to the cardinal and alar septa; rarely smooth and commonly with folds of growth. Calyx more or less deep with three fossulæ, the cardinal one most prominent placed on the dorsal or convex side of the corallum, with the others disposed laterally. Septa alternately large and small, slightly dentate, from 45 to 60 of the former in adult examples, while the youngest specimens observed have 30. Cardinal and counter septa long and prominent, alar septa short; between these primary septa the others are arranged in bundles, the large ones uniting at their inner ends, and are commonly twisted (rarely straight) forming a small pseudocolumella. Lower part of the visceral chamber somewhat filled up with stereoplasma. Tabulæ and dissepiments remote and very irregular.

This species can be readily separated from *S. profundum*, by the greater curvature of the corallum, shallower visceral cavity and more numerous septa, which, on approaching the center of the calyx become more or less twisted. The last named feature never occurs in *S. profundum*.

This common coral is more or less abundant at all exposures of the Galena shales throughout Minnesota. Specimens vary from 15 to 45 mm. in length. The large and small septa vary from 60 to 120. Since so great a variation in the number of septa obtains in this species, it is advisable to consider as synonymous with it, *S. crassa*, *S. multilamellosa* and *S. parvula* Hall. A similar conclusion was reached by Billings in 1863 and by Nicholson in 1875.

Several immature individuals of this species have been found growing on *Rhinidictya*, and occasionally an adult specimen will show traces near the base of the corallum of its former attachment to some bryozoan. That species of this genus are attached to foreign bodies, at least during their earlier growth, is almost certain. As the point of union is very small, it is also quite probable that the individuals, on reaching maturity, became broken off by the weight of the corallum.

Formation and locality.—Common in the Galena shales at many localities in Goodhue, Olmsted and Fillmore counties, Minnesota; Decorah, Iowa; Oshkosh, Wisconsin. It is also common in the Trenton limestone at Middleville, Trenton Falls, and elsewhere in New York; Montreal, Peterboro, and Ottawa, Canada.

Collectors.—E. O. Ulrich, W. H. Scofield and the writers.

Mus. Reg. Nos. 162, 207, 318, 364, 5840, 6750, 7744-7751.

STREPTELASMA BREVE *n. sp.* (*Ulrich*).

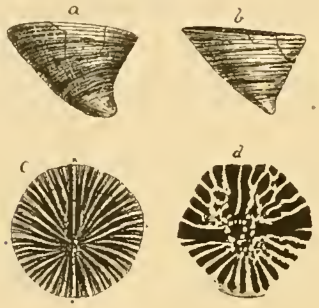


FIG. 7.

Fig. 7, *Streptelasma breve* Ulrich, Galena limestone, near Fountain, Minnesota. *a*, an average specimen, natural size; *b*, an unusually straight example; *c*, the flattened but entire calyx of another specimen; *d*, represents the greater part of the calyx of a fourth example, x 2, showing the central union and arrangement of the septa and foveæ in a very clear manner.

Corallum free, simple, conical, small, curved, expanding very rapidly, the width greater than the hight. An average specimen is about 11 mm. high and 16 mm. wide across the cup. In a small specimen the measurements are, respectively, 7 and 11 mm. Surface marked with fine encircling lines and stronger annulations of growth; occasionally also with delicate vertical ribs. The latter seem, however, to be restricted to the lower half of the corallum. Calyx deeply concave, the bottom extending to a point a little beneath the middle of the hight. Septa large and small, the latter shown only in the extreme outer part of complete calices, the ormer extending to the center where they unite into four bundles of from six to eight in each. Principal septum straight, sometimes stronger than the others, extending to the center through a well marked fovea. The septa on each side of it arranged in a pinnate manner, uniting centrally. Lateral foveæ narrow, but generally recognizable. Opposite septum forming the central one of usually fifteen septa that are radially arranged in the half of the calyx on the shorter or concave side of the corallum. As a rule it is distinguished by its greater strength and prominence. Lateral septa inconspicuous, shorter than the others. Total number of septa in a specimen of the average size about sixty-four, of which thirty-two are large and long, while an equal number belong to the intermediate rudimentary set. All of them seem to have been obscurely dentate, and but little elevated, so that they are to be termed ridge-shaped rather than lamellate. At the center of the calyx the septa inosculate, forming a limited number of cells bounded by spinulose walls. As shown in fig. 2*d*, the condition described is scarcely to be called a twisting of the septa. Internal structure unknown.

This species seems to be near *S. corniculum* Hall, but is readily distinguished by its smaller size, more rapidly expanding corallum, more distinct foveæ, and less twisted as well as less laminar septa. *S. profundum* Conrad (Hall) is straighter, has a deeper calyx, and is entirely without the central twisting or inosculation of the septa.

Formation and locality.—Rather rare at the top of the Trenton limestone, near Fountain, Minnesota. Ten specimens collected by the author are now in his cabinet.

STREPTELASMA RUSTICUM *Billings.*

PLATE G, FIGS. 22, 23

1851. *Streptelasma corniculum* EDWARDS and HAIME (non Hall). Monograph Poly. Foss. des Terr. Pal., pl. 7, fig. 4.
1858. *Petraia rustica* BILLINGS. Geological Survey of Canada; Report of Progress for 1857, p. 168.
1875. *Streptelasma corniculum* NICHOLSON (non Hall). Palæontology of Ohio, vol. ii, p. 208.
1875. *Streptelasma corniculum* (partim) NICHOLSON. Palæontology of the Province of Ontario, p. 26.
1882. *Streptelasma corniculum* HALL. Eleventh Report State Geologist of Indiana, p. 376, pl. 51. figs. 2-4.
1889. *Streptelasma rusticum* MILLER. North American Geology and Palæontology, p. 205.
1889. *Streptelasma corniculum* NICHOLSON. Manual of Palæontology, vol. i, p. 247, fig. 127B; p. 278, 279, figs. 156A, B; p. 280, fig. 157; p. 297, figs. 178a, 178b.

Original description.—"Straight or slightly curved, covered with a strong epitheca, which is more or less annulated with broad shallow undulations; radiating septa about one hundred or usually a little more; much confused in the center, where they form a vesicular mass; every alternate septum much smaller than the others, only half of the whole number reaching the center. Length from two inches and a half to three inches and a half. Diameter of cup one inch to one inch and a half; depth of cup half an inch or somewhat more."

This species attains a larger size than *S. corniculum* Hall, with which it is usually identified, and differs from it in having the septa more strongly twisted and coarser in approaching the center of the calyx, where they form a vesicular mass or pseudocolumella. This central twisting of the septa is not so pronounced in Minnesota specimens as it is in individuals from Richmond, Indiana. A large series of specimens will exhibit considerable variation in the extent of the central vesicular mass, and though it is usually of much coarser construction in the form described by Billings, it cannot be denied that the two species are very closely related.

Formation and locality.—In the Hudson River group near Granger, and at Spring Valley, Minnesota; Graf, Iowa; Richmond, Indiana; Oxford and Dayton, Ohio. Snake island, lake St. John, and Manitouwaning, Georgian bay, Canada.

Collectors.—W. H. Schofield, E. O. Ulrich, and the writers.

Mus. Reg. Nos. 7753, 7754.

Section MADREPORARIA PERFORATA.

Family PORITIDÆ.

PROTARÆA VETUSTA *Hall, sp.*

PLATE G, FIGS. 24, 25.

1847. *Porites? vetusta* HALL. Palæontology of New York, vol. i, p. 71, pl. 25, fig. 5a, 5b.
1850. *Astræopora vetusta* d'ORBIGNY. Prodrome de Paleontologie.
1851. *Protarea vetusta* EDWARDS and HAIME. Monograph Poly. Foss. des Terr. Pal., pl. 14, fig. 6.
1875. *Protarea vetusta* NICHOLSON. Palæontology of Ohio, vol. ii, p. 221.
1875. *Protarea vetusta* NICHOLSON. Palæontology of the Province of Ontario, p. 9.
1882. *Protarea vetusta* HALL. Eleventh Rep. State Geologist of Indiana, p. 378, pl. 49, fig. 4.

Original description.—"A sub-hemispheric coral, composed of irregular concentric laminæ; cells vertical to the laminæ; openings upon the surface, nearly circular, with internal vertical lamellæ which reach half way to the center."

The following description is that of Nicholson (Pal. Ohio, vol. ii, p. 221):

"Corallum forming thin crusts, about one-third of a line in thickness, which grow parasitically upon foreign bodies. Calices nearly equally developed, usually hexagonal, about one line in diameter or rather less, shallow, the bottom of the cup being tuberculated. Septa twelve in number, sub-equal, extending but a short distance inwards towards the center of the visceral chamber. Walls of the calices thick."

Mr. Ulrich has a specimen of this species from the upper layers of the Trenton shales of "St. Anthony hill," St. Paul, Minnesota. He writes us that the specimens from the Cincinnati group and identified with this species have larger calices than those collected by him from the Trenton at Pauquette Rapids, Canada, which are, undoubtedly, like the specimen from Minnesota. If this difference is a specific one, which is very probable, then the specimens from the Hudson River group and referred to this species should be distinguished by another name. It may be that this is the form named in 1851 by Edwards and Haime, *Protarea verneuili* (Pol. Foss. des Terr. Pal., p. 71.)

Formation and locality.—A single specimen of this species has been found in the Hudson River group at Spring Valley, Minnesota, upon a fragment of a species of *Rafinesquina*. It is also found in the upper portion of this group at Richmond, Indiana; Oxford, Waynesville, etc., Ohio, and Wilmington, Illinois. In the lower portion of the Trenton formation at Watertown, New York; Peterboro and near Ottawa, Canada, and St. Paul, Minnesota.

Mus. Reg. No. 7725.

? Order ALCYONARIA.

Family AULOPORIDÆ.

Aulopora (?) trentonensis, *n. sp.*

PLATE G, FIGS. 26-28.

Corallum adnate, growing on ramose bryozoa of various species, uniserially disposed. In most cases the bryozoan has kept pace with the *Aulopora* and grown over it, so that the sub-circular apertures of its corallites alone remain to attest its presence. Corallites short, about 2 mm. long, subconical, increasing rapidly to the aperture ; the latter elevated, slightly oblique, subcircular, about 1 mm. in diameter ; outer surface with faint encircling lines, and occasionally still finer longitudinal lines. Generally, every second corallite gives rise to two buds, and these in their turn to one each. The buds are developed from the under side in the anterior third of the parent corallite. In rare instances three buds seem to have been given off simultaneously, but one of these is always abortive, failing to attain full development. Interior of corallites apparently without structures of any kind, the cavities being filled with the matrix only, and where this is removed, in direct communication with each other throughout the colony. Blunt spine-like projections may be noticed on the inner side of the lower wall, but these occur only where the corallum has grown upon *Batostoma winchelli* Ulrich, or such other forms having well developed acanthopores, to show through the substance of the parasitic *Aulopora*.

The absence of septal striæ and spines, and of tabulæ throws some doubt upon the generic position of this interesting species, and we are not satisfied that it is an *Aulopora*. Still, as the coral agrees very well with the genus in all its external characters, and since the internal characters of but few of the species are known, we believe it sufficient for the present needs to classify the Trenton species as above.

This is the only coral of the nature of *Aulopora* known to us in Lower Silurian rocks, the *A. arachnoidea* Hall, being a bryozoan of the genus *Stomatopora*, Bronn. There is no associated fossil with which it might be confounded, with the possible exception of the tubiculous annelid *Conchicolites minor* Nicholson, the tubes of which, like the present species, frequently attach themselves to monticuliporoids, and were more or less completely overgrown by their host. Even in the latter event, the rounded aperture of the *Conchicolites* left open in the surface of the bryozoan may be distinguished by their less regular distribution and rather smaller size.

Formation and locality.—Not uncommon in the lower and middle beds of the Trenton shales at Minneapolis, St. Paul, three miles south of Cannon Falls, and near Fountain, Minnesota.

Collectors.—E. O. Ulrich, and the writers.

Mus. Reg. No. 8240.

CHAPTER IV.

ON LOWER SILURIAN BRYOZOA OF MINNESOTA.

BY E. O. ULRICH.

INTRODUCTORY REMARKS.

To the Bryozoa must be accorded the first rank among the various classes of fossils that are represented in the Lower Silurian rocks of Minnesota. They are entitled to this distinction, first, because of the great variety of form and structure found among them, and, second, because of their exceeding abundance, in the way of individuals. In both of these respects their representation exceeds that of the Brachiopoda, which doubtlessly held the second rank, in the approximate ratio of two to one. So plentiful are their remains in some of the beds, particularly in the shaly members, that they may be said to constitute no inconsiderable part of the strata. In the Trenton shales the intercalated plates of limestone are literally covered with them, and they are not rare even in the massive limestones above and beneath the shales, which were deposited under conditions much less favorable to their development. In short, of every impartial collection of the Lower Silurian fossils of Minnesota, the Bryozoa necessarily constitute a large proportion, not only of the number of species and specimens, but of its bulk as well.

The importance of the Bryozoa from the view of the stratigraphical geologist, is again second to no other class of fossil remains. Many of them have a wide geographical distribution, and as they usually occur in greater or less abundance, and are very persistent in their characters, their value as data upon which to base correlations of strata at widely separated localities cannot be overestimated. Many of them, especially of the suborder *Trepostomata*, are serviceable even where other fossils are too imperfect, since with the aid of thin sections mere fragments can often be identified with certainty.

Living Bryozoa are all inhabitants of water, and mainly of the sea, occurring in all zones and at varying depths, though seeming in general to prefer clear and shallow water. With the single exception of the genus *Loxosoma*, they are composite animals, which by the combined efforts of the individual polypides built up colonies of greater or less extent, and of either a calcareous, corneous, or membranaceous composition, by means of repeated, continuous gemmation. These colonies, in both the living and fossil forms, present so great a variety of form and habit, that it is difficult if not impossible, to express their growth by any definite formula. Sometimes they grow in plant-like tufts, composed of series of cells variously linked together; sometimes they spread over shells and other foreign bodies, forming entire crusts of exquisite pattern, or delicately interwoven threads; sometimes they rose into coral-like masses, branching stems, and narrow or broad fronds; at other times the cell-bearing branches formed most beautiful and regular open-meshed lacework.

However diverse the external aspect of the combined product, the small builders themselves conform to a simple and quite definite type. Considered briefly, the polypide consists of an alimentary canal in which three distinct regions, an œsophagus, stomach, and intestine, are recognizable. This is enclosed in a sac, and bent upon itself so that its two extremities or openings approximate, one of them, the oral, being furnished with a number of slender, hollow, and ciliated tentacles, whose movement causes the food to be brought to the mouth. As a rule, the anal opening is situated without the ring of the tentacles. Generally the upper surface of the sac is flexible and capable of being invaginated by the action of retractor muscles attached to the alimentary canal, so that when the animal retreats into its cell the inverted portion forms a sheath around the tentacles. Heart and vascular system are wanting, but a nervous ganglion is present, and reproductive organs are developed in various positions within the cavity of the cell. The ova may be developed in a special receptacle (*marsupium*) attached to the zoœcium, or in an inflation of the surface of the zoarium, sometimes called a *gonocyst;* in other cases a modified zoœcium (*gonœcium*) is set apart for reproductive functions. The general term *oœcium* is applicable to all these structures. Many Bryozoa are provided with appendicular organs called avicularia and vibracula. The avicularia may be pedunculate, and sway to and fro, or they may be immovably attached to the zoœcium. The vibracula are flexible, bristle-like appendages, set in the excavated summit of a knob-like elevation or blunt spine. The acanthopores found so frequently among paleozoic Bryozoa, were probably the supports of similar structures.

TERMINOLOGY.

Zoarium (=*polyzoarium* and *cœnœcium* auctt.):—The composite structure formed by repeated gemmation.

Zoœcium (=*cell* auctt.):—The true cell or chamber in which the polypide is lodged.

Mesopores (=*interstitial cells* auctt.):—The angular or irregular cells which occupy the spaces between the zoœcia in many of the *Trepostomata* and some of the *Cryptostomata*,

Vesicular Tissue:—The vesicles which occupy the space between the zoœcia in *Pachydictya*, the *Fistuliporidæ* and other paleozoic Bryozoa.

Acanthopores (=*spiniform corallites* Nicholson, *spiniform tubuli* Ulrich, *Wandrohrchen* Dybowski):—The tubular spines which are found in so many paleozoic Bryozoa, notably *Dekayia*, *Leioclema* and *Batostoma*.

Median Tubuli (*Wandstränge* Dybowski):—Very slender tubes which are present between the zoœcial walls and the median laminæ of certain double leaved forms (*e. g. Rhinidictyonidæ*). Their apertures at the surface are slightly elevated and present the appearance of series of minute granules. The small granules in *Rhombopora*, *Stenopora* and other genera, are supposed to be of the same character.

Communication Pores:—Small pores which pass through the walls of the zoœcia and establish communication between adjacent cells.

Oœcium (=*ovicell, gonocyst, gonœcium* auctt.):—A modified zoœcium set apart for reproductive functions, the inflation of the zoarium in which the embryos are developed, or a special receptacle (marsupium) which is attached to the zoœcium, and serves the same purpose.

Diaphragms (=*tabulæ* and *septa* auctt.):—The straight plates which cross the tubular zoœcia and mesopores in the *Trepostomata* and a few forms of the *Cryptostomata*.

Cystiphragms:—The convex plates which line the walls of the zoœcial tubes in some of the *Trepostomata* (*Prasopora*).

Zoœcial covers (*opercula*) and Perforated diaphragms:—Horizontal plates perforated subcentrally, covering the zoœcia in the *Trepostomata*. As growth proceeds in the colony these are left behind in the tubes, and mark the successive stages.

Hemisepta:—The superior hemiseptum is a plate or laminar projection within the posterior border of the primitive zoœcial aperture, common in the typical *Cryptostomata*. The inferior hemiseptum is a similar projection on the anterior wall, or on the median laminæ of bifoliate forms, situated a short distance beneath the superior hemiseptum. One or the other, or both may be absent.

Lunarium :—A more or less thickened portion of the posterior wall in many paleozoic Bryozoa, which is curved to a shorter radius and usually projects above the plane of the zoœcial aperture. It is of crescentic form, and generally a conspicuous feature in tangential sections.

Primary aperture :—"The original orifice" of the zoœcium in the *Cryptostomata.*

Superficial aperture :—The outer orifice of the tubular prolongation (vestibule) of the original aperture.

Obverse and reverse :—Two terms employed to designate, respectively, the celluliferous and non-celluliferous faces of the zoaria of the *Fenestellidæ*, *Acanthocladiidæ*, and *Phylloporinidæ.*

Dissepiments :—Short non-celluliferous bars connecting the cell bearing branches in the *Fenestellidæ*, at short and regular intervals. The rounded, hexagonal, or quadrate meshes of the network thus formed are known as the "fenestrules."

The following brief remarks upon the preservation, methods of study, classification, and geological distribution of fossil Bryozoa, the paleozoic forms of America in particular, may be of assistance to students. A more comprehensive general discussion of the subject is to be found in the introduction to my recent work in the eighth volume of the reports of the Geological Survey of Illinois.

PRESERVATION.

It is evident that the hard parts of the Bryozoa only could have been preserved in the fossil state. Equally obvious is the fact that these parts could consist only of the outer investment of the polypides. The opportunities of the paleontologist are restricted further to those in which this investment was calcareous, or corneo-calcareous. Judging from recent conditions, it would appear that of by far the greater part of the extinct forms, the colonies or zoaria were capable of preservation, since in a very large proportion of the living marine Bryozoa the skeleton is calcareous.

Certain changes in the composition and structure of the zoaria have always accompanied the process of fossilization. Indeed, it is probable that the mineral constituents of all fossils are never the same as they were in the living state. The least, and I am glad to state, the commonest alteration is where the originally amorphous calcite has been changed into the crystalline form of that mineral. In most cases this change has been so gradual, and the crystals formed so minutely, that very little of the structure has suffered obliteration. Very often many of the minutest details are still to be recognized. This favorable condition prevails among the majority of fossil Bryozoa, and is especially remarkable among those derived from Lower Silurian calcareous shales and limestones. When the shales are of a greenish color, as in parts of the middle third of the Minnesota Trenton shales at Minneapolis, and the shales of the Cincinnati group at Iron Ridge and Delafield in Wisconsin, the internal structure was generally completely destroyed through the coarseness of the crystallization. The same is true in a great measure of forms occurring in dolomitic limestones.

Silicified Bryozoa are comparatively of rare occurrence, especially in Lower and Upper Silurian rocks. In nearly all cases this method of preservation is confined to massive limestones, like the Corniferous and St. Louis, and in most cases it is unfavorable, so far as the minute internal structure is concerned. Still, in specimens so preserved, the external characters are often wonderfully perfect. Such specimens have been found at the Falls of the Ohio, where they occurred in the decomposed cherty limestones, from which they were washed free in as perfect a condition, so far as outer features are concerned, as when they were entombed. Silicified specimens may also be freed from the rock by means of dilute acids.

A rather common condition of preservation in Devonian and Carboniferous deposits, is where the calcareous zoaria have been dissolved away, leaving more or less perfect moulds in the matrix. This is usually a porous chert, like that frequently met with in the Corniferous limestone of New York and Canada, and the St. Louis limestone of Kentucky; or it is an arenaceous shale. This method of preservation is often very favorable, since, by pressing heated gutta percha into the empty moulds, it is possible to obtain very serviceable counterparts of the bryozoan that left them. Such casts, if carefully prepared, often bring out the most minute details of external marking with surprising fidelity. In the case of such delicate Bryozoa like the *Fenestellidæ*, these moulds are to be preferred to the usual preservation of calcareous specimens, the latter being too liable to attrition and decomposition.

METHODS OF STUDY.

The bulk of paleozoic Bryozoa, with which the American student is likely to be chiefly engaged, belong to the *Trepostomata* and *Cryptostomata*. In these the internal structure is of very diverse types, and it is impossible to arrive at a clear conception of them without the aid of thin sections. If possible, these should be prepared by the student himself, and even if he cannot command one of the new slicing machines, he may still obtain very excellent results by the simple home-made method which I am about to describe, and which served me in making thousands of sections.

The materials required are, (1) a piece of sandstone (not too gritty*) eight or ten inches wide, eighteen or twenty inches long, and of sufficient thickness to insure

*The Buena Vista freestone of the Ohio Waverly is the best known to me for the purpose.

solidity; (2) a piece of water hone one inch thick, a little wider, and four or five inches long; (3) a block of wood (walnut is the best) one inch thick, two inches wide, and four and one-half inches long. The edges of the upper side are rounded to fit the hand, while in the lower side a shallow excavation, one and one-sixteenth inches by three and one-eighth, is made to fit the ordinary glass slip. The excavation must be made so that the *central* portion of the glass slip will bear upon the block, while the ends may have a little play.

With a strong pair of "wire nippers" a fragment is pinched from the specimen of which sections are desired. This is taken into the fingers and rubbed upon the sandstone until the surface is perfectly flat. This is the most important part of the process, and the greatest care must be exercised to retain (or obtain, as the case may be) the desired angle. This surface is now rubbed smooth upon the hone, when the fragment is ready for mounting. A drop of Canada balsam is placed upon the glass slip, and the ground face of the fragment into it. The slip is now heated (on a heating stage or over a lamp) and the balsam allowed to boil for five or six seconds, when the slip is laid upon a horizontal piece of wood to cool. After it is cold the balsam should be tested, and, if it is not hard and brittle, must be reheated. If of the proper hardness, the block is moistened, the slip placed into the excavation, and the superfluous material rubbed away upon the sandstone. When nearly thin enough it is taken out of the block and finished upon the hone.

After thoroughly cleaning and drying, the section should be covered with a film of balsam and a thin sheet of glass. Air bubbles, if any are found, should be expelled by gently heating the slide and pressing upon the cover glass.

Of course it requires a certain amount of experience and time to make good sections, yet even the beginner ought to be able to make from twenty to thirty sections daily, while an expert may increase the number to forty and even fifty.

For reasons about to be mentioned, these sections must be prepared with a knowledge of certain peculiarities which are common to the Bryozoa, otherwise the sections will be misleading. Take for example any ramose or palmate form, and the student will find that the zoarium of such Bryozoa is composed primarily of two distinct zones, an inner or axial region where the zoœcia are tubular, more or less nearly vertical, and with very thin walls; and an outer or peripheral region composed of the same tubes bent outwards at varying angles in order to reach the surface. In this outer region the zoœcia are supposed to have entered the mature condition, and it is here only that such accessory features as the acanthopores and mesopores are developed.

The necessity of two sections, a vertical and a transverse, is at once obvious, but as neither of these sections will give us a cross section of the zoœcia in their peripheral region, where the adult and consequently the most important characters are to be found, it is evident that a third section must be prepared, which will enable us to investigate these characters. This section, which is called "tangential," must divide the zoarium along a plane parallel with the surface, and only a little below it.

Of bifoliate forms two tangential sections ought to be made, one passing through the zoarium just below the surface, and the other just above the median lamina. In thin examples of this style of growth one large section can be made to show the characters of the zoœcia from their origin to the aperture.

For massive, parasitic, or discoid zoaria, two sections (vertical and transverse) will ordinarily suffice to bring out the principal characters, but it is advised that two or more transverse sections be prepared, dividing the zoarium at different hights.

In beginning the study of Bryozoa the first essential is to learn to group them according to their outer form and mode of growth. The outward form, though extremely variable when the whole class is taken into consideration, is tolerably constant for each species, and not infrequently all the species of a genus will adhere more or less strictly to some particular method of growth. On the other hand many very distinct types may assume very nearly the same outward form. But the discrimination between these is a second step in the investigation.

The zoaria will usually exhibit one or the other of the following conditions:

1. The *parasitic* or *incrusting* zoarium, in which the colony is spread over foreign bodies. Examples, *Ceramoporella*, *Spatiopora*, *Stomatopora*, *Berenicea*, etc.

2. The *laminar* zoarium, is a thin, free expansion, having the lower side covered by a wrinkled epitheca. Examples, many species of *Fistulipora*, etc.

3. The *massive* zoarium, may be of irregular or rounded form, free, attached at the base, or grow around some foreign body. Examples, species of *Monotrypa* and *Monticulipora*.

4. The *discoid* zoarium has the form of a plano-convex, or concavo-convex disc; or it may be conical. The under side is concave or flat and covered with an epithecal crust. Examples, species of *Prasopora*, *Mesotrypa*, and *Leptotrypa discoidea* Nicholson.

5. The *bifoliate* zoarium, in which the zoœcia diverge from a double median lamina or basal plate, and open upon the two surfaces of a foliaceous expansion, or of flattened branches. Examples, all the *Rhinidictyonidæ* and *Ptilodictyonidæ*.

6. The *dendroid* or *ramose* zoarium, in which the entire free surface is celluliferous, is very common among paleozoic Bryozoa. Examples, *Batostomella*, *Bythopora*, *Hemiphragma*, *Nematopora*.

7. The *frondescent* or *palmate* zoarium is a modification of the ramose, differing from it in the flattening and expansion of the branches. Examples are *Heterotrypa frondosa* d'Orbigny and *Homotrypa flabellata* Ulrich.

8. The *jointed* zoarium, in which it is divisible into a greater or less number of subequal segments, that articulate with each other either terminally or by means of lateral sockets; is illustrated in *Helopora, Arthroclema* and *Arthropora.*

9. The *fenestrated* or *inosculating* zoarium, as in *Fenestella* and *Phylloporina.* The *pinnate* zoarium is a modification in which the parts of the fronds are feather-like in their arrangement. *Pinnatopora* and *Acanthocladia* are examples.

If the specimens under investigation fall under any except the last two modes of growth, they will probably exhibit either groups of cell-apertures larger than the average, commonly raised above the surface and therefore known as "monticules"; or clusters of small cells or smooth spots called "maculæ." The monticules may be rounded, low or conical, and sometimes ridge-like. Examples are shown on plate XXII, in figs. 1, 13 and 24. Frequently there is a combination of large and small cells as in figs. 18 and 19 of the same plate. True maculæ are best developed in the *Fistuliporidæ,* in which they consist of aggregations of lenticular vesicles, but on plate XVI, fig. 6, is a good example of the kind in which the cells are tubular. The non-poriferous margins, so common among the bifoliate Bryozoa, are most probably a modification of the maculæ; see plate VIII, fig. 19.

The presence or absence of interstitial cells between the ordinary zoœcia, and the determination of their character when present, is the third step in our investigation. These cells may be of the nature of "mesopores"—small, closely-tabulated tubes, as in *Prasopora* and *Callopora* (plates XVI, XXI, and XXII), or the interspaces may be occupied by "vesicular tissue" as shown in fig. 4 on plate IX, a vertical section of *Pachydictya frondosa.* The zoarium of *Monotrypa* is characterized by the complete absence of both mesopores and vesicles (see plate XXVII, figs. 24–29).

Important diagnostic characters are to be observed in the character of the mouths of the zoœcia. They may form short tubular projections (plate II, fig. 6), be enclosed by a smooth rim or peristome (plate I, figs. 17 and 28), or the rim may be minutely papillose (plate XIV, fig. 22); or the mouth may be depressed and situated in a sloping area (plate X, fig. 24). Other conditions, described by the terms "direct," "oblique," and "confluent," are obvious without the citation of examples.

Of other external features, the arrangement of the zoœcial apertures, and the character and marking of the interspaces should be noticed.

In the further progress of the investigation, which is now carried on chiefly by means of thin sections, it is necessary to determine the presence or absence, and the character of the "acanthopores," "median tubuli," "lunarium," zoœcial covers, and "hemisepta," the disposition and character of the "diaphragms" and "cystiphragms," and the minute structure and independence or amalgamation of adjoining zoœcial walls.

Acanthopores may be small (plate XV, figs. 15 and 17) or large (plate XXIII, fig. 35), and will generally have a very small cavity, but it may be comparatively large as in *Batostoma* (plate XXVII, fig. 10).

Median tubuli may be present between the mesial laminæ of bifoliate forms and between the erect portions of the zoœcia (plate IX, figs. 5 and 12).

The lunarium is shown in several types on plate 28. Zoœcial covers usually have a small subcentral perforation; they may be smooth (plate XXII, fig. 23) or with a radial ornamentation (plate XXIII, fig. 26). The opening may be laterally situated, and is often closed.

Hemisepta occur chiefly among the *Cryptostomata*. On plate VI, figs. 7*a* and 8 represent good examples of the superior one, while fig. 20 on plate XIV, shows the appearance of the inferior hemisepta.

Diaphragms may be remote or crowded (plate XXII, figs. 9, and 38), present in the axial region (see vertical sections on plate XXIII) or absent (plate XXVI, figs. 1 and 29). As a rule they are complete and straight, but they may be incomplete as in *Hemiphragma* (plate XXIV); and they are always more abundant in the mesopores than in the true zoœcial tubes. Cystiphragms when present, occur in conjunction with the diaphragms. Usually they overlap each other, as in most of the vertical sections on plate XVI. Occasionally they are separated and appear as semicircular lines lining one or both walls of the zoœcial tubes in vertical sections, as in fig. 16 of the same plate. In other cases they are oblique or funnel-shaped, as in figs. 3, 4, and 5, on plate XVII.

In most Bryozoa the walls of contiguous zoœcia are strictly independent and separable from each other, but in the *Ceramoporidæ* and *Fistuliporidæ*, they are completely fused together.

Among the remaining characters that are brought out by thin sections, it is important to observe the relative length and shape of the primitive or axial portion of the zoœcial tubes, and the strength and character of the curve in which they approach the surface.

CLASSIFICATION.

The class Bryozoa is divided by Ray Lankaster into two very unequal subclasses, the *Holobranchia*, in which the lophophore, or ring of tentacles, is unbroken and continuous, and the *Pterobranchia*, in which it is divided into two plumed arms or processes, bearing a resemblance to the branchial appendages of the Brachiopoda.

According to Nitsche the *Holobranchia* are again divisible into two very unequal groups, the *Ectoprocta*, in which the lophophore surrounds the mouth only, and the *Entoprocta*, in which it encloses both the orifices of the alimentary canal.

The former division embraces the great majority of the Bryozoa, and the second of the two orders, *Phylactolæmata* and *Gymnolæmata*, of Allman, into which it is almost universally divided, comprises, with very few exceptions, all the living and fossil marine forms. In the *Phylactolæmata* the lophophere is open on one side and horseshoe-shaped; in the *Gymnolæmata* it is complete and circular.

The second of these orders has been divided into five suborders, the *Chilostomata*, *Cryptostomata*, *Trepostomata*, *Cyclostomata*, and *Ctenostomata*, all of which seem to be represented in the paleozoic rocks of America.

SYSTEMATIC CLASSIFICATION OF PALEOZOIC BRYOZOA.*

Sub-kingdom MOLLUSCOIDEA.

Class BRYOZOA, Ehrenberg.

Sub-class HOLOBRANCHIA, Ray Lankester.

Order GYMNOLÆMATA, Allman.

Sub-order CHILOSTOMATA, Busk.

Orifice of zoœcium situated laterally, of smaller diameter than the zoœcium, closed by a movable cover (*operculum*). Ova usually matured in external marsupia. Appendicular organs (avicularia and vibracula) frequently present.

Family PALESCHARIDÆ, *Ulrich.*

Genus: *Paleschara* HALL.

Family WORTHENOPORIDÆ, *Ulrich.* (Provisional)

Genus: *Worthenopora* ULRICH.

Family PHACELOPORIDÆ, *Ulrich.*

Genus: *Phacelopora* ULRICH.

Suborder CRYPTOSTOMATA, Vine.

Primitive zoœcium as in the *Chilostomata*. Orifice concealed, at the bottom of a tubular shaft or vestibule, which may become intersected by straight diaphragms or hemisepta through the direct super-imposition of successively developed layers of polypides. External orifice rounded, often closed by a perforated or entire cover. External marsupia and avicularia wanting.

* The classification here published is a slight improvement upon the scheme in vol. viii, Ill. Geol. Sur. Rep'ts. That one represented the state of our knowledge on the subject in 1887-89.

Family PTILODICTYONIDÆ, *Zittel.*

Genera: *Ptilodictya* LONSDALE, *Clathropora* HALL, *Phænopora* HALL, *Graptodictya* ULRICH, *Arthropora* U., *Tæniodictya* U., *Ptilotrypa* U., *Stictotrypa* U., *Stictoporella* U., *Intrapora* HALL, *Coscinella* HALL.

Family RHINIDICTYONIDÆ, *Ulrich.*

Genera: *Rhinidictya* ULRICH, *Eurydictya* U., *Dicranopora* U., *Goniotrypa* U., *Euspilopora* U., *Phyllodictya* U., *Pachydictya* U., *Stictopora* HALL.

Family CYSTODICTYONIDÆ, *Ulrich.*

Genera: *Cystodictya* ULRICH, *Coscinium* KEYSERLING, *Dichotrypa* U., *Actinotrypa* U., *Tæniopora* NICHOLSON, *Prismopora* HALL, *Scalaripora* HALL, *Evactinopora* MEEK and WORTHEN, *Glyptopora* U., *Goniocladia* ETHRIDGE, *Acrogenia* HALL.

Family RHINOPORIDÆ, *Ulrich.*

Genus: *Rhinopora* HALL.

Family HELIOTRYPIDÆ, *Ulrich.*

Genus: *Heliotrypa* ULRICH.

Family ARTHROSTYLIDÆ, *Ulrich.*

Genera: *Arthrostylus* ULRICH, *Helopora* HALL, *Sceptropora* ULRICH, *Arthroclema* BILLINGS, *Nematopora* ULRICH, ? *Thamnotrypa* HALL.

Family RHABDOMESONTIDÆ, *Vine.*

Genera: *Rhabdomeson* YOUNG and YOUNG, *Cœloconus* ULRICH, *Rhombopora* MEEK, *Nemataxis* HALL, *Acanthoclema* HALL, *Bactropora* HALL, ? *Tropidopora* HALL.

Family STREBLOTRYPIDÆ, *Ulrich.*

Genera: *Streblotrypa* ULRICH, *Cyclopora* PROUT, ? *Proutella* ULRICH, ?*Cycloporella* U.

Family SPHRAGIOPORIDÆ, *Ulrich.*

Genus: *Sphragiopora* ULRICH.

Family FENESTELLIDÆ, *King.*

Genera: *Fenestella* LONSDALE, *Semicoscinium* PROUT, *Fenestrapora* HALL, *Isotrypa* HALL, *Tectulipora* HALL, *Unitrypa* HALL, *Hemitrypa* PHILLIPS, *Helicopora* CLAYPOLE, *Archimedes* LESUEUR, *Lyropora* HALL, *Fenestralia* PROUT, *Polypora* MCCOY, *Thamniscus* KING, *Phyllopora* KING, *Ptiloporina* HALL, *Ptiloporella* HALL, ? *Loculipora* HALL.

Family ACANTHOCLADIIDÆ, *Zittel.*

Genera: *Pinnatopora* VINE, *Septopora* PROUT, *Acanthocladia* KING, *Synocladia* KING, *Diptopora* YOUNG and YOUNG, *Ptilopora* MCCOY, ? *Icthyorachis* MCCOY, ? *Penniretepora* d'ORBIGNY, ? *Ramipora* TOULA.

Family PHYLLOPORINIDÆ, *Ulrich.*

Genera: *Phylloporina* ULRICH, *Chainodictyon* FOERSTE, *Drymotrypa* ULRICH, ? *Crisinella* HALL.

Suborder TREPOSTOMATA, Ulrich.

Zoœcia superimposed directly one upon the other so as to form long tubes intersected by straight or curved partitions (diaphragms and cystiphragms), representing the covers and floors of the successive layers. Two regions are distinguishable in the tubes, an axial or "immature" region in which the diaphragms are remote and the walls thin and prismatic; and a peripheral or "mature" region in which the walls are thickened and otherwise changed, the transverse partitions more abundant, and accessory elements, such as mesopores and acanthopores, developed. Zoœcial covers with a small central orifice.

Family MONTICULIPORIDÆ, *Nicholson.*

Genera: *Monticulipora* d'ORBIGNY, *Atactoporella* ULRICH, *Homotrypella* ULRICH, *Peronopora* NICHOLSON, *Homotrypa* U., *Prasopora* NICHOLSON and ETHRIDGE, *Mesotrypa* U.

Family HETEROTRYPIDÆ, *Ulrich.*

Genera: *Heterotrypa* NICHOLSON, *Dekayia* EDWARDS and HAIME, *Petigopora* U., *Dekayella* U.

Family CALLOPORIDÆ, *Ulrich.*

Genera: *Callopora* HALL, *Calloporella* U., *? Aspidopora* U.

Family TREMATOPORIDÆ, *Ulrich.*

Genera: *Trematopora* HALL, *Nicholsonella* U., *Constellaria* DANA, *Stellipora* HALL, *Idiotrypa* U.

Family BATOSTOMELLIDÆ, *Ulrich.*

Genera: *Batostomella* U., *Stenopora* LONSDALE, *Anisotrypa* U., *Bythopora* MILLER and DYER, *Callotrypa* HALL, *Leioclema* U.

Family AMPLEXOPORIDÆ, *Ulrich.*

Genera: *Amplexopora* U., *Monotrypella* U., *Petalotrypa* U., *Atactopora* U., *Leptotrypa* U., *? Discotrypa* U.

Family DIPLOTRYPIDÆ, *Ulrich.*

Genera: *Diplotrypa* NICHOLSON, *Monotrypa* NICHOLSON, *Batostoma* U., *? Hemiphragma* U.

Family CERAMOPORIDÆ, *Ulrich.*

Genera: *Ceramopora* HALL, *Ceramoporella* U., *Crepipora* U., *Diamesopora* HALL, *Chiloporella* U., *Ceramophylla* U., *Anolotichia* U., *Spatiopora* U.

Family FISTULIPORIDÆ, *Ulrich.*

Genera: *Fistulipora* McCOY, *Eridopora* U., *Chilotrypa* U., *Meekopora* U., *Strotopora* U., *Lichenotrypa* U., *Buskopora* U., *Selenopora* HALL, *Pinacotrypa* U.

Family BOTRYLLOPORIDÆ, *Miller.*

Genus: *Botryllopora* NICHOLSON.

Suborder CYCLOSTOMATA, Busk.

Zoœcia very simple, tubular, with a plain, inoperculate, circular orifice; wall thin, minutely porous. Marsupia and appendicular organs wanting.

Family TUBULIPORIDÆ, *Busk.*

Genera: *Stomatopora* BRONN, *Proboscina* AUDOUIN, *Berenicea* LAMOUROUX, *Diastoporina* U., *? Hederella* HALL, *? Hernodia* HALL, *? Reptaria* ROLLE.

Family FRONDIPORIDÆ, *Reuss.*

Genus: *Sceneltopora* ULRICH.

Family ENTALOPHORIDÆ, *Reuss.*

Genera: *Clonopora* HALL, *Mitoclema* U., *Diploclema* U., *Protocrisina* U., *? Cystopora* HALL.

Suborder CTENOSTOMATA, Busk.

Zoœcia usually isolated and developed by budding from the internodes of a distinct tubular stolon or stem. Orifice terminal, closed by an operculum of setæ. Zoarium horny or membranaceous. Marsupia wanting.

Family ASCODICTYONIDÆ, *Ulrich.*

Genera: *Ascodictyon* NICHOLSON and ETHRIDGE, *Rhopalonaria* U., *Vinella* U.

GEOLOGICAL DISTRIBUTION.

It is a singular fact that no remains whatever of Bryozoa are known from rocks of earlier date than the Chazy limestone of the Lower Silurian System. Here the class suddenly leaps into a prominence, not only in the way of individual representation, but in the matter of diversity of structure, that is both surprising and difficult of explanation. Nor was it, as might be expected, the simpler types that prevailed here. On the contrary, it is the more complex types like the *Trepostomata* and *Cryptostomata* that are the most abundant and diverse in their development. What may be even more surprising is that every suborder known in the fossil state was represented before the close of the Lower Silurian era.

The vertical range of a few of the Lower Silurian genera (*Stomatpora* and *Berenicea*), is likewise remarkable, and not equalled, so far as known, in any other class of animals, excepting the Brachiopoda, of which the genus *Lingula*, the same as the bryozoan genera alluded to, has living representatives. Still, as a rule, the vertical range of Bryozoa is restricted to comparatively narrow limits, and most genera and many families fail to pass from one system of rocks to the next.

Lower Silurian System: As has been stated, true Bryozoa are first met with in the Chazy rocks of this system. In this group, excepting some of the calcareous strata in New York and Canada, originally referred here, the conditions were often quite unfavorable, not only for their preservation but for their development as well. In the excepted beds several species of *Phylloporina* and *Rhinidictya* belonging to the *Cryptostomata*, a considerable number of mostly undetermined *Trepostomata*, and *Mitoclema*, a genus of the *Cyclostomata*, have been found. Following the rocks westward from Canada the calcareous beds are lost, but the arenaceous portion, there known as the St. Peter sandstone, a formation totally unfitted for their preservation, increases in thickness, and in Minnesota seems to be the only representative of the formation. The marble beds at Knoxville, Tennessee, which probably belong to the Chazy, are full of the remains of *Trepostomata*, none of which have, as far as we know, yet received critical study.

Following the Chazy are the Birdseye and Black River limestones and shales. The first of these divisions has a wide geographical distribution, being known from New York and Canada to Tennessee and Kentucky, as a fine-grained, massive or in parts somewhat shaly limestone. The shaly layers are full of Bryozoa, among which the *Cryptostomata* are preeminently developed. In Minnesota the greater part of the "Trenton limestone" and the lower two-thirds of the shales resting on it, are probably equivalent strata. Here the limestone is comparatively barren of Bryozoa, but the shales, on the contrary, are exceedingly rich, affording also a greater diversity of structure than is known from any of the more southern and eastern localities for the group.

Among the *Cryptostomata,* both the *Ptilodictyonidæ* and *Rhinidictyonidæ* reach their maximum development in this group, while the *Arthrostylidæ* and *Phylloporinidæ* are both well represented. The *Trepostomata* likewise are strongly represented, and in the Minnesota shales of the group every family of the suborder has been recognized. The *Cyclostomata* come in with *Stomatopora proutana*, a species that is continuously present to the top of the Lower Silurian, and *Berenicea.*

In the Trenton limestones and shales proper, the *Cryptostomata* have lost some of their strength, whilst that of the *Trepostomata* is increased by the addition of several genera—*Prasopora, Monticulipora, Stellipora* and *Diamesopora.* The *Cyclostomata* add *Protocrisina, Diploclema, Scenellopora,* and *Diastoporina.*

Nearly all the genera now introduced continue to the top of the Lower Silurian, and before the close of the era we find a representative of the last of the five suborders, the *Chilostomata,* in a species of *Paleschara.* The *Trepostomata,* however, again add greatly to their numbers in the Cincinnati group, in which nearly 200 distinguishable forms of this suborder are known to me. These belong to 35 genera, giving every family, with the exception of the *Fistuliporidæ,* a strong representation. Of the *Cyclostomata* also the indivividuals and species became more numerous, while the *Ctenostomata* added another species of *Vinella* and the new genus *Rhopalonaria.*

Upper Silurian System: The Bryozoa in the rocks of this system are very different from those of the Lower Silurian. The *Trepostomata* are greatly reduced by the almost total extinction of the families *Monticuliporidæ* and *Heterotrypidæ,* and a considerable reduction in the *Calloporidæ, Amplexoporidæ, Diplotrypidæ,* and the *Ceramoporidæ.* But the *Fistuliporidæ,* a family that reached its greatest development in Devonian and Subcarboniferous times, became prominent here. Of the *Cyclostomata* we have only *Diploclema sparsum,* a Niagara fossil, of the *Ctenostomata,* a few species, and of the *Chilostomata,* likewise only a few forms of *Paleschara.* But the *Cryptostomata* inaugurate a new and vigorous start. Two new genera, *Clathropora* and *Stictotrypa,* are added to the *Ptilodictyonidæ,* while the genera *Ptilodictya,* and *Phænopora,* of the same family, became fully established. *Rhinidictya, Pachydictya Phylloporina, Drymotrypa, Helopora* and *Nematopora,* belonging to three other families of the suborder, are also well represented. The *Fenestellidæ,* of which but a single Lower Silurian species is known, increase in abundance and variety from the Clinton to the Lower Helderberg, in which most of the generic types of the family, some of them, however, not yet fully established, are already distinguishable. Numerous species of *Fenestella* and *Polypora,* and one or more each of *Unitrypa, Hemitrypa,* *Isotrypa*, *Tectulipora*, *Semicoscinium*, *Ptiloporina*, and *Helicopora*, have been described. The *Acanthocladiidæ* begin in the Lower Helderberg with a few species of *Pinnatopora* and *Icthyorachis*, and *Rhombopora*, belonging to another family of the suborder, has one species in the Niagara and several in the Lower Helderberg. The *Cystodictyonidæ*, essentially a Devonian and Carboniferous family, is also met with for the first time, a species of *Dichotrypa* having been described from the Niagara of Illinois, and one or two of *Cystodictya* from the Lower Helderberg of New York. *Rhinopora* is known only from the Clinton.

The absence of so many characteristic Lower Silurian types, and the presence of most of the genera that are strongly developed in the Devonian, proves, so far as the Bryozoa are concerned, that the break between the Lower and Upper Silurian is sharper than the one between the Upper Silurian and the Devonian.

Devonian System: Several hundred species of Bryozoa have been described from the rocks of this age. The great mass of these are *Cryptostomata*, and of these the majority belong to the *Fenestellidæ*. Every genus of this family, excepting *Fenestralia*, *Lyropora* and *Archimedes*, is more or less largely represented. To the same suborder belong *Cystodictya*, *Dichtyotrypa*, *Prismopora*, *Scalaripora*, *Coscinium* *Tæniopora*, *Glyptopora*, and *Acrogenia*, of the *Cystodictyonidæ*; a Corniferous species of *Ptilodictya* (the last known of the genus), *Taeniodictya*, *Intrapora*, and *Coscinella*, of the *Ptilodictyonidæ*; *Euspillopora*, of the *Rhinidictyonidæ*; *Rhombopora*, *Nemataxis*, *Acanthoclema*, and *Bactropora*, of the *Rhabdomesontidæ*; *Streblotrypa*; and *Pinnatopora* and *Ptilopora* of the *Acanthocladiidæ*. The *Cyclostomata* are included in the genera *Clonopora*, *Cystopora*, *Hederella*, *Hernodia*, and *Reptaria*; *Ascodictyon* represents the *Ctenostomata*. The *Trepostomata* are represented chiefly by numerous species of *Fistulipora* and one or more of *Eridopora*, *Chilotrypa*, *Meekopora*, *Strotopora*, *Lichenotrypa*, *Buskopora*, *Selenopora*, *Pinnacotrypa*, *Botryllopora*, *Monotrypella*, *Amplexopora*, *Petalotrypa* *Batostomella*, *Leioclema*, and *Dekayia*.

Sub-carboniferous System: The Bryozoa of this age are very similar to those of the Devonian, and the majority of the genera of either are common to both systems. The principal difference is found in the absence of some of the peculiarly modified Devonian types of the *Fenestellidæ*, like *Unitrypa*, *Loculipora*, *Fenestropora*, etc. They are, however, replaced by the equally interesting genera *Archimedes*, *Lyropora* and *Fenestralia*. Among the *Cystodictyonidæ* we miss *Scalaripora* and *Acrogenia*, but their vacant places are more than filled by the remarkable genera *Evactinopora* and *Actinotrypa*. Other *Cryptostomata* are *Tæniodictya*, ? *Stictoporella*, *Pinnatopora*, *Septopora*, *Ptilopora*, *Diplopora*, *Sphragiopora*, *Cœloconus*, *Rhombopora*, *Bactropora*, *Acanthoclema*, *Streblotrypa*, *Cyclopora*, *Proutella* and *Heliotrypa*. The three last named, together with *Worthenopora*, belonging to the *Chilostomata*, are new types. Among the *Trepostomata*, the *Fistuliporidæ* are abundant, and *Stenopora*, *Leioclema*, *Anisotrypa*, and *Batostomella* not uncommon. Both the *Cyclostomata* and *Ctenostomata* are poorly represented, each by one or two insignificant species.

Carboniferous System: The rocks of this age are mostly unfavorable for the preservation of the Bryozoa, and only a few localities are known in this country where good specimens may be obtained. With the exception of *Stenopora* and *Fistulipora* all the observed forms belong to the cryptostomatous genera *Fenestella*, *Polypora*, *Thamniscus*, *Acanthocladia*, *Pinnatopora*, *Septopora*, *Diplopora*, *Sphragiopora*, *Chainodictyon*, *Prismopora*, *Cystodictya*, and *Rhombopora*.

In America Bryozoa are rare or entirely unknown in the strata above the paleozoic. Most of the species known are from the Cretaceous and Tertiary rocks of New Jersey, Mississippi and Arkansas. In Europe the Triassic system is equally poor in Bryozoa, but in the Jurassic they are represented by nearly eighty species, most of them *Cyclostomata*. This suborder continues to be almost exclusively represented to the Cenomanian in which the *Chilostomata* are present, though not yet in very great numbers. Even in the Upper Cretaceous, from which d'Orbigny mentions 662 species, the *Cyclostomata* and *Trepostomata* are nearly twice as numerous as the *Chilostomata*. In the Tertiary rocks the *Cyclostomata* have become less numerous and the *Chilostomata* more abundant, the ratio of representation at the close of the age being approximately like the present.

Class BRYOZOA, Ehrenberg.

Order GYMNOLÆMATA, Allmann.

Sub-order CTENOSTOMATA, Busk.

Family ASCODICTYONIDÆ, Ulrich.

Genus VINELLA, Ulrich.

Vinella, ULRICH, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 173.

Zoarium attached to foreign bodies (shells, etc.), consisting of exceedingly slender, ramifying, thread-like, tubular stolons, arranged more or less distinctly in a radial manner. Surface of tubes sometimes faintly lined longitudinally. A row of widely separated small pores along the center of the surface of the tubes. Zoœcia unknown.

Type: *Vinella repens* Ulrich.

The fossils for whose reception this genus was proposed are regarded as related to *Vesicularia*, Thompson, and probably also to *Mimosella*, Hincks, both of them genera of recent Bryozoa. The zoœcia must have been deciduous and developed by budding from the creeping stolons at the points now represented by the small pores. The form that is designated the type of the genus, though one of the rare fossils of the Trenton shales of Minnesota, is justly entitled to that distinction, because it is, so far as our knowledge at present extends, the earliest existence of the genus. Similar organisms are known to occur more or less rarely in the Hudson River, Niagara, ? Hamilton and Chester groups of rocks in America, while in the Wenlock of England and Gotland, the *Ascodictyon radiciformis* Vine, is unquestionably a congeneric form. Still another form that I would refer to this sub-order is represented in my collection by several zoaria from the Upper Coal Measures at Springfield, Illinois.

In the absence of the zoœcia a satisfactory classification of these mostly obscure organisms is perhaps impossible. Our observations are limited to the creeping stolons which, even in the recent *Ctenostomata*, are but illy diagnostic of generic types. Better material, carefully studied, may later on demonstrate the advisability of erecting other genera for some of the types now classed as *Ascodictyon* and *Vinella*. In the present state of our knowledge it is also most difficult to decide the exact limits of the genus *Ascodictyon*, Nicholson and Ethridge, jun., and the only plan that now appears feasible is to include all, and only such forms as possess the ovate or pyriform vesicles. As *Vinella*, on the other hand, I would class those forms in which they are absent. According to this arrangement the *Ascodictyon radiciformis* Vine, would fall under *Vinella*. Not so, however, the *A. filiforme* of the same author. This species, so far as I can learn, even in its most simple form, has always an occasional "lagena-like vesicle developed on the sides of the thread," while some of its more complex varieties make a decided approach toward the Devonian type of the genus, *A. stellatum* Nicholson and Ethridge, jun.

In the accompanying cut (fig. 8), *a* represents a cluster of vesicles of *Ascodictyon stellatum*, with a portion of the delicate stolon that connected it with similar clusters. One example in my collection consists of eight of such clusters. In the majority of the specimens seen, however, the clusters are much less regular, and in many cases the vesicles are distributed with little or no regularity over the surface of the body to which the zoarium is attached. In all cases, when the fossil is in a good state of preservation, these vesicles, whether isolated or arranged in radial aggregations will be found to be connected with each other by a delicate filament; and in this species at least, the surface of the vesicles exhibits a large number of minute pores.

FIG. 8.

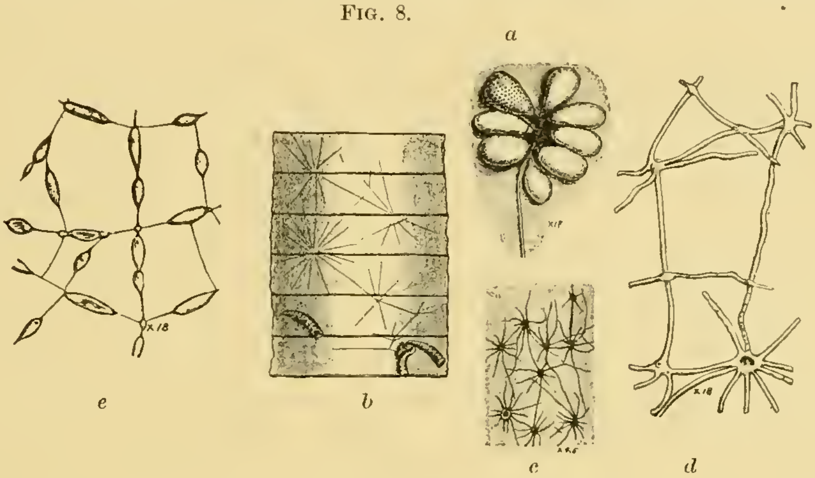


Figure *b* of the same cut represents a natural size view of the only specimen seen of the Cincinnati form, that I propose naming VINELLA RADIALIS. It consists of four principal colonies or nuclei, growing upon an *Orthoceras*. Only the form is preserved, and even that not well. However, sufficient remains to show that it belongs to an undescribed species, with the probabilities greatly in favor of *Vinella* as its final resting place. The radial arrangement is more regular, and the radii straighter than in any other form of the genus known to me.

Figures *c* and *d* of the same cut illustrate an unquestionable species of *Vinella*, of which a number of excellent specimens were collected in the Niagara shales near Waldron, Indiana. One of the figures is magnified four and a half diameters, the other eighteen. In the absence of good examples of the English Wenlock species, *Vinella radiciformis* Vine, sp., which these specimens must greatly resemble, I propose to designate the American form provisionally as var. CONFERTA, in allusion to the unusually close development of the nuclei.

The inclusion of all the paleozoic *Ctenostomata* in one family, the *Ascodictyonidæ*, (see Geol. Sur. Ill., vol. viii, p. 335) is likewise only a provisional arrangement. Indeed, I am satisfied that *Rhopalonaria*, Ulrich, at least, which is evidently related to the recent *Arachnidium*, Hincks, belongs to a distinct family.

Figure 8*e* is taken from the best example of *Rhopalonaria venosa* Ulrich, now at hand.* This species, so far as known, is restricted to the upper beds of the Hudson River group, and the specimen now illustrated is from those beds at Waynesville, Ohio. Usually nothing remains to attest the former presence of this bryozoan, except a series of shallow excavations in the substance of the body upon which it grew. These excavations, however, correspond very well with the form, or rather, the outline of the cells and extremely delicate connecting stolons of the zoarium itself. The latter must have been quite liable to destruction during the process of fossilization, and, though diligently searched for, not a single example, so far as I am aware, has yet been found in which it is preserved in even a fairly satisfactory manner. In the best specimens the stolons are clear enough, but the swollen portion of the zoœcia is always more or less obscure. Now and then, it is true, some evidence is presented to show that the orifice was situated near one end in the center of a slightly elevated portion of the surface. These facts, though unfortunate, tend nevertheless to establish the ctenostomatous affinities of the fossil. If, as already intimated, *Rhopalonaria* is related to *Arachnidium*, then perfect zoarial preservation is not to be expected. On the contrary, if such a condition were common, as in calcareous zoaria, the relationship might well be doubted, since the almost membranaceous zoarium of *Arachnidium* and many other *Ctenostomata*, is, perhaps, quite incapable of preservation in a fossilized state.

VINELLA REPENS *Ulrich.*

PLATE I, FIGS. 1-5.

Vinella repens ULRICH, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 174.

Original description.—"Zoarium repent, the stolons delicate, thread-like, often longitudinally striate, straight or flexuous; from 0.06 to 0.11 mm. in diameter; bifurcating often and sometimes arranged in a radial manner about a central node. Where best preserved, very small pores arranged uniserially along the center of the

*The original type of the genus and species has been mislaid or lost.

upper surface of the threads; about eleven in 2.5 mm. Zoœcia unknown, probably deciduous."

In the Hudson River species, *V. radialis*, the average thickness of the stolons is a little less. They are also straighter and arranged quite regularly in a radial manner. In the Niagara form, *V. radiciformis*, var. *conferta*, the stolons are likewise more slender and the nuclei much more frequent.

Formation and locality—Rare in the upper third of the Trenton shales at St. Paul, Minnesota. All the specimens seen have grown upon valves of *Strophomena septata* Winchell and Schuchert.

Sub-order CYCLOSTOMATA, Busk.

Genus STOMATOPORA, Bronn.

Alecto, LAMX., 1821, BLAINVILLE, JOHNSTON, M. EDWARDS, BUSK, etc. (Not *Alecto*, Leach, 1814.)
Stomatopora, BRONN, 1825, Pflanzenth., p. 27. D'ORBIGNY, 1852, Pal. Franc. t. v, p. 833. HAIME, 1854, Bry. Foss. Form. Jurassic, p. 159. ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 149, and 1890, Geol. Sur. Ill., vol. viii, p. 367. MILLER, 1889, N. Amer. Geol. and Pal., p. 325.
Stomatopora (part.), HINCKS, 1880, Brit. Mar. Polyz., p. 424.
Aulopora (part.), GOLDFUSS, REUSS, HALL, NICHOLSON.

Zoaria adnate; zoœcia subtubular, club-shaped, or ovate, not immersed, arranged in single branching series; apertures subterminal, more or less elevated, circular; walls finely porous.

Type: *Alecto dichotoma* Lamouroux.

In drawing up this diagnosis I continue to follow Jules Haime and d'Orbigny in discriminating between the uniserial and multiserial forms, despite the fact that a tendency to unite them under one name has of late become manifest. Hincks, for instance, places species here having precisely the same zoarial habits as the *Proboscina frondosa* (pl. I, fig. 28) of the Hudson River rocks. He would probably go far enough in this direction to include even *Berenicea minnesotensis*. And yet he retains *Diastopora*, with *Berenicea* as a synonym. The resulting classification is, to my mind, anything but satisfactory. With me the greatest difficulty is, not to separate the uniserial forms, but to draw a line between *Berenicea* (as typified by *B. diluviana* Lamouroux) and the bi- and multiserial forms of which *Proboscina auloporoidea* Nicholson, sp., *P. tumulosa*, *P. frondosa* Nicholson, sp., and *Berenicea minnesotensis* are progressive examples. That some of these, and several Secondary, Tertiary and recent species of this type, sometimes have the zoœcia arranged uniserially at the base and at the beginning of the branches is scarcely a sufficient reason for regarding them as congeneric with such invariably uniserial forms as *Stomatopora dichotoma* Lamouroux, *S. proutana* S. A. Miller, *S. inflata* Hall, sp., and a host of others. As I view the matter, the former in their mature or ultimate development, are much nearer *Berenicea* (Lamouroux, Haime, Zittel and others; *Diastopora* of Busk and other British authors). Sharply defined genera are an impossibility in nature. She follows paths altogether too intricate to be expressed in a system of classification. The best result that we can obtain must be a happy medium between convenience and natural affinity. Convenience, and stability as well, are surely sacrificed when we throw together a number of genera and then divide the composite genus, that has now been made to assume the rank of very nearly a family, into sections of questionable utility that no one is obliged to recognize, because they have no established validity in any system of classification. Is it not better, because it is convenient and saves time, to have it understood at once that when one says *Stomatopora*, he refers to uniserial forms; *Proboscina*, to forms with similar zoœcia but partly immersed and in two or more series, and *Berenicea*, to such as have them forming entire, flabellate, circular or irregular crusts?

The only change from the arrangement here retained that I am willing to enter into, and for which good and probably sufficient reasons can be advanced, is one that would drop *Proboscina*, leaving *Stomatopora* to stand as at present for the uniserial species, and extend *Berenicea* so as to include the ground now occupied by *Proboscina*.

Stomatopora tenuissima *Ulrich.*

PLATE I, FIGS. 6 and 7.

Stomatopora tenuissima ULRICH, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 175.

Original description.—"Zoarium adnate, consisting of frequently branching uniserially arranged zoœcia. Zoœcia exceedingly slender, about seven in 8 mm., each from 1.0 to 1.5 mm. long, usually increasing very gradually from the proximal end, where the diameter is about 0.04 mm., to near the slightly bulbous anterior or upper end, which varies from 0.11 to 0.18 mm. in diameter. Aperture circular, small, about 0.05 mm. in diameter, situated very near the anterior end of the zoœcium.

"This and *S. turgida* illustrate the extremes of difference in shape and size of the zocœia of *Stomatopora* so far noticed. *S. tenuissima* is closely related to *S. proutana* Miller, but its zoœcia are much longer. Miller's species, with scarcely any modification, ranges from low in the Trenton (Birdseye limestone) to the top of the Hudson River group.

Formation nad locality.—Toward the top of the Utica horizon of the Hudson River group at Cincinnati, Ohio, 150 to 175 feet above low water mark in the Ohio river.

Stomatopora proutana *S. A. Miller.*

PLATE I, FIGS. 8-12.

Stomatopora proutana S. A. Miller, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, p. 39.
Ropalonaria pertenuis Ulrich, 1886. Fourteenth Ann. Rept. Geol. Nat. Hist. Sur. Minn., p. 59.

Zoarium adnate, consisting of frequently branching, uniserially arranged zoœcia. Zoœcia slender, clavate, about 0.04 mm. in diameter at the proximal end, increasing gradually in size to from 0.12 to 0.15 mm. at the rounded anterior end; each 0.6 to 0.8 mm. long, with from eight to ten in 5 mm. Aperture subterminal, small, circular, with a slightly elevated rim-like border; 0.05 to 0.06 mm. in diameter.

The above describes the usual form of the species, but fig. 12 represents a variety occurring in the lower layers of the Trenton shales of Minnesota, and in the "Pierce" limestone of Tennessee, having unusually large zoœcia. In this their length varies from 0.8 to 1.1 mm., while the diameter in the anterior third is generally over 0.2 mm., and sometimes as much as 0.3 mm.

In my preliminary report on the Minnesota Bryozoa this species was erroneously placed under the ctenostomatous genus *Rhopalonaria*. At the time I thought it advisable to extend the limits of that genus so as to include these delicate species of *Stomatopora*. Later studies have fully demonstrated the fallacy of such a view.

Compared with American species, only *S. tenuissima* and *S. inflata* Hall, sp., will be found to exhibit any close relations. In the first the zoœcia are more slender and longer; in the second they are much more inflated. *S. elongata* Vine, from the Wenlock of England, has slightly shorter zoœcia of a form very nearly intermediate between those of *S. proutana* and *S. inflata.*

Formation and locality.—This species occurs in the "Pierce" limestone of Tennessee, the Birdseye limestone of central Kentucky, and the Trenton shales of Minnesota at Minneapolis, St. Paul and Cannon Falls; also at Decorah, Iowa. So far it has not been recognized in the Galena, but it is to be found, rather rarely though, in the Utica horizon at Cincinnati, Ohio, and more abundantly near the tops of the hills at that locality. It occurs also higher in the Hudson River rocks at several localities in Ohio and Indiana, and at Wilmington, Illinois.

Mus. Reg. Nos. 5926, 8066.

Stomatopora inflata *Hall.*

PLATE I, FIGS. 13-21.

Alecto inflata Hall, 1847. Pal. N. Y., vol. i, p. 77.
Hippothoa inflata Nicholson, 1875. Pal. Ohio, vol. ii, p. 268.
Stomatopora inflata Vine, Nov., 1881. Quar. Jour. Geol. Soc. London.

Zoœcia resembling those of *Hippothoa*, short and wide when compared with the preceding species, pyriform, the proximal end contracted and springing from the under side of the anterior end of the cell beneath; eight or nine in 5 mm. Apertures circular, direct, with a peristome, about 0.09 mm. in diameter, situated near the anterior end. Mural perforations minute and but rarely preserved.

In the Trenton or typical form of this species the zoœcia, as a rule, are less swollen and the adnate zoarium divides less frequently than in the better known Cincinnati form. In the latter, therefore, the network is closer, and occasionally the growth is so luxuriant that the rows cross each other to such an extent that but little space is left between the cells. No distinction, however, can be based upon these characters since, when good series of specimens are studied, it is found that among those from Trenton localities some have more than commonly swollen and crowded cells, while in some of those from the geologically higher localities the growth is lax and the zoœcia comparatively narrow.

Formation and locality.—Trenton group, at Trenton Falls, New York; Ottawa, Canada; Cannon Falls, and other localities in Minnesota where the upper third of the Trenton shales are exposed; Hudson River group at Cincinnati, Ohio, (350 to 425 feet above low water mark in the Ohio river), and in the upper beds at Richmond, Indiana; Wilmington and Savannah, Illinois, and other localities.

Mus. Reg. Nos. 5924, 8045.

STOMATOPORA TURGIDA *Ulrich.*

PLATE I, FIGS. 22 and 23.

Stomatopora turgida ULRICH, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 176.

Original description.—"Zoarium adnate, consisting of a single branching series of zoœcia. Zoœcia comparatively very large, the anterior half much swollen, rapidly tapering posteriorly, with the slender, tubular proximal end inserted beneath the turgid anterior end of the preceding zoœcium. Five zoœcia in 5 mm.; length of each zoœcium varying from 0.85 to 1.30 mm.; the greatest diameter of the anterior half from 0.4 to 0.6 mm. The longest cells are the least turgid, while the shortest are the most. Apertures round, bordered by an elevated margin, small, 0.1 mm. in diameter, and situated about one-fourth of the length of the zœocium from its anterior end.

"I have a number of specimens of this species, and all consist of comparatively few zoœcia. Nor do the series of cells in any of them branch often; from which it appears that the production of two "gems" was a much less frequent occurrence than in the related *S. inflata* Hall. *S. turgida* is further distinguished from that and all other species of the genus known to me, by the much larger zoœcia."

Formation and locality.—Upper beds of the Hudson River group at Wilmington, Illinois.

Genus PROBOSCINA, Audouin.

Proboscina (part.), AUDOUIN in Savigny, Desc. de l'Egypte, Pol., p. 236, 1826.
Proboscina, d'ORBIGNY, 1852, Pal. Fr. terr. cret., t. v, p. 844. HAIME, 1854, Bry. de la form. Jurass., p. 10. Ulrich, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 149, and 1890, Geol. Sur. Ill., vol. viii, p. 368.
Not *Proboscina*, of SMITT and others.

Zoaria wholly adnate. Zoœcia as in *Stomatopora*, excepting that they are more or less immersed and not uniserial, being arranged in two or more contiguous rows.

For remarks relating to this genus see under *Stomatopora*.

PROBOSCINA TUMULOSA, *n. sp.*

PLATE I. FIG. 24.

Zoarium adnate, branching dichotomously, or inosculating, in the latter case forming an irregular large-meshed network. Branches narrow, generally with two or three, rarely four or five, alternating series of cells. Zoœcia subpyriform, or obovate, not wholly immersed, generally appearing as bulbous swellings on the surface of the zoarium. Apertures subterminal, contracted, circular, slightly oblique, about 0.09 mm. in diameter, with a slight peristome. About five or six cells in 3.0 mm.

Compared with *Proboscina frondosa* (plate I, fig. 28) and *P. auloporoidea* (both Nicholson, sp.), two Hudson River forms, this species is distinguished by its shorter and more bulbous zoœcia, their shape being more like those of *Stomatopora inflata* and *Berenicea minnesotensis*. The resemblance to the last is so marked that I would not be surprised if coming discoveries prove *P. tumulosa* directly descended from it.

Formation and locality.—Rare in the upper third of the Trenton shales at St. Paul; more abundant in the same beds near Cannon Falls, Minnesota.

Mus. Reg. Nos. 7620, 8047, 8101.

PROBOSCINA FRONDOSA *Nicholson.*

PLATE I, FIG. 28.

Alecto frondosa NICHOLSON, 1875. Pal. Ohio, vol. ii, p. 266.
Proboscina frondosa ULRICH, 1889. Contri. to the Micro-Pal. of Canada, pt. ii, p. 28.

A figure, taken from an excellently preserved example of this species, is introduced for the better understanding of, and comparison with, Minnesota *Cyclostomata*. This specimen is from the hill quarries at Cincinnati, Ohio, but the species also occurs in the upper beds of the formation at many localities in Ohio, Kentucky and Indiana, at Nashville, Tennessee, Wilmington and Savannah in Illinois, and at Stony Mountain, Manitoba. My belief that it will yet be found at Spring Valley, Minnesota, and other points in the southern part of the state, where equivalent beds are exposed, is therefore within the bounds of probability.

Mus. Reg. No. 8102.

Genus BERENICEA, Lamouroux.

Berenicea (part.), LAMOUROUX, 1821. Exp. meth. des genres de pol., p. 80.
Rosacilla, F. A. ROEMER, 1840, Verst. des norddeutsch. Kreidegeb., p. 19.
Berenicea, d'ORBIGNY, 1852. Pal. Fr. terr. cret., t. v, p. 858. J. HAIME, 1854, Bry de la form. Jurass., p. 19. ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p 194, and 1890, Geol Sur. Ill., vol. viii, p. 368.
Diastopora, d'ORBIGNY, 1850, and BUSK and other English authors. (Not Lamouroux.)
Diastopora (part.), HINCKS, VINE and others,
Saganella, HALL, 1852. Pal. N. Y., vol. ii, p. 172.
Diastoporetta, VINE, 1883. Brit. Assoc. Rep. Foss. Pol., iii; and Proc. Yorks. Geol. Soc., n. s., vol. ix, pt. ii, p. 190.

Zoaria incrusting, forming circular or irregular patches. Individual zoœcia as in *Stomatopora* and *Proboscina*, but contiguously arranged in more or less regular spreading series.

Type: *B. diluviana* Lamouroux.

For remarks relating to this genus see under *Stomatopora*.

BERENICEA MINNESOTENSIS *Ulrich*.

PLATE I, FIGS. 25, 27 and 29; PLATE II, FIG. 1.

Berenicea minnesotensis ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 58.

Zoarium forming exceedingly thin, irregular crusts upon foreign bodies. The crust may be entire, with irregularly distributed and unequal non-celluliferous spots, or, especially at the edges of large expansions, it may throw off broad branches and include a few open spaces. In one example, provisionally referred here, the latter are so large and conspicuous that the zoarium may well be described as consisting of wide, irregularly inosculating branches.* Ordinarily the crust is nearly entire, and the non-celluliferous spaces, which, like the rest of the surface between the zoœcial apertures, are marked with obscure transverse lines or wrinkles, constitute a conspicuous feature. Zoœcia more or less immersed, in the latter condition appearing as subelliptical convex spaces, about 0.2 mm. wide, with an oblique circular aperture, 0.13 mm. in diameter, at their upper ends. In such examples (see fig. 29) the aperture is scarcely produced, but in others, more matured, it is prominent, while all the remainder of the cell is completely immersed. The arrangement of the zoœcia is,

*Perhaps this specimen is to be considered as indicating a departure that later on resulted in *Proboscina tumulosa* of this work.

on the whole, inclined to be irregular, though fairly regular longitudinal series, and sometimes diagonally intersecting rows can generally be made ont. The average number in 2 mm. is five or six.

Compared with *B. primitiva* Ulrich, from the Hudson River group of Ohio, this species is distinguished by its larger and less tubular zoœcia, the interstitial wrinkles, and the non-celluliferous spaces. *B. vesiculosa* Ulrich, from the Utica shales horizon at Cincinnati, is a nearer relative, but also has smaller zoœcia, with the apertures less prominent. In most respects the position of the Minnesota species is intermediate between the two Ohio species.

Formation and locality.—Not uncommon in the lower and middle beds of the Trenton shales, at Minneapolis and St. Paul, Minnesota.

Mus. Reg. No. 5925.

Genus DIASTOPORINA, Ulrich.

Diastoporina, Ulrich, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 177.

Zoarium bifoliate, in general resembling *Diastopora* (Lamouroux, not Busk). Zoœcia subtubular, prostrate, immersed; apertures constricted, subcircular, not prominent. Interspaces finely punctate and striated longitudinally.

As only one species is known, it is difficult, if, indeed, it is not impossible in all such cases, to determine the really essential characters of the genus. The striation of the interspaces is a peculiar feature and the chief ground for separating the species from *Diastopora*, a genus so far not known in strata older than Jurassic. The Minnesota species, however, presents many points of agreement with species of that well known genus, and it may yet be shown that it represents merely an early type of same. This resemblance or possible relationship is paralleled in *Mitoclema*, Ulrich, and *Entalophora*, Lamouroux; *Diploclema*, Ulrich and *Bidiastopora*, d'Orbigny; *Protocrisina*, Ulrich, and *Crisina*, d'Orbigny; and *Scenellpora*, Ulrich, and *Defrancia*, Bronn, and *Discocavea*, d'Orbigny. In each case the first is founded upon lower paleozoic species, while none of the genera with which they compare are as yet known in rocks earlier than Jurassic. With the exception of *Entalophora* (*?Mitoclema*) one or more species of which occur in the Devonian at the Falls of the Ohio, and in New York (*Clonopora*, Hall, 1887, Pal. N. Y., vol. vi), none of these cyclostomatous genera are known to have had an existence in Devonian and Carboniferous times. Precisely the same is true of *Stomatopora*, *Proboscina*, and *Berenicea*.* But

* Since writing the above, a paper has been received from the Canadian Geological Survey, in which Prof. J. F. Whiteaves describes one species each of *Stomatopora* and *Proboscina*, from the Devonian rocks of the far north. At my request, Prof. Whiteaves kindly sent me the types of the two species. These were carefully examined by me, with the result, that I still hold that we have no positive evidence of the existence of these genera in Devonian deposits. The first is unquestionably very closely related to *Rhopalonaria botellus* Vine, and not a *Stomotopora*. The other may be a *Proboscina*, but it is so different from any type of that genus known to me that I am obliged to view its relations as highly problematical.

in these cases the Lower and Upper Silurian species are so nearly like the Secondary, Tertiary, and recent forms of the genera, that a generic separation has so far seemed impracticable. And yet, considering their apparent absence in the Devonian and Carboniferous deposits, would we not be justified in denying the lineal descent of the recent forms from the early paleozoic species? However, questions of this kind cannot be considered as they deserve in the space here at my disposal, and, as they are also a little out of place in a publication of this kind, they will be merely touched upon, leaving their real discussion for some more fitting occasion.

DIASTOPORINA FLABELLATA *Ulrich.*

PLATE II, FIGS. 2 AND 3.

Diastoporina flabellata ULRICH, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 176.

Zoarium small, arising from an attached basal expansion into thin flabellate fronds. The largest and only complete example seen is 5.5 mm. wide. Surface with obscure concentric wrinkles, and fine interrupted striations arranged parallel with the direction of the zoœcia. Under a high power of magnification the latter appear as delicate lines separating rows of exceedingly minute pores. Zoœcia rather scattering, in young examples partly exposed, appearing as convex oval spaces with a small oblique aperture, about 0.05 mm. in diameter and but little, if at all, elevated at the distal extremity. In some fragments of seemingly older examples the entire cell is immersed, leaving only the aperture, which, in these cases, is nearly direct and subtubular, to project over the nearly even surface. Their arrangement is often quite irregular, particularly in the vicinity of certain small non-celluliferous spots, but where rows are to be made out, about six or seven apertures occur in 2 mm.

This is the only bifoliate cyclostomatus bryozoan known to me in paleozoic rocks.

Formation and locality—Rare in the Galena shales near Cannon Falls and at St. Paul, Minnesota. At the first locality it is associated with a very interesting fauna, consisting principally of *Ostracoda* and minute bryozoans, among the latter species of *Nematopora*, *Helopora* and *Arthroclema.*

Genus MITOCLEMA, Ulrich.

Mitoclema, ULRICH, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, p. 150; and 1890, Geol. Sur. Ill., vol. viii, pp. 336 and 369.

Comp. *Clonopora*, HALL, 1886. Pal. N. Y., vol. vi, p. 25; also, abstract Trans. Albany Inst., vol. x, p. 20, 1881.

Comp. *Entalophora*, LAMOUROUX, 1821. Exp. meth. des genres de pol., p. 81.

Zoaria ramose, slender, subcircular in cross-section. Zoœcia tubular, long, prismatic and thin-walled in the axial region, gradually diverging in all directions from an imaginary axis to the surface where they bend outward abruptly, often becoming free and much produced. Apertures circular, sometimes scattering, usually arranged in regular transverse or subspiral series.

Type: *M. cinctosum* Ulrich, Chazy (perhaps lower Birdseye) limestone of Kentucky.

Fuller investigations and comparisons with typical and authentic examples of *Entalophora* and *Clonopora* are necessary before we may be said to be in a position to decide permanently the merits of this genus. *Entalophora*, as now understood by Hincks and Waters, seems to me to be too comprehensive and might be, with advantage to classification, divided into at least two groups of generic rank, and it is not at all improbable that *Mitoclema* stands upon unoccupied ground. In the mean time no harm can result from the use of the name for these early paleozoic species.

MITOCLEMA(?) MUNDULUM *Ulrich.*

PLATE II, FIGS. 4-6.

Mitoclema ? mundulum ULRICH, 1890. Jour. Cin. Soc. Nat.Hist., vol. xii, p. 177.

Zoarium ramose, very small, the branches cylindrical, 0.5 or 0.6 mm. in diameter, with faint transverse striæ or wrinkles over the spaces between the zoœcial apertures. The latter are drawn out tube-like, about 0.15 mm. in diameter, and project strongly upward and outward from the surface of the small stems. Their arrangement is in rapidly ascending spiral series, with four or five in 2 mm. As near as can be determined from the material at hand, the zoœcial tubes diverge equally to all sides of the branches from an imaginary axis.

Owing to the absence of specimens suitable for slicing the internal characters of this species have not been determined. The generic position is therefore somewhat questionable, since it may prove to have the structure of *Diploclema* Ulrich (Geol. Sur. Ill., vol. viii, p. 368), founded upon *D. trentonense* Ulrich, a similar form occurring in the Trenton limestone of New York. In *Diploclema* the branches are slightly compressed, and the zoœcial apertures somewhat constricted and less prominent.*

Formation and locality.—Associated with the preceding in the topmost beds of the Trenton shales, at Cannon Falls, Minnesota.

Mus. Reg. No. 8103.

---

* In his paper on Wenlock shales Bryozoa Mr. Vine has described several similar species which he originally referred to *Spiropora* and later to *Entalophora*. Of these *S. regularis* is an unquestionable *Diploclema* and closely allied to our Niagara *D. sparsum* Hall, sp. The others I have not had an opportunity of examining.

Suborder CRYPTOSTOMATA, Vine.

Family RHINIDICTYONIDÆ, n. fam.

Stictoporidæ, ULRICH, 1890. Geol. Surv. Ill., vol. viii, p. 388.
Stictoporidæ (part.), ULRICH, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, p. 152.

This name is proposed instead of *Stictoporidæ*, for the reason that the type genus is not, as I have heretofore held, properly expressed by the term *Stictopora*. Since Hall, the author of that name, and others, insist that *S. elegantula* is the type of *Stictopora*, it follows that the genus and family as described by me (*loc. cit.*) cannot stand. In my Illinois work, namely, I had taken the stand that *S. fenestrata* is to be regarded as the type, and as that species is unquestionably congeneric with *Rhinidictya*, Ulrich, (Jour. Cin. Soc. Nat. Hist., vol. v, p. 152), the latter was reduced to synonomy. Though the minute internal and external details of structure of *S. elegantula* have not yet been made public, enough is known of it to prove conclusively that it represents a genus to which *S. fenestrata* has no claim. This being the case, *Rhinidictya* will stand and include *fenestrata*.*

Genus RHINIDICTYA, Ulrich.

Stictopora (part.), HALL, 1847. Pal. N. Y., vol. i, p. 73.
Stictopora, ULRICH, 1890. Geol. Surv. Ill., vol. viii, p. 388.
Rhinidictya, ULRICH, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, p. 152; HALL, 1887, Pal. N. Y., vol. vi, p. 20.

"Zoaria composed of narrow, compressed, dichotomously divided branches, with the margins sharp, straight, and essentially parallel; attached to foreign bodies by a continuous expanded base. Zoœcial apertures subcircular or elliptical, arranged alternately in longitudinal series between slightly elevated, straight or flexuous ridges, carrying a crowded row of small blunt spines. Space immediately surrounding apertures sloping up to summits of ridges." (Geol. Surv. Ill., vol. viii, p. 388.)

Type: *R. nicholsoni* Ulrich, Birdseye Limestone, Kentucky.

This genus finds its strongest development numerically, both as regards species and individuals, in the rocks of the Trenton formation. The Minnesota shales of this group are especially rich in specimens, and so far as species are concerned, there is no other section of the country from which as many are known. Unfortunately, however, the various forms of the genus are not by any means easily distinguished from each other. It is true also that of those species which have a wide geographical range, as for instance from Minnesota to Kentucky and Tennessee, or to New

* For objections to the use of *Sulcopora*, d'Orb., instead of *Rhinidictya*, see Geol. Surv. Ill., vol. viii, pp. 683 and 687.

York and Canada, the specimens at each of these localities are marked by individual peculiarities, causing their identification to be, in some cases at least, unsatisfactory and generally rather difficult. Nothing less than monographical work can do the genus justice. Manifestly, even if possible in the present state of our knowledge, such work would be out of place here.

I shall therefore largely restrict my remarks to the Minnesota forms, while those occurring in other sections of the country will be mentioned incidentally only, and chiefly when comparisons are desirable.

RHINIDICTYA MUTABILIS *Ulrich.*

PLATE VI, FIGS. 1-6, 12-13; PLATE VII, FIGS. 10-23, and 25-28; and PLATE VIII, FIGS. 1-3.

Stictopora mutabilis (part.) ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 66.
Stictopora mutabilis, var. *minor* ULRICH. Ibidem, p. 67.

Zoarium a branching bifoliate stipe, varying considerably in width and superficial aspect.

Typical form :—In the commonest or typical form, the branches vary in width from 2.3 mm. to 3.2 mm., and in thickness from 0.7 mm. to 1.9 mm.; they divide dichotomously at intervals varying from 7 to 16 mm., but on an average a bifurcation takes place every 10 to 12 mm.; edges generally sharp, but with age become blunter as the stipes increase in thickness; non-celluliferous margins very scant, often practically wanting. Zoœcia arranged in from ten to eighteen rows ; the usual number is fourteen or fifteen, but just beneath a bifurcation it generally exceeds twenty. Between the rows are straight longitudinal ridges, angular and crowned with a single series of small granules in well preserved young and average examples, thicker, rounded, and with stronger and more numerous granules in old examples (see plate VII, fig. 10). In young examples again the spaces between the ends of the apertures are slightly depressed, causing them (the apertures) to appear as openings in the bottom of shallow channels. In such specimens (see plate VII, fig. 15) the interspaces are comparatively thin and the zoœcial apertures correspondingly large, the long diameter of the latter being about 0.20 mm., and the short or transverse diameter about 0.12 mm. With age the transverse diameter may be reduced to less than 0.5 mm., while the channelled appearance becomes obsolete in the general thickening of the interspaces. In a few fragments, apparently representing the condition of extreme age, the zoœcial apertures are scarcely recognizable, the entire surface appearing as simply granulo-striate. In most cases the zoœcial apertures in one or more of the marginal rows are directed upward and outward. Measuring transversely, about eleven of the central rows in 2 mm. (extremes ten and twelve); longitudinally, about seventeen zoœcia in 5 mm. Except in a variety to be considered presently, the zoœcial apertures always appear as direct.

Vertical sections (plate VI, figs. 3 and 5) show that the zoœcial tubes, in their course from the basal (median) plate to the superficial aperture, form an angle of about 50 degrees with the surface. In the primitive portion of the zoœcia (*i. e.* that part which lies on each side close to the median laminæ) the posterior side curves outward and forward so as to form a curve about equaling one-fourth of a circle. The anterior extremity of the curve terminates abruptly at the primitive aperture ; from this point to the surface of the zoarium, or in what has been described as the "vestibular portion of the zoœcium," the course of the wall is nearly straight. In a few species of this genus (*e. g. R. fidelis* and *R. minima*) the junction between the "vestibule" and the curved posterior side of the "primitive cell", is prolonged into a short septum that I have designated as the "superior hemiseptum." In *R. mutabilis*, however, this septum is but little, if at all, developed, the junction being merely angular. When the section shows the transverse interspaces (this is often the case because of the great thickness of the interspaces in the vestibular region) they will be seen to exhibit interrupted dark vertical lines. These represent the tubular internal extensions of the minute granulations noticed at the surface. Stages in the growth of the zoarium may also be determinable. These are marked by dark lines, sharpest in the inner portions of the zoarium.

In transverse sections the chief point of interest is the row of minute tubuli that exists between the two parts of the duplex mesial lamina. (See plate VI, fig. 6.)

Tangential sections present a variety of appearances depending (1) upon the age of the fragments sectioned, and (2) the depth beneath the surface represented in the section. Using an old example the section may be made, with judicious manipulation, to show all the conditions through which the zoarium has passed, from the beginning of the zoœcia on the mesial laminæ to their mouths. Taking such a section, which, to be satisfactory, should not be less than 10 to 15 mm. long, the following features are likely to result: Starting with the mesial laminæ, which will be recognized as a faintly dark space, the first character worthy of notice are the "median tubuli." These are represented by very delicate parallel lines, longitudinal in the central third of the zoarium, but gradually diverging or curving toward its edges in the lateral thirds. Though not yet clearly demonstrated in this species, I nevertheless assume it to be a fact (because of observations in other forms possessing such tubuli) that the "mesial tubuli" connected with the minute tubes between the walls of the zoœcia, the surface extensions of which have been described as granules. (See plate VI, fig. 18.) Just above the mesial laminæ the section presents the basal or primitive portion of the zoœcia as sharply defined, thin-walled, oblong-quadrate spaces, the end walls of which, while approximately at right angles with the longitudinal lines at the center of the zoarium, gradually assume an oblique upward direction toward the sides. (Compare plate VI, fig. 13.) The next condition is when the anterior wall or side of the zoœcium becomes convex, while the posterior side begins to extend over the cell till at last the oval aperture is formed. Now the anterior and posterior walls are no longer recognizable in the section, but the division between the longitudinal walls is clearly marked by a dark line, that, when the preservation of the specimen is sufficiently favorable, will be noticed to consist of a connected series of minute tubuli. Besides these, an occasional dark spot or tubulum may be noticed in the end spaces. Most of the stages so far described are shown in fig. 13, on plate VI, and all further phases are to be classed as old conditions. They consist principally of an increase in the number of minute interstitial tubuli. (See plate VI, figs. 1 and 4.)

The above description does not include two forms that deserve recognition as varieties. Their peculiarities are not sufficiently constant to entitle them to the rank of species. In my preliminary report on the Minnesota Bryozoa (*loc. cit.*) another form of the species was separated as var. *minor*. The better and much more complete material since studied proves, however, that the specimens so designated are merely young examples and therefore not deserving of a distinct name.

Var. Major *Ulrich.*

The zoarium in this variety is more robust, the branches being wider, in some cases attaining a width of over 8 mm.; usually the thickness is also greater, but thin examples are not uncommon. Perhaps the chief peculiarity of the variety is found in certain grano-striate or smooth spots, which occur at rather irregular intervals along the center of the branches. The internal structure agrees in all essential respects with that of the typical form of the species, the only feature not seen in the latter being the solid maculæ.

Mus. Reg. No. 5940.

Var. Senilis, *n. var.*

PLATE VI, FIGS. 2 and 3; PLATE VII, FIGS. 16 and 17.

In this rather rare form the general appearance of the zoarium is like that of well developed examples of the typical variety. On comparison, however, it is found that the non-celluliferous margin is unusually wide and sharply defined. Connected with this are certain narrow, irregular or subelliptical, depressed spaces just within the axes of bifurcation. A more important peculiarity is presented by the zoœcial apertures. These, generally, instead of being placed in longitudinal furrows (as is usual in the genus), are oblique and inclosed by a strongly elevated peristome, highest at the posterior side. They manifest further a tendency to arrangement in transverse or diagonal rows. The result is quite unlike what is to be expected in *Rhinidictya*, and reminds one more of certain species of *Cystodictya*. Thin sections, however, demonstrate that this is merely a case of superficial resemblance and not of true relationship. On the contrary these prove, as is already clearly enough shown at the growing extremities of the branches, that we are dealing with a true *Rhinidictya* with affinities to *R. mutabilis* too close to admit of even specific distinction. Indeed, it is not improbable that the variety represents merely an unusual condition of senility. Still, the interior, as exhibited in the sections at hand, has one feature that may be accepted as corroborating my present estimation of the form.

Plate VI, fig. 2, represents a portion of a tangential section showing, besides one of the solid axillary maculæ, that the minute interstitial tubuli are exceedingly numerous, there being often three longitudinal rows between adjoining zoœcia. Figure 3 of the same plate presents a portion of a vertical section of the same specimen. This compares very nearly with figs. 5 and 12 (pl. VI) prepared from old examples of the typical form. The absence of horizontal lines in the lower part of the walls may be the result of imperfect preservation.

This species, especially in its typical form, is to be regarded as closely allied to *R. nicholsoni* Ulrich (Jour. Cin. Soc. Nat. Hist., vol. v. p. 170, pl. viii, figs. 6, 6a, 6b; 1882). Without taking into account certain slight though recognizable internal differences, that species is distinguished by its narrower, more strictly parallel, and less frequently bifurcating branches, the obliquity of its zoœcial apertures, and the lesser elevation and rigidity of the transverse interspaces. A nearer congener, perhaps, is the *R. basalis* (*Stictopora basalis* Ulrich, *op. cit.*, p. 169, plate viii, figs. 4 and 4a), but the very frequent bifurcation of the zoarium characterizing that species serves to distinguish them at a glance.* For comparisons with *R. trentonensis*, *R. fidelis*, and other species described in this report see under descriptions of each.

Formation and locality.—The typical form is extremely abundant in the middle and lower beds of the Trenton shales about Minneapolis and St. Paul, Minnesota. It occurs in these beds, but much less abundantly, also at Cannon Falls, Lanesboro, Fountain, Preston and other localities in the southern part of the state, and at Decorah, Iowa. The var. *major* is fairly abundant at the three localities first named, but the Cannon Falls specimens are less robust than usual. From the Galena shales at Cannon Falls, I have identified with the species something over forty fragments. In these, however, the zoœcial apertures are more oblique than usual. Respecting the Kentucky form, which I have heretofore referred to this species (14th Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 67, 1886), I prefer to await further investigations before expressing a conclusive opinion. This course seems the wisest also with respect to similiar forms from the Trenton rocks of Illinois, Tennessee, New York, Vermont and Canada.

Mus. Reg. Nos. 5938, 5939, 5941, 5956, 5957, 7597, 7599, 7606, 7621, 7663.

*A very good illustration of the necessity of thin sections for the determination of the generic relations of these bifoliate Bryozoa is furnished by my 1882 work on them in the publication cited. Had they been prepared of all the species therein defined. I would not have fallen into errors that now appear only too obvious. There I placed, for instance, *Pachydictya acuta* Hall, sp., *Cystodictya gilberti* Meek, sp., and *Rhinidictya basalis* under *Stictopora*, while *Rhinidictya* was founded, correctly enough, upon both external and internal peculiarities of *R. nicholsoni*. With sections I could scarcely have failed in determining the true position of these four species.

Rhinidictya paupera *Ulrich.*

PLATE V, FIGS. 19-21.

Stictopora paupera (part.) Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 69.

Zoarium usually less than 30 mm. high, consisting of narrow parallel-sided branches, dividing dichotomously at intervals of from 4.0 to 12 mm. Near the base the intervals are usually less than 6.0 mm., but further up the prevailing distance between bifurcations is about 8.0 or 9.0 mm. The width of the branches is fairly constant, deviating but little either way from 1.3 mm. Their thickness has not been noticed to exceed 0.5 mm. Zoœcia with nearly direct oblong apertures, their shapes varying with age from subquadrangular to elliptical. Interspaces rather narrow, or of moderate thickness. Zoœcial apertures usually in ten or eleven rows, but eight or nine and twelve rows often occur just after and before bifurcations. The central five or six rows are arranged between raised longitudinal lines, minutely granulose when perfect, while the two or three rows on each side are, besides being slightly larger than usual, directed obliquely outward. Five of the central rows in 0.7 or 0.8 mm; measuring lengthwise along same eighteen or nineteen apertures in 5.0 mm. Internal structure very much as in young examples of *R. mutabilis* Ulrich.

In the above diagnosis I have restricted my observations to the Minnesota form occurring in the upper division of the Trenton shales at St. Paul and Cannon Falls. This form should be regarded as the type of the species, and, pending further investigations, the wisest course seems to be to restrict the use of the name to it. The Kentucky and Tennessee form, occurring in the shaly upper member of the Trenton group in those states, which I have referred to this species (*loc. cit.*), is now regarded as distinct and next described as *R. neglecta.* I have two specimens from the "Phylloporina beds" at St. Paul that are exceedingly like, if not identical with the latter, but so far it has not been found in the shales above these beds, nor in the Galena limestone division of the Trenton in Minnesota. But several examples collected from the Galena shales at localities near Cannon Falls, seem to be identical with the Canadian form referred to *R. paupera* in 1886. A very fine example, with branches spread over a space 50 mm. wide by 75 mm. long, collected at Ottawa and kindly given to me by Mr. Walter R. Billings, causes me to doubt the strict propriety of that reference. This specimen shows that the Canadian form agrees with typical *R. paupera* in this, that the number of zoœcial apertures in 5 mm., measuring lengthwise, is eighteen to nineteen. Continuing our comparisons, however, we find the following differences: (1) the apertures are smaller and rounder, and have a more distinct peristome; (2) the interspaces on the whole are thicker, while the elevated lines enclosing the depressed quadrangular spaces in which the apertures are situated, are sharper; (3) the arrangement of the apertures between longitudinal lines prevails throughout, there being no oblique rows; and (4) while the width of the branches is about the same or greater (the average is very nearly 1.5 mm.); there are only seven to nine rows of cells instead of ten to twelve. In all these respects, however, the Canadian form agrees more closely with *R. neglecta*, but before I commit myself definitely upon the matter of their true relations I shall want to institute careful comparisons of their respective internal characters—a step that I am not yet prepared to make. Still, in the meantime, it may be desirable occasionally to refer to the Canadian form, in which case a distinctive appelation would be convenient. I propose, therefore, the provisional designation *Rhinidictya neglecta*, var. *canadensis*.

Comparing *R. paupera* (*sens. strict.*) with other species of the genus, we find that it is distinguished from *R. mutabilis* by its smaller zoarium, narrow and more frequently dividing branches, more numerous zoœcia in a given space, and the greater differentiation in the direction of the central and marginal zoœcial apertures; from *R. trentonensis* and *R. nicholsoni* in much the same features, though in a different degree. To them is to be added, for the former, that its zoœcial apertures are not only much larger, but more nearly quadrate or hexagonal, with the longitudinal ridges between them nearly or quite obsolete; and for the latter, that its zoœcial apertures are more oblique. *R. exigua* is very close, differing mainly in its narrower branches and less oblique arrangement of its zoœcial apertures in the marginal rows. *R. minima* has thicker and more ornamental zoœcial interspaces, and differs internally in having the superior hemiseptum well developed.

Formation and locality.—Not uncommon in the upper third ("Phylloporina beds") of the Trenton shales, at St. Paul and south of Cannon Falls, Minnesota, and Decorah, Iowa. Probably also in the Galena at Neenah, Wisconsin.

Mus. Reg. Nos. 5935, 7564, 7612.

Rhinidictya neglecta, *n. sp.*

PLATE V, FIGS. 22-25

Stictopora paupera (part.) Ulrich, 1886. Fourteenth Ann. Rept. Geol. Nat. Hist. Sur. Minn., p. 69.

Zoarium small, branches dividing dichotomously at intervals of from 4 to 7 mm., rather convex, the margins parallel, not very sharp, and with the non-celluliferous border variable. Width of branches rather constant at about 1.5 mm. Zoœcia in eight to eleven ranges, the usual number nine, with rather small, elliptical; oblique apertures, about seventeen in 5 mm. lengthwise, and 6 in 1 mm. transversely. In most cases all the apertures are directed longitudinally or parallel with the edges of the branches; in others, however, those forming the marginal row on each side may be turned slightly outward. Interspaces comparatively thick, less ridge-shaped than usual, often slightly zigzag, with the range of granules well developed.

Internal structure chiefly diagnostic in vertical sections. These show that the primitive or prostrate cell is comparatively elongate, and that at the turn into the "vestibule" the wall is merely sharply curved and not angular, as in *R. mutabilis.*

Associated with this species is a larger form, agreeing in all other respects quite closely with it. At first I thought it identical with *R. mutabilis*, and so figured it in 1890 (Ill. Geol. Surv. Repts., vol. viii, p. 304, fig. 2, d, f, and g). At present I should prefer regarding it as a variety of *R. neglecta*. For the Canadian variety of this species see remarks under *R. paupera*.

Compared with other species, *R. nicholsoni* will be found to have grown differently, the bifurcation of the branches being much less frequent; the zoœcial apertures are also more oblique, and vertical sections quite different.. *R. mutabilis* has wider branches, more direct zoœcial apertures, and different vertical section.

Formation and locality.—Not uncommon in strata equivalent to the Galena limestone of the Northwest, at Frankfort, Kentucky, and several localities in Boyle and Mercer counties of that state. Also in rocks of the same age at Nashville, Tennessee. Two fragments supposed to be identical with these Kentucky and Tennessee specimens were collected at St. Paul from the upper shales.

Mus. Reg. No. 8104.

RHINIDICTYA EXIGUA *Ulrich.*

PLATE VIII, FIGS. 6-10.

Rhinidictya exigua ULRICH, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 184, fig. 9.

Zoarium bifoliate, small, growing from an expanded basal attachment. Lower portion of branches subcylindrical, with the zoœcial apertures here largely filled with a smooth solid deposit of sclerenchyma. Above the first bifurcation the branches have become acutely elliptical in cross-section, their width varying from 0.5 mm. to 1.2 mm., with parallel margins, the edges sharp, but in no case seeming to have more than just an appreciable non-celluliferous border. Zoœcia in from three to seven rows on each face, their apertures, in the usual state of preservation, appearing as impressed, nearly direct, subelliptical or subquadrate, those in the central rows 0.2 mm. long by 0.1 mm. wide, those in the marginal row on each side of the branch sometimes a little larger and often directed somewhat obliquely outward; all regularly arranged longitudinally, seventeen or eighteen in 5 mm., and separated from each other by rather thin, seemingly smooth interspaces, the latter forming slightly elevated longitudinal ridges. In the specimens originally described and figured, the apertures are somewhat obscured by remains of the shaly matrix, but with several fragments lately discovered among my material from Fountain, Minn., this is not the case. The latter are also exceptionally well preserved and show that the apertures are really rather strongly oblique, with a slight "lip" at the posterior border. Not in these specimens, even, have I detected satisfactory evidence of the presence of the row of granules on the longitudinal ridges usual in species of this genus. Yet, as is shown by thin sections, the minute inter-zoœcial tubuli, whose superficial extension forms the granules, are developed in the usual manner.

The obliquity of the zoœcial apertures allies this species to the larger *R. nicholsoni*, but not closely enough to cause confusion between them. The zoœcia are larger in that species, there being thirteen to fifteen where we have seventeen to eighteen in this form. It also resembles *R. paupera* and *R. minima*, but they are distinguished: the first by having more ranges of zoœcia with the apertures in several of the marginal rows on each side of the branches oblique; the second by its smaller zoœcial apertures and much wider granulo-striate interspaces.

Formation and locality.—Comparatively rare in the lower third of the Trenton shales at Minneapolis, St. Paul and near Fountain, Minnesota.

Rhinidictya minima *Ulrich.*

PLATE V, FIGS. 13-18.

Rhinidictya minima Ulrich, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 183, fig. 8.

Zoarium small, branches 0.8 to 1.2 mm. wide, commonly 1.0 mm., bifurcating at intervals of 2 or 3 mm. Zoœcia in five or six longitudinal rows, increasing to seven, eight, or nine before bifurcation takes place; sixteen in 5 mm. lengthwise. Size and shape of apertures, and character of interspaces, varying with age. The enlarged figures on plate V represent the usual appearance of the oldest examples. In these the zoœcial apertures are small and narrow-elliptical (about 0.11 mm. by 0.06 mm.) and the interspaces very wide, with the granulose ridges projecting but little above the level of the peristomes surrounding the apertures. Under a glass of low power the interspaces appear as rather flattened, and marked with straight or slightly flexuous longitudinal striæ. Under a higher power the striæ resolve into rows of small papillæ, with one continuous series, a little stronger than the others, separating the apertures into longitudinal rows, and one or two short series in the slightly depressed spaces between the ends of the apertures. When in a good state of preservation, a row of granules, rather smaller than the others, is found to crown the peristomes as well. These were overlooked in drawing fig. 15. In younger examples the principal longitudinal ridges are relatively higher, causing the zoœcial apertures, which in these cases are wider, and the intermediate spaces to appear as set in shallow channels. Not infrequently the peristomes of succeeding zoœcial apertures are connected in a manner causing the transverse interspaces to appear as bearing three longitudinal striæ or rows of granules. Margin of branches acute, the non-celluliferous band rather wide and occupied by one or more lines of papillæ.

Of internal characters it will suffice to mention that there is a well-developed superior hemiseptum, and a greater number of median tubuli in the end spaces between the zoœcial apertures (see fig. 18) than in any other species known to me.

This pretty little species is not likely to be confounded with any of the preceding, unless it be with *R. exigua*. But the surface characters, especially when well preserved, are so very dissimilar that confusion, even in that case, is inexcusable.

Var. MODESTA *n. var.*

PLATE V, FIG. 17.

Under this subordinate name I propose provisionally to classify an associated form, differing in some respects constantly from the typical variety. Both are represented by numerous specimens, with no question in any case as to where each belongs. They agree, however, too closely in the more important elements of structure to admit of specific separation. Except in the case of subsequent discoveries in other regions proving the supposed new variety to hold its own geographically, the above degree of separation seems to me sufficient. My studies of the paleozoic bifoliate Bryozoa have taught me to distrust mere deviations in the width of the branches as being good specific characters.

In the variety the branches are wider, the width varying from 1.7 mm to 3.0 mm., the zoœcial apertures larger, and the interspaces correspondingly narrower. Still, the number of apertures in 5 mm., measuring lengthwise, is, as in the typical form, about sixteen. In the best preserved specimens the superficial characters resemble those of young examples of typical *minima* very closely, the chief difference being that the zoœcial apertures, as already stated, are larger, and the non-poriferous band generally wider and grano-striated obliquely instead of longitudinally. The striæ also project slightly beyond the edge, causing the latter to be minutely serrate.

When the drawings for this species were prepared I possessed, unfortunately, only a few specimens. The number was subsequently greatly increased by pickings from washings of shales from the original locality, kindly sent me by Mr. W. H. Scofield, of Cannon Falls.

Formation and locality.—Galena shales, near Cannon Falls, Minnesota; associated with species of *Nematopora*, *Arthropora armatum*, *Diastoporina flabellata*, and other small Bryozoa characterizing the horizon.

Mus. Reg. No. 8105. Var. *modesta*, 8106.

RHINIDICTYA FIDELIS *Ulrich.*

PLATE VI, FIGS. 7, 7a, 7b AND 8.

Stictopora fidelis (part), ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 68.

To save repetition it will suffice to say of the external characters of this species that they are exceedingly like those of the next described *R. trentonensis*, a slightly greater width of the also more nearly quadrangular zoœcial apertures, being rather inconspicuous differences.

In tangential sections the deepest parts show the prostrate portion of the zoœcia lying on each side of the mesial laminæ. The latter themselves may be shown as in fig. 7b with the inclosed "median tubuli." These horozontial tubuli seem to connect with the vertical sets that form series separating the rows of zoœcia. At first the zoœcia appear as simple quadrangular spaces, their width equalling about half of the length. In the next stage these spaces are divided by a line, transversely in the central rows, and obliquely upward in the marginal ranges. This line represents the incurving superior hemiseptum, which is developed to an unusual degree in this species. In the stage immediately succeeding, the posterior half is covered, while the open anterior part is gradually reduced in width till it assumes the elliptical shape commonly presented by the "vestibular" portion of the zoœcia. From now on to the surface, the distance depending upon the age of the specimen, the section exhibits little if anything to distinguish it from similar sections of other species. There are rows of subelliptical apertures separated by thick interspaces, and between the rows a dark, faintly flexuous line, which, when carefully examined, is found to contain a series of minute pores.

Vertical sections are highly characteristic, especially when they have been carefully prepared and show the primitive region of the zoœcia in a satisfactory manner. The anterior side of the zoœcial cavity is almost straight from the mesial lamina to the superficial aperture. The posterior and upper side is concave and the curve produced in front into a strongly developed hemiseptum, projecting over half the distance toward the base of the anterior wall. An occasional complete diaphragm-like structure may be detected crossing the tubular vestibule. All of these characters are shown very well in fig. 8.

As has been stated, it is not an easy matter to distinguish this species, by means of external characters alone, from *R. trentonensis*, and until the observer has become thoroughly familiar with the various forms of this genus occurring in the Minnesota rocks, he is cautioned to secure the evidence of thin sections before he places much confidence in his identification, of this species, at any rate. The strongly developed superior hemiseptum will distinguish the sections at once from those of all other species except *R. minima*. That species occurs at a higher horizon (Galena shales), grew differently, has smaller elliptical zoœcial apertures and much thicker, as well as quite differently marked interspaces.

Formation and locality.—Rare in the lower third of the Trenton shales at Minneapolis, Minnesota. *Mus. Reg.* Nos. 5936, 5937.

Rhinidictya trentonensis *Ulrich.*

PLATE VI, FIGS. 14-18; PLATE VII, FIGS. 6-9.

Dicranopora trentonensis Ulrich, 1882. "Amer. Pal. Bry.," Jour. Cin. Soc. Nat. Hist., vol. v, p. 160, pl. 6, figs. 15, 15a.
Stictopora fidelis (part.) Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 68.

Zoarium branching dichotomously at intervals of from 8 to 20 mm. Branches 2 mm., or a little less, wide, sharp-edged, the non-poriferous margin very narrow Zoœcia in from eight to eleven ranges, nine or ten the commonest numbers. Apertures nearly direct, comparatively large, of elliptical, subquadrate or hexagonal form, with sixteen, rarel yseventeen, in 5 mm. longitudinally, and five in 1 mm. transversely; those forming the marginal row usually a little larger than the average and directed slightly outward. Interspaces thin, apparently without granules, the longitudinal ones but little, if at all, elevated over those running transversely, the former generally a little zigzag in their course.

In tangential sections dividing the zoarium just beneath the surface, the interspaces are moderately thick, and contain a line of very minute pores running lengthwise between the rows of cells. Here the zoœcia, or rather their "vestibular" portions, are elongate-elliptical, but at a deeper level, where the section cuts down into the primitive portion of the zoarium, they have the usual oblong-quadrate, or subrhomboidal shape. In one of the sections showing this region (see pl. VI, fig. 18) a row of "median tubuli" is distinctly visible in the transverse partitions.

Vertical sections remind us much of *R. nicholsoni* and *R. grandis*, in this, that the interspaces or walls are rather thin, and that there is not even a sign of a superior hemiseptum at the base of the "vestibule," the walls being merely thickened a little abruptly. In sections of thick examples a complete diaphragm may cross the tubes. In such cases it is common to find each half of the zoarium, in part at least, to consist of two superimposed layers of cells.

A re-examination of the Tennessee type of this species has shown conclusively that it is not a *Dicranopora* but a *Rhinidictya*, with relations to *R. nicholsoni* and *R. grandis*, its systematic position being nearly intermediate between them. From the first of those species it differs mainly in its wider and nearly direct zoœcial apertures and narrow interspaces, these being also without surface granulations so far as observed. Still, some of the Minnesota specimens referred here resemble *R. nicholsoni* more closely than do the Tennessee types. It is therefore not improbable that more detailed comparisons than I have found time to make may show that, as I believed in 1886, *R. nicholsoni* also is represented in the Minnesota strata. *R. grandis* is readily distinguished by its wider branches and larger cells. *R. pediculata* likewise seems closely related, but its peculiar growth and somewhat wider branches will, it is believed, serve to separate them. Lastly, *R. fidelis* so closely resembles this species in its *external* characters that I am at a loss to point out really serviceable distinguishing features. As a rule the zoœcial apertures of *R. trentonensis* are a trifle narrower and less often of quadrate shape. Comparing their internal characters, we at once notice a decided difference in the inner part of the zoœcia where that species presents a well developed superior hemiseptum. This is a point of such importance that I am obliged to view the two species as widely distinct.

Formation and locality.—"Glade" limestone (Birdseye) at Lebanon, Tennessee: lower third of Trenton shales at Minneapolis, Minnesota. Rather rare. It has also been collected by Mr. C. Schuchert in the "Lower Blue beds" at Janesville, Wisconsin, and Rockton, Illinois.

Mus. Reg. Nos. 7549, 7560.

Rhinidictya grandis *n. sp.*

PLATE V, FIGS. 11 and 12; PLATE VI, FIGS. 19 and 20.

Zoarium bifolate, large, branchy, the branches flattened, 2.5 to 3.5 mm. wide, the edges obtuse, with the non-poriferous margin of moderate width. Zoœcia in from eleven to fifteen alternating rows, with large, almost direct, slightly oblong, hexagonal apertures, fourteen or fifteen in 5 mm. longitudinally, and nine of the central rows in 2 mm. transversely. Interspaces thin, without papillæ, ridge-shaped, sloping down into the apertures from the summit, the latter reaching to about the same level in both the cross and longitudinal partitions. In conforming with the hexagonal shape and alternate arrangement of the zoœcial apertures, the longitudinal walls usually take a decidedly zigzag direction. In the marginal rows the apertures are commonly more or less irregular in shape, size and arrangement. An occasional small cell may be noticed.

In vertical sections the comparative erectness of the zoœcia is to be noticed; also the shape of the walls. These show no sign of a superior hemiseptum, though a slight angularity is often perceptible at the turn into the vestibular region.

Tangential sections give a good idea of the unusual size of the zoœcia. When the section cuts deeply the prostrate portion of the cells is shown. Here they have the usual characters—thin walls, the longitudinal ones straight, the transverse ones at right angles to them in two or three of the central rows, and directed obliquely upward in the lateral series, the obliquity increasing with each successive row. Just beneath the surface the apertures are elliptical, with a faint line about them, while a series of exceedingly minute dots, or a fine double line instead, passes longitudinally through the interspaces.

The large size of the zoœcial apertures distinguishes this species from all others of the genus known to me. Their hexagonal shape, and the absence of longitudinal ridges are two more features that may be relied on in separating it from such species as *R. mutabilis*, *R. nicholsoni*, *R. fidelis* and *R. neglecta*. but *R. pediculata* and *R. trentonensis* approach it in these respects. The last is, I believe, its nearest congener, but is distinguished readily enough by its narrower branches and smaller zoœcia.

Formation and locality.—The types are from the Birdseye horizon of the Trenton formation at Dixon, Illinois. Other examples were noticed in Wisconsin material collected for the State Museum by Mr. Charles Schuchert and sent me for identification. All the specimens are from the "Lower Blue Beds" of the Wisconsin geologists, in which the species is sometimes associated with *R. trentonensis*. Mr. Schuchert's localities are near Beloit, Mineral Point and Janesville.

Mus. Reg. Nos. *7548*, *7554*, *7593*, *7594*.

Rhinidictya pediculata *n. sp.*

PLATE VII, FIGS 1-5.

Zoarium bifoliate, apparently growing to but little more than 25 mm. in hight. It begins with a small expansion, by means of which it was evidently attached to foreign bodies. Arising from this is a small and short, rounded, subsolid and striated footstalk, that soon flattens and spreads into rapidly bifurcating branches, all spreading approximately in the same plane. The branches have an average width of about 3.0 mm., are very thin, with unusually sharp edges, wide and obliquely striated nonporiferous margin.* Zoœcia in from eleven to fourteen ranges, the usual number twelve, with the outer row on each side irregular in their arrangement, larger than the average, and directed obliquely outward. In the central rows the apertures are commonly elliptical, or subangular, and sunken into oblong hexagonal spaces, bounded by thin walls, of which the lateral ones form slightly zigzag, low ridges. The last feature, however, is to be seen only in the best preserved examples, those in the usual condition seeming to have the interspaces rising to the same level on all sides of the aperture. Measuring lengthwise along the central ranges fifteen or sixteen

*The latter is not shown in fig. 5. (pl. VII) the drawing having been made from a weathered example.

zoœcial apertures are to be counted in 5 mm., while twelve rows occur on a branch 3.0 mm. wide, on which the non-poriferous borders occupy space amply sufficient to accommodate another row on each side.

Internal characters not observed, the process of fossilization having been too unfavorable to preserve the minuter details of structure.

The small footstalk, rapid spreading of the zoarium, and the wide marginal space, are the characters relied upon in distinguishing this species. In other respects the species is very near *R. trentonensis* and *R. grandis.*

Formation and locality.—All the specimens seen were collected by the author from the lower limestone of the Trenton formation, at Minneapolis, Minnesota.

Mus. Reg. No. ? 5934.

Genus EURYDICTYA, Ulrich.

Eurydictya, ULRICH, 1889. Miller's N. Amer. Geol. and Pal., p. 301; 1890, Geol. Surv. Ill., vol. viii, pp. 389 and 520.

Zoaria bifoliate, consisting of broad, simple or irregularly divided expansions, the surfaces of which exhibit more or less conspicuous, though usually small, maculæ or monticules. Zoœcia of the same type as in *Rhinidictya.*

Type: *E. montifera* Ulrich, 1890. Geol, Surv. Ill., vol. viii, p. 521.

This genus was established for the reception of a small group of Lower Silurian species that, though intimately related to *Rhinidictya,* Ulrich, it seemed desirable to distinguish from that genus. The broad and undefined zoarial expansion pertaining to the several species gives them a very different aspect from that presented by the narow, parallel-margined, and regularly branching stipes so strictly adhered to by all the true species of *Rhinidictya.* That intermediate forms occur is true, nor can we doubt that the dividing line between the two genera will continually grow more shadowy with the discovery of new species. But, as that difficulty is encountered by the systematist throughout all organic nature, it cannot be regarded as a bar to the formation of generic groups, because, theoretically, if the course were carried to its logical conclusion, all necessity for classification would cease. Some recognition of obvious departures from a type is necessary, and in the present incompleteness of our knowledge the only satisfactory plan to accomplish this is to adhere strictly to the binomial nomenclature. In this declaration I am to be understood as aiming at subgeneric rather than varietal designations.

Eurydictya multipora (? Hall's sp.), the only species of the genus so far known to occur in Minnesota, is the least typical of the genus. In shape and structure of its end walls the species approaches *Phyllodictya varia.* The type of the genus, *E. montifera,* may be looked for in the upper beds of the Hudson River group in Fillmore and other counties in the southern part of Minnesota where that horizon is exposed.

Eurydictya multipora ? *Hall*, sp.

PLATE VI, FIGS. 9-11; PLATE VII, FIGS. 24 and 29-31; PLATE XIV, FIGS. 9-11.

? *Phænopora multipora* HALL, 1851. Geo. Lake Sup. Land Dist., vol. ii, p. 206.
Phænopora (?) *multipora* ULRICH, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, p. 171.
Eurydictya multipora ULRICH, 1890. Geol. Surv. Ill., vol. viii, p. 520. (Referred to new genus only.)

Zoarium forming irregularly divided wide fronds, 6 to 20 mm. in width, or simple undulating expansions, or a combination of the two. The Minnesota example figured on plate XIV is a fragment of a slightly undulating expansion, 0.7 mm. to 1.5 mm. thick, that must have been no less than 20 mm. wide. The others are of less width, and one (plate VII, fig. 24) deviates so widely from the ordinary growth that it was at first believed to belong to *Rhinidictya mutabilis* var. *major*.

Surface with irregularly distributed small maculæ, often very inconspicuous and scarcely interrupting the regularity of the longitudinal ridges. In other cases they may appear as smooth solid spots, fully 1 mm. in diameter. As a rule they give one the impression of a variable number of elongate zoœcia filled with a solid deposit of calcareous material. Zoœcial apertures subelliptical, more or less oblique, (generally more so than in fig. 11, plate XIV) with a slight peristone, strongest at the posterior margin, arranged between rather prominent, granulose, longitudinal ridges, seventeen or eighteen in 5 mm.; also in curved diagonal series, but these are never very regular and frequently turn into transverse rows. Measuring transversely, from twenty-three to twenty-six of the longitudinal rows may be counted in 5 mm. The width of the interspaces is usually about equal to the diameter of the apertures. When the latter are partially filled with the clayey maxtrix, they may appear as of subquadrate shape, with the interspaces thinner than usual. In the narrow or basal part of the fronds, the spreading edges are sharp, non-poriferous, and striato-granulose, while several of the marginal rows of the zoœcial apertures may be directed obliquely outward.

Vertical sections show that the primitive cell is rather high, short, and has thin walls. These curve over it to a point marking the beginning of the vestibular portion of the tube, when they bend sharply outward. At the same time the interspaces (walls) are greatly widened, and three to five shallow vesicles are developed in direct sequence. Above these the interspaces are solid and seemingly structureless, if we except a dark line running lengthwise through them. No diaphragms observed.

Tangential sections may present one or all of three distinct phases or stages in the development of the zoarium. Their exhibition depends upon the distance from the median laminæ at which the zoœcia are cut by the section. In the first or deepest part of the section, the zoœcia are quadrate, thin-walled, and arranged in regular rows between longitudinal plates. The end or transverse partitions appear less sharp than the longitudinal lines, are generally a little curved, and cross the spaces at either a right angle to the direction of the growth, or somewhat obliquely. In the latter case the primitive cell is subrhomboidal in shape. In the succeeding stage we see the structure immediately following the formation of the original aperture, *i. e.*, the beginning or lower part of the vestibular portion of the zoarium. Now the zoœcial cavity is rounded, of elliptical shape, with a thin ring-like wall, generally in contact with the longitudinal plates. The latter appear usually as dark structureless lines separating the rows of cells. The end spaces, in part at least, may be empty (*i. e.*, filled with clear calcite) thus indicating the presence of interstitial vesicles. In the third or superficial stage, the interstitial vesicles have been filled with solid tissue and the diameter of the zoœcial cavities generally reduced a little by a thin internal deposit, while the dark longitudinal lines are now clearly resolvable each into a crowded row of exceedingly minute tubuli.

Some of the St. Paul specimens look very much like wide examples of the large variety of *Rhinidictya mutabilis*, but after one becomes familiar with the peculiarities of each, it is not difficult to distinguish them. In the first place the zoaria of the var. *major* have always an aged appearance, being heavy, with subparallel, rounded edges, thick interspaces, and correspondingly narrow zoœcial apertures. The small specimens of *E. multipora*, on the contrary, are thin, sharp-edged, oftener and more irregularly divided, and with comparatively thin interspaces. When we compare thin sections the differences are as shown on plate VI, by figs. 1 and 9, 6 and 10, and 11 and 12.

Both *E. calhounensis* Ulrich, and *E. montifera* Ulrich, have a well developed superior hemiseptum, but no interstitial vesicles. In other respects the first is rather closely simulated by the present species. There is no associated species with which *E. multipora* is likely to be confounded. The *Rhinidictya* var. *major* is not found, as far as known, so high in the shales, being restricted apparently, like *Phyllodictya varia*, another wide bifoliate form, to the middle division of the Trenton shales.

This species, as above cited, was described by me from Kentucky specimens. Since then I have found it in Tennessee, and in 1885 a single example in the Minnesota State collection proved to belong to the same species. Two years later Mr. Schuchert and the writer secured about ten specimens at St. Paul.* Respecting the specific identity of all these specimens with the originals of Hall's *Phænopora multipora*, I should say, that I am still of the opinion expressed in 1882, but having since

* During the past two weeks (to April 10th, 1892,) the writer secured no less than fifty specimens at St. Paul.

then learned to esteem caution, the present less positive stand on the question will suffice till we have been informed of the minute structure of Hall's types. These were derived from the northern part of Wisconsin, and if they prove to be identical with the specimens here described, a considerable extension of the geographical range of the species will result. The species is an important one too, in being highly characteristic of one horizon.

Formation and locality.—In Minnesota known only from the upper third of the Trenton shales, at St. Paul. In Kentucky, rather common in the shales above the "Modiolopsis beds." In Tennessee it holds the same horizon (Safford's Middle Nashville Series) at Nashville.

Mus. Reg. No. 5942.

Genus PHYLLODICTYA, Ulrich.

Phyllodictya, ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 153: MILLER, 1889, North Amer. Geol. and Pal., p. 315; ULRICH, 1890, Geol. Surv. Ill., vol. viii, p. 390.

Zoaria bifoliate, simple or iregularly branched, growing from an expanded basal attachment. Zoœcial tubes long, with complete diaphragms but no hemisepta; from the central axis they bend outward very gradually, causing the apertures to be more or less strongly oblique, with the posterior edge raised lip-like. Interspaces wide, subsolid, transversed vertically by one or two rows of minute tubuli, which appear as so many papillæ at the surface.

Type: *P. frondosa* Ulrich.

This genus requires more study before the relations to *Eurydictya* on the one side, and *Pachydictya* on the other, can be determined and satisfactorily established. The questions involved are rendered difficult of solution by the commingling of characters found in *Pachydictya splendens* Ulrich. and *P. firma* Ulrich, of the upper beds of the Hudson River group, and *Eurydictya multipora* (? Hall) of the Trenton group. All three of these species have certain features in common that do not pertain to the more typical forms of either *Pachydictya* or *Eurydictya*. It is, however, precisely in those characters that these species remind us of *Phyllodictya*.* Though having an abundance of specimens of, at any rate the majority of the species, bearing directly upon the points at issue, I have been obliged, chiefly because of a lack of time, to defer pushing my investigations to a satisfactory conclusion. I realized also that all partial studies of the group of bifoliate Bryozoa, and consequent rearrangements of species, are only too likely to prove premature and faulty when the full results of a complete study of the group shall have become available. For the present it is sufficient to point out the obscure and perhaps weak spots in the classification now in use.

*Another genus presenting points of agreement with *Phyllodictya* is *Ptilotrypa* Ulrich, founded upon a single species from the upper beds of the Hudson River group. But the absence of "median tubuli" in the latter is a difference of such importance that the two genera must be regarded as widely distinct and as belonging to different families.

Phyllodictya frondosa *? Ulrich.*

(Not figured.)

Phyllodictya frondosa Ulrich, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, p. 174, pl. 8, figs. 11. 11a and 11b.

The name of this species occurs in the list appended to my preliminary report on the Minnesota Bryozoa (Fourteenth Ann. Rep. Geol. Surv. Minn., p. 102; 1886). The identification was based upon several small fragments, none of them in a condition to afford satisfactory thin sections. Nor did any of the more numerous and larger specimens of *Phyllodictya* collected subsequently for my own cabinet by Mr. Charles Schuchert and others, as well as by myself, prove any better for that purpose. I was, therefore, unable to verify the identification until last year, when I detected a single well preserved fragment, about 15 mm. square, in a lot of fossils kindly given me by Prof. C. W. Hall, of the State University. Both the superficial and internal structure of this specimen, which was obtained too late to appear on the plates, agrees closely enough with that of one of the original Kentucky types of the species. Ordinarily, this would be quite sufficient to establish the identification of a species, but in this case, a fact about to be mentioned causes me to use the question marks. Recently I had occasion to prepare a set of thin sections of a specimen supposed to belong to this species. These seem to differ so much from the original set, that one of two things is evident: either I included two species in my original diagnosis of *P. frondosa*, or the species is more variable in its internal structure than I supposed. It is probable that the differences observed are only the result of age, but as I have not had time to make the sections necessary to prove this, I thought it best to mention the difficulty, leaving its removal to some future time. Before giving the following brief description of the Minnesota specimens, it would be well to mention that the one received from Prof. Hall agrees best with the specimen represented by fig. 11 of the original work on the species, while the resemblance to the specimen that furnished the original thin sections and the enlarged surface view is much less.* Also, that I now believe that none of the specimens catalogued by me in 1886 as *P. frondosa* really belong there. Most of them, perhaps all, are to be referred to the new species *P. varia*.

Zoarium leaf-like, 1.5 mm. thick; size unknown, only fragments having been seen. At intervals of 3 or 4 mm. the surface presents smooth or grano-striate solid spots, 1 mm. or more in diameter. These spots may be on a level with the general plane of the surface, or slightly depressed. Zoœcial apertures ovate, a little

*The new set of sections were prepared from an example like the first.

drawn out anteriorly, with the posterior edge abrupt and slightly elevated, arranged in straight or curved, diagonally intersecting lines, and, less obviously, in longitudinal series, with about seventeen in the former and twelve in the latter in 5 mm. Interspaces separating the apertures in the diagonal rows narrower than the apertures, while those between their ends may be wider and concave instead of rounded, with the posterior rim extending up along their sides. When in a good state of preservation a row of minute papillæ crowns this rim, and thus extends around the posterior margin of the zoœcial apertures and up their sides to the row belonging to the succeeding aperture. There are therefore two rows of these papillæ between neighboring apertures, but it is not uncommon to find the spaces between the apertures in the diagonal rows too narrow for their full development, and then they are crowded into an irregular single row.

In vertical sections the zoœcial tubes begin with a rather long prostrate cell from which they proceed to the surface by a gentle outward curve; the continuance of this curve causes the apertural portion of the tube in old examples to be much more nearly direct to the surface than in their younger stages. In an average example a line drawn from the aperture to the proximal extremity of a tube forms an angle of about 35 degrees with the central laminæ. Complete diaphragms to the number of five have been observed to cross each tube. Near the central axis the walls are thin, but soon they begin to spread, admitting of the intercalation of from three to five successive vesicles. Above these the interspaces are filled with solid matter, seemingly structureless except for the minute dark tubuli traversing them in a direction at right angles to the plane of the zoarium. These tubuli arise in a dark line running along the posterior side of the tube.

Tangential sections show a considerable deposit of solid material on the inner side of the tubes. This is scarcely to be described as ring-like, since it is not sharply defined nor of equal thickness all around, being widest and rather indistinct anteriorly, and but illy distinguished at any point from the interspaces. The latter are occupied by minute dark spots (median tubuli) in single or double rows, representing and corresponding with the arrangement of the minute superficial papillæ described.

The above description is based almost entirely upon the specimen mentioned as having been received from Prof. C. W. Hall. Its characters, as has been stated, agree very closely with one type of *P. frondosa*, but not nearly as well with the other, possibly distinct form, originally united with it. Compared with *P. varia*, to which I shall provisionally refer nearly all of the Minnesota specimens of *Phyllodictya* so far seen, it will be found to differ in having thinner interspaces, and larger apertures, with the diagonal instead of the longitudinal arrangement predominating. Further differences are to be found in the character of the interspaces, and in the shape of the zoarium.

Formation and locality.—Rare in the Trenton shales, at Minneapolis, Minnesota. The types of the species are from the Birdseye limestone at High Bridge, Kentucky.

PHYLLODICTYA VARIA, *n. sp.*

PLATE XIV, FIGS. 1-8.

Comp. *Stictopora labyrinthica* HALL, 1847. Pal. N. Y., vol. i, p. 50.

Zoarium variable, consisting of broad, leaf-like, thin expansions, either simple or with irregular marginal incisions, or of wide branching fronds, with the edges subparallel, sharp, and non-poriferous. At intervals of about 4 mm. the surface exhibits subsolid, even or slightly depressed spots or "maculæ," smooth when worn, finely grano-striate as well as faintly channeled longitudinally when well preserved. In the youngest examples these maculæ are small and sometimes scarcely distinguishable, but with age they seem to increase in size (compare figs. 2 and 7). The most obvious and normal arrangement of the zoœcial apertures is in longitudinal series, twelve or thirteen in 5 mm., between delicate papillose ridges; but the general aspect of the surface varies greatly in the specimens before me. Some of these differences are doubtlessly due to, or exaggerated, by weathering and other accidental causes, yet others are as clearly changes consequent upon increasing age, and thus are to be regarded as expressing different stages in the development of the zoarium. In the youngest the zoœcial apertures are very oblique, with a rim, strongly elevated at the posterior side, and dying out at the sides or seeming to unite with the delicate ridges separating the rows. This condition is represented in figs. 2 and 3. In later stages the longitudinal ridges becomes indistinct, the interspaces flatter, the posterior "lip" less pronounced, the apertures less oblique and, sometimes, a little smaller, while in other cases, probably representing a weathered condition, they appear larger, with the interspaces rounded. The longitudinal arrangement also becomes less obvious but never, so far as observed, quite subordinate to the diagonal. This may seem to have occurred over limited spots, especially when the maculæ are unusually large as in the specimen represented by figs. 6 and 7.

Only one specimen proved suitable for sectioning. This even failed to preserve the minuter details of structure as well as was desired. So far as the internal characters could be made out they are shown in figs. 4 and 5, excepting that by an unaccountable oversight the diaphragms were not drawn in the vertical sections. Each tube should have shown one diaphragm crossing it at right angles at a point about midway between its aperture and the mesial line.

This species is closely related to a common form of the Birdseye limestone in central Kentucky, which I regard as likely to prove identical with Hall's *Stictopora labyrinthica*, described from the some horizon in New York. But in the absence of any knowledge of the interior of that species, it would be highly injudicious, surely unwarranted, to assert their identity. Still, it is possible that even the Minnesota form may be only a local variety of that species. However, the probability of that supposition is so remote that I feel no hesitation in proposing the new name *varia* for the form here described.

Formation and locality.—Restricted to the middle third of the Trenton shales at Minneapolis, Minnesota. A single example from about the same horizon at Cannon Falls.

Mus. Reg. No. 5953.

Genus PACHYDICTYA, Ulrich.

Pachydictya Ulrich, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 152; Foerste, 1887, Bull. Sci. Lab. Denison Univ., vol. ii, pt. ii, p. 162; Miller, 1889, N. Amer. Geol. and Pal., p, 313; Ulrich, 1890, Geol. Surv. Ill., vol. viii, p. 390.

This genus, in its fullest sense, falls into three distinguishable, yet not entirely natural sections, having precisely the same relations to each other as *Rhinidictya* and *Eurydictya*, *Cystodictya*, *Dichotrypa* and *Prismopora*. These genera, being based entirely upon zoarial deviations, are evident to the unassisted eye, and the microscope is not necessary in distinguishing them. To be consequent, a similar splitting up of *Pachydictya* is suggested, but such a course would be only too liable to lead to misunderstandings, since we would be obliged, for the same reason, to follow the plan to its logical conclusion in dealing with *Ptilodictya* and *Phænopora*, in which precisely the same divisions, as well as others equally marked, obtain. It is, therefore, deemed sufficient for present needs to designate two of them with the non-committal terms of Section *a* and Section *b*. The third, however, being a departure in a more obvious and seemingly more important direction, is entitled to better attention. For it the name Trigonodictya is proposed.

The following diagnosis embraces the characters of the two sections, but those features that may be considered as especially characteristic of one or the other, are indicated by the letter *a* or *b* in parentheses following the statements.

Zoaria bifoliate, consisting of irregular wide branches, large or small, and more or less undulating, leaf-like expansions (*a*), or of narrow, subparallel-margined, and dichotomously branching stipes (*b*). Margins acute, with a non-poriferous border, obliquely striate or grano-striate. Surface with small maculæ and, about them or taking their places, clusters of zoœcia of more or less obviously larger size than the average; occasionally montiferous (*a*). In other cases (*b*) these clusters are represented by the marginal rows of apertures which are commonly of larger size, with wider interspaces, and less regularly arranged than those of the central rows. Zoœcial tubes rising rather abruptly from the mesial laminæ, the primitive cells with thin walls, longitudinally arranged, of elliptical, semicordate, or subquadrate form, in most cases partially separated from neighboring cells by small interstitial vesicles. Toward the surface their walls are thickened, often ring-like, subelliptical in cross-section, usually completely isolated, the interspaces solid excepting that they are transversed by one or more, straight or flexuous, series of minute tubuli. One or more (the number depends upon age of example) complete diaphragms in each zoœcial tube. Apertures usually elliptical, rarely subangular, the "closures" with a subcentral small opening. Interspaces grano-striate, concave and forming a peristome about the zoœcial apertures, or thrown up into longitudinal ridges. Median tubuli between the halves of the double mesial plate.

Type: *P. robusta* Ulrich.

The distinguishing characters of section *a*, which includes the type of the genus, are (1) the wide, palmate or foliar zoarium, and (2) the maculæ and clusters of large zoœcia. The section might be still further subdivided according to whether the longitudinal arrangement of the zoœcial apertures predominates, or that in diagonally intersecting series. The latter would include the species *robusta*, *everetti*, *foliata*, *magnipora* and *hexagonalis*, all, save the last, described by me from the lower beds of the Trenton formation; while the former would embrace the species *occidentalis* Ulrich (upper Trenton), *fenestelliformis* (Nicholson), *firma*, *gigantea*, and *splendens*, Ulrich (upper beds of Hudson River group), and species *obesa* and *turgida*, described by Foerste from the Clinton rocks of Ohio.

In section *b*, the zoarium is narrow, and its margins subparallel, while the longitudinal arrangement of the zoœcia is always the predominating one. It seems that maculæ, or merely an unusual width of the interspaces, must always accompany the clusters of large cells, and as the room was insufficient in these narrow zoaria for their proper development, or, it may have been that their presence would have interfered too greatly with the regular growth of the branches, they (the large cells) are instead arranged along the margins, where we may assume, the necessary conditions to have been afforded by the non-poriferous border, which is constructed essentially upon the same principle as the maculæ.*

The following species are to be arranged under Section *b*: *acuta* (Hall) *fimbriata*, *pumila*, and *triserialis*, from the Trenton; *alcyone*, *arguta*, and *rustica*, of Billings, from

*It is a fact worth remembering that as soon as the width of the zoarium of one of the paleozoic bifoliate Bryozoa exceeds 4 or 5 mm., a maculum or cluster of cells larger than the average is found a short distance beneath the axes of bifurcation. A still greater increase and we have a row of maculæ or monticules along the center of the surface. Several instances of this kind are illustrated on the plates accompanying this volume. (See plates VII and VIII.)

the Anticosti group; *crassa* (Hall), *bifurcata* (Van Cleve), *emaciata* (Foerste), *farctus* (Foerste), and *rudis* (Foerste), from the Clinton, and *scitula* (Hall) from the Niagara.*

In placing *Pachydictya* under the *Rhinidictyonidæ* I follow the course adopted in my 1882 work on the "American Paleozoic Bryozoa," (Jour. Cin. Soc. Nat. Hist., vol. v), and more recently in the eighth volume of the reports of the Geological Survey of Illinois, published in 1890. I have always had some doubt as to the strict propriety of the arrangement, and the chief reason for its continance in the last work is found in the fact that the genus agrees with *Rhinidictya* and all true genera of the family in having "median tubuli." Now that I am employing the classification for the third time, it seems desirable to publish at the same time some account of my objections. At first I thought some of proposing a new family for *Pachydictya* and the new genus *Trigonodictya*, but was restrained from doing so by the fear that I could not, in the present state of our knowledge, satisfactorily establish the distinctness of the new family from the *Rhinidictyonidæ*. The difficulties are encountered when we attempt to draw sharp lines between certain species of *Pachydictya* on the one side, and *Phyllodictya* and *Eurydictya* on the other. Had I made the presence or absence of diaphragms the test, I would very likely have struck the popular chord, but as I know that test to be unreliable only too often when applied to groups of high rank, I could not employ it before knowing more of its value in this particular case.

The suggested removal from the *Rhinidictyonidæ* is not caused through any depreciation in the value of the character mentioned (median tubuli), but is founded upon a better appreciation of certain features wherein *Pachydictya* and *Trigonodictya*, and in a lesser degree also *Phyllodictya*, differ from the more typical members of the family: *Rhinidictya*, *Dicranopora*, *Goniotrypa*, and *Eurydictya*. In all of the latter the primitive or prostrate portion of the zoœcial tube is of an oblong-quadrate or rhomboidal shape, the thin wall of adjacent cells being, moreover, in contact with each other on all sides. Nor are interstitial vesicles or mesopores present in any of them with the single exception of *Eurydictya multipora* (? Hall's sp.). Diaphragms, also, are very unusual, while a more or less well developed hemiseptum is common. Finally, the interspaces, as shown in tangential sections, continue uninterruptedly from zoœcial cavity to cavity, there being no sharply defined ring-like wall around the latter.

In *Pachydictya*, *Trigonodictya* and *Phyllodictya*, however, the hemisepta are never present, but complete diaphragms seem to have been developed in all examples old enough to have them. Tangential sections bring out peculiarities fully as striking and important, but their statement should be premised with the admission that some of them are but illy developed, possibly quite unrecognizable, in some of the species.

*I am convinced that several, perhaps over half, of these nine Middle and Upper Silurian species are synonyms.

Perhaps, the chief ones of the characters about to be mentioned, are those that have resulted in the presence and early development of interzoœcial spaces. These begin, generally at any rate, the same as in the *Cystodictyonidæ* and the bifoliate *Fistuliporidæ* (*Meekopora* Ulrich) at the basal (mesial) plate, causing the primitive cell of the zoœcial tubes to be in part separated from its neighbors, and to have a shape quite different from that of the *Rhinidictyonidæ*. Indeed, the resemblance to the semicordate cell so prevalent among the *Cystodictyonidæ*, is often very striking. (See plate IX, figs 8 and 13.) A common condition is when a small triangular interspace has been cut off from each of two diagonally opposite corners of the primitive cell. These interspaces increase in size and form shallow vesicles as growth proceeds, and as soon as the tubes have assumed an erect position, they are completely isolated by the superimposed vesicles. At the same time their walls become more or less thickened and ring-like, and, from now on to the surface, the zoœcial investment remains, almost invariably, clearly distinguishable from the interspaces proper, the sharpness of definition between them being in most cases even increased after the interspaces have been filled with the usual solid deposit. These changes in the zoœcial structure are shown in the various figures on plate IX.

In *Phyllodictya* and *Trigonodictya*, as well as in some of the small species of Section *b* of *Pachydictya*, we have no positive evidence of the development of the interstitial vesicles until after the zoœcia have left the mesial plate. In these, therefore, the basal portions of adjoining zoœcia are in contact, and in that respect the same as in *Rhinidictya*. To what extent this fact depreciates the value of the character of the partial separation mentioned in the preceding paragraph, I am not prepared to say. Perhaps it finds an explanation in this that the character, or rather the peculiar shape of zoœcium to which the early presence of interstitial vesicles is due, and which is so characteristic of Devonian and Carboniferous bifoliate Bryozoa, had not in those earlier times become fully established.

A remarkable agreement of structure is presented by certain forms of *Pachydictya* (Section *a*) with the Carboniferous fistuliporoid genus *Meekopora* (*e. g. M. clausa* Ulrich). That there exists real or ancestral affinity between them I doubt, yet, if there is none, the similarity between them is all the more curious. Nor does it seem likely that the relations with the *Cystodictyonidæ* are any closer. Still, it cannot be denied that the evidence at hand points to a relationship with those families on the one side and the *Rhinidictyonidæ* on the other.*

*A point of general interest presents itself here. As is well known, Nicholson and perhaps the majority of European paleontologists regard *Fistulipora* and its allies as belonging to the *Alcyonaria* group of corals. Now, if we will take the various species of *Pachydictya*, starting with the small forms comprised in Section *b*, which everyone concedes to be unequivocal Bryozoa, and going through to such forms of section *a* as have the vesicular interstitial tissue well developed, we establish a chain of evidence tending very strongly to prove their view wrong. The lunarium only is lacking to make the chain complete, but, as is well known, that feature is not restricted to the *Fistuliporidæ*. Indeed, it is as well, if not better, developed in such universally conceded Bryozoa as the *Cystodictyonidæ* and *Ceramoporidæ*. But this is only one of many chains that I would very willingly publish if it were not for the time consumed in writing them up.

Section *a: Species in which the zoarium is not limited, and maculæ or clusters of large zoœcia are present.*

PACHYDICTYA FOLIATA *Ulrich.*

PLATE IX, FIGS. 1-5; PLATE X, FIGS. 5-10.

Pachydictya foliata ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 73.

Zoarium growing from an attached basal expansion into erect, thin fronds, undulating and simple, or dividing palmately or irregularly; both sides celluliferous; attaining a hight and width of 50 mm. or more, but specimens larger than 25 mm. square are rare; usual thickness about 1.2 mm., but in some old examples it is quite 3.0 mm. Margin of fronds acute or rounded, often with a distinct non-periferous border. At intervals of 3.5 or 4.0 mm. the surface presents solid, substellate spots or maculæ, that in most cases are on a level with the general plane of the surface, in others occupying the summits of low monticules, while in rare instances they may be even slightly depressed. These maculæ usually appear smooth, but when well preserved are seen to be finely grano-striate. Zoœcial apertures large, oval, arranged in regular diagonally intersecting series, in which fourteen or fifteen of the average size is the usual number in 5 mm. In the immediate vicinity of the maculæ they are larger, attaining a size of 0.4 mm. by 0.3 mm., the average size in the spaces between the maculæ being about 0.3 mm. by 0.2 mm. There is a slight difference also in the size of the apertures of the old and young specimens, they being largest in the latter. Interspaces usually of less width than the zoœcial apertures, concave and forming a distinct peristome around the aperture in the young examples; becoming flattened and even faintly convex, also minutely granulose with age. Interstitial vesicles seen at the surface in the youngest specimens only.

In vertical sections the zoœcial tubes arise rather abruptly from the mesial laminæ, the course to the surface throughout being also unusually direct. The prostrate or primitive cells may be in contact, with a thin divisional wall; but this is not the rule since the interstitial vesicules are developed at the same time. The character of the latter is clearly preserved for a distance of about 0.5 mm. on each side of the mesial laminæ, but beyond this they are filled with solid material in which they are but illy traceable. Occasionally it is possible to detect faint dark lines passing vertically through this solid filling, indicating that communication was maintained with the horizontal median tubuli. The zoœcial tubes are bordered on each side by a double line, and crossed, according to age, by from one to five complete diaphragms. These occur approximately on the same level in all the tubes, and at intervals corresponding more or less nearly with the diameter of the tube. If my view is correct, each of these diaphragms represents the floor of distinct zoœcia which have succeeded each other by direct sequence, the formation eventually of the present "tube" being the necessary result.

In tangential sections, obtained by grinding down into one of the faces of the zoarium, we notice characters as follows: Beginning with the base of the zoœcia, *i. e.*, the mesial laminæ, we find them represented by a darkened space, (usually a meandering streak across the deepest part of the section) crossed by two sets of parallel lines, one, colorless, representing the "median tubuli" that are inclosed between the two halves of the basal plate, the other, of a dark tint, the longitudinally directed side walls of the zoœcia and intertstitial vesicles. Immediately above this space the zoœcia are slightly elongate, with the anterior end widest and rounded, and the posterior end usually truncated. Behind this is a darkened narrow space which, though really an interstitial vesicle, often appears to be a part of the zoœcium. The two together are somewhat bottle-shaped. Directly following this stage the zoœcia become shorter, broadly elliptical in shape, and separated from each other by narrow interspaces in which the elongated interstitial vesicles are more or less plainly visible. In the next stage the vesicles are more and more obscured by a seemingly structureless deposit of sclerenchyma, while the bounding wall of the zoœcia becomes more ring-like. If the section is a good one and the preservation favorable, this wall will be seen to consist of a closely arranged row of minute tubes, apparently of the same nature as the minute tubuli between the mesial laminæ. In the last stage observed (seen in a section showing the structure just beneath the surface of an old example) the interspaces are traversed by one or two intertwining lines of minute dark spots (median tubuli) and a ring of sclerenchyma, of light color and laminated structure, deposited on the inner side of the zoœcial wall. The maculæ, consisting of aggregations of interstitial vesicles, go through the same changes as the ordinary interspaces.

Good transverse sections dividing the zoarium vertically, but at right angles to the direction of growth, show, among other features, the minute tubuli between the mesial laminæ in a very satisfactory manner. A significant fact is that one of these tubuli seems always to be placed immediately beneath the walls of both the zoœcia and the intercalated vesicles. This is true, I believe, of all the *Rhinidictyonidæ*, and is strong evidence in favor of my view that the two sets of minute tubuli, horizontal and vertical, prevailing in this family of Bryozoa, communicated with each other.

A very similar form occurs near the river level at Ottawa, Canada, but as it presents several internal peculiarities, especially in the form and arrangement of the primitive portion of the zoœcia, I will pass it by with this mere mention.

The foliaceous zoarium of this species will distinguish it from all associated Bryozoa excepting *Stictoporella frondifera.* Both occur commonly on the same slabs, and a careless collector might confound them. Still, after a little study, the difference in the size and shape of their respective zoœcial apertures will become so evident that they may be distinguished at a glance.

Formation and locality—Restricted to and very characteristic of the the lower third of the Trenton shales. It is very abundant at Minneapolis and St. Paul, and has been found in greater or less abundance marking this horizon in the shales at localities near Cannon Falls, Preston, Fountain and other points in Minnesota.

Mus. Reg. No. 5948.

Pachydictya occidentalis *Ulrich.*

PLATE VIII, FIGS. 20-27; PLATE IX, FIGS. 6-10.

Pachydictya occidentalis Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 75.

Zoarium variable, sometimes consisting of narrow branches with subparallel margins, in other cases spreading rapidly into slightly undulating fronds ; but the commonest mode of growth is represented in figures 20 and 24 on plate VIII. In these we have wide branches, with more or less divaricating margins, often of subpalmate form, with three or more small divisions above. Width 4 to 25 mm., greatest thickness 1 to 2 mm. Margins acute, usually with a narrow, smooth or finely striated border, best developed in the narrowest examples. The wider specimens generally with only a single row of small solid spots having the same structure as the non-poriferous border. These vary considerably in size, and are not uniform even on the same specimen. In the narrow examples they are absent except one or two just beneath each bifurcation. Zoœcial apertures elliptical, arranged in comparatively irregular series, the longitudinal predominating. Curved, transverse, and diagonally intersecting rows are also to be made out. Measuring lengthwise, thirteen or fourteen in 5 mm.; transversely, seven or eight in 2 mm. Interspaces generally rather narrow, but unequal. When an alternating arrangement of the zoœcial apertures prevails, the end spaces are decidedly the narrowest, averaging in that case only about 0.1 mm., or scarcely more than half the width of the lateral spaces. When however a transverse arrangement obtains they are nearly equal at 0.13 mm. As a rule we may say that the shorter or transverse diameter of the zoœcial apertures is about equal to the width of the interspaces. Generally the interspaces are to be described as flattened, finely grano-striate, the striæ, however, appearing to be irregular or interrupted at short intervals. In old examples they may be convex, but in no case have I detected longitudinal ridges between the rows of cells. Figure 26 represents one of a number of specimens, the growth of which for some unknown reason has not been regular and continuous over the whole surface. There seems to have been a cessation of developement in some places, causing the formation of irregular furrows, in which the old zoœcial apertures are partly closed by a sheet of dense material. Thin sections failed to reveal anything unusual, hence, we may safely assume that these specimens present merely an abnormal condition of the species.

Of internal peculiarities brought out by tangential sections the most striking are, (1) the unusual brevity of the end spaces. In many cases these are so short that the outer lines of the ring-like walls of succeeding zoœcia are often nearly in contact. Generally the length of these spaces is less or about equals half the transverse diameter of the zoœcia; (2) the continuous longitudinal lines of median pores (there is as a rule only one in each interspace between the rows of zoœcia) appears more flexuous than usual; and (3) the maculæ or solid spots, which do not interrupt the course of the lines of median tubuli. A number of isolated tubuli, otherwise seemingly of the same nature, occur between the lines mentioned.

In vertical sections the zoœcial tubes frequently have diaphragms, their course to the surface is less direct than common, and the interspaces or walls unusually thin.

The growth and maculose surface distinguishes this species from the other Minnesota forms of the genus, none of which are found, however, in the same beds with *P. occidentalis.* Though perhaps still to be regarded as intermediate in some respects between *P. acuta* Hall, sp., and *P. fenestelliformis* Nicholson, sp., further investigation proves the relationship to those species to be more remote than I thought at first. It seems also to have preceded both in time. Compared with the first it is found to differ in its mode of growth, the zoarium being wider, in the character of the interspaces, and in the maculæ which are wanting in that species. The second has larger zoœcia, and both present well marked internal differences.

Formation and locality.—Rather abundant in the upper third of the Trenton shales at St. Paul, Minnesota. A few specimens also from the same horizon in Goodhue county.

Mus. Reg. Nos. 5949, 7646.

Section *b: Species in which the width of the zoarium is limited, and the margins subparallel.*

PACHYDICTYA FIMBRIATA *Ulrich.*

PLATE VIII, FIGS. 28-34; PLATE IX, FIGS. 13 and 14.

Pachydictya fimbriata ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 75.

Zoarium rather small, ramose, the branches with subparallel margins, from 2 to 5 mm. wide, averaging a little over 3 mm., thin, the thickness rarely exceeding 0.5 mm.; bifurcations dichotomous, occuring at variable though generally at long intervals; angle of bifurcation unusually wide. Non-poriferous margin very wide, extremely thin and sharp, and wavy or ruffled; its surface is obliquely striated, the striæ really rows of minute hollow papillæ, which communicate with the horizontal median tubuli between the mesial laminæ. Zoœcia in from seven to twelve ranges, the usual number ten or eleven; their apertures elliptical, usually a little wider than the transverse interspaces, and longer than the end spaces. In the five, six, or seven central rows the apertures are arranged in regular alternating or subalternating longitudinal series, in which thirteen or fourteen occur in 5 mm.; measuring transversely six rows take up a space of 1.5 mm. wide. The one to three marginal rows are not so regular in their arrangement, they being, besides, appreciably larger and separated by wider interspaces, while their long diameter is, usually at least, directed somewhat obliquely outward.

On plate IX, fig. 13 represents part of a tangential section, showing, at the top, the primitive or prostrate portion of the zoœcia, and mesial laminæ with horizontal tubuli; along the right side, the wide non-celluliferous border, which in thin sections is irregularly outlined and incomplete, because of its "ruffled" character; and in the lower left-hand fourth, the zoœcia and interspaces as they appear just beneath the surface. In the last portion of the figure the chief feature to be pointed out is the unusual clearness and thickness of the ring-like zoœcial investment. In common with perhaps every species of this section of the genus, and many of section *a*, the longitudinal arrangement of the zoœcia between distinct lines, either straight or flexuous, and proving on closer inspection to be series of minute pores, prevails in the central rows through all stages, saving, perhaps, the last in very old examples.

Good examples of this species cannot be confounded with any other known to me, since the great width and wavy or ruffled character of the non-poriferous margin gives them a very striking and highly characteristic aspect. In most other respects the species resembles *P. acuta* Hall, sp., and its western varieties rather closely. It may be compared also with *P. elegans* and its *described* variety. In that species and variety the non-poriferous margin is also rather wide, but it is not wavy and the inter-apertural spaces are wider, especially those between the ends of the zoœcial apertures, while the whole surface of the zoarium strikes one as more highly ornamental. Considerable differences are likewise to be noted in tangential sections as may be seen in comparing figures 8 and 13 on plate IX.

Formation and locality.—Rather common in the lower half of the Trenton shales at Minneapolis and St. Paul, Minnesota. It occurs also in the "Pierce" limestone of Tennessee.

Mus. Reg. Nos. 5950, 5951.

Pachydictya elegans. *n. sp.*

PLATE VIII, FIGS. 18 and 19. PLATE IX, FIGS. 8 and 9.

The nearly complete type specimen began its growth on the extremity of some undetermined ramose bryozoan. The basal expansion is small, and its surface largely covered with granulose striæ. At its edges, where it grew downward on the foreign body, a few apparently normal zoœcia were developed. From the exceedingly short, neck-like constriction above the base, the erect portion of the zoarium divides at once into three branches, and two of these continue to divide dichotomously with extraordinary frequency, the average distance between bifurcations being only 5 or 6 mm. This frequent division caused the zoarium to spread with unusual rapidity; some of the inner branches must have overlapped if continued. We may assume, however, that with age, beyond that shown in this example, the outer or subsequent divisions became less frequent, or at any rate, dependent upon the space available for lateral development. Branches 2.5 mm. to 5.0 mm. wide, thin, edges sharp, non-poriferous, border wide, obliquely grano-striate. In the thickest specimens the celluliferous portion of the branch rises abruptly from the wide non-poriferous borders, the growth of the latter having failed to keep pace with that of the zoœcia. Under a good hand lens the surface presents a highly ornamental appearance, the arrangement of the zoœcia and sculpture of the interspaces being very regular. Apertures elliptical, separated from each other by spaces as wide as their shorter or transverse diameter. In the central rows the arrangement is alternate, with thirteen or fourteen in 5 mm., measuring lengthwise, and seven of the central rows in 2 mm., transversely. Those in the marginal rows slightly oblique, a little larger than the average and separated by correspondingly wider interspaces, so that a smaller number occurs here in a given space than in the central series. Surrounding each aperture a sharply defined rim or peristome, and rising from the center of the depressed spaces between the longitudinal rows, a faintly flexuous, thread-like line. On the best preserved portions of the surface, both the longitudinal lines and the peristomes are seen to carry a row of minute papillæ. Over the central part of the surface the depressed end spaces are narrow and usually empty, but toward the margins, where they are wider, they are occupied by a gradually increasing number of papillæ, at first isolated, then forming short outwardly tending rows.

Provisionally I propose to place here a number of specimens agreeing in all respects with the type of the species, save in this, that they bifurcate at less frequent intervals. The interspaces in many are a trifle thicker, but as these specimens are heavier and evidently older, that is to be expected.

The internal characters, which in most respects remind us greatly of *P. occidentalis*, surely more of that species than of *P. acuta*, were obtained from thin sections of one of the last mentioned specimens.

Compared with other species *P. occidentalis* offers many points of agreement, but, so far as known, is distinguished readily enough by its maculæ, and the less regular arrangement of its zoœcia and inter-apertural markings. *P. fimbriata* is also closely related, but the peculiar wavy character of its borders serves well in separating them. In *P. acuta* and varieties the spaces separating the rows of apertures are more ridge-like, and the end spaces longer. The branches also are, except in rare instances, narrower.*

Formation and locality.—Not uncommon in the Galena shales at St. Paul, Minnesota, where it is associated with an abundance of *Zygospira recurvirostris* (Hall) and segments of *Arthroclema*. *Arthropora reversa* is found on the same slabs of rock. Also at Decorah, Iowa.

Mus. Reg. No. 7596.

Pachydictya acuta *Hall*, and varieties.

PLATE VIII, FIGS. 11-17; PLATE IX, FIG. 7.

Stictopora (?) *acuta* Hall, 1847. Pal. N. Y., vol. i, p. 74, pl. xxvi, figs. 3a, b.
Stictopora or *Ptilodictya acuta* (part.) of many authors.
Stictopora acuta Ulrich, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, p. 168, pl. viii, figs. 1, 1a, 1b.
Pachydictya acuta Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat Hist. Sur. Minn., pp. 75 and 76. (Merely mentioned as a species of *Pachydictya*.)

This so frequently yet so often incorrectly quoted species, has given me no little trouble, first, because of the difficulty of determining exactly what species Hall originally intended, and second, because of its variability. The species might be subdivided, but I doubt the advisability of doing so, since most of the varieties are exceedingly difficult to recognize. The species, with all its varieties, is also restricted to the Trenton limestone, or rocks equivalent to that horizon. Hence, we have not the usual though good excuse for proposing varietal distinctions. The species is to be regarded as one of the most characteristic and widely distributed fossils of the Trenton proper, being also abundant at many localities in New York, Vermont, Canada, Kentucky, Tennessee, Illinois, Wisconsin, Minnesota, and Manitoba. It has been reported to occur in the Birdseye and Black River horizons, but that is most likely an error, species of *Rhinidictya*, which abound in those rocks, having but too often been confounded with *P. acuta*.

Figure 11 of Plate VIII, represents one of seven fragments from the original locality, Trenton Falls, New York, which I owe to the kindness of Mr. C. D. Walcott. Its surface magnified nine diameters is shown in fig. 12 of the same plate. In this

* Though now obliged to regard *P. elegans* as specifically distinct, I expect, with material soon to be gathered, to be able to show that it is merely a later development of *P. occidentalis*. Perhaps also that it is really an intermediate stage between that species and *P. acuta*.

specimen, which may be assumed to represent the typical form of the species, the zoœcial apertures are elliptical, rather small in the central rows where, however, they are separated by comparatively long intervals, with twelve in 5 mm. In the marginal row the zoœcial apertures are rather oblique and conspicuously larger, and here only eight or nine are to be counted in the same space. The non-poriferous margins are wide, and where the preservation is good, have the usual oblique granulose striation. The interspaces form faint longitudinal ridges, while a delicate rim is to be detected here and there around the sunken apertures. In some of the other fragments the surface is preserved better, or, as is more likely, it presents a less aged condition, and in these the peristome is more distinct, as is also a thin raised line passing between the central longitudinal rows of apertures. The general effect, therefore, is much as in fig. 32 of the same plate, only the zoœcial apertures are narrower and farther apart, and the marginal ones larger.

The New York, Canadian and Vermont specimens, or as we may call them, the eastern form of the species, is fairly constant in every respect. The zoarium divides dichotomously at rather long intervals, the length of these varying between the extremes of 10 and 20 mm., while the width of the branches between the bifurcations, where the margins are parallel, is rarely more than 3.0 mm., and so far as noticed, never less than 2.5 mm. The number of rows of zoœcia is generally seven or eight.

In the western form, however, we find a greater or less degree of instability in nearly every character. This is to be remarked especially of the Minnesota specimens. The branches, as a rule, are considerably wider, the average varying between 3.5 mm. and 5.5 mm. Still, it is not rare to find specimens, particularly among those from the lower beds of the Galena limestone, that are narrower, with the average at about 2.0 mm. Figure 16 represents an example that may be compared with the eastern form in the matter of branching, but in a great majority of the western specimens the divisions are much closer, the average distance between them being about 10 mm., and in many less. Another point to be noted is the tendency to irregularity in the growth of the zoarium of the western form, abortive branches, trifurcations and unparallel margins being common, while its appearance in general is less rigid than is prevailingly the case in the eastern form. The non-poriferous margin may be wide or narrow, but it is rare, if it ever occurs, to find an amount of difference in the size of the zoœcial apertures in the marginal and central rows equalling that prevailing in the eastern form. As a rule, the difference may be stated to be greatest in the smaller examples and least in the wide ones. The number of zoœcia rows varies from six to eighteen, with eleven, twelve and thirteen the number most frequently met with. In the central rows twelve, thirteen or fourteen apertures, the two last numbers more common than the first, occur in 5 mm. In well preserved examples a thin peristome is clearly distinguishable, and, running lengthwise between the rows of apertures, a thin ridge raised considerably or only slightly above the level of the peristomes. The interspaces are always as wide as the zoœcial apertures, and in many specimens nearly twice as wide. One specimen preserves a few "closures" or zoœcial covers. These are faintly convex, with a small rounded opening in the anterior half.

Of internal characters, I shall mention, (1) the absence of interstitial vesicles between the primitive or prostrate cells of the zoœcia; (2) the contact of those portions of the zoœcia with each other on all sides, resulting from the absence of the vesicles; (3) the peculiar convex shape of the anterior or transverse partitions of the primitive cells; (4) the density and early beginning of the solid interstitial filling, and consequent indistinctness of the vesicles. Diaphragms are usually present, one or two in each tube.

Compared with other species, *P. elegans* is found to differ, externally, in its usually wider and more rapidly branching zoarium, and flatter interspaces; internally in the shape of the primitive cell and the earlier development of the intersititial vesicles. *P. occidentalis* is sufficiently distinguished by its mode of growth and its maculose surface, and *P. fimbriata* by its peculiar ruffled non-poriferous margin.

Formation and locality.—This species is one of the commonest fossils of the Galena shales, having been found at perhaps every one of the numerous localities in the state where that horizon is exposed. Also at Decorah, Iowa. It occurs also in the lower layers of the overlying limestones, at Fountain, and several specimens have been collected from the *Phylloporina corticosa* horizon. Its wide geographical distribution outside of the state has been mentioned already.

Mus. Reg. Nos. 7607, 7609, 7616, 7619, 7623, 7632, 7639, 7643, 8027.

PACHYDICTYA PUMILA *Ulrich.*

PLATE X, FIGS. 1-4.

Pachydictya pumila ULRICH. 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 186, fig. 11.
Rhinidictya humilis ULRICH, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 185, fig. 10.

Zoarium bifoliate, small, usually less than 1 cm. in height, growing rather irregularly. Branches from 1.0 to 1.5 mm., wide, generally bifurcating at intervals of from 2 to 4 mm., but some fragments observed are undivided for a distance of 6 or 8 mm. Zoœcia in from three to six ranges, with four or five the average number shortly after bifurcations. The arrangement of their oval apertures is inclined to be rather irregular, though more or less longitudinal rows prevail in most cases. Over the basal parts of the zoarium this irregularity is apparent in a higher degree than in the distal portions. In the latter five to seven occur in 2 mm. longitudinally. The size of the apertures and the general appearance of the surface varies with age and other conditions. Nearly complete examples may show all the phases.

In the very young specimens, or at the distal extremities of the branches of the more mature ones, the zoœcial apertures are comparatively large, the lateral interspaces correspondingly narrow, and the end spaces with one or two depressions. In this stage the interspace granulations are very faint, but in the succeeding stages they are much better defined, the apertures often smaller, with the width of the interspaces increasing with greater rapidity, the increase in the circumference of the branches being divided between the lateral interspaces. In most of these specimens the interspaces are now flat or faintly concave, with a more or less distinctly recognizable though thin peristome about the apertures. In others a row of the interstitial papillæ occupies a faint longitudinal ridge, that may be elevated to slightly above the level of the peristomes. In more rare instances the peristomes appear to be wanting over parts of the surface, and the whole interspace convex and irregularly granulose, and seeming to slope down into the apertures. These specimens have quite a different aspect from the ordinary form of the species, indeed, so much so, that I mistook them for a species of *Rhinidictya.* Non-poriferous margin never wide, often so narrow as to be practically wanting. Its surface is papillose. Not infrequently large patches of the surface, where the zoœcial apertures have been closed by a thin deposit of calcareous material, are covered with such papillæ.

Internal characters vary much as in *P. acuta,* excepting that they are all a little smaller, and the transverse walls between the prostrate cells of the zoœcial tubes straighter.

When the preliminary description of this species was written I had unfortunately mislaid the two specimens regarded as the types of the form named *Rhinidictya humilis,* and which I believed to have been derived from the lowest shales at Minneapolis. In preparing the Minnesota material for my final studies they were found and the label with them proves that they were really collected at the same time and from the same beds as the original specimens of *P. pumila.* Later washings of the shales from this locality have added greatly to the number of specimens. With this more complete representation of the species I have become satisfied that the supposed *Rhinidictya* exhibits merely another phase of surface marking of *P. pumila,* deserving not even subordinate distinction. Among the lot, however, there is a form of which I have over twenty specimens, that might be distinguished as var. *sublata.* The zoarium does not appear to have been much larger than in the typical form, but its branches are wider, and though there are generally two or three rows of zoœcia more than in the largest of the type form, the greater width of the branches is chiefly due to a wide non-poriferous margin.

The small, dwarfish appearance of the zoarium of this species will distinguish it from all others of the genus known to me. In other respects the species resembles *P. acuta* Hall, which occurs associated with it, but because of the much smaller size of *P. pumila* confusion between them is rendered highly improbable. Another associated species, *Rhinidictya minima*, is more likely to be confused with it, but after a little comparative study, the student will find himself able to distinguish them almost at a glance. The rather rigid and subcylindrical character of the stems of the next described *P. triserialis* are sufficiently distinctive of that species, and render further comparisons unnecessary.

Formation and locality.—Base of the Galena shales, near Cannon Falls, Minnesota, where it is associated with species of *Nematopora*, *Arthroclema armatum*, *Helopora mucronata*, and other small Bryozoa, all of them characteristic of the horizon. A single example apparently referable to this species, was found at the horizon of *Phylloporina corticosa*, and another occurs on a slab of Trenton limestone, from Trenton Falls, New York.

Mus. Reg. No. 8107.

Pachydictya triserialis *Ulrich.*

PLATE X, FIGS. 11-14.

Pachydictya triserialis Ulrich, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 187, fig. 12.

Zoarium consisting of very slender, parallel-margined, subcylindrical or compressed branches, 0.6 to 0.8 mm. wide, and 0.3 to 0.55 mm. thick; branches bifurcating at intervals of from 5 to 10 or more mm., oval or obtusely hexagonal in cross-section, the margins never, or at any rate but rarely, acute, in most cases to be described as narrowly rounded. Each face with three rows of longitudinally arranged zoœcial apertures, occasionally with a fourth row, but only for a short distance. These rows are often not exactly parallel with the margins of the branches, a faint tendency to arrangement in long spirals being perceptible in those cases. Zoœcial apertures elliptical, nearly twice as long as wide, largest in young or worn examples, separated by intervals equal to their long diameter, with from 11 to 13 in 5 mm.; occasionally enclosed by a delicate rim or peristome, but oftener with sloping edges. Between the rows an obtuse ridge. Entire surface, especially of the older portions, minutely papillose. Non-poriferous margins narrow, readily overlooked, generally wider on one side than on the other.

Internal characters similar to those of *P. acuta* Hall, and *P. pumila*. In such a small species the interstitial vesicles are necessarily reduced to a minimum, and in this one the solid filling of the interspaces is so dense that their original presence is not easy of demonstration.

The subhexagonal narrow branches of this species present considerable resemblance to species of *Nematopora* like *N. lineata* (*Helopora* Billings). Of course, there is no real affinity between them, this being, as is clearly shown by transverse sections, a bifoliate zoarium, while in *Nematopora* the zoœcia diverge equally in all directions from the center of the branch. I am not acquainted with any species of *Pachydictya*, nor with any associated species of bryozoan, with which the slender ramulets of *P. triserialis* might be confounded.

Formation and locality.—As yet known only from the Trenton limestone at Montreal, Canada, but it is not at all unlikely that the species is to be found in the Minnesota equivalent of that horizon.

Genus TRIGONODICTYA, n. gen.

Zoaria with triangular branches, constructed upon the plan of *Prismopora*, but with zoœcia and all minute details of structure precisely as in *Pachydictya*.

Type: *Pachydictya conciliatrix* Ulrich.

Another species occurs in the Clinton rocks near Eaton, Ohio, which, because it is the only bryozoan with triangular branches known to me from Upper Silurian strata, and may therefore be distinguished from associated forms with ease, I propose to name *Trigonodictya eatonensis*, n. sp. It is rather more slender than the Trenton species, and its branches divide at less frequent intervals. The three surfaces are also flat instead of concave, while in thin sections the interspaces between the comparatively large oval zoœcia are thinner, and the lines of erect median tubuli much less distinct and not so numerous.

Trigonodictya conciliatrix *Ulrich.*

PLATE IX, FIGS. 11 and 12; PLATE X, FIGS. 15-20.

Pachydictya conciliatrix Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 76.

Zoarium of irregular growth, dividing at frequent intervals, consisting of equal-sided triangular branches, with the three faces concave, each averaging about 3 mm. wide; or of more or less rapidly spreading, small, flabellate fronds, with from one to five salient, divaricating ridges on only one or both sides. All intermediate conditions between these two extremes occur. Each of the surface ridges has a non-poriferous, sharp summit, and, beginning as a mere line, it rises gradually until it is sufficiently high to permit of the formation of a new triangular branch, when it forms one of its edges. Zoœcial apertures elliptical, slightly oblique, smallest and arranged longitudinally over the central half of each face; here with 12 or 13 in 5 mm., a faintly elevated line between the rows, and the width of the longitudinal and lateral interspaces generally about equal to the respective diameters of the apertures. Toward the non-poriferous edges the apertures are directed obliquely upward and outward, and increase in size gradually till those in the outermost row are quite twice as large as those in the central rows. When the surface is weathered the zoœcial apertures are larger than normal, and their longitudinal arrangement less obvious, the interspaces rounded, and without the series of minute papillæ that are always present when the surface is well preserved.

In considering the internal characters it should be borne in mind that but few tangential sections are at all likely to be made that will show the structure as fully and clearly as in fig. 12 (plate IX). The section from which this drawing was made is an exceptionally good one, having been prepared from a fragment in an unusually good state of preservation; so that it shows the structure just beneath the surface in a very satisfactory manner. At the sides of the figure, the left-hand one especially, the horizontal median tubuli are represented, and a short distance from the edge we see how the vertical series of these tubuli arise out of the horizontal set.* At a deeper level than any shown in the figure, the zoœcia are larger and rounder, and the interspaces proportionally narrower, and, with the exception of a dark line running longitudinally between the rows of zoœcia, generally appear structureless. A little deeper and a few irregular lines, representing the walls of interstitial vesicles, may be noted in the interspaces.

Transverse sections show that in the regularly developed triangular branches each is divisible into three subequal triangular parts, bounded by a mesial line from which the zoœcial tubes of each part proceed to their respective external faces. New angles and faces are produced by raising one of the plate-like longitudinal walls until it has assumed the characters of a mesial plate.

The zoarial features of this species are so strikingly different from all known Lower Silurian Bryozoa that comparisons are unnecessary. For remarks on the Clinton group species of the genus, see under the generic description.

Formation and locality.—Apparently restricted to the upper third (Phylloporina horizon) of the Trenton shales, near Cannon Falls, Minnesota.

Mus. Reg. No. 5952.

Family PTILODICTYONIDÆ, Zittel.

For a description and remarks on this important family, the reader is referred to my recent work in the eighth volume of the reports of the geological survey of Illinois, pp. 348 and 390.

Five genera of this family are represented in the Trenton shales of Minnesota, and, so far as known, the species here described of each are the earliest existences

*This is not only an interesting fact, but, as are all that relate to the intercommunication of the zooids, also one of great importance morphologically.

of not only their respective genera but of their entire family. In every case the generic features are fairly developed, indicating that the primal stock is yet to be discovered in previously deposited rocks. Still, in the three most typical members of the family, *Ptilodictya*, *Escharopora* and *Phænopora*, the resemblance between the primitive species of each is more evident than in the species that occur in deposits of later date.

Indeed, in these early Bryozoa we often meet with species that combine, sometimes to a very perplexing degree, characters which in latter times have attained the stability and importance of generic structures. *Escharopora confluens* and *E.* (?) *limitaris* are cases in point, since they have much to remind us of *Phænopora;* not of the fully differentiated Upper Silurian forms of that genus, but of the Lower Silurian species which obviously had not yet attained the full expression of the generic characters. From the facts already available we are, I believe, justified in assuming either that *Ptænopora* and *Escharopora* are contemporaneous offshoots from a more primitive stock, with characters in general like those of *E. confluens;* or that *Escharopora* was the stock from which first *Phænopora* and then *Ptilodictya* were evolved. In the development of the former, the connecting channel between the apertures was cut off by the formation of a rim at their ends. The mere depression to which the channel was thereby reduced, was next deepened, chiefly at the ends, thus giving rise to the two mesopores between the ends of the zoœcial apertures. These are already well developed in *Phænopora incipiens*, but like all incipent characters are as yet a little unstable. The later development of the genus consisted principally in the greater separation of the longitudinal walls between which the primitive cells were arranged. This caused a shortening of the longitudinal inter-apertural spaces, with the result that the "two mesopores" were obliged to change their arrangement from the longitudinal to the transverse.

The prostrate portion of the zoœcial tubes of early *Phænopora* is very narrow and elongate, just as in the contemporaneous species of *Escharopora*, and the tendency to shorten and widen the primitive cell (already mentioned) exhibited in Middle and Upper Silurian times, seems to have obtained through all the most typical members of the family.

The systematic position of *Stictoporella* is undoubtedly near that of *Intrapora*, Hall, *Tæniodictya*, *Stictotrypa*, and *Ptilotrypa*, Ulrich. These five genera, it seems to me now, should be classed together, but whether they ought to be regarded as con stituting a distinct family by themselves, or had best be retained as members of the *Ptilodictyonidæ*, the position assigned to them in my recent work on the Illinois Bryozoa, is a question that I am not yet prepared to solve. The *Ptilodictyonidæ* would surely be a more compact and obviously characterized group if they were removed, for in that case we would have one easily recognized though not peculiar character running through the family that is not represented in *Stictoporella* and allied genera.* A basal articulation, namely, pertains to *Ptilodictya*, *Escharopora*, *Phænopora*, *Clathropora*, *Graptodictya*, and *Arthropora*, while in *Stictoporella* and genera of that type, the zoarium is continuous throughout, and attached below in the ordinary manner, *i. e.* by a simple basal expansion forming one piece with the erect frond.

If removed from the *Ptilodictyonidæ* it would be necessary to establish a new family for their reception, since they cannot, because of the absence of median tubuli between their mesial laminæ, be placed with the *Rhinidictyonidæ*, the only remaining family of paleozoic Bryozoa with which they have any affinity. It was because they agree in this and most other respects with *Escharopora*, that I arranged them with the more typical *Ptilodictyonidæ*. The new family would hold an intermediate position between the *Rhinidictyonidæ* and *Ptilodictyonidæ*, differing from the former in its zoœcial characters, and from the latter in its continuous zoarium, presumably a zoarial modification.†

Genus PTILODICTYA, Lonsdale.

Flustra (part.), Goldfuss, 1826. Petref. Germ.
Ptilodictya, Lonsdale, 1839, Murch. Sil. Syst., p. 676.
Ptilodictya (part.), Nicholson, 1874. Geol. Mag., n. s., vol. i, p. 123, and Pal. Ont., p. 97; Vine, 1881 Second Brit. Assoc. Rep. Foss. Poly., Quar. Jour. Geol. Soc. Feb. 1882, and 1884, Fourth Brit. Assoc. Rep. Foss. Pol., p. 37; Ulrich, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 151, and 1890, Geol. Surv. Ill., vol. viii, p. 390; Hall, 1887, Pal. N. Y., vol. vi, p. 19.
Escharopora, Hall, 1874 and 1879. Twenty-sixth and Thirty-second Rep. N. Y. State Mus. Nat. Hist. (Not 1847, Pal. N. Y., vol. i.)
Heterdictya, Nicholson, 1875. Geol. Mag., and Pal. Ont., (ii) p. 79.

In my preliminary report on the Bryozoa of Minnesota (Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p, 64; 1886) I mention the two sections into which *Ptilodictya*, as understood by me in 1882 (*loc. cit.*), may be divided. Since then I have given the subject further study, with the result that I now believe they may be distinguished in a generic sense.

*An articulated zoarium is of rather common occurrence among both the living and extinct Bryozoa. Of Paleozoic types the *Arthrostylidæ* and true *Ptilodictyonidæ* are the best representatives of this method of growth. It is also characteristic of *Acrogenia*, Hall, and *Dicranopora*, Ulrich.

†In drawing this distinction the systematist is once more called upon to decide between zoarial and zoœcial variations as furnishing the best and most reliable tests of relationship. The more I study these questions of relationship, the less practical seems the adoption of strict rules for our guidance in the delimitation of the classificatory sections whereby we attempt to express our ideas of natural modifications. What may appear as, and probably is, sufficient ground for the erection of a genus or family in one case, does not necessarily suffice in another. There are so many points to be taken into account before anything even approximately expressing nature's handiwork can result. Among them, environment, association, and relative position in the geological scale, are of great importance. The last, if judiciously used, is always an excellent clue to relationship, and one that has been but too rarely taken into consideration by students of recent zoology. Volumes are to be written upon these intricate questions, but I have said enough probably to show that a successful classification cannot be worked out in a day, nor is any yet drawn up that will not suffer greater or less modification in time. The stability of a classification depends not a little upon the collector, since it is his discoveries that build it up or tear it down.

The divisions are perfectly natural, and each based upon readily detected peculiarities. In the first, including *P. lanceolata* Goldf., sp., and therefore *Ptilodictya* in the strict sense about to be proposed, we have a character that is wanting in the second: Namely, a variable number of regular longitudinal rows of zoœcia running through the center of the fronds from the pointed articulating base upward. In the earliest species having this peculiarity, these longitudinal central rows do not always extend through the frond to its upper extremity, but they are sometimes found to pass into the diagonal arrangement prevailing over the lateral portions of the surface. In *P. magnifica* Miller and Dyer, for instance, the longitudinal rows obtain only in the middle of the lower half of the full grown zoaria, the diagonal arrangement being present on all other parts of the surface.

These central zoœcia are oblong-quadrate in shape, narrower than the lateral ones, and always the first to be developed. In the youngest examples of all the species they alone occur, and it is only in later stages that the differently arranged and wider lateral zoœcia are developed. It is possible that this condition, which, as said, is an immature or youthful one in most of the species, may have persisted in some, and that in these no lateral zoœcia were produced. *P. gladiola* Billings, and *P. flagellum* Nicholson, may be said to support this view, only longitudinal zoœcia being as yet known of them. Still, as the evidence is merely negative, and in the light of facts brought out in a study of complete suites of *P. variabilis* of the Hudson River group, I am obliged to regard the matter as doubtful.

Used in this restricted sense *Ptilodictya* admits of subdivision into two groups, both obvious enough, but, as they now appear to me, not quite natural. In the first, with *P. lanceolata* as the type, we have either nothing but longitudinal rows of zoœcia, or these are flanked on each side by spaces of greater or less width over which the apertures are arranged in an oblique manner, giving the fronds the fancied resemblance to a feather that suggested the generic name. The lateral rows proceed to the edges of the zoarium without interruption from either groups of large cells, monticules, or maculæ.

In the second subdivision, and of this *P. magnifica* M. & D. may be considered as typical, the zoœcial apertures on the lateral extensions of the zoarium are arranged in diagonally intersecting series, with clusters of large cells, monticules, or maculæ, at regular intervals. The pinnate arrangement of parts prevailing in the lanceolate subdivision is therefore scarcely recognizable in this, but the presence of monticules is an even more striking peculiarity.

In the second division, for which I propose to adopt Hall's name *Escharopora*,* the

* I have some slight doubts respecting the specific characters of *E. recta*, Hall, the original type of the genus, but none whatever so far as its generic characters are concerned.

diagonal arrangement of the zoœcia prevails throughout; so that instead of narrow oblong-quadrate zoœcial apertures along the center of the fronds, we have there, the same as on all other parts of the surface, rounded apertures situated in rhomboidal or hexagonal spaces.

A subdivision of *Escharopora* is likewise possible, but in this case we make out three instead of two. In the first we have simple narrow zoaria, with the diagonal lines of zoœcia extending without interruption, completely across the celluliferous faces. *E. recta* and *Ptilodictya falciformis* Nicholson, are good examples. In the second the zoaria are also simple, but wider, occasionally very large (*e. g. Ptilodictya pavonia* d'Orb.) and at regular intervals their surfaces exhibit clusters of large cells. The latter are commonly elevated into rounded or conical monticules.

These two subdivisions though obvious enough and in the main indicative of natural relations, are nevertheless not entirely so, since they separate species like *P. falciformis* Nicholson, and *P. maculata*, that most certainly are closely allied, and in practice sometimes difficult to distinguish even specifically. Again, we know forms, *Escharopora* (*Ptilodictya*) *subrecta* for instance, in which old examples, or may be they are entitled to the distinction of a variety, have one, two, or even three rows of monticules. On the other hand, I am fully convinced that in the young zoaria of the normally montiferous species, the monticules were, to say the least, a very inconspicuous feature compared to what they are on the fully matured zoaria (See footnote, ante p. 146.)

The third subdivision includes the branching forms. So far as known, it is a natural grouping, and distinguished from the preceding by the branching of the zoaria, and parallel margins of the branches after the first or basal division. When the branches are wide, clusters of large cells and monticules are developed, but when they are narrow, the monticules are absent, and the large cells distributed along the non-poriferous edges. A subdivision of the branching forms is possible therefore precisely as in the simple species.

In accordance with the above I offer the following amended definition of *Ptilodictya* and *Escharopora*, and classification of species.

Genus PTILODICTYA, Lonsdale, 1839.

Zoaria bifoliate, simple, umbranched, lanceolate or falciform, terminating below in a solid, striated, pointed base, which originally fitted loosely in the centrally situated cupshaped depression or socket of a small basal expansion. The latter grew fast to foreign bodies, is radially striated, and has small cell openings in the furrows between the striæ. In very young examples, and in certain small species in which this condition seems to be permanent, the entire zoarium consists of longitudinally arranged, narrow, oblong-quadrate zoœcia. As growth proceeded new zoœcia, both wider and differently arranged, were added on each side. These lateral zoœcia may be arranged in oblique or transverse rows, so as to produce the "pinnate" or "plumose" arrangement prevailing in the typical species, or they may form diagonally intersecting rows, with groups of large cells or subsolid spots raised at regular intervals into monticules. Zoœcial apertures subquadrate, rhomboidal, or rounded, the shape depending largely on their arrangement.

Both hemisepta usually well developed. Primitive cell, with thin walls, subelongate, quadrangular, hexagonal, or lozenge-shaped, in contact at all sides. In the vestibular or outer region, the walls are more or less thickened, solid, and with a double row of exceedingly minute dots ; the latter rarely preserved and seen only in tangential sections. No median tubuli.

Type : *P. lanceolata* Goldfuss, sp.

CLASSIFICATION OF SPECIES.*

Section *a;* without monticules.

P. lanceolata Goldf., Upper Silurian, Europe.
P. expansa Hall (not *Phænopora expansa* Hall and Whitefield), Clinton group, Ohio.
P. gigantia (*Heterodictya gigantia* Nicholson), Corniferous limestone, Canada.
P. canadensis Billings, Hudson River group, Canada.
P. flagellum Nicholson, Cincinnati group, Ohio.
P. gladiola Billings, Hudson River and Anticosti groups, Anticosti.
P.(?) sulcata Billings, Anticosti group, Anticosti.
P.(?) angusta Hall, Niagara group, Indiana.

Section *b;* with monticules.

P. magnifica Miller and Dyer, Cincinnati group, Ohio, Illinois and Indiana.
P. plumaria James (as figured by Ulrich) Cincinnati group, Ohio, Indiana and Illinois.
P. variabilis Ulrich, Cincinnati group, Ohio and Indiana.
P. whiteavesi Ulrich, Hudson River group, Manitoba.
P. nebulosa Hall, Lower Helderberg group, New York.

No species of *Ptilodictya*, as here restricted and defined, have yet been brought to my notice from Minnesota deposits, but it is not improbable that *P. magnifica* M. and D., occurs in the upper beds of the Hudson River group in the southern part of the state, that species having been noticed as far to the northwest as Wilmington and Savannah in Illinois.

* A number of foreign species have been described as *Ptilodictya*, but in the absence of specimens I do not consider myself warranted to attempt their classification.

Genus ESCHAROPORA, Hall.

Escharopora, HALL, 1847. Pal. N. Y., vol. i, p. 72.
Ptilodictya (part.), ULRICH and many other authors.

Zoaria bifoliate, simple or branching, pointed below, and articulating into a spreading base as in *Ptilodictya*. Zoœcia arranged in regular diagonally intersecting series throughout. In the small species these rows extend in a continuous line across the fronds, but in the larger forms their course is interrupted at more or less regular intervals by the development of raised clusters of large cells. Apertures rounded, elliptical or subcircular, set into sloping areas; the latter generally of rhomboidal or hexagonal shape and sharply defined, in other cases longitudinally confluent, and connected by a narrow channel.

Internal structure essentially as in *Ptilodictya*, the differences chiefly due to the different zoœcial arrangements.

Type: *E. recta* Hall, Pal. N. Y., vol. i, p. 72; 1847.

Better known examples are *Ptilodictya falciformis* Nicholson, Pal. Ohio, vol. ii, p. 259, 1875, and *P. pavonia* d'Orbigny, Prodr. de Pal., vol. i, p. 22, 1850.

CLASSIFICATION OF SPECIES.

Section *a*; zoaria simple, without monticules.

E. acuminata (James), Galena limestone, Iowa; Utica horizon of the Cincinnati group, Ohio and Kentucky.
E. angularis, n. sp., lower Trenton, Minnesota.
E. falciformis (Nicholson), Cincinnati group, Ohio, Indiana, Kentucky.
E. recta Hall, Trenton limestone. New York, Canada, ?Galena shales, Minnesota.
E. subrecta (Ulrich) lower Trenton shales, Minnesota.

Section *b*; zoaria simple, with monticules.

E. hilli (James, as figured by Ulrich), Cincinnati group, Kentucky.
E. libana (Safford), Birdseye limestone, Kentucky, Tennessee.
E. maculata (Ulrich), Cincinnati group, Ohio, Kentucky.
E. pavonia (d'Orbigny), Cincinnati group, Ohio, Indiana, Kentucky.
E. n. sp., Birdseye limestone, Tennessee.
E. n. sp. (near *pavonia*), top of Trenton, Nashville, Tennessee.
E. n. sp., Cincinnati group, Kentucky.

Section *c*; zoaria branching.

E. briareus (Ulrich), Birdseye limestone, Tennessee.
E. confluens, n. sp., lower Trenton shales, Minnesota, Tennessee.
E. ramosa (Ulrich), Birdseye limestone, Tennessee, Kentucky.
E. n. sp., Utica horizon of the Cincinnati group, Kentucky.

From the preceding classifications we learn that *Escharopora* began in the "Birdseye" or earlier, and ceased apparently in the age of the Cincinnati group—strictly speaking, in the middle division of that formation. True *Ptilodictya* is first met with in the upper beds of that group of rocks, and continues with varying representation up into the Lower Devonian.

ESCHAROPORA ANGULARIS *n. sp.*

PLATE XII, FIGS. 1-4, 30 and 31.

Zoarium simple, falciform, curved, 10 to 30 mm. or more in length, 2 to 9 mm. wide; articulating base pointed, with comparatively a small part of the extremity solid and striated. Zoœcial apertures polygonal, commonly hexagonal, arranged in transverse and diagonally intersecting series, the first predominating, and both less regular than usual for the genus. Here and there the presence of one or more small cells (?abortive zoœcia) may cause considerable interruption in the ordinary arrangement. On an average nineteen or twenty apertures in 5 mm. diagonally, and nine or ten in 2 mm. transversely. Walls very thin, the thickness about equal on all sides. Non-poriferous margin very inconspicuous.

Of internal characters the most striking are (1) the unusual tenuity of the walls, and (2) the erectness of the zoœcial tubes. Tangential sections greatly resemble such sections of certain *Trepostomata* (*e. g. Monotrypella quadrata* Rominger, sp.).

The comparatively irregular arrangement of the zoœcial apertures, their angular form, and the fact that their also thinner walls commonly form hexagonal or polygonal instead of subrhomboidal spaces, distinguishes this species from *E. falciformis* (*Ptilodictya falciformis* Nicholson) of the Cincinnati group. In other respects, especially in the shape of the zoarium, the two species resemble each other very greatly. Embedded in the limestone, with only a portion of the surface exposed, *E. angularis* might very easily be mistaken for some monticuliporoid. Not so, however, with *E. subrecta*, which abounds at the same localities though not at the same geological horizon. The zoarium of the latter is always straighter, and the zoœcial apertures quite different.

Formation and locality.—Rare in the Trenton limestone at Minneapolis, Minnesota.

ESCHAROPORA SUBRECTA *Ulrich.*

PLATE XII, FIGS. 5-29.

Ptilodictya subrecta ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 63.

Zoarium simple, flattened, straight or slightly curved, 12 to 40 mm. or more long, 1.3 to 9.0 mm. wide, the two faces obscurely ridge-shaped, or evenly convex. Average size about 25 mm. long, and 2.5 mm. wide in the upper half. Greatest thickness varying with age from 0.6 to 1.5 mm. Lower half tapering gradually to to the pointed basal articulating extremity, the latter often turning a little to one side, subcylindrical, finely striated longitudinally, the grooves widening slowly upward till they graduate into the elongate, confluent zoœcial apertures. Arrangement and appearance of zoœcial apertures and interspaces varying with age. In young examples, or those less than 25 mm. in length, and these seem to be by far the most abundant, the surface appears as in figures 18 to 21. In these the zoœcial apertures over the entire surface, excepting near the base and along the edges, are elongate elliptical, sometimes almost acute at the ends, and arranged between alternately converging and receding ridges, which, failing to close around the ends of the apertures, permit confluence between them through a narrow channel. The result is a very pronounced longitudinal arrangement, though the diagonal rows, and sometimes the transverse as well, are scarcely less evident and regular. Measuring lengthwise there are about eleven zoœcial apertures in 5 mm.; diagonally nine or ten in 2.5 mm.; transversely six of the central rows in 1 mm. The marginal rows are always larger, and occasionally have the oblique character shown in fig. 21. In specimens 25 mm. long the upper extremity will already indicate the changes that took place in later growth. The shallow channel connecting the zoœcial apertures is gradually lost through the closer convergence of the enclosing ridges, till at last we have a simple ridge-like separating wall as shown in figs. 23 and 24. These figures show further that the apertures are now wider, with only five in 1 mm. transversely, and of subrhomboidal or hexagonal form. The increased width is accounted for partly by the loss of the channels, and the remainder by the increased circumference of the zoarium. The largest specimens usually exhibit a central row of small monticules. In some there are two irregularly alternating rows, while in the fragmentary original of fig. 17, there are three rows. The last specimen is peculiar also in having an arrangement of the zoœcial apertures foreshadowing true *Ptilodictya*, namely, oblique "pinnate" rows predominate on the spaces between the outer monticules and the edges of the frond, yet over the central part of the surface the usual diagonally intersecting series prevail.

All the changes produced by age are chiefly apparent in the upper half of the zoarium, the appearauce of the early stages being more or less preserved in the basal portions. Still, very old and thick examples, like the original of figs. 15 and 22, are likely to develope mesopores here in place of mere channels between the zoœcial apertures.

Of internal characters shown in the excellent and instructive sections illustrated, I wish to point out (1) the elongate form of the primitive cell, (2) its shape just before being roofed over to form the primitive aperture, and (3) the two at first distinct then coalescing lines in the transverse interspaces. (See upper parts of figs. 25 and26.)

In 1886 I believed this species to be a close relative and, perhaps, the western representative of Hall's *E. recta*. Since making my final investigations, with augmented material in all stages of growth, much of it in an excellent state of preservation, I find that the relationship is more remote than it seemed at first. Although I have not had an opportunity of examining authentic examples of *E. recta*, Hall's original figures are sufficiently diagnostic to warrant us in saying that the New York species has zoœcial apertures agreeing both in shape and arrangement with those of *E. falciformis* (Nicholson) and the closely related *E. acuminata* (James). The last is the form referred to (*loc. cit.*) as occurring "in the lower beds of the Cincinnati group (Utica shale ?) in Ohio." The form mentioned at the same time as found in Tennessee ("Glade" limestone) greatly resembles *E. acuminata*, but as I have not yet examined its interior structure, I cannot say that it is really the same. Whatever it may turn out to be I am satisfied that it is distinct from *E. subrecta*. Comparing ordinary examples of the Minnesota species with any of these forms, indeed with all of the known simple species of the genus, we find that in none of the latter, save for a short distance above the pointed base, are the zoœcial apertures confluent longitudinally, *i. e.* connected by narrow channels, as is the case in *E. subrecta*. Nor do any of them exhibit as much difference in the size of the marginal and central rows of apertures. Of unbranched species, *E. subrecta* is also the only one known to me in which the primitive cell assumes the peculiar claviform shape shown in figs. 25 and 26. In most of the other species, perhaps all save *E. angularis*, the hemisepta are more pronounced. These two features alone are sufficient in distinguishing thin sections of *E. subrecta*. Compared with the branching forms, we find one, and it is associated in the same beds, that agrees in many respects. This is the next described *E. confluens*, having confluent zoœcial apertures, a similar difference in the size of the marginal and central rows, and an internal structure nearer that of *E. subrecta* than any other species. But the zoœcial apertures are wider, a fact noticeable enough to enable one to distinguish the merest fragments. There is, of course, no likelihood of confusion when complete zoaria are available.

Formation and locality.—Common in the middle third of the Trenton shales at Minneapolis and other localities in the state, and Decorah, Iowa. Perhaps, also, in the lower third of the shales, but rare in these and smaller than usual. A single example collected by Mr. Charles Schuchert from the "Lower Blue beds" near Beloit, Wisconsin, seems to belong to this species.

Mus. Reg. Nos. 5929, 7558 and 7597.

Escharopora confluens *n. sp.*

PLATE XIII, FIGS. 1-12.

Zoarium branching, the smallest seen less than 25 mm. high, with the branches averaging about 2.5 mm. in width; the largest fragments indicate a hight of from 80 to 120 mm., and in these the width of the branches varies from 4 to 8 mm. The two surfaces of the branches are generally obtusely ridge-shaped, and in the largest a row of monticules, or simply clusters of large cells, occurs on the summit of the ridge. Edges thin and sharp, commonly with a coarsely striated or pitted narrow border. Through all stages, though less distinct in the oldest, the zoœcial apertures are narrow and appear to be drawn out at the ends so as to connect by means of a narrow channel. This confluent character of the zoœcial apertures is better shown and more regular in the central rows, where they are also narrower and on the whole considerably smaller than toward the margins. (See fig. 5.) In the central rows, ten in 5 mm. lengthwise; eighteen or nineteen in 5 mm. diagonally, and five and one-half in 1 mm., and ten in 2 mm. transversely; of longitudinal rows there are nineteen or twenty in 2 mm.

Tangential sections show that the base of the zoœcia, excepting those in the marginal rows, is bounded by very thin, straight, longitudinal walls, and equally thin transverse partitions. This portion of the zoœcium therefore may be described as a parallelogram, with the length and breadth respectively as four is to one. At about the middle of the hight of the primitive cell its sides have spread a little and the ends contracted in a corresponding degree. Just as the posterior half is about to be roofed over two projections from the side walls, at a points a little behind the middle, gradually converge until they meet and thereby cut off and enclose the elliptical primitive aperture. In the succeeding stages the principal change is a reduction in the size of the apertures, caused by an internal deposit. These stages are all shown in figs. 6, 7 and 8, but to insure a trustworthy idea of the internal structure of the species, they should be studied in connection with figs. 10 and 11.

Compared with associated Bryozoa, the next described *E.* (?) *limitaris* only will be found difficult to distinguish. This, however, is due chiefly to the imperfect preservation of the surface of most specimens. Good examples of the latter are quickly distinguished by the different character of the longitudinal interspaces, these being occupied by one elongated pit or two smaller ones.

The zoarium of *E. subrecta* is always strictly of the simple type, and never branches except under abnormal conditions.

Specimens of this and the following species were catalogued by me in 1886 as *Ptilodictya ramosa* Ulrich (now *Escharopora ramosa*).* Comparison with the Kentucky

*Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 102.

and Tennessee tpyes of that species was not possible before the following year, when I became satified that the Minnesota specimens were really quite different, though similar in their growth. In *E. ramosa* the zoœcial apertures are set into regularly hexagonal spaces, and are in no sense to be called "confluent."

Formation and locality.—Apparently restricted to the middle third of the Trenton shales, at Minneapolis, Minnesota. Fragments of a very similar, perhaps identical, species have been observed in the "Pierce" limestone at Murfreesboro, Tennessee.

Mus. Reg. No. 8208.

ESCHAROPORA (?) LIMITARIS, *n. sp. or var.*

PLATE XIII, FIGS. 12 and 13.

Under this name I propose to arrange a form that may well be regarded as the beginning of the branching section of the genus *Phænopora*, Hall. I would have placed it under that genus but for the fact that I found it impossible to draw a satisfactory line between it and *E. confluens*. Ordinarily the branches of the present form are smaller and more evenly convex, their edges less sharp, and with a wider non-poriferous border than in typical *E. confluens;* but in other specimens, one in particular, the shape and general aspect of the zoarium is precisely as in the most typical examples of the species. The single constant peculiarity of *E.* (?) *limitaris* consists in the development of an elevated rim at the ends of the zoœcial apertures, causing them to lose their confluent character, and to assume a definite elliptical shape. At the same time the "channel" has been transformed into an elongated inter-apertural pit. Frequently, instead of the single long pit, the space is divided into two short ones, as in *Phænopora wilmingtonensis*, and *P. incipiens.*

The usual appearance of the surface may be imagined when I say that it is a intermediate between the appearances represented in fig. 20, plate XII, and fig. 5, plate XIII, on the one side, and figs. 14 and 23, plate XIII, on the other.

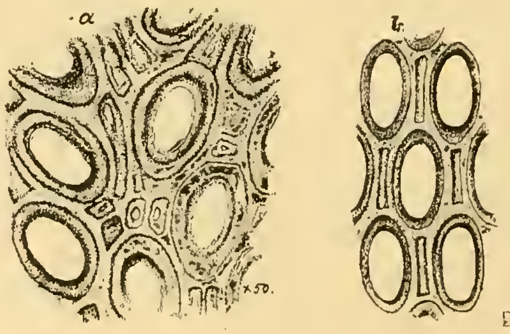


FIG. 9. *Escharopora* (?) *limitaris* ULRICH. *a*, small part of tangential section, x50, showing structure immediately beneath the point of bifurcation ; *b*. another portion of same where the zoarial margins are parallel.

As shown in the accompanying cuts, the internal structure brought out in tangential sections is often almost exactly as in *Ph. incipiens* (plate XIII, fig. 17); other sections, however, in portions at least, show a structure more in accordance with fig. 7, plate XIII.

It is evident that *E.* (?) *limitaris* and *E. confluens* are varieties of one species, but because of their intermediate position between *Escharopora* and *Phænopora*, it is scarcely advisable to decide now which of the two names shall take the rank of a species, and which that of a variety. Such decisions should be deferred till we are better acquainted with the developmental history of fossil Bryozoa.

Formation and locality.—Not uncommon in the lowest third of the Trenton shales, at Minneapolis, Minnesota. Also in the middle third of the shales at the same locality, but less common and of more robust growth. A single specimen was observed among a lot of Bryozoa marking the lower shales, collected by Messrs. Schuchert and Scofield, near Preston, Minnesota.

Mus. Reg. No. 5930.

Genus PHÆNOPORA, Hall.

Phænopora, Hall, 1852, Pal. N. Y., vol. ii, p. 46; Ulrich, 1882, Jour. Cin. Soc. Nat. Hist., vol. v. p. 152, and 1890, Geol. Sur. Ill., vol. viii, p. 392; Foerste, 1887, Bull. Sci. Lab. Denison University, vol. ii, p. 157.

Zoaria bifoliate, simple or branching, the base pointed and articulating into a small basal expansion, the same as in *Ptilodictya* and *Escharopora.* Zoœcial arrangement regular, in longitudinal, diagonally intersecting and transverse rows, with either the longitudinal or the diagonal series predominant. Two mesopores behind each zoœcial aperture, one on each side, or one behind the other. Primitive cells elongate, commonly oblique or lozenge-shaped, at other times with the ends rectangular, always arranged between straight, longitudinal walls. Monticules, or mere clusters of large cells and mesopores, present when zoaria are wide enough.

Type: *Phænopora explanata* Hall, 1852, Pal. N. Y., vol. ii, p. 46.

From the above description it is obvious that the presence of the two mesopores is the only character to be relied upon in distinguishing the genus from *Escharopora* and *Ptilodictya.* The genus attains its highest development in the Clinton group, and in most of the species from that horizon the primitive cell has a peculiar oblique shape that is not seen in the Lower Silurian representatives of the genus, nor in any species of *Escharopora,* but is not uncommon among true Upper Silurian *Ptilodictya.* As might be expected, it is among the unbranched species that the greatest resemblance to *Ptilodictya* obtains. Indeed, such species as *Ph. ensiformis* Hall, and *Ph. lonsdalei* (*Ptilodictya lonsdalei* Vine) are in every respect, save in this that they possess the characteristic mesopores, precisely like narrow species of *Ptilodictya.*

In the following classification I have arranged the species in sections the same as under *Escharopora.* Except in one instance, I have not been able to obtain specimens of the European species, described mainly as *Ptilodictya*, that I suspect to belong to this genus. Under the circumstances it would not be safe to include them.

Section *a*, zoaria simple, without monticules.

Phænopora ensiformis Hall, Clinton group, New York, Canada, Ohio and Indiana.
P. lonsdalei (*Ptilodictya lonsdalei* Vine), Wenlock shales, England.
P. tenuis Hall, Lower Helderberg group, New York.

Section *b*, zoaria simple, with monticules.

Phænopora bipunctata (*Ptilodictya bipunctata* (Van Cleve) Hall,) Clinton group, Ohio.
P. constellata Hall, Clinton group, New York and Canada.
P. expansa Hall and Whitfield, Clinton group, Ohio.
P. punctata (*Ptilodictya punctata* Nicholson and Hinde), Clinton group, Canada.
P. superba (*Ptilodictya superba* Billings), Anticosti group, Anticosti.
P. wilmingtonensis Ulrich, Cincinnati group, Illinois.

Section *c*. zoaria branching.

Phœnopora excellens (*Ptilodictya excellens* Billings), Anticosti group, Anticosti.
P. explanata Hall, Clinton group, New York and Canada.
P. fimbriata (*Ptilodictya fimbriata* James), Clinton group, Ohio.
P. incipiens Ulrich, Trenton group, Canada and Vermont.
P. lindstrœmi Ulrich, Upper Silurian, Gotland.
P. magna (*Stictopora magna* Hall and Whitfield), Clinton group, Ohio.
P. multifida (*Stictopora multifida* (Van Cleve) Hall), Clinton group, Ohio.

Though fully convinced that some of these species are synonymous, it seemed best to retain all names until an opportunity offers to treat the genus in a monographical way.

PHÆNOPORA INCIPIENS *n. sp.*

PLATE XIII, FIGS. 14-17.

Zoarium small, dividing dichotomously at rather long intervals; basal extremity long, slender, subcylindrical, with fewer and more elongate zoœcial apertures than above the first bifurcation. Branches 1.5 to 2.0 mm. wide, compressed, rigid, edges sharp, parallel, with moderately developed striato-punctate, non-poriferous border. Zoœcia in from twelve to fifteen alternating ranges, very regularly arranged in longitudinal, diagonally intersecting and transverse rows, with respectively eleven in 5 mm., ten in 2.5 mm., and five in 1 mm. Zoœcial apertures of equal size, elliptical, enclosed in a minutely papillose rim or peristome, the latter slightly depressed at the ends, and generally in contact with each other at four points, so that with a side-light the apertures may appear as arranged between alternately converging and diverging raised lines. End interspaces elongate, depressed, commonly occupied by two mesopores, in other cases by three, and rarely, except in the marginal rows, by four or more now in double rows; always disposed in a longitudinal manner. Non-poriferous border occupied by two or more rows of mesopores.

This form is easily distinguished from all the branching Clinton group species of the genus by the longitudinal arrangement of the mesopores. It is, however, especially in its internal structure, very similar to, and perhaps a descendant of, *Escharopora* (?) *limitaris*. Still, its branches are narrower and more rigid, and there is not that difference in the size of the central and marginal rows of zoœcia that pertains to that Minnesota species.

Formation and locality.—Trenton limestone, Montreal, Canada, and Chimney Point, Vermont. Recently a fragment apparently identical with the eastern types of the species was collected at St. Paul, Minnesota, by the author, in the Galena shales.

Collectors, Mr. T. C. Curry and Prof. Henry M. Seely.

PHÆNOPORA WILMINGTONENSIS *n. sp.*

PLATE XIII, FIGS. 22-26.

Zoarium a simple lanceolate frond, straight or slightly curved, tapering to a point below, 40 to 100 mm. or more in length, 6 to 24 mm. wide, and 1.0 to 2.5 mm. thick at the center; edges acute, non-poriferous margin inconspicuous, surfaces gently convex, sometimes a little flattened on each side of the center, exhibiting, according to the width of the frond, from one to ten rows of low monticules. The latter occur at intervals of 2 or 3 mm., are usually arranged in rather irregular longitudinal and diagonal rows, and occupied by greater or smaller aggregations of mesopores and zoœcia, the latter of slightly larger size than the average. Zoœcial apertures subcircular or ovate, arranged in regular diagonally intersecting and transverse rows ; often, especially in the lower half of the zoarium, with the enclosing rim depressed at the ends, in which case they appear to be longitudinally confluent. Longitudinal interspaces depressed, generally with two small mesopores, one just in front of, the other immediately behind each aperture. Toward the center of the monticules the number of the mesopores in each interspace is gradually increased to four or more. Measuring lengthwise, about twelve apertures in a direct line 5 mm. long, and twenty-three or twenty-four of the transverse rows in the same distance ; diagonally, twenty, and transversely twenty-three or twenty-four in 5 mm.

In tangential sections the base of the primitive cells is greatly elongate and bounded by subparallel sides and slightly oblique end walls. Very soon after, the anterior two-thirds is swollen and a curved hemiseptum thrown out from one side, which continues till it joins the opposite wall, thus enclosing the primitive aperture. Preceding this the walls are very thin, but now they add to their thickness by internal deposit. At the same time the aperture assumes a more rounded shape, the walls approach laterally so that each cell is, normally, in contact with six of its neighbors. Between these points there is a triangular open space or mesopore.

The walls consist, first, of the original, transversely lined (? minutely perforated) investment, and, second, of an inner laminated deposit (see fig. 25). This structure prevails in all the typical genera of the *Ptilodictyonidæ*, but, unfortunately is rarely preserved.

Every important feature noticed in vertical sections is represented in fig. 26.

When plate XIII was lithographed the specimen thereon illustrated was the only one then available. When, several months later, the remainder of my collections from Wilmington, Illinois, was unpacked, I was fortunate enough to find seven more examples, three of them with the pointed basal extremity.

The presence of mesopores distinguishes this species from Lower Silurian *Escharopora*, like *E. maculata* Ulrich, while their longitudinal arrangement serves to separate it from the unbranched Upper Silurian species of *Phænopora*.

Formation and locality.—Upper beds of the Hudson River group, at Wilmington, Illinois.

Genus ARTHROPORA, Ulrich.

Ptilodictya and *Stictopora* (part.), of several authors.
Arthropora, Ulrich, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 152; S. A. Miller, 1889, North Amer. Geol. and Pal., p. 293: Ulrich, 1890, Geol. Surv. Ill., vol. viii, p. 393.

Zoaria bushy, spreading in a plane, composed of numerous, essentially equal segments; joints simple, bifurcating, or with several short lateral branchlets, the extremities solid and rounded for articulation with succeeding segments. Zoœcial apertures elliptical, surrounded by a delicate peristome. Interspaces with one or more thread-like ridges, variously disposed, sometimes short and vermicular, at other times forming continuous longitudinal wavy lines, or ranged in a concentric manner about the apertures. Peristomes and ridges each with a row of minute papillæ. Interior with the primitive cell elongate, narrow, one or both hemisepta, and lined with minute dots (? median tubuli) between the zoœcia in the peripheral region. Mesial laminæ zigzag in transverse sections, without "median tubuli."

Type: *Arthropora shafferi* (*Stictopora shafferi* Meek). Range, from base of Trenton formation to top of Hudson River group.

This genus is closely related to *Graptodictya*, the only difference being that in the species of that genus the zoarium is continuous above the basal articulation, while in *Arthropora* it is divided into subequal joints. In certain of the internal characters, (*e. g.* the rows of interstitial dots) we are reminded of the *Rhinidictyonidæ*, but the general agreement with the *Ptilodictyonidæ*, especially in the absence of minute tubuli between the mesial laminæ, precludes all likelihood of near relationship with *Rhinidictya*.

The three species next following and *A. shafferi* (Meek) are the only species so far published of which we know positively that they belong to *Arthropora.* There are, however, at least three other distinguishable forms in the Cincinnati group of Ohio, Indiana and Kentucky, each marking a particular horizon in the group. Most of the species are abundant, but it is exceedingly rare to find any number of the segments still joined together, or lying in their original order.

Arthropora simplex *Ulrich.*

PLATE XIV, FIGS. 12-21.

Arthropora simplex Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 65.

Zoarium jointed, rarely found except as isolated segments. Normally developed, the segments are narrow, more or less compressed, unbranched, straight stems, rounded and solid at each end, with sharp edges and striated non-poriferous border; 12 to 19 mm. long (average length about 18 mm.), 1.0 to 1.8 mm. wide, and always less than 1.0 mm. in thickness. The basal or primary segment is irregularly branched, and occasionally some of the succeeding segments are divided, but such divisions are evidently abnormal. A single specimen preserves several joints in their natural position. From this it appears that, as a rule, the upper extremity of each segment articulated with two succeeding segments. Basal segments thickest, sometimes nearly cylindrical, their superficial characters obscured, the peristomes and interstitial ridges thickened and the zoœcial apertures reduced in size through age. In the younger segments, and most specimens are to be so classed, the characters are as follows: zoœcia very regularly arranged in transverse and diagonally intersecting series, with five in 1 mm. transversely, and eleven or twelve in 3 mm. diagonally; twenty-four to twenty-six of the transverse rows in 5 mm. longitudinally. Zoœcial apertures elliptical, surrounded by a very thin, granose peristome. The latter is easily overlooked, strongly depressed at the sides, but elevated and prolonged at each end, in most cases not far enough to connect succeeding apertures; separating the longitudinal rows an elevated, thin, papillose, wavy ridge. In passing around the zoœcial apertures these ridges alternately diverge and converge, two coming close together, often even uniting, in the spaces between the sides of the apertures. In many segments only the raised ends of the inner depressed ring of papillæ are distinguishable. In these cases the longitudinal ridges combine in front and behind the apertures so as to produce an appearance similar to fig. 22, plate XIV.

In figures 21 *a*, *b*, *c*, I have endeavored to show all the characters of the zoœcia that are to be brought out in tangential sections. The right sides of *a* and *b* represent the structure just beneath the surface, while the left sides show it at a deeper level in the section. In 21 *c* only the primitive or prostrate portion of the zoœcia is shown.

The unbranched character of the segments of this species, as well as their greater length, will distinguish them at once from all other species of the genus.

Formation and locality.—Very abundant in the lower and middle thirds of the Trenton shales, at Minneapolis, St. Paul, Fountain and other localities in Minnesota; Decorah, Iowa.

Mus. Reg. Nos. 5933, 8075.

ANTHROPORA BIFURCATA *n. sp.*

PLATE XIV, FIGS. 22-25.

Segments small, thin, with sharp edges and rather wide non-poriferous border, the lower ones bifurcating, usually only once; so far as observed not over 8 mm. long, and from 1.2 to 1.8 mm. wide; the upper joints shorter, their length occasionally less than 5 mm., bifurcating, or with a single lobe-like projection on one or both sides. Young segments with comparatively large, ovate zoœcial apertures, not very regularly arranged in longitudinal and diagonally intersecting series, with about nine in 3 mm. lengthwise, and five in 1 mm. diagonally. Apertures enclosed in distinct granulose rims, connecting longitudinally. Interspaces depressed, sometimes with a few indistinct striæ. With age the zoœcial apertures become more circular and smaller, and the peristomes and connecting ridges thicker.

This species is related to *A. shafferi* (Meek) but differs in having only one ridge or line in the interspaces, instead of from one to four. *A. simplex* has longer and unbranched segments, while *A. reversa* has a peculiar horseshoe-shaped ridge about its zoœcial apertures.

Formation and locality.—Detached segments rather common in the Galena shales and in the upper third of the Trenton shales at St. Paul, and Cannon Falls, Minnesota. A closely allied species, perhaps it is identical, in the Trenton limestone of Kentucky, Tennessee, and Canada.

Mus. Reg. No. 8108.

ARTHROPORA REVERSA *n. sp.*

PLATE XIV, FIG. 26.

Of this species I have seen only two segments, but their superficial aspect is so distinctive that I do not hesitate in proposing a new name for them. One of these is 8 mm. long, and divides dichotomously about midway the length. The two forks are of the same strength as the lower half, averaging 1.2 mm. wide, the three extremities abrupt and tipped for articulation with the preceding and succeeding segments. The other, apparently the basal or primary segment, is pointed below trifurcately divided 4 mm. above the lower extremity, with the three branches of equal strength and the central one again divided, this time merely bifurcating, at its upper end; total length 8 mm., width about 10 mm. The zoarial growth and general aspect of the segments seems therefore to be precisely as in *A. bifurcata*.

Zoœcial apertures small, subcircular, separated from each other by spaces fully equalling their diameter; arranged in rather irregular, more or less oblique transverse series, about six in 1 mm., and in six to eight, more regular, longitudinal rows, with twelve to fourteen in 3 mm. Immediate border of apertures formed by a ring of very minute granules. This ring is depressed except at the lower end, so that it is not likely to be seen save under the most favorable circumstances. The lower end is commonly prolonged into one or two short rows of granules, perhaps extending completely across the end interspaces. The most striking peculiarity of the species is a horseshoe-shaped ridge, open below, which, in the usual state of preservation, appears to enclose the sides and upper end of each zoœcial aperture. This ridge is papillose, thick, and strongly elevated in the middle (in front of each aperture) gradually tapering to the ends. The strong elevation in front of the apertures, causing them to appear as oblique and turned backward, suggested the name *reversa*. The ends of the horseshoe ridge may be free, (see fig. 26) or they may unite with the sides of the one next beneath. Non-poriferous border rather wide, with distinct, oblique rows of papillæ.

Formation and locality.—Upper third of the Trenton shales, at St. Paul, Minnesota. Recent collections made at this locality from this horizon and the overlying Galena shales afford a considerable number of detached segments agreeing in all essential features with the described types of the species.

Mus. Reg. No. 8109.

Genus STICTOPORELLA, Ulrich.

Stictoporella, ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, pp. 152 and 169; and 1890, Geol Surv. Ill., vol. viii, p. 394; VINE, 1884, Fourth Rep. Brit. Assoc. on Foss. Poly., p. 44; MILLER, 1889, North Amer. Geol. and Pal., p. 325.

Zoaria bifoliate, growing from a broad basal expansion into narrow, parallel-margined, branching stipes, simple leaf-like fronds, or cribrose expansions. Zoœcia with the primitive portion tubular, unusually long, generally without hemisepta, the inferior one only occasionally present. Apertures elliptical, placed at the bottom of a sloping area, the latter usually polygonal. More or less numerous, thick-walled, untabulated mesopores occur between the zoœcial apertures and line the zoarial margins. Maculæ, composed of clustered mesopores, and sometimes of zoœcial apertures of larger size than the average, commonly scattered over the surface of the frondescent species.

Tangential sections of favorably preserved specimens show that both the zoœcia and mesopores are separated from each other by a sharply defined line of minute pore-like dots. True median tubuli and diaphragms wanting.

Type: *S. interstincta* Ulrich. Range, Lower Trenton to Chester.

For remarks on the relations and systematic position of this genus see *ante* p. 162.

The range of zoarial diversity allowed in this genus is unusually comprehensive. Perhaps it is too much so, and that the cribrose species ought to be distinguished generically. Most certainly they look very different from the others and are, I grant, as much entitled to generic separation as *Clathropora*, Hall, *Coscinium*, Keyserling, and other genera that might be mentioned, all differing from related genera chiefly or solely in the cribrose character of the zoaria. Though inclined to favor a separation, I have decided to leave them with *Stictoporella* for the present.

CLASSIFICATION OF AMERICAN SPECIES.

Section *a:* zoarium branching.

Stictoporella interstincta Ulrich, Utica horizon, Cincinnati group, Kentucky.
S. angularis Ulrich, base of Trenton shales, Minnesota.
S. angularis var. intermedia Ulrich, base of Trenton shales, Minnesota.
S. dumosa Ulrich, Trenton shales, Minnesota.
S. rigida Ulrich, Trenton shales, Minnesota.

Section *b:* zoarium wide, leaf-like, with maculæ.

Stictoporella frondifera Ulrich, base of Trenton shales, Minnesota.
S. ? basalis Ulrich, Keokuk group, Illinois, Iowa.
S. ? undulata Ulrich, Chester group, Kentucky, Illinois.

Section *c:* zoarium cribrose.

Stictoporella cribrosa Ulrich, middle Trenton shales, Minnesota.
? Clathropora flabellata Hall, Trenton, Wisconsin.
Stictoporella proavia (*Coscinium proavium* Billings, ? Eichwald), Trenton, Canada.
S. n. sp. (with smaller meshes than in the others), "Pierce" limestone, Tennessee.

STICTOPORELLA RIGIDA *Ulrich.*

PLATE XI, FIGS. 20 and 21.

Stictoporella rigida ULRICH, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 188.

Original description: "Zoarium a narrow branching, bifoliar stipe. Branches flattened, 1.0 mm. or a litle more wide, with straight parallel and sharp margins, acutely elliptical in cross-section. Zoœcia in seven to nine or ten rows on each face, their apertures arranged in very regular longitudinal and diagonally intersecting series, with sixteen or seventeen in 5 mm. lengthwise and four in 1 mm. obliquely. Apertures elliptical, 0.2 mm. long, half that wide, impressed, the sloping area narrow for this genus, and appearing sometimes a little oblique because of a slight elevation of the posterior border; those in the marginal rows are directed slightly outward.

Between the ends of succeeding zoœcial apertures one or two small mesopores. There is usually a row of these small pores along the border of the branches. Interspaces narrowly rounded or ridge-shaped, comparatively thin."

This neat species is near *S. interstincta* from the Utica horizon of the Hudson River group, but has somewhat narrower branches, fewer mesopores, and much thinner walls. In *S. angularis* the walls are much thicker, branches wider, sloping areas about the zoœcial apertures polygonal, and the mesopores less numerous and irregularly distributed. *S. dumosa* has wider and oftener divided branches.

Formation and locality.—Rare in the lower part of the upper third of the Trenton shales, at St. Paul, Cannon Falls, and near Fountain, Minnesota.

Stictoporella dumosa *n. sp.*

(Not figured.)

Zoarium forming bushy masses, as much as 100 mm. in diameter and 50 mm. high, consisting of very irregularly divided, free or coalescing, small branches, 1.5 to 2.0 mm. in width, and usually less than 0.5 mm. in thickness. Zoœcial apertures subcircular or elliptical, set into rather wide sloping areas of polygonal or rounded outline, the shape depending upon the number of mesopores present. Arrangement rather irregular; occasionally longitudinal rows, with the mesopores between the ends of the zoœcial apertures, prevail, in which case the surface appearance is much the same as in *S. rigida*. More commonly, however, a diagonal arrangement predominates, with the mesopores distributed more at random. In these, especially when the mesopores happen to be fewer than usual, the general appearance is much more like that of *S. angularis*. Where the arrangement is the most regular there are ten or eleven zoœcial apertures in 3 mm. diagonally, and about eight in the same space longitudinally. Apertures often closed by a slightly convex plate, in which a minute subcentral perforation may be detected. Walls ridge-shaped, generally wider than the diameter of the zoœcial apertures. Mesopores varying in number; sometimes a fragment will show about one only to each zoœcium, while others may have them three or four times as numerous. Edges sharp, generally exhibiting two or three rows of mesopores.

Internal structure, especially in transverse and vertical sections, very similar to that of *S. cribrosa*. In tangential sections the mesopores are not as distinct, and the divisional line between the zoœcia less sharply defined, than in similar sections of that species.

As a rule, I do not favor descriptions of species without illustrations, but in this case the form is so easily recognized that the omission may be pardoned. Compared with *S. angularis* it is distinguished by its more irregular and stronger growth, and more abundant mesopores. The occasional inosculation of the branches points to a relationship with *S. cribrosa*, and this is further evidenced by the agreement in their internal structure. The position of the species is probably intermediate between *S. angularis* and *S. cribrosa*.

Formation and locality.—Upper third of the Trenton shales at St. Paul, Minnesota.

Mus. Reg. No. 8110.

Stictoporella angularis *Ulrich.*

PLATE XI, FIGS. 1-3, 6, and 8-11.

Stictoporella angularis Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 71.

Zoarium branching dichotomously at intervals varying from 4 to 10 mm.; branches more or less compressed, 1.5 to 3.0 mm. wide, 0.7 to 2.0 mm. thick, with sharp or narrowly rounded, subparallel edges. Zoœcial apertures small, subcircular, set into wide sloping polygonal areas, with the subrhomboidal and hexagonal shapes commonest. Walls ridge-shaped, angular in the middle, their thickness usually greater than the diameter of the apertures. Zoœcial apertures arranged in moderately regular curved diagonally intersecting series, nine in 2.5 mm. When longitudinal rows are to be made out (as in upper part of fig. 6) six are to be counted in the same space lengthwise. Mesopores comparatively few, small, sometimes appearing to be absent entirely on parts of the central three-fifths of the surface, while for some distance above or beneath such a spot they may occur regularly one to each zoœcium. Near the margins, however, some are always present, with one and occasonally two rows bordering the edges.

In tangential sections, showing the structure in the peripheral part of the zoarium, the zoœcial cavity is ovate, in old examples sometimes nearly closed by internal deposits of sclerenchyma, the interspaces always thick enough to separate the cells by a distance greater than their diameter. Boundary line between the zoœcia and mesopores sharply defined, consisting of a crowded row of very minute, pore-like dots. These, however, are not recognizable except in the most favorably preserved specimens. Mesopores few, here completely filled with laminated sclerenchyma.

In vertical sections the thin-walled prostrate part of the zoœcial tube is long, but, as is usual in this genus, this portion of the section appears irregular. Hemisepta absent. In turning to the surface the tube bends abruptly, and at once the walls become very thick and marked with ʌ-shaped lines representing the sloping areas about the apertures at previous stages of growth.

The angularity of the zoœcia, together with the unusual paucity of the mesopores, distinguishes this species from *S. interstincta*, *S. rigida*, *S. dumosa* and *S. cribrosa*.

The broad, maculose zoaria of *S. frondifera* are not likely to be confounded, although the two species are undoubtedly closely related. The following variety is good evidence of that.

Formation and locality—Not uncommon in the lower third of the Trenton shales, at Minneapols, St. Paul, and several localities in Goodhue and Filmore counties, Minnesota.

Mus. Reg. Nos. 5943. 7617.

Stictoporella angularis, var. intermedia *n. var.*

PLATE XI, FIGS. 4, 5 and 7.

This name is proposed provisionally for a form that is common at several localities in Filmore county, but rare in the more northern exposures of the same beds. It differs from typical *S. angularis*, with which it is often associated, in forming wide, irregular branches, the growth and size being in many instances precisely as in the branching form of *S. frondifera.* At intervals the surface presents clusters of zoœcia with thinner walls and larger apertures than usual. The mesopores are very few, in most cases restricted to the center of the clusters mentioned. Here they may form aggregations, but these are never, as far as observed, so extensive as in *S. frondifera* One or two rows of them are also commonly present at the rounded margins of the branches.

In having very few mesopores the variety agrees with *S. angularis*, while in its wide branches and general aspect it is like *S. frondifera.* The name *intermedia* alludes to its position between those species.

Formation and locality.—Rare near the base of the Trenton shales, at Minneapolis, but common in the same beds near Fountain, Lanesboro and Preston, all localities in Minnesota; also at Decorah, Iowa

Mus. Reg. Nos. 7597, 7599, 7984.

Stictoporella frondifera *Ulrich.*

PLATE XI, FIGS. 12-19.

Sticloporella frondifera Ulrich, 1886. Fourteenth Ann. Rept. Geol. Nat. Hist. Surv. Minn., p. 72.

Zoarium consisting of broad, irregularly branching, flabellate or undulate expansions, 1 or 2 mm. in thickness, the whole attaining a hight of from 50 to 100 mm. Edges rounded, with small pits (mesopores) in two or more rows. Surface with conspicuous maculæ consisting of greater or lesser aggregations of mesopores, sometimes a hundred and more, generally about fifty or less. These maculæ are from 3 to 5 mm. apart, sometimes arranged in rows, but oftener their distribution is decidedly irregular. Between them the surface is occupied by the rounded zoœcial apertures and mesopores, the latter small and unequally distributed, varying in number from one, two, or even three to each of the former. Walls ridge-shaped, thick, usually nearly equalling the diameter of the zoœcial apertures. Arrangement variable, rather irregular, generally in diagonally intersecting series, with from fifteen to eighteen, but averaging sixteen in 5 mm.

Internal structure, as shown in thin sections, very similar to that of *S. angularis*, the only differences noticed resulting from the much greater development of mesopores.

The much greater abundance of mesopores distinguishes this species from *S. angularis*, var. *intermedia*, while the frondescent habit of its zoarium separates it from all the other Lower Silurian species of the genus. Associated in the same strata are *Pachydictya foliata* and *Phyllodictya frondosa ?*, two bifoliate species likewise characterized by foliaceous zoaria. In other respects, however, they differ so obviously from *S. frondifera*, that detailed comparisons are rendered unnecessary.

Formation and locality.—Rather abundant in the lower beds of the Trenton shales, at Minneapolis, St. Paul, Preston, near Fountain, and other localities in the state where this horizon is exposed.

Mus. Reg. Nos. 5945, 5947, 7650.

STICTOPORELLA CRIBROSA *Ulrich.*

PLATE X, FIGS. 21-25; PLATE XI, FIGS. 22 and 23.

Stictoporella? cribrosa ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 69.

Zoarium growing from a small expanded basal attachment into thin erect fronds, perhaps 50 mm. in diameter, composed of branches that inosculate at short intervals till there is produced a broad expansion perforated at more or less regular intervals by circular or elliptical fenestrules. Both sides of frond celluliferous, consisting of two equal layers of cells grown together back to back in the manner usual with bifoliate Bryozoa. Fenestrules elliptical, sometimes circular, varying greatly, the average size about 1.3 mm. by 1.8 mm., or less than the width of the branches; but the same frond may show extremes like 1 mm. and less, and 3.5 mm. Their arrangement is therefore more or less irregular, and taking other cribrose species of the genus into consideration, this irregularity in the size and distribution of the fenestrules is to be considered as a characteristic of the present species. Width of branches generally 2.0 mm. or 2.5 mm. but varying between the extremes of 1.5 mm. and 3.1 mm. Zoœcial apertures small, subcircular or elliptical, the average size about 0.1 mm. by 0.12 mm., set into sharply defined, polygonal or rounded, sloping areas, about nine in 2.5 mm. Mesopores small, numerous, often completely isolating the zoœcia. Generally, however, the latter are in contact with each other at limited points. Around the fenestrules there is a band, 0.5 mm. or less wide, occupied solely by mesopores. As in other species of the genus the zoœcial apertures are often closed by a convex plate, with or without a minute subcentral perforation.

Tangential sections show that the polygonal boundary of the zoœcia is marked by a dark line, which under favorable preservation will probably consist of a row of exceedingly minute pore-like dots. Visceral cavity ovate or subcircular, generally of less width than the walls. Mesopores numerous, of irregular shape and unequal dimensions, often completely filled, or only preserving a very small central cavity.

Vertical sections show that the divisional laminæ are somewhat flexuous, the tubes at first thin-walled and prostrate, overlapping each other for some distance, that they subsequently bend abruptly outward, and that their walls at the same time are much thickened and marked with oblique lines parallel with the form of the apertures. The mesopores appear as narrow open spaces when not entirely filled by the secondary deposit of sclerenchyma. Diaphragms and hemisepta wanting.

The Canadian Trenton limestone species identified by Billings with Eichwald's *Coscinum proavium*, is closely related to *S. cribrosa*, but differs in having narrower branches, subequal and more regularly disposed fenestrules, and less numerous mesopores. Another cribrose species, but in every respect smaller than these, occurs in the "Pierce" limestones at Murfreesboro, Tennessee. Still another Lower Silurian bryozoan with inosculating branches has been described by Hall from the Trenton rocks of northern Wisconsin.* He named it *Clathropora flabellata*, but both the description and figures are entirely inadequate for anything like satisfactory identification. It may belong to *Clathopora*, but *Stictoporella* is more likely to be right. Then again it is not impossible that it is a *Coscinella* or even a *Coscinum*, since in all of these paleozoic genera the zoarium is cribrose. Compared with the characters shown in Hall's figures, it is evident that he had before him a more robust species, with branches and fenestrules much larger than in *S. cribrosa*.

Formation and locality.—Abundant in the middle third of the Trenton shales at Minneapolis and St. Paul, Minnesota. The species seems to be restricted to this horizon.

Family ARTHROSTYLLIDÆ, Ulrich.

This interesting family of small Bryozoa is strongly represented in the Lower Silurian rocks of Minnesota. On account of the minute proportions of most of them their dismembered zoaria are generally to be found only by searching the surface of the slabs of fossiliferous limestone that occur so abundantly in certain parts of the Trenton shales. These are often full of the separated joints. The most satisfactory

*Foster and Whitney's Report, vol. 2, p. 207, 1851.

specimens, however, are those which are obtained by picking over the residue of washings of the shales themselves. These are better, not only because they can be studied from all sides, but because their preservation is, in most cases, more favorable.

Unfortunately, I had neither the time nor the opportunity of making extensive washings of shales in Minnesota, and that method of collecting was employed to only a very limited extent. Here and there a pound or two of unusually rich clay was carried away and washed during leisure moments after my return home. One of these packets proved to contain so many interesting things, and withal was so rich in individuals, that it deserves mention. The shale was from the lower part of the Galena shales, which, according to my reckoning, is the exact equivalent of the Trenton limestone of New York. After washing away less than half its bulk nearly two-thirds of the residue consisted of good fossils, of which the larger ones, mainly species of *Prasopora*, *Homotrypa*, *Callopora*, *Constellaria*, *Eridotrypa* and some *Brachiopoda*, were separated by sifting the finer material away from them. A large proportion of this fine material consisted of small fossils, among them five or six species of *Ostracoda*, (most of them described in this volume as new) and at least eleven species of small Bryozoa. Of the latter eight belong to the family under consideration, two of them being species of *Arthroclema*, three of *Helopora*, and three of *Nematopora*.

The jointed character of the zoarium is the most conspicuous and perhaps also the most important feature of the family. It is well shown in all the genera except *Nematopora*, in which articulation occurs only at the basal extremity, the zoarium above the base being a dichotomously dividing, continuous stem. In *Helopora*, Hall, *Sceptropora* and *Arthrostylus*, the segments are simple and terminally joined together, and doubtlessly formed bushy zoaria. But in *Arthroclema*, Billings, the zoarium forms a more or less plumose expansion, divisible into numerous primary, secondary and tertiary segments, those of the first and second order being connected terminally and ranged in straight lines. A deep socket occurs on one or two opposite sides of each of the strong joints of the primary series and a shallow one in most of those of the smaller secondary set, in which respectively the first of the series of the second and third order is inserted.

The zoœcia are arranged in a radial manner around a central axis and, excepting *Arthrostylus* in which one side is marked with longitudinal striæ only, open on all sides of the subcylindrical segments. In transverse sections the primitive portion of the zoœcia is wedge-shaped, but in longitudinal sections they often appear tubular. The length of the tubes depends very largely upon the diameter of the segment, since all of them reach the central axis. It is evident that the obliquity of the tubes also has something to do with their relative lengths. They are, however, not to be considered tubular in the sense attaching to that term when applied to the *Cyclostomata*. On the contrary they are no more so than are the zoœcia of the most typical *Rhinidictyonidæ*. In tangential sections they are oblong-quadrate or hexagonal in outline. Hemisepta have not been observed, but rows of minute tubuli occur between the walls of adjoining zoœcia and sometimes in the longitudinal interspaces in the vestibular region. A minute tube is also to be detected running from end to end through the axis of the segments.

Respecting the position of the family the jointed character of the zoaria leads us to look for its relationship first with the similarly constructed *Cellariidæ*. The latter embraces living forms chiefly, and of many of these I have secured specimens, so that I am now in a position to speak intelligently upon their characters, as compared with paleozoic forms. I would be glad to do this here were it not that I would thereby interfere with my plans for a general work on inter-relation of bryozoan types. It will probably be sufficient to say that the two families are distinguishable, and that the relationship between them, if any exists, is almost certainly less intimate than that between the *Arthrostylidæ* and *Rhinidictyonidæ*.

Aside from the wedge-shaped form of the primitive cells in the *Arthrostylidæ*, which it is evident resulted necessarily from their radial arrangement about a linear central axis, they are precisely like those of true *Rhinidictya*. They agree also in possessing median tubuli between the walls of adjoining zoœcia. Then again I am convinced that the minute axial tube of the *Arthrostylidæ* is functionally identical with the median tubuli between the mesial laminæ that are such a characteristic mark of the *Rhinidictyonidæ*. The jointed character of the zoarium even, is not unknown in the latter since it pertains to *Dicranopora*, Ulrich, a genus that in all other respects is precisely like *Rhinidictya*. Really, I find only one structural difference between the two families, and that is that while the zoœcia in the *Rhinidictyonidæ* are arranged so as to form bifoliate zoaria—in other words, are disposed in two equal expansions grown together back to back, they are arranged radially around a central axis, forming subcylindrical zoaria, in the *Arthrostylidæ*.

Genus ARTHROSTYLUS, Ulrich.

Arthronema, ULRICH, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, pp. 157 and 160 (not ESCHSCHOLTZ, who used the name for a genus of Colpodea).
Arthrostylus, ULRICH, 1888. Amer. Geologist, vol. i, p. 230; 1890, Jour. Cin. Soc. Nat. Hist., vol, xii, p. 188; 1890, Ill. Geol. Sur., vol. viii, p. 400.

Zoaria bushy, branching dichotomously, the whole consisting of numerous, exceedingly slender, subquadrate, equal segments, joined to each other by terminal articulation. Zoœcia arranged in three (perhaps more) rows, usually between longitudinal ridges; the fourth face, commonly the widest, with longitudinal striæ only.

Type: *Arthronema tenue* Ulrich (*Helopora tenuis* James), of the Utica horizon of the Cincinnati group. (Jour. Cin. Soc. Nat. Hist., vol. v. p. 160, 1882.) The lower fig. 16 on Plate III, represents a transverse section of this species. It should have been been numbered 16*a*.

Besides the type species only three others are known to have the characters demanded by this genus. Two of these are from the Trenton shales of Minnesota, and are next described. The third species, *A. curtus* Ulrich, from the Hudson River rocks of Ohio, is still a little doubtful, no further material having been found to throw light upon the rather imperfect originals of the species.

Arthrostylus conjunctus *Ulrich.*

PLATE III, FIGS. 13 and 14.

Arthrostylus conjunctus Ulrich, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 189.

Original description. "Zoarium jointed; segments very slender, straight, needle-shaped, 3 or 4 mm. long, quadrangular in cross-section, 0.25 mm. wide, 0.18 mm. thick, with zoœcial openings on three sides, the fourth being without them, but marked instead with four parallel longitudinal striæ. Zoœcial apertures broad-oval, direct, 0.11 mm. long, 0.09 mm. wide, enclosed by a sharply marked peristome. Peristomes of each row of apertures joined together by a thin ridge, having a length about equal to the larger or outer diameter of the peristomes. Eight zoœcial apertures in each row in 2.5 mm. A thin ridge on each side of the range of apertures of the obverse face of the segment separates it from the lateral rows. Apertures usually arranged alternately in the three rows.

"This species is closely related to *A. tenuis* James, sp., but is distinguished by having the non-celliferous side narrower and with fewer striæ, causing transverse sections to be more nearly square. The *A. obliquus* differs in having oblique zoœcial apertures."

Formation and locality.—Rare near the base of the Trenton shales, near Fountain, Minnesota. In the original description the locality is given, inadvertently, as Minneapolis.

Arthrostylus obliquus *Ulrich.*

PLATE III, FIGS. 15 and 16.

Arthrostylus obliquus Ulrich, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 190.

Original description: "Zoarium jointed, segments very slender, needle-shaped, straight or slightly curved, about 4 mm long, subquadrangular in cross-section, 0.2 mm wide, 0.15 mm. thick, slightly expanding toward the upper extremity. Zoœcia in three rows, occupying as many faces of the segment, the fourth side with three longitudinal striæ, and no zoœcia. Profile of a segment in an obverse or reverse view, wavy on both sides; in a lateral view only on one side.

"Zoœcial apertures small, oblique, the posterior margin very prominent, arranged alternately in the three rows, with nine in each, in 2.5 mm. A short ridge from the upper depressed edge of each zoœcial aperture is flanked on each side by the prolonged lateral borders of the aperture. No ridge between the lateral and central row of the zoœcia.

"The oblique zoœcial apertures, the prominent lower border and absence of ridges between the rows of apertures, distinguish this species from *A. conjunctus* and *A. tenuis*, both of which it resembles in other respects."

Formation and locality.—Trenton shales, Minneapolis, Minnesota; rare.

Genus HELOPORA, Hall.

Helopora, HALL, 1852, Pal. N. Y.. vol. ii, p. 44; BILLINGS, 1866, (part.) Cata. Sil. Foss. Isl. Antic., p. 36; ULRICH, 1888, The Amer. Geologist, vol. i. No. 4, p. 231, 1890, Jour. Cin. Soc. Nat. Hist., vol. xii, p. 191, and 1890, Geol. Surv. Ill., vol. viii, pp. 401 and 642.

Zoaria consisting of numerous, subequal, small, cylindrical segments, articulating terminally, poriferous on all sides. Zoœcial tubes somewhat oblique, geniculated or proceeding to the surface in a straight line. Apertures slightly oblique or appearing direct, suboval, arranged in diagonally intersecting series (section *a*) or between more or less well defined longitudinal ridges (section *b*). In section *a* the apertures are usually without a peristome, but an acanthopore occurs immediately beneath each. In section *b* the acanthopores are wanting, but a peristome, generally incomplete and prominently elevated posteriorly, is present. Axial tube very slender.

Type: *A. fragilis* Hall, a common fossil of the Clinton group.

As is indicated above, this genus may be divided into two sections. These were noted in my previous work on the genus (*loc. cit.*) and in one of them I express the opinion that, when these fossils are better understood, these two sections will probably be separated generically. Although the study of the genus, necessitated by the present work, has strengthened this opinion, I am not yet ready to make the separation. Still, I shall go a step farther here and follow the practice adopted in treating many of the preceding genera. As in those cases I believe this non-committal division of the species into sections will suffice until we are in a position to work up the genus monographically. Except in that way it is not only difficult but almost impossible to distinguish nearly related genera in a fully satisfactory manner.

Section *a* embraces the species which agree nearest with the type of the genus, and all of them, as far as known, belong to Upper Silurian rocks (including the Anticosti group). They are distinguished from the species of section *b* (1) by the presence of acanthopores, one of which is commonly situated in each end space ; (2) the absence of longitudinal ridges and inter-apertural striæ ; (3) the predominance of the diagonal arrangement of the zoœcial apertures ; (4) the absence of a peristome, the interspaces being highest midway below the zoœcial apertures and sloping into them, and (5) the lesser separation of the zoœcial apertures longitudinally.

Under section *a* I would place *H. fragilis* Hall, from the Clinton of New York, Canada, and probably Ohio ; *H. bellula*, *H. armata*, and *H. nodosa*, three species described by Billings from the Anticosti group, and *H. lindstrœmi* Ulrich, from the Upper Silurian of the island of Gotland.

Section *b* differs from the typical section (1) by the absence of acanthopores; (2) the presence of straight or wavy ridges and minor striations of the surface; (3) the predominance of the longitudinal and transverse arrangement of the zoœcial apertures ; (4) the prominence of the zoœcial apertures, especially at the inferior side, and (5) in the more ornamental appearance of the segments resulting from the peculiarities noted.

Helopora spiniformis, originally described by me as *Arthroclema spiniforme* (Jour. Cin. Soc. Nat. Hist., vol v, p. 161, 1882), may well be accepted as the type of this section. This species is fairly abundant on slabs of "Glade" limestones, at Lebanon, La Vergne, and other localities in Tennessee. Figs. 4, 5 and 6, on plate III, introduced chiefly for comparison with *H. divaricata*, illustrate its principal characters. Segments of apparently the same species were collected also in the lower limestones at Dixon, Illinois.

All the other known Lower Silurian species referred to the genus must be arranged in section *b*. These are *H. quadrata*, n. sp., *H. mucronata* Ulrich, and *H.* (?) sp. undet., from the Galena shales of Minnesota, the last two with rather striking resemblances to certain Cylostomata ; *H. harrisi* James, *H. elegans*, n. sp., and *H. imbricata* Ulrich, from the upper beds of the Cincinnati group of Ohio and Illinois ; and *H. alternata* Ulrich, from the Trenton shales of Minnesota. The last represents a peculiar type of the section that is again met with, but less strongly expressed in the new species *H. elegans*.

As is to be expected, it is in section *b* that *Helopora* most nearly approaches the other genera of the family. The species of section *a* represent a further differentiation of the type. Comparing the former with *Arthroclema* we note a general agreement of structure, which, if we knew nothing of the segments of the primary and secondary order of that genus, might really be said to amount to identity. But we do know that the zoarial combination of the segments in *Arthroclema* is by both terminal and lateral articulation, while in *Helopora* they unite at their ends only. The difficulties, therefore, which we may experience in correctly classifying some of the dismembered segments, are not at all encountered when we deal with complete zoaria. Even granting that the latter condition is exceedingly rare, the trouble of discriminating between the isolated segments of the two genera is not of very common occurrence, because it is restricted to those of the third order of *Arthroclema*, those of the primary and secondary set being easily distinguished from *Helopora* by the lateral articular socket. In practice I think we are nearly safe under this working rule: When of a number of isolated segments occurring on slabs of rock or in the residue of shale washings, none have lateral sockets, it is safe to classify them as *Helopora*, providing, of course, that they agree with that genus in other respects. When, however, one or more of them possess such sockets, it is to be recommended that the investigator determine the three sets of segments of the *Arthroclema* before he classifies any of them as *Helopora*.

Of the remaining genera of the family, *Sceptropora* is distinguished by the wide expansion or swelling of the upper half of the segments; *Arthrostylus* in having one side simply striated and without zoœcial apertures, and *Nematopora* by its branching zoaria and the absence of joints above the basal articulation. The placing of such species with *Helopora*, by Billings, was an error that I am convinced he would not have committed had he known that *Helopora* originally consisted of numerous subequal segments joined together into bushy zoaria.

Helopora divaricata *Ulrich.*

PLATE III, FIGS. 1-3.

Helopora divaricata Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 59.

Zoarium jointed; segments about 7.0 mm. long, obtuse at both extremities, subcylindrical, polygonal in cross-section, the number of the angles and corresponding rows of zoœcial apertures six, seven or eight. Their diameter varies with age and according to the number of zoœcia contained from 0.5 to 0.9 mm. Zoœcial apertures comparatively large, oblique, ovate, seeming to widen anteriorly, arranged in troughs between strong longitudinal ridges, twelve in 5 mm. lengthwise and generally in regular transverse rows. Posterior border of apertures thick, prominent, sloping backward into the aperture next below. This border is continued upon the sides of the zoœcial aperture as two diverging ridges which extend on each side to the summit of the longitudinal keels where they meet with similar ridges from the adjoining rows. These divaricating ridges cause the strong vertical keels to appear as being marked by a succession of narrow ∧-shaped furrows and ridges. Occasionally, and this is true more especially of the young and slender segments, the rounded posterior slope is divided by a central furrow into two small ridges, the same as in *H. spiniformis* and *H. mucronata.*

Except the transverse section figured on plate III, the thin sections prepared of this species are not satisfactory. As far as they go it appears that the internal structure is not materially different from that of *H. spiniformis*, (see plate III, figs. 5 and 6) to which species it is closely related. In *H. divaricata* the zoœcial apertures are wider, as are also the troughs into which they open, whilst the vertical ridges which separate the rows of zoœcia are always a more pronounced feature than in *H. spiniformis.* When segments of the two species having the same diameter are compared, those of the latter species will be found to have at least one more row of zoœcia, and to be more nearly cylindrical. With age the angles become entirely effaced, the zoœcial apertures relatively smaller than shown in my figures, all the interspaces nearly on a level, and the striation almost equal throughout. The lower extremity of the segments of *H. spiniformis* also are always more pointed than in *H. divaricata.*

Formation and locality.—Rather rare in the lower third of the Trenton shales, at Minneapolis, Minnesota.

Mus. Reg. No. 5928.

Helopora alternata *Ulrich.*

PLATE III, FIG. 9.

Helopora alternata Ulrich, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 192.

Segments exceedingly slender, slightly curved, about 5.0 mm. long, and scarcely 0.25 mm. in diameter; lower extremity obtusely pointed, the upper rounded. Zoœcial apertures oval, nearly direct, comparatively large, about 0.13 mm. in length, arranged alternately, four in each cycle, twelve cycles in 2.5 mm., and twelve or thirteen in a direct line 5 mm. long. Interspaces rather thin, generally appearing to be simply rounded, but, with the light coming from the side, two narrow furrows, passing in a sinuous manner between the apertures, are to be seen. The result is thin peristomes united longitudinally by a thin connecting ridge.

The exceeding delicacy of the segments and the comparatively large size and alternate arrangement of the zoœcial apertures of this species causes it to be distinguished without difficulty from all known Trenton forms.

Formation and locality.—Rare at the base of the middle third of the Trenton shales, Minneapolis, Minnesota.

Helopora mucronata *Ulrich.*

PLATE III, FIG. 10.

Helopora mucronata Ulrich, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 192.

Segments spine-like, slightly curved, 3.5 to 4.0 mm. long, tapering downward from the truncate upper end, where the diameter is 0.6 or 0.7 mm., to the acute and finely striated basal extremity. Zoœcial apertures oblique, the inferior and lateral margins elevated, arranged longitudinally and spirally, with from six to eight forming a complete volution, and six in about 2.5 mm. lengthwise. Above each zoœcial aperture two short striæ. Obscure longitudinal ridges sometimes formed by the coalescence and continuance of the elevated lateral margins of the zoœcial apertures.

The curved and tapering form, the acute lower extremity, and the very slight development of the longitudinal ridges, distinguish this species from all the associated jointed Bryozoa, as well as from *H. divaricata* and *H. spiniformis*. None of the other species of the genus are sufficiently near to require comparisons.

Though readily distinguishable from all the known varieties of segments of the associated *Arthroclema armatum*, it may yet be shown by complete zoaria of the latter that *H. mucronata* is but another form of segment of *Arthroclema*. Until such evidence is discovered we had best leave them as at present.

Formation and locality.—Galena shales, near Cannon Falls, Minnesota, where it is associated with *Helopora quadrata*, *Arthroclema armatum*, and several species of *Nematopora*. Also at St. Paul.

Mus. Reg. No. 8112.

Helopora quadrata, *n. sp.*

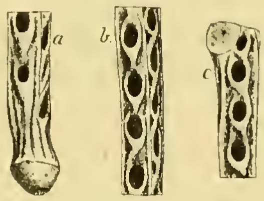


Fig. 10, *Helopora quadrata* Ulrich. Galena shales, near Cannon Falls, Minnesota. *a*, basal par of a segment: *b*, the central portion of another, and *c*, the upper extremity of a third, all x 18.

Segments very slender, quadrate in cross-section, the angles sharp, the sides each about 0.28 mm. wide; entire length unknown, none of the segments at hand being complete, probably between 5 and 6 mm.; lower end bulbous, the upper with two flattened articulating faces. Zoœcial apertures in four longitudinal rows, one on each of the concave sides; ovate, a little oblique, the inferior and lateral margins with a strong rim, produced backward, either straight or obliquely, as a sloping ridge. Zoœcial apertures separated by distances very nearly equal to their long diameter, with nine or ten in 3 mm.

This is the only species of the genus known to me having quadrate segments and only four rows of zoœcia. Fragments look a little like small pieces of *Nematopora ovalis,* an associated species, but are readily enough distinguished by their sharper angles, and the relatively much greater elevation of the posterior margin of their zoœcial apertures.

The exceeding delicacy of the segments, and their structure in general, gives them very much the appearance of species of *Arthrostylus.* But as all of the four faces are occupied uniformily each by a row of zoœcial apertures, it is evident that the species does not belong to that genus.

Formation and locality.—Comparatively rare in washings of the Galena shales, near Cannon Falls, Minnesota.

Helopora elegans, *n. sp.*

Fig. 11, *Helopora elegans* Ulrich, Cincinnati group, Blanchester, Ohio. A segment of this species of the natural size and x 18.

Segments small, subcylindrical, obtusely hexagonal in cross-sections, about 3.0 mm. long and 0.3 mm. in diameter; upper extremity truncate, the lower rounded and tapering slightly. Zoœcia in six longitudinal ranges, their apertures narrow-elliptical, slightly depressed in front, their length apart, arranged alternately in adjoining rows. Entire surface beautifully grano-striate, the striæ flexuous, forming connected peristomes, with a short row of granules between the ends of the apertures and a continuous row at each angle of the segment. The latter winds itself between the zoœcial apertures so as to arrange them into longitudinal series, with seven or eight in the length of the segment.

Of all the species known to me *H. alternata* seems to be the nearest to this. The differences between them are however too obvious to require pointing out. *H. harrisi* occurs in the same beds, but its segments are longer and more slender, its zoœcia smaller, and the surface marking quite different.

Formation and locality.—The types are from the upper beds of the Cincinnati group, at Blanchester, Ohio, but the species has been noticed at other localities in Ohio, and at Richmond and Versailles in Indiana. I have also noticed similar segments in equivalent rocks at localities in Illinois, so that the species may be expected to occur in these beds at localities in southern Minnesota.

Helopora harrisi *James.*

PLATE III. FIGS. 11, *b*, *c*, and 12.

Helopora harrisi JAMES, 1883. "The Paleontologist," p. 58.

Segments very small, acerate, about 3.5 mm. long, 0.22 mm. thick, hexagonal in cross-section ; upper extremity slightly expanded, conical or pyramidal, with the angles prominent, the lower end striated, tapering, obtusely pointed or slightly bulbous ; between the ends the sides are nearly parallel. Zoœcia in six longitudinal ranges, their apertures small, narrow-elliptical, often drawn out anteriorly, their margins thickened, about twice their length apart, with seven (usually) on each of the six faces. Peristomes connected lengthwise, their sides being co-incident or merged into the moderately developed ridges forming the angles of the segment. The later are nearly always straight. Interspaces between the ends of the zoœcial apertures occupied by a low rounded ridge, rising and spreading at each end into the peristomes. The best preserved examples exhibit a row of exceedingly minute papillæ on the peristomes and angle-ridges.

In transverse sections the zoœcia appear as six subequal wedge-shaped cells, arranged around the central axis. The outer investment is rather thin, but in most cases the projecting angles and the intermediate ridges are distinguishable. In vertical sections the anterior side of the zoœcia is nearly straight, forming an angle of about fifty degrees with the axis. The zoœcia are comparatively elongate, but the overlap is unusually little. Sections on the whole are much like those of *Nematopora lineata* Ulrich, as figured in Vol. viii, Ill. Geol. Sur., pl. XXIX, fig. 7, but the zoœcia are more elongate in *H. harrisi.*

I cannot doubt that this is the species named by Mr. James in the publication cited above, since the greater part of my specimens are from the same spot and layer that furnished his types. But for this certainly I would not be able to identify the species, Mr. James' description being very incomplete and incorrect in some of the points mentioned by him. I succeeded in obtaining free from the matrix fully one thousand segments, and as many of these as have been examined show clearly and uniformily six rows of cells, not two, three, or four as he supposed. He states also that the sides are constricted at the ends of the apertures, "giving them a chain-like appearance." This is most certainly not true of any specimen seen by me. His figures of the species too are as little or even less trustworthy. Indeed the two plates which accompany that number of "The Paleontologist" may be said to burlesque art illustration.*

*It is really a fair question whether a species so illy and insufficiently characterized as this, has any claim to recognition. In this case it happened that I had selected the same specific name for it, we having both intended to honor Mr. I. H. Harris, of Waynesville, Ohio, who sent each of us one of the original specimens.

The dismembered zoaria of this species literally made up a thin limestone layer, 5 to 35 mm. thick, and about 2 meters square, which occurred in the soft shales near Waynesville, Ohio. It is impossible to say how many segments may have belonged to a single zoarium, but judging from their exceeding abundance here it is more than probable that the number was often very large.

Formation and locality.—Rather a characteristic fossil of the upper beds of the Cincinnati group. The species is known from localities in Ohio, Indiana and Illinois, and has been found at Stony Mountain, Manitoba.

Mus. Reg. No. 8113.

HELOPORA (?) *sp. undet.*

PLATE III, FIG. 8.

Of this form my collection contains several segments that were found associated with *Helopora mucronata*, *H. quadrata* and *Arthroclema armatum*. After careful comparisons with those species, the last especially, I am obliged to regard them as probably belonging to an undescribed species, which, because of the paucity of the material at hand, I thought best to leave unnamed. A small one of what I believe to be the tertiary or last set of segments of *A. armatum* is illustrated, beside one of the supposed new species, on plate III by fig. 7. This is a little shorter than usual, agreeing in that respect very nearly with the form under consideration, but in the greater strength of its longitudinal ridges and in the character and number of the zoœcial apertures in a given space, it differs from the present species, while it agrees in these features with the ordinary form of the third set of segments of *A. armatum.* The segments in question are shorter than the average forms of either the secondary or tertiary segments of *A. armatum*, and taking into consideration the absence of a lateral socket, which should be present in segments of this diameter, if they belong to a species of *Arthroclema*, I think I am justified in maintaining, provisionally, that they belong to a species of *Helopora*, with characters, briefly, as follows:

Segments short, a little over 2 mm. in length, about 0.5 mm. in diameter, cylindrical, the upper extremity truncate, the lower tapering slightly but not pointed. Zoœcia in from eight to ten longitudinal rows, but the more obvious arrangement is in five transverse or subspiral rows. Apertures subovate, oblique, widely separated longitudinally, closely arranged transversely, the last fact, together with the prominence of the posterior border, giving the stems an annulated appearance. Delicate ridges, which do not cross over the elevated margins of the zoœcial apertures, define their longitudinal arrangement.

Compared with species of *Helopora*, only two, *H. spiniformis* and *H. mucronata*, require mention. Both have larger segments and the lower extremity more acute. In the first the ridges and superficial striations are also more conspicuous, while in the second the segments are curved and taper downward.

Formation and locality.—Galena shales, near Cannon Falls, Minnesota.

Genus ARTHROCLEMA, Billings.

Arthroclema, BILLINGS, 1862, Pal. Foss., vol. i, p. 54; ULRICH, 1886, Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 60; 1888, The American Geologist, vol. i, p. 232; 1890, Jour. Cin. Soc. Nat. Hist., vol. xii, p. 192, and Geol. Sur. Ill., vol. viii, p. 400.

Arthroclema (part), ULRICH, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, p. 151.

Zoarium jointed, composed of numerous subcylindrical segments, celluliferous on all sides, arranged in a pinnate manner; articulation both terminal and lateral. Segments of three kinds, primary, secondary and tertiary. The first set forms the strong central stem, of which each part has normally one or two sockets on opposite sides for articulation with the smaller segments of the second set. The latter generally articulate in like manner, terminally with each other and laterally with the still more slender segments of the third set. Zoœcia subtubular, each occasionally with a diaphragm, their apertures ovate, oblique, the inferior border more or less prominent, arranged in rows between longitudinal ridges. Interspaces usually striated, often grano-striate.

Type: *A pulchellum* Billings.

Complete zoaria are known of only two species of this genus, the type and *A. billingsi*. This is unfortunate because of the difficulty of determining the range of variation that may obtain in the three sets of segments. If the student will examine fig. 7, on plate II, he may appreciate the difficulties referred to. This illustration represents the fine type specimen of *A. billingsi*, and gives a good idea of the arrangement and the differences in the size and length of the segments of the three sets that may occur in a species of *Arthroclema*. As shown in the figure the segments of the same set even may not be of uniform length. In *A. billingsi* the first of the secondary set is twice the length of those succeeding it. Then again it shows that while some of the secondary segments may articulate laterally with one of the tertiary set, many others may be without them. As all the zoarial parts spread approximately in the same plane, the development of tertiary segments must depend very largely upon the space available. In *A. billingsi* this was much less than in the other species since it is the only one known in which the primary segments articulate with four (two on each side) secondary joints. In all the other species there is only one on each side, so that their growth was less compact, and the chances for tertiary segments better. Still, it is possible that the third set of joints may not, in some species, have been developed at all. This seems to be true of *A. cornutum,* since lateral sockets have not been observed on any of the numerons secondary segments of that species seen.

Regarding the present work on the genus I regret that I have not been able to do the species justice in the way of illustration. I have sought to figure them as fully as the plates at my disposal admitted. But with so many conditions demanding representation, I was often at a loss in selecting the specimens which would go farthest in aiding the student to identify the species.

Respecting the distribution of the species, *A. cornutum* and *A. striatum* are known as yet only from the middle third of the Trenton shales of Minnesota. The next species is the *A. pulchellum* Billings, described from the Trenton limestones of Canada, and with which I am inclined to identify a number of segments found by me in the upper division of the shales at St. Paul and Cannon Falls. *A. billingsi* is from a similar (perhaps a little lower) horizon at Ottawa, Canada. The detached segments of *A. armatum* were abundant in washings of the Galena shales obtained from a locality near Cannon Falls. The last species is the *A. angulare,* described in vol. viii, Ill. Geol. Surv., from the upper beds at Wilmington, Ill. It occurs also at Stony Mountain in Manitoba.

The relations of *Arthroclema* to *Helopora* have already been discussed in the remarks on the latter genus.

Arthroclema striatum, *n. sp.*

PLATE II, FIGS. 22 and 24, and PLATE III. FIGS. 28-33.

Under this name I propose to arrange a variety of segments that, though closely related to *A. pulchellum* Billings, are evidently distinct. The specimens consist (1) of a relatively small number of segments like the original of fig. 28; (2) hundreds like figs. 22 and 23, and (3) equally numerous more slender segments. They agree with each other in what I regard as specific characters, and in the following description are referred to as respectively as primary, secondary and tertiary segments.

Primary segments 2.5 to 3.0 mm. long, from 0.7 to 1.0 mm. in diameter in the middle, spreading at the ends to a diameter of 1.2 mm. or more, the upper extremity flat, generally subcircular, the lower also abrupt but rising centrally into an obtusely conical elevation. Sometimes with only a single, large, deep and sharply defined socket, situated very near the base; more commonly with two, placed on opposite sides of the segment. Occasionally a third socket, this one small and illy defined, is placed near the upper end. Zoœcia in five or six longitudinal rows, with small oblique apertures, the posterior margin prominent; arranged in transverse rows, with six the usual number in the length of the segment; short segments (2.5 mm.) have five. Surface distinctly striated lengthwise, often thrown into strong, but never sharp, ridges between which the zoœcial apertures are arranged. The latter are always difficult to see. In drawing fig. 30 I overlooked them entirely, having mistaken certain depressions, which are often met with in these segments, for them. Since freeing the specimen from the matrix I find that it has really five rows of apertures, both longitudinally and transversely, of the same size as shown in fig. 33. With this correction the figure may still be of aid in the identification of the species, because it shows the striation of the surface better than the original of fig. 28. It should be added, however, that the latter shows the usual shape of the segments better.

Secondary segments five-sided, 2.7 to 3.2 mm. long, the length depending upon the number (six or seven) of transverse rows of zoœcial apertures, 0.35 to 0.5 mm. in diameter, the ends usually a little wider, the upper flat, the lower rounded. Zoœcial apertures in five longitudinal and six or seven transverse rows, small, oblique, drawn out above, their ends widely separated. Interspaces finely striated lengthwise, the angles sharp or rounded, formed by a raised central line and one or two similar lines on each side of it. An articulating scar or shallow socket has been observed just above one of the first cycle of zoœcial apertures, but their presence in the segments of this set is to be counted as an unusual occurrence. For this reason it is more than probable that most of the segments which are next described as tertiary are really young or terminal joints of the second order.

Tertiary segments about 3.0 mm. long, less than 0.35 mm. in diameter, very slender, four or five-sided, with sharp angles, the lower end rounded and tapering slightly, the upper sharply truncate. Zoœcia in four or five longitudinal rows, in six, but oftener in seven cycles, their apertures small, oblique, the raised margin highest posteriorly and running out on each side to the angle ridges. Behind each aperture usually a pair of very delicate striæ, the conditions being very much as in *Helopora spiniformis* (see plate III, fig. 4). Angles formed by a single raised line. These segments are distinguished from those of the second order by their greater tenuity, more oblique zoœcial apertures, and absence of striæ on the sides of the angle ridges.

As stated in the paragraph preceding the last, it is possible that many of the segments just described as of the tertiary set really represent the young stage of the secondary set. In that case it is probable that the four-sided joints only are tertiaries.

This species is readily distinguished from its associate, *A. cornutum*, by its longer and differently shaped segments, narrower zoœcial apertures and simply striated surface. It is closely allied to *A. pulchellum* Billings, but that species differs in having the segments a trifle shorter (eight or nine in 20 mm.), the articulating sockets situated near the middle instead of near the bottom of the joints, the primary segments less expanded at the ends, the zoœcial apertures more direct, larger and separated lengthwise by shorter interspaces.

Formation and locality.—The detached segments of this species are very plentiful on some of the thin plates of limestone found in the lower part of the Trenton shales at Minneapolis and St. Paul, Minnesota.

Mus. Reg. No. 8114.

ARTHROCLEMA CORNUTUM *Ulrich.*

PLATE 11, FIGS. 16-21 and 23.

Arthroclema cornutum ULRICH, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 193.

Zoarium jointed, the segments five-sided, consisting possibly of three sets, but only two are positively known. For the sake of convenient reference these will be termed primary and secondary.

Primary segments five-sided,* about 2 mm. long, 0.5 to 0.7 mm. in diameter, with the five angles more or less well-defined, though never sharp, produced at the truncated and hollow upper extremity into as many horn-like projections. Near the lower extremity, which is often a little bulbous and radially striated, there is usually one rather shallow, subcircular articulating socket. It would appear that the sockets were placed in these alternately on opposite sides of succeeding segments. There may have been, as I believed, originally two sockets on some of the segments, but no more than one is to be seen on any of those that have since been freed from the matrix. Zoœcia in five longitudinal rows, and generally in four, rarely in five, cycles, the apertures of those in the uppermost cycle more oblique than the others and situated very near the upper extremity of the segment. Angles of segments, peristomes of oval zoœcial apertures, and the longitudinal interspaces more or less regularly papillose. With age the number of rows of papillæ at the angles increases from one to three or four.

Secondary segments also five-sided, 0.4 to 0.5 mm. in diameter, from 1.0 to 1.8 mm. long, the usual length about 1.2 mm., with five in about 6.2 mm. The length depends upon the number of cycles of zoœcial apertures. These are commonly only three, but four cycles are not infrequent. Lateral articulating sockets apparently wanting in this set. Otherwise very similar to the primary series. The papillose ornamentation of the surface however is generally more regular.

*In the original description I say "six-sided", but this proves to be an error.

Compared with other species *A. armatum*, of the Galena shales, has larger and much longer segments, six or seven rows of zoœcia, and the lower border of their apertures prominently produced. *A. striatum*, which is associated and more abundant on the same slabs, differs in having longer and differently shaped segments, smaller zoœcial apertures, generally six cycles of them, the surface striation finer and without papillæ, and in having the angles but little if at all produced at the upper extremity. *A. pulchellum* Billings, differs in a similar manner.

Formation and locality.—The detached segments of this species are rather plentiful on certain layers of the limestone plates in the lower part of the Trenton shales exposed in the railroad cut near the State University at Minneapolis.

Mus. Reg. No. 8115.

Arthroclema armatum *Ulrich.*

PLATE II, FIGS. 8-11, 25 and 28-33, and PLATE III, FIG. 7.

Arthroclema armatum Ulrich, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 194, fig. 19, a, b, c, and, d; not e, f, g, h.*

Zoarium jointed, consisting of three sets of segments, primary, secondary and tertiary, the first and second sets readily separable, the second and third probably indistinguishable in many cases.

Primary segments generally subcylindrical, often compressed and irregularly shaped, without regular longitudinal angles, the surface usually appearing as simply striated, with strong spines and zoœcial apertures indistinct; length unusually variable, depending upon the number of cycles of zoœcia in the segment, 3.0 mm. with seven cycles, 3.3 mm. with eight, 4.0 mm., the commonest size, with ten, and so on to 4.5 mm.; diameter varying with age from 0.5 to 1.0 mm.; ends truncate, the upper flat or raised centrally, the lower usually with a nipple-shaped prominence. Lateral articulating sockets deep, sharply defined, situated at or slightly above the middle of the length, so far as observed, never more than one to each segment; some are without any. Zoœcia in six ranges, their apertures oval, small, slightly oblique, easily overlooked, sometimes, especially in the vicinity of the articulating socket, closed, with seven in about 2.5 mm.; width of lateral interspaces varying with age. A strong tubercle just behind or near each aperture.

Secondary segments of about the same length as the primary set, usually about 3.6 mm. They are, however, more slender, none being more than 0.5 mm. in diameter, ranging from that down to 0.3 mm. Upper end terminating abruptly, spinous; lower end rounded. Lateral sockets faint, centrally situated, not often detected in this set. Zoœcia rarely in five, commonly in six, occasionally in seven longitudinal

*In the original work on this species one vertical section and three transverse sections of a Canadian example of *A. pulchellum* Billings, were inadvertently given as *A. armatum*. These figures which are magnified x 25 instead of x 18, are reproduced in this volume on plate II.

rows, arranged between prominent ridges that become stronger with age. A transverse arrangement also prevails, with about seven in 2.5 mm.; according to its length from seven to twelve cycles, the usual numbers nine or ten, are to be counted in each segment. Apertures ovate, oblique, the inferior border very prominent, spine-like. With a favorable light, two exceedingly delicate striæ may be noticed in the longitudinal interspaces. These striæ are not only generally present in species of this genus, but also occur frequently in species of *Helopora*. They are not shown in figs. 10 and 11, having been overlooked.

As tertiary segments I propose to denominate a large number that seem to belong to this species but are more slender and differ in other respects from the ordinary forms of the secondary set. As a rule, they have tapering, subequal, rounded extremities, are shorter, 2.5 to 3.3 mm. long, 0.3 mm. or less in diameter, five or six-sided, the latter generally, with the angles obscure in the youngest, but becoming fairly prominent with age. At the same time the raised border of the zoœcial apertures, which at first is very thin, increases in strength and prominence. Six to eight cycles of zoœcial apertures in the length of a segment. Figure 7, on plate III, represents an average segment of this set. In still younger specimens the angle ridges are less conspicuous, while in going the other way an almost continuous chain of variation from it to fig. 10 on plate II, can be selected from the material before me.

This species is nearer *A. pulchellum* Billings, than I suspected at first. The only differences that I now would insist on are (1) the greater average length of the segments, those of the second order especially, of the present species; (2) the spine-like elevation of the inferior border of the zoœcial apertures, and (3) the less frequent branching of the zoarium. In the Canadian species, of which I have some very good material, the primary segments have almost invariably two lateral articulating sockets, while the majority of those of the second order have one at least. In *A. armatum*, however, the primaries have only one or none, and the secondaries are in most cases without any. The two species of the lower shales, *A. striatum* and *A. cornutum*, are readily enough distinguished. Both have the lateral articulating sockets situated lower on the segments; the former has, furthermore, smaller zoœcial apertures, more numerous and finer surface striations and only five instead of six ranges of zoœcia in the secondaries. The segments of *A. cornutum* are of a different shape and much shorter.

If complete zoaria of this species could be studied, it would not surprise me if they proved that the curved and tapering segments which I have named *Helopora mucronata*, and which are found in the same beds, are really parts of this *Arthroclema*.

Such a possibility may seem remote, yet its realization is rendered almost probable by the recent discovery of similarly curved and pointed segments that belonged unquestionably to the tertiary series of a small example of *A. pulchellum.*

Formation and locality.—Galena shales, near Cannon Falls, Minnesota, where it is associated with many other small Bryozoa. Also in the upper shales at St. Paul, Minnesota.

Mus. Reg. No. 8116.

ARTHROCLEMA, *sp. undet.* (1).

PLATE II, FIGS. 26 and 27.

This species is represented in my cabinet by five segments collected from the Trenton shales near Fountain, Minnesota. It may be distinct, but the material at hand is insufficient for the foundation of a species of this genus. Figures 26 and 27 (plate II) represent the two offering the greatest differences shown in the lot. One is incomplete, having lost the two upper cycles of zoœcia. It was evidently a younger segment than the other, being less coarsley marked, with the angle ridges straighter and more prominent. One of these segments shows a lateral scar situated near the center, but it is very faintly impressed and easily overlooked. The zoœcia form six rows, but one segment seems to have had only five, with rather large, oblique apertures; aside from the incomplete segment (fig. 26) the transverse arrangement of the apertures in the others is more or less irregularly spiral; five apertures, one at the extreme top, is the usual number in the segment length. Inter-apertural spaces rather irregularly grano-striate. Length of segments about 2.4 mm., diameter of same 0.35 to 0.4 mm.

The species to which these segments belong is probably a close ally of *A. pulchellum* Billings, on the one hand, and *A. striatum* on the other. These relations, however, cannot be determined satisfactorily until more complete collections are available.

ARTHROCLEMA, *sp. undet.* (2).

PLATE III, FIGS. 35-37.

Of this form, which is evidently related to the preceding and to A. *pulchellum* Billings, but, so far as I can see, not identical with either, I have over twenty-five more or less imperfect segments. These vary in length from 1.7 to 2.3 mm., and in diameter from 0.3 to 0.5 mm. In several a faint, centrally situated, lateral socket is distinguishable, and in most of them the zoœcial apertures, of which there are four or five cycles and six longitudinal rows, are inclined to be irregular in their arrangement. A number of specimens are preserved as casts of the interior, and in these (see plate III, figs. 36 and 37) a spiral arrangement of the zoœcia commonly prevails. The surface is striated, especially on the more regularly constructed segments, very much as in *A. pulchellum.* Though inclined to regard it as an illy nourished variety of that species, with shorter and more slender segments, I prefer, for the present, to leave the form unclassified specifically.

All the specimens of this form were collected by me in the upper part of the Trenton shales at St. Paul, Minnesota.

Genus NEMATOPORA, Ulrich.

Nematopora, ULRICH, 1888, The American Geologist, vol. i, p. 234; 1890, Illinois Geol. Surv., vol. viii, pp. 401 and 644.

Zoaria very slender, branching, continuous above the pointed basal extremity. Zoœcia subtubular, short, arranged in a radial manner around one or two exceedingly minute axial tubes. Apertures arranged in longitudinal series between smooth or granulose ridges, nearly direct, generally elongate-ovate and enclosed by a thin peristome. One or two diaphragms occasionally present.

Type: *N. ovalis* Ulrich (*N. quadrata* Ulrich, Ill. Geol. Surv., vol. viii, 1890).

Of this genus we now know about fourteen species. Seven of these are from Trenton rocks, one (undescribed) from the Cincinnati and Hudson River groups, five from the Anticosti, and one, *N. minuta* Hall, sp., from the Niagara of Indiana.

The genus differs conspicuously from the other generic types included in the *Arthrostylidæ* in having the zoarium continuous and dichotomously branched, the jointed character prevailing in the family being confined to the basal extremity. This part of the zoarium is, however, known of only one or two of the species, and it may yet be proven that in some of the species there is no basal articulation. But in the meantime, especially since the various forms agree very closely in zoœcial features, we may assume that the lower extremity was pointed and articulated with a small basal expansion. The relations to *Helopora*, Hall, are therefore very nearly the same as between *Escharopora*, Hall, and *Arthropora*, Ulrich.

NEMATOPORA OVALIS *Ulrich.*

PLATE III, FIGS. 24 and 25.

Nematopora ovalis ULRICH, March, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 197.
Nematopora quadrata ULRICH, Dec., 1890. Ill. Geo. Surv., vol. viii, p. 644.

Original description: "Zoarium ramose; branches birfurcating at intervals of about 2 mm., 0.3 to 0.4 mm. in diameter, subquadrangular or pentagonal in cross-section, each face with a row of zoœcia. Zoœcial apertures direct, very large, oval, nearly 0.3 mm. long by 0.15 mm. wide, enclosed by a sharply defined peristome. A short ridge joins the peristomes of each row of apertures, and longitudinally divides the concave spaces between the ends of the apertures. These spaces are larger in the subquadrate examples than in those having five rows of zoœcia. They also have the thin ridge that bounds each face more distinct from the elevated margins or peristomes of the zoœcial apertures, which, in the pentagonal specimens, to a large extent also form the border of the faces. Longitudinal interspaces generally shorter than the length of the zoœcial apertures; about five of the latter in 2.5 mm."

Careful comparisons between the New York types of *Nematopora quadrata* (*loc. cit.*) and the originals of *N. ovalis* have convinced me of their specific identity. My belief that the latter had larger zoœcia proved incorrect, and as many of them have also the double ridges at the angles of the branches, which were regarded as the main peculiarity of the former, nothing is left to distinguish them. It is to be admitted, however, that none of the New York examples of the species so far seen have more than four rows of zoœcia.

The large size of its zoœcial apertures will distinguish *N. ovalis* from the three species next described. *N. lineata* Billings, sp., of the Anticosti group, is a larger species with six or seven rows of zoœcia.

Formation and locality.—Galena shales, near Cannon Falls, Minnesota; Trenton limestone, Trenton Falls, New York, and Montreal, Canada.

Mus. Reg. No. 8110.

Nematopora granosa *Ulrich.*

PLATE III, FIGS. 17-20.

Nematopora granosa ULRICH, 1890. Jour. Cin. Soc. Nat. Hist, vol. xii, p. 196.

Original description: "Zoarium ramose; branches bifurcating at rather long intervals, from 0.25 to 0.38 mm. in diameter, the smallest quadrangular in cross-section and with only four rows of zoœcia; those of the average size, pentagonal, and with five rows of cells. Zoœcial apertures small, narrow, about seven in each range in 2.5 mm., enclosed by a series of minute granules. Longitudinal interspaces with a small number of similar granules. Rows of apertures separated by more or less well-developed straight or slightly flexuous granulose ridges."

The papillose ornamentation of the ridges and interspaces, and the narrowness of the zoœcial apertures of this species distinguish it from all the others having the essential characters of *Nematopora* known to me. Under the microscope the general appearance of the zoarium is strikingly different from that of *N. ovalis*, with which it is associated. Equally marked differences will be noted when it is compared with *N. delicatula* and *N. conferta*, both of which likewise occur in the same beds. Externally, *N. granosa* presents not a little resemblance to small species of *Rhombo-*

ora like *R. lineinodis* Ulrich, and *R. regularis* (*Trematopora* and later *Orthopora regularis* Hall), but it is to be doubted that this resemblance is indicative of even remote relation. In *Rhombopora* the primitive cells are drawn out into long tubes which originate, just as they do in nearly all of the ramose *Trepostomata*, in various parts of the axial region. In *Nematopora*, on the other hand, the zoœcia are comparatively short and arise along a definite axial line.

Formation and locality.—Galena shales, near Cannon Falls, Minnesota.

Mus. Reg. No. 8111.

NEMATOPORA DELICATULA *Ulrich*.

PLATE III. FIGS. 26 and 27.

Nematopora delicatula ULRICH, 1890. Geol. Sur. Ill., vol. viii, p. 646.

Zoarium very small and exceedingly slender, ramose above the pointed basal extremity. Branches quadrangular, with the angles rather sharp, and the solid sides flat or gently convex, each from 0.15 to 0.18 mm. wide. Zoœcia rather long, in four ranges; apertures ovate or subcircular, about 0.12 mm. in length, separated by long, smooth intervals, each from 0.7 to 1.0 mm. in length; average length of zoœcia about 0.95 mm. Peristome thin, easily broken away; when perfect it forms a sharply elevated rim about each aperture.

The widely separated zoœcial apertures, and the exceeding delicacy and quadrangular form of the zoarium of this species distinguish it from all other species of the genus known. The associated *N. ovalis* often has only four ranges of zoœcia, but their apertures are so much larger that the two species cannot be confounded. The possibility of confusion with *N. granosa* and *N. conferta* is equally remote. Indeed, all of these four associated species are distinguished by sharply marked and easily recognized peculiarities.

Formation and locality.—Galena shales, near Cannon Falls, Minnesota. The original types of the species were collected from an equivalent horizon in Alexander county, Illinois.*

NEMATOPORA CONFERTA *Ulrich*.

PLATE III, FIGS. 21-23.

Nematopora conferta ULRICH, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 198.

Zoarium ramose, spreading nearly in a plane; branches dividing dichotomously at intervals varying from 1 to 3 mm., 0.4 to 0.5 mm. in diameter, subcircular in cross-section. Zoœcia in five or six longitudinal ranges, their apertures frequently arranged

*In the Ill. Geol. Surv. vol. viii, this horizon is given, in conformity with the preceding volumes of publications of that survey, as Cincinnati group, but at the top of p. 645 (*op. cit.*) it will be seen that I express a doubt as to their exact age, saying that "I am inclined to regard them as more likely representing an upper member of the Trenton group." I have now satisfied myself that they are equivalent to the Galena of the Northwest and the Trenton limestone of New York.

also in rows encircling the stems. Apertures rounded or broad-oval, slightly oblique, about 0.15 mm. in diameter, separated lengthwise by intervals a little greater than their diameters, with seven or eight in 2.5 mm.; peristomes thin, strongest and most elevated posteriorly. Interspaces striated, occasionally rising into strong ridges which separated the longitudinal ranges of zoœcial apertures for a short distance.

The smaller, subcircular apertures and differently marked interspaces, distinguish this species from *N. ovalis*. In *N. granosa* the zoœcial apertures are much narrower and alternately arranged, while the interspaces are papillose. *N. alternata* Ulrich, from a similar horizon in southern Illinois, has the zoœcial apertures arranged in quincunx, and differs in other obvious particulars.

Because of the rounded zoœcial apertures and their prevailing mode of arrangement, the branches of this species sometimes resemble those of *Protocrisina exigua* Ulrich, a cyclostomatous form that is associated with it at Cannon Falls. This resemblance may prove a little troublesome when the surface of the *Nematopora* is slightly abraded so that the striation of the interspaces is obscured. In all cases, however, when the specimens can be observed free from the matrix they may be distinguished at once by the fact that in the *Nematopora* the surface is celluliferous on all sides, while in the *Protocrisina* one side of the branches is striated longitudinally and *without* zoœcial apertures.

Formation and locality.—Galena shales, near Cannon Falls, Minnesota, where it is associated with the preceding species and many other small Bryozoa. *Prasopora insularis* Ulrich, is the commonest and most characteristic fossil of this horizon.

Family PHYLLOPORINIDÆ, Ulrich.

The genera comprised in this family, *Phylloporina*, *Drymotrypa* and *Chainodictyon*, are not very important in the way of specific and individual representation, but viewed from a biologic standpoint they are decidedly interesting. This interest attaches chiefly to the fact that they furnish excellent examples of what have been very aptly termed "comprehensive types."

A careful investigation of the internal structure of the various species of *Phylloporina* leads us to the conviction that at some time prior to the age of the Chazy there existed Bryozoa that combined characters which, during subsequent periods, became separately specialized and characteristic of widely different groups of families. Take, for instance, *P. trentonensis* Nicholson, sp., or *P. sublaxa*, *P. halli* and *P. corticosa* of the present work. In all of these remarkable forms we are reminded very strongly of typical *Trepostomata*, the subangular zoœcial tubes, their long "immature" region, diaphragms, mesopores and acanthopores being, all of them, characteristic of species of that suborder.

On the other hand, in *P. aspera* Hall, *P. reticulata* Hall, *P. dawsoni* Ulrich, and *P. asperato-striata* Hall, the zoœcial tubes are shorter and thus approach the ordinary cryptostomatous cell more nearly. Indeed, *P. dawsoni* can be, I think, shown to be the first recognizable stage in the line of development that later on resulted in the highly diversified *Fenestellidæ*. This same species, however, and the remark applies with equal force to *Drymotrypa dichotoma* Ulrich, has much to remind us of *Cyclostomata* like *Protocrisina*, the zoœcial orifice being but little constricted and the enclosing rim similarly prominent in all of them.

We can show, therefore, apparent relations to three suborders of Bryozoa, and it becomes a question of some difficulty to decide where the family had best be placed. The *Cryptostomata*, however, seem best adapted to receive them, chiefly for the reason that the *Phylloporinidæ* and *Fenestellidæ* are doubtlessly derived from the same stock, and the latter developed from the branch of the former mentioned.

Genus PHYLLOPORINA, *Ulrich*.

Retepora, as applied by various authors to Lower and Upper Silurian anastomosing Bryozoa (not Lamarck, 1801).
Gorgonia ?, HALL, 1847, (not Gorgonia Linnæus, 1745).
Intricaria, HALL, 1847; MILLER and DYER, 1878, (not Defrance, 1823).
Phyllopora (part.), ULRICH, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, p. 150.
Nov. gen. (undesc.), ULRICH, 1886. Contri. to Amer. Pal., vol. i, No. 1, p. 5.
Phylloporina, ULRICH, 1890. Geol. Surv. Ill., vol. viii, pp. 399 and 639.

Zoaria retiform, consisting of somewhat irregularly anastomosing, slender branches, with from two to eight ranges of zoœcia on the obverse side. Reverse convex, longitudinally striated, without apertures. Zoœcia tubular, often with the immature region very long, commonly with diaphragms. Apertures simple, unconstricted, rounded or subangular, generally with a peristome. Mesopores present, sometimes numerous, always closed at the surface; with diaphragms. Acanthopores often present.

Type: *P. trentonensis* (*Retepora trentonensis* Nicholson,* compare *Retepora fenestrata* Hall†).

This genus includes some of the earliest types of Bryozoa known. Beginning in the Chazy with three closely related species, the genus continues in the Birdseye and Trenton with six or seven well-marked forms, four of which are described in the following pages. In the Cincinnati group we have two species, in the Clinton one, and in the Niagara one. The genus is not known from later deposits.

The affinities and natural relations of the genus have already been touched upon in discussing the family. There remains to compare with *Retepora*, Imperato,

*Geological Mag., vol. 2, p. 37, 1875.
†Third Report N. Y. St. Mus. Nat. Hist., p. 178, 1850.

and *Phyllopora*, King, two genera that previous to 1888 were commonly employed in designating species of *Phylloporina*. The three genera agree in having similarly anastomosing zoaria, but the first belongs unquestionably to the *Chilostomata*, and is not known in rocks earlier than the Cretaceous. In the second the zoaria are short and constructed in every respect like those which characterize the *Fenestellidæ*. *Phyllopora* was not derived from the Lower Silurian *Phylloporina*, but from some type of *Polypora* subsequent to the extinction of the Silurian forms. Yet I am much inclined to believe that all three genera were derived successively from the same primal stock—not from each other—and that we have here merely a case illustrating the "tendency to variation in certain directions."

Compared with *Drymotrypa*, Ulrich, a genus beginning in the Trenton, and continuing to the Lower Helderberg, the present genus is distinguished chiefly, perhaps solely, by the anastomosis of the branches, these being dichotomously branched and free in *Drymotrypa*. In the Carboniferous genus *Chainodictyon*, Foerste, the zoœcia are somewhat shorter, and the back or "reverse" flatter and marked concentrically instead of longitudinally.

Phylloporina sublaxa *Ulrich.*

PLATE IV, FIGS. 1-7.

Phylloporina sublaxa Ulrich, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 179.

Zoarium an undulating flabelliform expansion, attaining a diameter of 5 cm. or more, consisting of irregularly inosculating slender subcylindrical branches, varying in width from 0.3 to 0.6 mm., but averaging about 0.45 mm. Fenestrules large, subacutely elliptical, varying considerably in shape and size, generally two or three times longer than wide; measuring, longitudinally, the average number in 1 cm. is between five and six; transversely, nine or ten in the same space. These measurements apply to the Tennessee specimens. In the Minnesota form of this species the fenestrules are smaller, averaging between six and seven in 1 cm. lengthwise.

Reverse of the Tennessee specimens strongly rounded, nearly smooth, or with faint longitudinal striæ. In very young examples the latter would probably be more distinct. Figure 2 on plate IV represents an enlargement of the reverse of a small fragment obtained from the lower part of the limestone at Minneapolis, Minnesota, by splitting a block of limestone. As usual under such conditions the outer layer of sclerenchyma has adhered to the opposite side of the matrix and exposed a more youthful stage in the development of the zoarium, in which the reverse side was strongly striated.

Obverse face of branches strongly convex, carrying three to five rows of zoœcial apertures. These are subcircular, with a scarcely appreciable peristome, 0.09 mm. in diameter, and twenty-three to twenty-five in 5 mm. in each row. Interspaces depressed, generally forming distinct pits between the ends of the cells. Sometimes obscure raised lines may be detected between the rows of apertures. Acanthopores small, usually abundant, with no definite arrangement.

Thin sections show that the tubular primitive portion of the zoœcia, which is long and prismatic, is often intersected by from one to three diaphragms. Just before bending outward to open at the surface the tubes become rounded, leaving irregularly shaped interspaces or shallow mesopores. It is here also that the acanthopores are developed.

In some respects this species occupies an intermediate position between *P. trentonensis* Nicholson, sp., and *P. granistriata* Ulrich, both of which occur in higher beds of the Trenton, proper. The first is more robust, with stronger branches, more numerous rows of zoœcia, and the primitive portion of the zoœcia longer and straighter. The zoœcial apertures are also more angular. The second has more rigid branches, longer and narrower fenestrules, and the reverse side of the branches grano-striate and on the whole more delicately marked. The fenestrules of *P. reticulata* Hall, sp., are so much smaller that even very small fragments may be distinguished at once.

Formation and locality.—The Tennessee type specimens are from the Glade limestone at Lebanon and La Vergne. Fragments of probably the same species occur in the "Pierce limestone" at Murfreesboro. The Minnesota examples were obtained from the lower part of the limestone at Minneapolis.

Mus. Reg. No. 5954.

Phylloporina reticulata *Hall.*

PLATE IV, FIGS. 8–15.

Intricaria reticulata Hall, 1847. Pal. N. Y., vol. i, p. 17.
Phylloporina reticulata Ulrich, 1890. Ill. Geol. Surv., vol. viii, pl. LIII, figs. 2, 2*a*.

Specimens as seen, consisting of small, flat or undulating, reticulate expansions, being in each case evidently fragments of a depressed, funnel-shaped zoarium, probably not exceeding 5 cm. in diameter. Branches rounded in section, 0.2 to 0.3 mm. in diameter, inosculating at unusually frequent and regular intervals. Fenestrules somewhat elongate, about as wide as the branches, subrhomboidal in shape in the more regularly constructed fragments; their number in a given space is fairly constant, the extremes noticed in 1 cm. being ten and twelve. Reverse of branches convex, finely striated lengthwise.

Obverse strongly convex, with three rather irregular rows of zoœcia, their apertures subcircular, with a distinct peristome, about 0.1 mm. in diameter, eight or nine in 2 mm. Acanthopores abundant, irregularly distributed, rather large, especially so in the earliest forms of the species. Interspaces slightly concave, occasionally faintly pitted and striated.

In tangential sections the zoœcia are rather short, with a row on each side directed obliquely outward, and one series between them. The latter are wedge-shaped, and in deep sections appear as a more or less narrow central space. Diaphragms, one in each tube, have been observed.

None of the other Minnesota species of the genus are closely related. All of them are larger and stronger in both the branches and fenestrules. Nor are any of them found in the same beds with *P. reticulata*.

Formation and locality.—Both the geological and geographical distribution of this species is extended. It was described originally from the Trenton limestone of New York, and in that position occurs also at many localities in Canada and Vermont, and at one or two points near Cannon Falls in Minnesota. In this state, however, a form occurs in the lower and middle thirds of the Trenton (Birdseye) shales at Minneapolis and St. Paul, that is indistinguishable. As yet it has not been found in the upper third of the shales, but, as stated, it reappears in the Galena shales (typical Trenton) near Cannon Falls. It is not improbable that *P. clathrata* (*Intricaria clathrata* Miller and Dyer), of the Cincinnati group of Ohio and Kentucky, is not specifically distinct from *P. reticulata*. At any rate I have so far failed to detect sufficient points of difference.

Mus. Reg. No. 5955.

Phylloporina halli *Ulrich.*

PLATE IV, FIGS. 16-21.

Phylloporina halli Ulrich, 1890. Jour. Cin. Soc. Nat. Hist., vol. xii, p. 181.

Original description: "Zoarium an undulating foliate expansion of unknown dimensions; the largest fragment seen is 3.5 cm. in diameter; thickness of strongest varying between 1.5 and 2.0 mm. Branches scarcely distinguishable as such, the zoarium having the appearance of a perforated plate rather than consisting of inosculating branches.

"*Reverse* with the fenestrules small, subcircular or oval, arranged more or less regularly in longitudinal and diagonal series, with from eight to ten in 1 cm. either way. When the arrangement is regular they are approximately of the same size, but when that is not the case some may be much smaller than the average. The latter are about 0.4 mm. in diameter. Over portions of old examples there may be a secondary deposit of sclerenchyma which occasionally fills the fenestrules completely. Such deposits are, however, much less frequent than upon the celluliferous face. Branches convex, smooth, with an average width of 0.65 mm. Occasionally one may be swollen to twice that width.

"*Obverse* generally presenting a very irregular appearance. This is largely due to irregular, noncelluliferous deposits of sclerenchyma that occur at variable intervals. The fenestrules, however, also seem less regularly arranged than upon the reverse face. Surface of branches strongly convex, carrying from three to six or more rows of alternating and scarcely circular zoœcial apertures. These are about 0.09 mm. in diameter, without peristomes, and separated by intervals of less width generally than their diameter. Some of the interspaces are a little prominent. These may have contained acanthopores. Five or six cell apertures in 1 mm.

"Although the preservation of the material is not the best for microscopical determination of internal characters, thin sections still bring to light the more salient features. They show that the zoœcial tubes are intersected by numerous diaphragms; that near their apertures they are still prismatic, resembling the zoœcia of a Monticuliporoid, and that a few small cells, perhaps acanthopores, are scattered among the true zoœcia.

"This is an easily recognized species, being also quite distinct from all the others of the genus known. In its proportions it is somewhat like *P. corticosa*, from the same horizon, but they are not likely to be confounded, the strong carinæ on both sides of the branches in that species serving amply in distinguishing them."

Formation and locality.—Rather rare in the upper third of the Trenton shales, at St. Paul, Minnesota.

PHYLLOPORINA CORTICOSA *Ulrich.*

PLATE V, FIGS. 1-10.

Phyllopora ? corticosa ULRICH, 1886. Fourteenth Ann. Rep. Geol. and Nat. Hist. Surv. of Minn., p. 61.

Zoarium reticulate, arising from an expanded base, at first funnel-shaped and poriferous on the outer side, later on becoming irregularly undulating. Poriferous side presenting the appearance of a *Fenestella* or *Semicoscinium* with strongly carinate and more or less flexuous anastomosing branches, and much depressed dissepiments. Width of branches varying from 0.35 mm. to 0.9 mm., but averaging about 0.5 or 0.6 mm.; thickness of branches and frond varying between 1.0 and 1.6 mm.

Obverse: On each side of the sharp, and, apparently, spiniferous median ridge, there are rarely one, usually two, rows of irregularly alternating, circular peristomate zoœcial apertures, with nine or ten in each in 2 mm. As a rule, the dissepiment-like connections between the branches are short, depressed, and may or may not carry a small number of zoœcial apertures distinct from the series belonging to the branches. Occasonally this division of the frond into rigid or flexuous branches and depressed dissepiment-like connections is not recognizable on all parts of the fronds. In such cases the branches anastomose rather irregularly and are simply convex, not carinate, the median ridge being absent. Fenestrules small, irregular, narrow, often indented by the projecting zoœcial apertures.

Reverse of branches very finely striated, tending, though less strongly than on the obverse face, to form median longitudinal ridges. Fenestrules varying in outline from elongate-elliptical to subcircular, their width rarely more, usually a little less than that of the branches, their length from one to three times the width; measuring transversely, six or seven in 5 mm.; longitudinally, the average number in the same space is three.

Tangential sections, cutting the frond parallel with the plane of its expansion and near the middle of its thickness, show that the branches are generally divided into approximate halves by an obscurely double vertical lamina, thicker than the walls of the zoœcial tubes diverging slowly from it toward each side. The tubes have thin walls, are long, and crossed by straight lines representing diaphragms. The number of the latter depends upon age. Where the section divides the tubes just beneath their apertures they are rounded or subangular, with slightly thickened walls, partially separated from each other by solidly filled interspaces or mesopores, that may be considerably smaller or even a little larger than the true zoœcia. Here and there, along the middle of the branches, a small acanthopore may be detected.

Vertical sections show that the zoœcial tubes arise also from a thick, laminated, basal layer, from which they diverge in an upward and outward direction. Their course toward the surface is very gradual in the lower half of the branch, but in the upper half the curve is slightly accelerated so that their apertures are nearly direct at the surface. Several diaphragms occur in the prostrate or primitive portion of each tube and in young examples (plate V, fig. 10) they may be absent in the more erect superficial portion. With age, however, additional diaphragms, now the diameter of a tube distant from each other, are introduced. Near the surface the tubes separate, leaving obconical interspaces, which are subsequently filled with solid or laminated tissue.

In transverse sections the branches are subrhomboidal, the lateral diameter being the shortest. The median ridge is shown to be an extension of the double vertical wall already mentioned. Between the two laminæ forming this wall, a series of very minute tubuli, similar to those found between the median laminæ of many bifoliate Bryozoa, may be observed. On each side of this mesial wall the zoœcial tubes are piled over each other, in one or two series, three or four high. These and other characters are well shown in fig. 9 on plate V.

This is a very remarkable species, and probably the most "comprehensive" type known to me among the Bryozoa. That its place is with *Phylloporina* will, I believe, be recognized at once, since it embraces every essential character of the genus. But it has others that are not possessed by any of the other species. Chief among these is the mesial ridge of the branches that brings to mind *Semicoscinium* and *Fenestralia* of the *Fenestellidæ*. As shown, this ridge is the superficial extension of a double median lamina constructed upon the same plan as in the *Rhinidictyonidæ*. Of course there is a difference in this that in the ordinary bifoliate Bryozoa the median lamina is horizontal while in the *P. corticosa* it is vertical to the plane of expansion. We find however precisely the latter condition in *Goniocladia*, Ethridge, jun., a Carboniferous genus with relations to the *Cystodictyonidæ*, and in *Reticulipora*, d'Orbigny, a Cretaceous genus of the *Cyclostomata*. If we add to these peculiarities the general resemblance of the zoœcial tubes of *Phylloporina* to those of ordinary *Trepostomata*, and the common possession of mesopores and acanthopores, we are confronted in *P. corticosa* by, to say the least, an unexpected mixture of characters. These facts are not mentioned because they are believed to indicate true relationships among the diverse types enumerated. On the contrary, it is more than doubtful that any two of them belong to the same line of development. Still, there is more than mere coincidence in the combination of characters seen in *P. corticosa*, and in the genealogical studies that will be in order sooner or later, they should be borne in mind.

Formation and locality.—Upper third of the Trenton shales, near Oxford Mills, Goodhue county, Minnesota, where it is abundant. A few specimens have been found also at St. Paul, in equivalent beds.

Mus. Reg. No. 3495.

Suborder TREPOSTOMATA, Ulrich.

In nearly every respect this suborder is to be considered pre-eminent among the Bryozoa of the Lower Silurian rocks; and this is as true of those in the lower horizons of the system as developed in Minnesota, as it is of those that have been so long known in the Cincinnati rocks. As was stated in the introduction, the lower beds holding Bryozoa in Minnesota are really very near the apparent inception of the class, the oldest forms known being from the Chazy. This fact should not be forgotten when the characters of the species and genera seem unstable and troublesome to classify. That is to be expected, because, near their point of origin all classes of animals sufficiently studied may be shown to have been unsteady in their development, new features having been introduced or dropped with surprising rapidity and frequency. Some of these, at first wavering characters, later on, when the class became fully established, assumed fundamental importance.

In the Minnesota shales, the minor or generic types of structure especially were as yet most unstable, and the mixture that resulted in consequence is sometimes so great and perplexing that it is perhaps impossible to do full justice to the affinities of many species by any known practical method of classification.

The nearest approach probably to this desirable end is to be attained by the strictly genealogical system of classification, which I may confess I am more than inclined to adopt fully. The intricacy of this comparatively new and little understood system seems to be the chief bar to its early and complete acceptance by naturalists. And yet, so far as my experience goes, there is nothing very simple in the ramifications of organic differentiation. On the contrary, forms are so intertwined in their relations that to unravel them is a matter of the utmost difficulty and patient inquiry. One of the more common of these difficulties is when we find a number of forms agreeing apparently closely in all characters assumed to be generic, and of which we have traced out the derivation of each so that we know them to have originated in different stocks or lines of development. Among many cases of this kind, that of *Homotrypella ? ovata* may serve as an example. This species has all the *essential* characters of *Homotrypella*, and yet I believe I can show conclusively that it represents a departure from a line that originated in *Homotrypa* and later on, indeed soon, developed into the *Eridotrypa mutabilis* Ulrich, group of species.

We know other species as well that stand in similarly equivocal relationship to *Homotrypa*. A careful study of these brings us to two conclusions: (1) *Homotrypa* generally manifested an inherent tendency to variation in that direction (*i. e.* to develop mesopores), and (2) that such forms as *Homotrypa similis* Foord, are to be regarded as *reversions* from the line of *Homotrypa-Eridotrypa*. Some of the questions involved would be more easily answered were it not for the almost contemporaneous existence of the variously differentiating types.*

*My studies have served in a number of instances to throw light upon several as yet little developed thoughts in evolution. Chief among these is the one occasionally referred to by me as a "Tendency to variation in certain directions." This expression may sound simple enough, but the conditions expressed, providing they have been read aright, are really of great importance in the classification of animal nature. Of course I cannot here enter into a full discussion of the theory, but a few ideas and facts bearing upon it seem desirable.

As results of presumed "tendencies" we find conditions that may be expressed as follows: After a species has once thrown off varieties of certain kinds, and these have died out, you may expect similar variations from continued decendants of the type or species. Cases: (1) *Dekayella prænuntia* and varieties, and corresponding *D. ulrichi* and varieties (see remarks under description of *Dekayella*); (2) the lower and middle Trenton species of *Callopora, ampla, pulchella, persimilis* and *dumalis*, described on succeeding pages, corresponding respectively to species *subplana, dalei* and *ramosa*, and an undescribed species, of the Cincinnati rocks; (3) the Lower Helderberg and Devonian species now classed as *Thamniscus*, though derived, like the more typical Carboniferous and Permian species of that genus, from *Polypora*, are not the *direct* ancestors of the latter, the first set of species having died out before the second were evolved; (4) *Fenestella* exhibited a continual tendency to throw off varieties and species that gradually assumed the characteristics of *Polypora*. Many other cases might be cited, but if those mentioned are followed up by the student I have no doubt he will find enough to convince himself that tendencies in variation or evolution were preserved dormant under retrogression, but manifested quickly enough when the proper conditions were presented. May not this idea explain the peculiar reapparition of cyclostomatous types discussed on pp. 121 and 122?

Two other thoughts have suggested themselves in this connection. The first is that varieties and species were in some instances reabsorbed into the parent stem. The other relates to an *approximation in structure* (1) by contemporaneous forms or species that have had a common origin (*e. g. Callopora undulata, C. incontroversa, C. angularis* and *C. ampla*, all varying toward *C. multitabulata*), and (2) by forms known to have been derived through different lines of development gradually assuming similar characters, as in the case of *Homotrypa minnesotensis-Homotrypella ? ovata* above described.

On plate XIX the figures up to No. 19 give an idea of the beginning of the line of development referred to in the latter part of the paragraph preceding the last. In *Homotrypa minnesotensis* we have what must still be regarded as a true species of the genus.* Even here, as shown in fig. 3, a tendency to interpolate mesopore-like interspaces is occasionally manifest. In *H. exilis* this tendency is more strikingly expressed and permanent, (see figs 13–16), while in *H. separata* it has progressed to such an extent that the zoœcia are rounded in shape instead of angular. These three forms all occur in the lower third of the Trenton shales. In the middle third we find a fourth stage in the development toward the Galena shales species provisionally called *Homotrypella ovata*. This fourth stage has been named *Homotrypa* (?) *intercalaris* and, as may be seen from the cut on a succeeding page, its characters are very nearly intermediate between those of the species *separata* and *ovata*.

Difficulties like these were encountered all through my work on the Minnesota Bryozoa, and now as it nears completion I realize, probably better than any one else can, that the result, despite my utmost efforts, is not final nor even entirely satisfactory in some parts. Had I followed my inclination and adopted a genealogical arrangement throughout it might have been better, because I believe it would have proven more permanent. But the criticism sometimes made that individual peculiarities are magnified into specific, and specific into generic, seemed to indicate a state of knowledge not sufficiently advanced for the proper appreciation of all the innovations that it would have been necessary to enter into. Perhaps I ought not to have noticed criticisms which, like these, originate in ignorance of the fact that characters preserved in hundreds of specimens are not to be viewed as "individual." But I have done so, and now must hope that the use of the interrogation point in cases of the kind discussed may be deemed sufficient for immediate needs.

To prohibit repetition as much as possible I shall, in the course of the following pages, frequently refer the student to the preceding paragraphs.

Family MONTICULIPORIDÆ, Nicholson, emend. Ulrich.

This family is strongly represented in the Lower Silurian rocks of Minnesota, there being here one or more species of every genus included in the family except *Peronopora*, Nicholson. The individuals of the species too are generally abundant, especially those of *Prasopora* and *Homotrypa*, so that they constitute no inconsiderable part of the collections from the various horizons.

H. subramosa, illustrated on the same plate, is more nearly like the prevailing Hudson River group types of the genus.

The principal and almost infalliable distinguishing peculiarity of the family is the cystiphragm. As a rule these structures form continuous series in the zoœcial tubes, and in all such cases their nature is at once determinable in either vertical or tangential thin sections. But in the genera *Monticulipora* and *Mesotrypa* they are often modified so that they might be mistaken for simple, oblique or slightly curved diaphragms. On plate XV figures 8 and 9 illustrate the latter, while of the usual form of the cystiphragms many examples are figured on plates XV to XIX.

Genus MONTICULIPORA, d'Orbigny.

Monticulipora, d'ORBIGNY, 1850. Prodr. de Paleont., t. i, p. 25.
Monticulipora (part.), NICHOLSON, 1879. Struct. and Affin. of the Pal. Tabulate Corals, p. 269.
Peronopora (part.), NICHOLSON, 1881. "The Genus Monticulipora," p. 215.
Monticulipora, ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, pp. 153 and 232; 1890, Geol. Surv. Ill., vol. viii, pp. 370 and 407.

Zoarium massive, lobate, subramose, laminar, incrusting, or frondescent. Surface usually tuberculated, sometimes even. Monticules closely arranged, usually conical, often elongated or compressed. Zoœcia polygonal, generally rather small, with thin and, internally, peculiarly granulose walls. Mesopores few, generally absent entirely. Cystiphragms present in the zoœcial tubes, both in the axial and peripheral regions of the zoarium, usually in continuous series, but often isolated. Acanthopores small, more or less numerous.

Type: *M. mammulata* d'Orbigny.

As now restricted this genus embraces but a small part of the incongruous material for which the genus was a receptacle from the day it was established. Still, no less than eighteen species having the essential characters of *M. mammulata*, all of them Lower Silurian save one, are known to me. The earliest of these is from the Birdseye limestone, and several belong to the Trenton proper; but it is in the Hudson River rocks that the genus has its strongest development. So far the genus is not known in Upper Silurian deposits, and it is possible that all its species became extinct at the close of the Lower Silurian. If that should prove to be true the *M. winchelli* Ulrich, described from the Hamilton of Michigan, could not be retained as a true member of the genus, since its line of development would necessarily be different.

Monticulipora wetherbyi *Ulrich*.

PLATE XV, FIGS. 7 and 8.

Monticulipora wetherbyi Ulrich, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 239, pl. X, figs. 4-4*b*; 1889, Contri. to the Micro-Paleon. of the Cambro-Silurian Rocks of Canada, pt. ii, p. 30.

Zoarium attached to foreign objects, forming thin crusts or small depressed-conical masses. Surface gently monticulose, sometimes nearly even. Zoœcia polygonal, with very thin walls, the diameter of those of the ordinary size about 0.25 mm. Clusters of larger cells attaining a diameter of from 0.3 to 0.38 mm. occupy the summits and slopes of the monticules, or in the smooth forms are scattered over the surface at intervals of about 2.5 mm., measuring from center to center. A few small cells (? mesopores) may be detected, especially at the center of the monticules, but they are always an inconspicuous feature and being of various sizes are probably to be regarded as merely young zoœcia. Acanthopores rather large and numerous in the original Kentucky types of the species, small and few in the northwestern form.

In longitudinal sections the zoœcial tubes have thin walls with the granulose structure characteristic of the genus. The transverse partitions, occurring at intervals of a tube-diameter or more in the lower half of the tubes and little more than a third of that distance apart near the surface, seem really to be all of the nature of cystiphragms, though frequently appearing in the sections as straight diaphragms. In transverse sections the tubes are angular and thin-walled, with strong acanthopores—one at most of the angles—in the Kentucky specimens, and much smaller and fewer ones in the Minnesota and Manitoba form of the species. The cystoid nature of the diaphragms is generally recognizable in these sections, but the cresentic line, which is the unfailing mark of these structures, may not be detected except in only a few of the zoœcia.

Formation and locality.—Rare in the Birdseye limestone of central Kentucky. A single example was found in the lower limestone at Minneapolis. The species also occurs at St. Andrews, Manitoba.

Mus. Reg. No. 5967.

MONTICULIPORA INCOMPTA, *n. sp.*

PLATE XV, FIGS, 9-12.

Zoarium parasitic, forming inconsiderable crusts or small masses upon shells, 1 or 2 cm. in diameter and several mm. thick. Surface even, with inconspicuous clusters of cells of slightly larger size than the average. Zoœcia polygonal, with thin walls (comparatively thick for the genus), the ordinary size varying between 0.2 and 0.25 mm, in diameter, while those in the clusters mentioned do not exceed 0.32 mm.; about eight in 2 mm. True mesopores wanting, the small cells being shown by thin sections to be merely young zoœcia. Acanthopores small, inconspicuous externally.

The internal structure is so well illustrated on plate XV that a detailed description is rendered superfluous. The chief peculiarity of the species is the minutely cellulose and roughish character of the zoœcial walls. In all other respects the species agrees closely enough with *M. wetherbyi* and *M. lamellosa* Ulrich, the latter from the Hudson River rocks of Illinois.

Formation and locality.—Rather rare in the middle third of the Trenton shales, at Minneapolis, Minnesota.

Mus. Reg. No. 5968.

MONTICULIPORA GRANDIS *Ulrich.*

PLATE XV, FIGS. 1-6.

Monticulipora grandis ULRICH, 1886. Fourteenth Ann. Rep. Geol. and Nat. Hist. Surv. Minn., p. 78.

Zoarium irregularly massive, often tending to become lobate or subramose. Zoœcia polygonal, with thin walls. Surface without monticules, but exhibiting at intervals of about 5 mm. conspicuous groups of cells larger than the average ; of the latter nine or ten occur in 3 mm, while some of those in the clusters have been observed to reach a diameter of 0.5 mm. No mesopores. Acanthopores very small, few, practically wanting. When perfectly preserved (see plate XV, fig. 4) the cystiphragms are often to be seen in the mouths of the zoœcia, giving them the false appearance of being very small and situated at the bottom of a wide sloping area.

Internal structure: In the vertical sections the zoœcial tubes proceed to the surface in straight or curved lines, according to the form of the zoarium. They are provided with thin walls and usually two more or less closely arranged series of cystiphragms, one on each side of the tube, the narrow intervening space being crossed by an approximately equal number of straight diaphragms. The variation and relative disposition of parts is shown in fig. 6 of the plate cited. The lower half of the figure is taken from the lower part of the section where the transverse partitions are less closely arranged than near the surface of the zoarium. The walls have a lineo-granose structure. Tangential sections show that the zoœcial tubes are polygonal and thin-walled, the opening left by the cystiphragms ovate or subcircular and situated laterally or subcentrally. At the angles of junction the walls are slightly thickened, and there is some evidence to show that very small acanthopores were developed at these points.

This fine species has an external resemblance to irregular examples of *M. lævis* Ulrich, from the Cincinnati group of Ohio, but the zoœcia and internal structure of *M. grandis* are so much larger and different that the relation between the two species must really be quite remote. Excepting that mesopores are wanting entirely, the interior, as brought out by thin sections, is very similar to *Prasopora contigua* Ulrich, and I have considered the advisability of referring the species to *Prasopora* rather than *Monticulipora*. For the present, however, we must conclude that the absence of mesopores and lobate-massive instead of discoid growth are features sufficient to disbar the species from *Prasopora*.

Formation and locality.—At the base of the Trenton shales and the top of the underlying limestone at Minneapolis and Cannon Falls, Minnesota. Vertical range apparently very limited.

Mus. Reg. No. 5969.

MONTICULIPORA ARBOREA, *n. sp.*

PLATE XX. FIGS. 1-9 and 13, 14.

Zoarium dendroid, rising to a hight of 4 or 5 cm.; branches subcylindrical, dividing at intervals varing between 5 and 20 mm.; surface with low monticules, or smooth. Zoœcial apertures small, subangular, enclosed by rather thick, minutely granulose walls, on which small acanthopores, one or two to each zoœcium, are to be distinguished from the numerous small granules, which, together with the acanthopores, are quickly removed when exposed to the weather. About fourteen of the cells between those occupying the monticules or those in the clusters occur in 3 mm. Mesopores wanting.

Internal characters: The tabulation of the zoœcial tubes is compact throughout, and very much so in the peripheral region. The tubes bend outward in a gradual curve from the imaginary axis, and have cystiphragms from the beginning. In the axial region these are large and about two-thirds of the tube-diameter apart, becoming gradually a little nearer to each other until the fully matured condition of the species is reached, when they recur at intervals scarcely equalling one-fourth of the diameter of the tube. They also change their shape here, the opening which had been lateral (see transverse section, pl. XX, fig. 3) is now narrower and produced so that it extends nearly across the center of the zoœcial cavity. This is shown best in tangential sections, parts of two of which are represented in figs. 4 and 6 on plate XX. Figure 4 shows the structure immediately beneath the surface, with small acanthopores and numerous smaller pores in the walls and cystiphragms. In figure 6, showing the appearance at a slightly lower level, the walls are thinner and the acanthopores apparently wanting. Figs. 13 and 14 (plate XX) represent tangential and vertical sections of a Kentucky specimen of this species in which we note an unusual condition, namely, in some parts of the axial region there is a total absence of both diaphragms and cystiphragms. In other parts of the same section, however, these structures are developed in the usual manner, so that it is allowable to assume that their occasional absence is merely an abnormal condition. The tangential section represents a condition very nearly intermediate between figs. 4 and 6 of the same plate.

In many respects this species resembles *Atactoporella ramosa*, occurring in the bed of shales next beneath, but the surface of the latter is more abundantly spinulose. Thin sections, especially tangential, are easily distinguished. The true position of the species seems to be nearer the frondescent variety of *M. mammulata* d'Orbigny, described by Nicholson from the Cincinnati rocks under the name of *M. molesta*.

Formation and locality.—Galena shales at several points near Cannon Falls, Minnesota, and at Decorah, Iowa. In Kentucky the species occurs in the Trenton shales between Burgin and Danville, and at Frankfort.

Mus. Reg. Nos. 7631, 8035. 8048, 8062.

MONTICULIPORA (?) CANNONENSIS, *n. sp.*

PLATE XX, FIGS. 10-12.

Zoarium ramose, branches subcylindrical, 6 to 9 mm. in diameter, surface even, without monticules, but exhibiting the usual clusters of large cells. These, however, are inconspicuous in this species. Zoœcia angular, with thin walls, about twelve in 3 mm. Mesopores and acanthopores apparently wanting, the occasional small cells wedged between the ordinary zoœcia being merely young or abortive.

Internal characters: All that is known of these is shown in figures 10 to 12 on plate XX. The characteristic features are (1) the greatly crowded diaphragms and cystiphragms, (2) the presence of the latter throughout the length of the tubes, (3) the unusual tenuity of the walls in tangential sections, and (4) the almost total absence and exceedingly small size of the acanthopores.

The generic position of this species is somewhat in doubt. The ramose habit of growth, and all the other characters save one, are indicative of *Homotrypa*. This character is the development and continuous presence of cystiphragms in the axial region of the zoarium. In this respect the species agrees with *M. arborea* and *M. grandis*, and differs from all species of *Homotrypa* in which these structures should be developed in the peripheral region only. Even granting the importance of this distinction it should be understood that the present arrangement of the species is regarded as provisional.

Compared with *M. arborea*, the species under consideration is distinguished by having larger zoœcia and thinner walls. The internal differences will be appreciated at once in comparing the various figures of the two species given on plate XX. *Homotrypa callosa*, illustrated on the same plate, has thicker walls, fewer diaphragms and no cystiphragms in the axial region.

Formation and locality.—Rare in the Galena shales, near Cannon Falls, Minnesota.

Genus ATACTOPORELLA, Ulrich.

Atactopora (part.), ULRICH, 1879. Jour. Cin. Soc. Nat. Hist., vol. ii, p. 119.
Atactoporella, ULRICH, 1883, Jour. Cin. Soc. Nat. Hist., vol. vi, p. 247; 1890, Geol. Surv. Ill., vol. viii, p. 370.
Peronopora (part.), NICHOLSON, 1881. "The Genus Monticulipora," p. 215.

Zoarium generally forming thin crusts over foreign bodies, rarely lobate or subramose. Surface commonly with monticules. Zoœcia with very thin inflected walls, their apertures irregularly petaloid; internally with cystiphragms. Mesopores angular, numerous, often completely isolating the zoœcia; at first open and distinctly tabulated, but, when fully matured, largely or entirely filled by a deposit of sclerenchyma. Acanthopores very numerous, varying in size with the species, encroaching more or less upon the zoœcial cavity.

Type: *Atactoporella typicalis* Ulrich.

The affinities of this genus are with *Monticulipora* on the one side and *Peronopora* on the other. From the first it is distinguished by the abundant development of mesopores and the more numerous acanthopores. These are not only usually smaller in *Monticulipora*, but they also do not inflect the zoœcial walls. In *Peronopora*, as restricted by me, the zoarium is bifoliate, and the mesopores are not filled up with age in the manner characteristic of *Atactoporella*.

There may be in all about twelve species of this genus known to me, six of which are described from the Cincinnati rocks in the papers cited above. The same series of beds afford at least two new forms, and the Trenton of Kentucky and Tennessee two more, while the Birdseye and Trenton of Minnesota add the following species to the list.

Atactoporella typicalis, var præcipta, *n. var.*

PLATE XV, FIGS. 16 and 17; PLATE XVIII. FIGS. 1-4.

This form, though much earlier, is too much like the Cincinnati *A. typicalis* Ulrich (Jour. Cin. Soc. Nat. Hist., vol. vi, p. 248, 1883), to be distinguished specifically. The resemblance is so close that the original description may, with a few trifling alterations, be made to fit the Minnesota form. Hundreds of feet of strata, however, intervene between the two horizons respectively held by the two varieties, in which the species is unknown. It would seem, therefore, to be a case of reapparition, not necessarily of the same species, but of the same type of structure, similar to the cases of *Callopora* and *Dekayella* noticed in this work.

The characters of var *præcipta* are as follows:

Zoarium forming small thin crusts, rarely exceeding 1 mm. in thickness, over ramose Bryozoa and shells. Surface minutely spinulose, without monticules, except in rare instances (see plate XVIII, fig. 4), but exhibiting at intervals of about 2.5 mm., measuring from center to center, clusters of cells slightly larger than the average between which the interspaces are also a little thicker than usual. Zoœcial apertures floriform, the walls thin and at each inflection raised into a small spine, the surface extension of an acanthopore, arranged in moderately regular, diagonally intersecting series, averaging fourteen in 3 mm. Interspaces narrowing with age, very thin, with the zoœcial walls largely in contact, the apertures direct and the mesopores small and easily overlooked in fully matured examples; thicker, with the mesopores more distinct and the zoœcial apertures drawn out obliquely in younger stages of growth. Acanthopores numerous, small but sharply elevated, situated in the zoœcial walls, four to seven, usually five or six, around each aperture.

Internal characters: In tangential sections the zoœcial walls are very thin and indented more or less sharply at from four to seven points in their circumference These inflections of the wall are emphasized by the acanthopores, one of which occurs at each point and appearing in nearly all cases to be formed on the inner side of the wall. A few of the zoœcia may be completely isolated by the intervention of irregularly-shaped mesopores, but as a rule they are in contact at limited points. The mesopores never form more than a single row, and their walls are entirely without acanthopores. The crescentic cut edges of the cystiphragms, sometimes two or even three in each, are to be seen in each zoœcium. On account of the nearly equal thickness of these edges and of the walls of the zoœcia and mesopores, it is often difficult to discriminate between the various lines shown in tangential sections. Good vertical sections are difficult to prepare, because of the tenuity of the zoarium. On plate XV, fig. 16 illustrates the characters as brought out in a section taken from a young example. The section drawn on plate XVIII, fig. 2, was prepared from the thickest specimen seen. Between these two figures the student will be able to work out the essential features without further comment. It might be well, however, to direct attention in the last figure to the infilling and contraction of the mesopores in the upper half. Also to the fact that some of the zoœcial tubes in vertical sections, and the same remark applies to all Bryozoa having cystiphragms, may *appear* to be, in part at least, crossed by complete diaphragms. This appearance however, is merely the result of the different directions in which the cystiphragms cross the various tubes shown in the section. To obtain the characteristically curved line of the cystiphragm it is necessary that the section pass nearly *across* them. When the section passes through the tube parallel with the inner edges of the cystiphragms they must necessarily appear as straight or oblique lines, thus simulating true diaphragms.

This variety differs from the typical form of the species in the following particulars: The zoœcia are a little larger, the mesopores less numerous and often of larger size, the acanthopores one or two more to each zoœcium, and the tabulation a little more compact. Compared with other species, *A. typicalis* is readily distinguished by the exceeding tenuity of the zoœcial walls, and the greater projection inward of the acanthopores. The latter are more numerous than in any of the other Minnesota species known.

Formation and locality.—The types of *A. typicalis* are from the Utica horizon of the Cincinnati section at Cincinnati, Ohio, and vicinity. The present variety *prœcipta* is from the middle third of the Trenton shales at Minneapolis, St. Paul, Fountain, and other localities in Minnesota.

Mus. Reg. Nos. 5983, 5984.

ATACTOPORELLA INSUETA, *n. sp.*

PLATE XV, FIGS. 13-15; PLATE XVIII, FIGS 5-8.

Zoarium forming thin crusts over shells, crinoid columns, and ramose Bryozoa, generally about 1 mm. in thickness. Surface with clusters of large cells at intervals of 3.3 mm., usually little or not at all elevated, at other times rising into low and broad monticules. Zoœcial apertures in old stages subangular and with thin interspaces in which the mesopores are not readily distinguishable; in younger stages more rounded, often ovate, with the interspaces usually somewhat wider and the mesopores obvious; walls thin, but little inflected. In the commonest form of the species there are from thirteen to fifteen zoœcial apertures in 3 mm., but in the variety illustrated in figs. 7 and 8 on plate XVIII, only eleven are to be counted in the same space. Acanthopores of medium size, two to four to each zoœcium, situated in the angles of junction and between the angles in the walls of both the zoœcia and mesopores. In most cases the acanthopores are not very conspicuous at the surface. This is in part due to attrition, since on protected spots they are distinct enough, giving the surface a minutely granulose character of somewhat coarser and looser pattern than in *A. typicalis.* In a variety represented by a dozen or more specimens these structures are much more strongly developed. Indeed, these specimens remind one very much of *A. schucherti* Ulrich, so far known only from the upper beds of the Cincinnati group in Ohio.

Internal characters: These are so well illustrated on the two plates above cited that detailed descriptions are rendered unnecessary. It will suffice to say that the mesopores, though usually rather large, are variable in size and distribution, that the zoœcia in the spaces between the aggregations of large cells are often in contact with each other for more than half their circumference, that the walls are a little thicker than in *A. typicalis*, the acanthopores less numerous, larger, and yet not projecting inward so much, while the tabulation of both sets of tubes is much less compact.

As has been intimated, two varieties might be distinguised from the typical and more common form of the species. The first differs in having larger zoœcia, the second in having much stronger acanthopores, these being larger and prominent enough at the surface to obscure the view of the zoœcial apertures. The latter may be compared with *A. crassa*, the following species, but they are too distinct in vertical sections to be confused.

Formation and locality.—Middle third of the Trenton shales at Minneapolis, St. Paul, Fountain, and other localities in Minnesota where that horizon is exposed.

Mus. Reg. No. 5985.

Atactoporella crassa, *n. sp.*

PLATE XV, FIGS. 18-21.

Zoarium a small, irregularly hemispheric mass, growing upon some foreign object, 2 or 3 cm. in diameter and 5 to 10 mm. in hight. Surface without monticules, nor have distinguishable clusters of either large or small cells been detected. Zoœcial apertures subangular, rounded or irregularly outlined, inclosed by thick walls, prominently elevated at most of the angles of junction into strong acanthopore spines; about fourteen apertures in 3 mm. Mesopores less numerous than usual, small and difficult to detect at the surface.

Internal characters: Considerable variety of structure, depending upon age, is exhibited in different tangential sections or in parts of the same section. These, as is shown in figures 18 to 20 (pl. XV), consist of a gradual thickening of the zoœcial walls, and strengthening of the acanthopores, causing the mesopores, which in the thin-walled regions are large and distinct enough, though never as numerous as in most other species of the genus, to be more or less completely obliterated. Cystiphragms occur in every zoœcial tube. The opening in them varies from subcircular to semiovate, according as they are situated subcentrally or at one side of the zoœcium. Vertical sections (pl. XV, fig. 21) show that the cystiphragms and diaphragms in both sets of tubes are equally crowded. It is, therefore, difficult to distinguish the mesopores from those zoœcial tubes in which the curved section of the cystiphragms is not shown.

This is a well marked species and readily separated from *A. schucherti* Ulrich, and certain varieties of *A. insueta*, which it resembles chiefly in the large size of the acanthopores, by the much greater abundance of transverse partitions in the tubes. The zoarium is also heavier, and the zoœcial walls thicker. A nearer relative apparently than either of the species compared is found in an undescribed species occurring near the tops of the hills at Cincinnati, Ohio.

Among associated species that might be confounded there are two of *Leptotrypa*, one, a parasitic undescribed form, the other, subglobular, described in this volume as *L. acervulosa*. Both are distinguished externally by having much thinner walls and inconspicuous acanthopores. When sectioned the *Leptotrypas* will of course be separated at once by the total absence of cystiphragms.

Formation and locality.—Galena shales, St. Paul and near Cannon Falls, Minnesota.

ATACTOPORELLA RAMOSA, *n. sp.*

PLATE XX, FIGS. 22-27.

Zoarium erect, subramose, branches compressed, dividing once or twice, 3 to 6 mm. thick, 5 to 10 mm. wide. Surface minutely spinulose, and elevated at intervals of about 2 mm. into small monticules, varying in different examples from low and rounded to prominently conical in shape. Slopes of monticules occupied by cells of slightly larger size than the average; their summits, however, often appear solid, these being, in most cases, formed by small aggregations of closed mesopores. Zoœcial apertures small, floriform, about sixteen in 3 mm., separated by interspaces, in which but few mesopores can be detected, of less width than their diameter; each surrounded by from five to seven small acanthopores, projecting well into the zoœcial cavity. This describes the fully matured and ordinary appearance of well preserved specimens. Young stages are quite different, the zoœcial apertures being a little larger, angular, with very thin walls, and while the mesopores are readily distinguishable and one or two to each zoœcium, the acanthopores are so small as to be practically wanting.

Internal characters: To obtain the fully matured characters of this species it is necessary to make the tangential section as nearly superficial as possible. In this outermost region the zoœcial wells are of moderate thickness and inflected more or less strongly at the points occupied by the acanthopores. The mesopores here appear as mere irregular interstices between the rounded walls of the zoœcia. At deeper levels in the section the acanthopores become smaller and at last indeterminable, the zoœcia prismatic and their walls thin, and the mesopores more distinct. The appearances now are just as in transverse sections of the axial region. Vertical sections show that cystiphragms and diaphragms are developed throughout the tubes from their origin in the axial region to their superficial orifices. These structures are, however, a little more closely arranged near the surface of the zoarium than in the axial region. Mesopores are likewise present in both regions, but these seem gradually to expand as they bend out of the axial region and to assume the characters of true zoœcia. At the same time new mesopores are interpolated, but these do not develop into zoœcia. On the contrary the tendency is to close them up by deposit on the zoœcial walls.

This is the second species of the genus in which the zoarium rises into the ramose form. The first is the *A. newportensis* Ulrich, from the lower beds of the Cincinnati group at Newport, Ky. The latter has larger monticules, more numerous mesopores, less abudant acanthopores, and thinner zoœcial walls. The ramose habit of growth will distinguish it from the other species of the genus. Several species externally similar, but internally widely different, occur in the same beds with *A. ramosa*. One of these is the *Callopora pulchella*, var. *persimilis*, another is the *Homotrypa tuberculata* of the present work, while a third is the *Batostoma montuosum*. With a little practice these will be distinguished readily enough, even without the aid of thin sections. When the surface is a little worn the student may find it difficult to separate the species from montiferous examples of *Monticulipora arborea*, a species found chiefly in the overlying Galena shales. When both are in a good state of preservation he will find that the walls of the *Monticulipora* are somewhat thicker and much more minutely granulose, and that true mesopores are wanting.

Formation and locality.—Upper third of the Trenton shales, near Cannon Falls, Minnesota, where it is associated with an abundance of *Prasopora conoidea* and *Phylloporina corticosa*.

Genus HOMOTRYPELLA, Ulrich.

Homotrypella, ULRICH, 1886. Fourteenth Ann. Rep. Geol. and Nat. Hist. Surv. Minn., p. 83.

Zoarium somewhat irregularly ramose, occasionally palmate or frondescent; monticules wanting, but small maculæ, consisting of clusters of mesopores, often present. Zoœcia with rounded apertures, the latter sometimes inflected by the acanthopores. Mesopores small, abundant, in some cases completely isolating the zoœcia. Acanthopores abundant, of medium size, generally imparting to the surface a minutely granulose character. Cystiphragms developed chiefly in the median region of the zoœcial tubes, being absent usually just beneath the surface and never present in the axial region.

Type: *H. instabilis* Ulrich.

This genus was established for the reception of a small but eminently natural group of Lower Silurian species that could not be included in any of the other genera of the family. Since then other forms have been discovered, and the classification of several others changed, so that now no less than eleven, perhaps twelve, species of the genus are known to me. These range from the Birdseye to the top of the Lower Silurian, each of the more important subdivisions containing one or more species.

In the ramose habit of growth the genus resembles *Homotrypa* Ulrich, but the abundant mesopores are a distinguishing mark of some importance. A comparison with *Peronopora* Nicholson, and *Atactoporella* Ulrich, shows the following differences: In the first the zoaria are bifoliate, in the second usually parasitic, and in both the cystiphragms are developed in an almost uninturrupted series throughout the length of the zoœcial tubes.

Fuller investigations into the affinities of these fossils have shown good grounds for redistributing the species heretofore referred to *Batostomella*. That genus must, therefore, be restricted to the Devonian and Carboniferous species originally intended as types.* This leaves the Lower Silurian species unplaced generically. Since large specimens of *B. gracilis* Nicholson, and many of the ordinary forms of *B. meeki* James, sp., from the Cincinnati group of Ohio, often have a few cystiphragms developed in the curve of the tubes, and as their other characters are in no wise strongly opposed to a union with *Homotrypella*, it seems best, at any rate provisionally, to place them here. However, the *B. simulatrix* Ulrich, group of species cannot be admitted, and to accommodate them a new generic name will have to be proposed.

**Trematella*, Hall, 1887, Pal. N. Y., vol. vi, p. 14, is evidently a synonym of *Batostomella*, Ulrich, 1882. Jour. Cin. Soc. Nat Hist., vol. v, p. 154.

The latter continue into the Lower Helderberg and may really be the stock that eventually produced *Batostomella annulata* (*Trematella annulata* Hall) and *B. perspinulata* Hall, sp., of the Devonian, and *B. spinulosa* Ulrich, the Chester type of the genus. But I am satisfied that the *gracilis* group, indeed the whole genus *Homotrypella*, did not survive into the Niagara.

Homotrypella instabilis *Ulrich.*

PLATE XVIII, FIGS. 9-20.

Homotrypella instabilis Ulrich, 1886. Fourteenth Ann. Rep. Geol. and Nat. Hist. Surv. Minn., p. 83.

Zoarium ramose, growth rather irregular; branches rounded, sometimes nodular or lobate, and varying in diameter from 3 to 8 mm.; surface generally without monticules, and when these are present they are low and broad; small maculæ or clusters of mesopores are not infrequently present. Superficial characters of zoœcia and mesopores variable. In some, and these are in most cases well-preserved examples, the zoœcial apertures are irregular both in form and arrangement, with thin walls, partly separated by mesopores numbering one or two to each zoœcium. In these specimens the acanthopores are small yet prominent and sharp, and number from one to three to each zoœcium. The mesopores are always smaller than the zoœcia, but vary occasionally in shape, size and arrangement. In many other examples both the zoœcia and mesopores are smaller and their walls correspondingly thick, while the acanthopores are blunt and thicker. In most cases a little wearing suffices to obscure the mouths of the mesopores, so that they are readily overlooked. Twelve or thirteen of the zoœcia occur in 3 mm.

Internal characters: As may be seen by comparing figures 13 and 14 with 18 and 20 (plate XVIII) tangential sections of this species present an unusual variety of appearances. In the majority of sections, providing they are not too deep, the walls of the cells are very thick, with not a sign of cystiphragms in the zoœcial cavities. When a second or peripheral series of cystiphragms has been developed (see figs. 17–20) a very different appearance is obtained. Now the walls are thinner, and a cystiphragm, leaving from one-third to one-half of the zoœcial cavity open, is to be seen in each of the zoœcia. In all cases the polygonal lines of contact between the two sets of cells is sharply defined, and the walls of both approximately of equal thickness. The acanthopores are conspicuous features of these sections, but their relative abundance varies somewhat in different examples. In the axial region of vertical sections the walls of the tubes are very thin and finely wavy, and the diaphragms straight and remote, or wanting entirely. As the tubes enter the peripheral region the number of diaphragms is greatly increased, the walls thickened, and cystiphragms, mesopores and acanthopores developed. The mesopores are distinguished from the zoœcia by their shortness and in having no cystiphragms. The latter structures number from three or four to fifteen in a direct series in each zoœcial tube. In most cases they occur only in the region intervening between the fully matured peripheral and the immature axial region. Beyond them the diaphragms are crowded and essentially horizontal. In the mesopores the diaphragms are often thick and situated about the same distances apart as in the zoœcial tubes, with from fourteen to seventeen in 1 mm. In the axial region of transverse sections the zoœcial tubes are of unequal sizes and of peculiarly irregular shapes.

Formation and locality.—Rather abudant in the middle third of the Trenton shales, at St. Paul. Minneapolis, Cannon Falls, near Fountain, and other localities in Minnesota.

Mus. Reg. Nos. 5025, 5981, 5982.

Homotrypella multiporata, *n. sp.*

PLATE XVIII, FIGS. 21, 22.

Zoarium ramose, branches cylindrical, 8 or more mm. in diameter. Zoœcia small, about twelve in 3 mm., with thin walls, rounded or petaloid apertures, their margins raised slightly and separated by a conplete ring of small mesopores. Acanthopores small, numerous. Cystiphragms seen only in the turn of the zoœcial tubes, as far as observed, varying between two and six in each tube. Diaphragms in zoœcial tubes exceedingly delicate, five or six in 1 mm.; a little stronger in the mesopores, and here numbering about nine in each tube ; apparently wanting in the axial region, where the tube walls are minutely crenulate and thin. In the axial region of transverse sections the tubes are very unequal.

This species, so far as observed, forms thicker branches, has much more numerous mesopores, and smaller and thinner-walled zoœcia than its associate *H. instabilis.* Internally the diaphragms are wider apart in both sets of tubes and more delicate. They differ again in being twice as numerous in the mesopores as in the zoœcial tubes. None of the other species are sufficiently related to require comparisons.

Formation and locality.—Rare in the middle third of the Trenton shales, at St. Paul and Minneapolis, Minnesota.

Homotrpella (?) subgracilis, *n. sp.*

PLATE XXVI, FIGS. 10-16.

Zoarium small, ramose, dividing irregularly; branches subcylindrical, 2 to 4.5 mm. in diameter; surface without monticules and maculæ. Zoœcia rather irregular in size, shape and arrangement, varying also in the thickness of their walls, these being often stronger than shown in figs. 15 and 16, plate XXVI; twelve or thirteen in 3 mm. Apertures oblique in some of the young examples, nearly or quite direct in the others; in the latter the numerous small acanthopores cause more or less irregularity in the outline of the apertures. Mesopores of unequal sizes, irregular in arrangement, scarcely more numerous than the zoœcia, from which it is sometimes difficult to distinguish some of the larger ones.

Internal characters: These are but illy preserved in the two sets of sections prepared, and all the characters shown in them are brought out in figs. 10, 11 and 12, on plate XXVI. Four vertical sections fail to exhibit any positive evidence of either diaphragms or cystiphragms, the tubes appearing as open throughout. This condition, however, seems unnatural and probably due to imperfect preservation. There should be some transverse partitions in the tubes, though these, especially the cystiphragms, must have been comparatively few in this species. A similar absence of diaphragms, in this case obviously due to imperfection, is sometimes met with in sections of *H. gracilis* (*Chætetes gracilis* Nicholson), of the Hudson River rocks, which the present species is believed to resemble more than any other. And yet I am satisfied that, when sufficiently good material can be studied, the internal characters will prove equally as near to those of the associated *H. instabilis*, with which I had at first confounded it.

Formation and locality.—Rather rare in the middle third of the Trenton shales, at Minneapolis and St. Paul, Minnesota.

Homotrypella (?) ovata, *n. sp.*

PLATE XVIII, FIGS. 23-30.

Zoarium small, ramose, branches generally compressed, sometimes subcylindrical, varying between 2 and 5 mm. in diameter or width, dividing at unequal intervals. Surface without monticules, but exhibiting at intervals of 2 or 3 mm. clusters of cells of larger size and more widely separated than the average. Zoœcial apertures rounded, commonly a little oblique, oval and enclosed by a thin but slightly elevated peristome on which a single small acanthopore is in most cases to be detected, though generally with some difficulty. Interspaces depressed, with the mouths of the rather large mesopores occupying them, closed or open, probably according to the state of preservation. The zoœcial rims are nearly always in contact with each other at limited points, yet many individual zoœcia, especially of those in the clusters mentioned, may be completely separated from their neighbors by mesopores. In some specimens, preserved unusually well, the interspaces are granulose, the granules seeming to form rows on the walls separating the mesopores. Long diameter of average zoœcium 0.17 mm.; some of the largest in the clusters 0.25 to 0.30 mm.; ten to twelve in 3 mm.

Internal characters: Vertical sections show that the peripheral region is narrow, that here, and in the turn of the zoœcial tubes, the diaphragms are closely arranged, with from six to eight in 0.5 mm. Just in the turn of the tubes, along the upper wall, one, two or three cystiphragms were developed. The mesopores begin at the same point, and in these the diaphragms are more crowded and thicker. In the central part of the axial region the tubes are larger than farther out, and intersected by diaphragms at intervals of about 0.5 mm. In nearing the surface the tubes become narrower and the diaphragms closer. Tangential sections are distinctive in showing the wide interpaces, large and sharply-defined mesopores, and the ring-like definition of the zoœcial walls. In most cases the zoœcia are completely separated or rarely touch each other without sacrificing any of their roundness of outline.

Compared with other species, the *Homotrypa ? intercalaris* of this work seems to be the nearest and distinguished chiefly in vertical sections, diaphragms being absent in the axial region of that species and cystiphragms more numerous in the peripheral. For further remarks on this relationship, see p. 216. For comparisons with *H. mundula*, see under that description.

Formation and locality.—Galena shales, near Cannon Falls, Minnesota. Two fragments from the middle Trenton shales at Minneapolis seem to be identical in nearly every respect, but so far the species has not been found in the upper third of the shales intervening between these two horizons.

Mus. Reg. No. 8124.

HOMOTRYPELLA MUNDULA, *n. sp.*

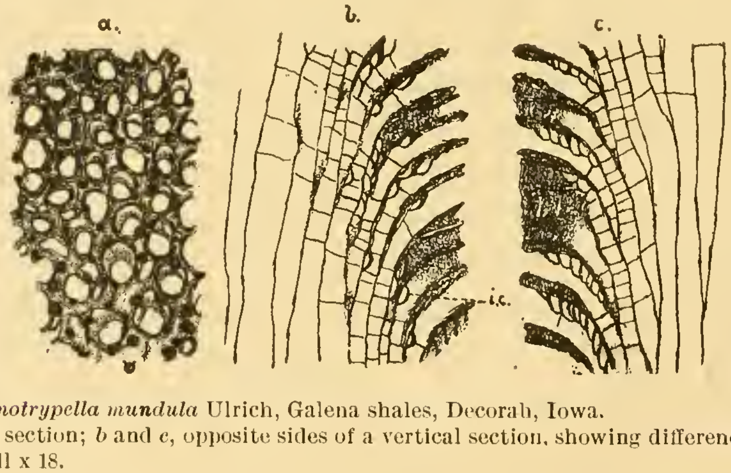


Fig. 12. *Homotrypella mundula* Ulrich, Galena shales, Decorah, Iowa.
a, tangential section; *b* and *c*, opposite sides of a vertical section, showing differences in the number of cystiphragms; all x 18.

Zoarium dendroid, branches subcylindrical, small, 2.5 to 5.0 mm. in diameter, dividing, generally dichotomously, at irregular intervals. Monticules wanting, but in most cases clusters of zoœcia, slightly larger and more widely separated than the average, are to be distinguished. Zoœcial apertures somewhat irregularly distributed, ten to twelve in 3 mm., slightly oblique in young stages, ovate or irregular in shape, in the best preserved examples more or less obscured by the rather large and abundant projections of the acanthopores. Interspaces varying, even in small spaces, from contact between the zoœcial walls to a width fully equalling the diameter of a zoœcium. Where widest they are depressed, and in a few instances show the mouths of mesopores, but as a rule these appear as closed solidly.

Internal characters: In the axial region of vertical sections the tubes sometimes appear to have grown irregularly, and where this is the case they are intersected by a few remote diaphragms. However, in the normally developed straight tubes, these structures are wanting in the axial region except in zones, 2 or 3 mm. apart, extending through the branches. In these each tube has a few. Such a zone is shown in the upper part of figs. *b* and *c*. As the tubes turn to enter the peripheral region, diaphragms become numerous, and in their midst a series of cystiphragms is developed in most of the tubes. The development of the cystiphragms is not uniform, being, as shown at *i. c.*, fig. *b*, often isolated, while in other cases they may form continuous series of as high as ten or twelve. Such extremes may be noted in a single section, and it seems evident that in the development toward *H. gracilis* Nicholson, sp., they had by this time lost some of their importance and were gradually being dropped. The mesopores are inconspicuous features in vertical sections, being filled almost solidly with sclerenchyma in which their diaphragms are but illy distinguishable.

In tangential sections the zoœcia commonly present a dark ring-like investment, in which the sharply defined acanthopores are mostly situated. The interspaces are of a lighter color, and but rarely exhibit any positively defined mesopores. Cystiphragms, so far as observed, may be detected in perhaps half of the zoœcia.

A closely related but smaller species than *H. granulifera* (*Chætetes granuliferus* Ulrich) from the Trenton of Kentucky. In its general aspect it is exceedingly like *H. gracilis* Nicholson, sp., of the Hudson River rocks, and it is almost certain that the two represent stages in one line of development. However, comparative abundance of cystiphragms in the present species will distinguish them at once, these structures being of very rare occurrence in *H. gracilis*. In the latter the acanthopores also are smaller, so that the surface granulation is less coarse.

Formation and locality.—Galena shales. Common at Decorah, Iowa; rare in the vicinity of Cannon Falls, Minnesota.

Mus. Reg. No. 8080.

Homotrypella rustica, *n. sp.*

PLATE XVIII, FIGS. 31-33.

Zoarium irregularly ramose, branches 5 to 10 mm. in diameter. Low swellings of the surface, scarcely to be called monticules, occasionally present. Surface very rough under a hand lens, the acanthopores being strong and numerous, though not materially inflecting the zoœcial walls. Zoœcial apertures rounded, about eleven in 3 mm. Mesopores abundant, though but rarely separating the zoœcia completely, of unequal sizes, rounded at the surface.

Internal characters: In tangential sections, showing the characters immediately beneath the surface, (upper part fig. 32) the zoœcia are rounded, with only moderately thick walls, the mesopores sharply defined, subangular, of unequal sizes, and averaging three or four to each zoœcium, the acanthopores strong, perhaps two to each zoœcium, and situated chiefly in the zoœcial walls, which they occasionally only cause to bend inwardly. At a deeper level (lower part fig. 32) the walls are thinner, the acanthopores smaller, and the mesopores larger. At both levels the zoœcia almost uniformly exhibit the cut edges of cystiphragms. In vertical sections the most striking feature of the species is the abundant tabulation of all the tubes. Diaphragms occur all through the axial region, and both the mesopores and acanthopores began earlier than usual. The outward curving of the tubes also is unusually gradual. The diaphragms in the two sets of tubes are subequally distributed, and it is often difficult to discriminate between them when the curved edges of the cystiphragms are not shown. At about the middle of the curve nine or ten diaphragms occur in 1 mm.; nearer the surface they are a little closer, while more toward the center of the branch they are further apart. The cystiphragms are unusually superficial in this species, forming crowded series almost to the mouths of the zoœcia.

This species is distinguished from *H. granulifera* and *H. mundula* by the greater number and open character of the mesopores; from *H. multiporata* by its larger zoœcia, fewer and more unequal mesopores, and more crowded as well as different tabulation of the tubes. *H. instabilis* has thicker walls, and is quite different in other respects.

Formation and locality.—The sections illustrated were prepared from a single example collected by the author in the upper beds of the Hudson River group, at Spring Valley, Minnesota. This specimen seems identical with a common species occurring at an equivalent horizon in Indiana and Ohio, to which I had applied the name *rustica* in my MS. notes.

Mus. Reg. No. 8125.

Genus HOMOTRYPA, Ulrich.

Homotrypa, ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 240; 1890, Geol. Surv. Ill., vol. viii, pp. 370 and 409; 1883, FOORD, Contri. Micro-Pal, Can., pt. I, p. 9.

Zoaria erect, generally ramose, at other times frondescent, with or without monticules. Zoœcial tubes with very thin and finely crenulated walls and remote diaphragms in the axial region. Cystiphragms, isolated or in series, developed in the peripheral region only. Apertures polygonal or subcircular, the shape depending upon the thickness of the walls and the character of the interspaces. Mesopores occasionally wanting, typically few and gathered into clusters; in several aberrant cases (*e. g. H. separata*), comparatively numerous and causing a greater or less separation of the zoœcial walls. Acanthopores usually present, of varying sizes. What appear to be large communication pores have been detected under favorable circumstances in several species.

Type: *H. curvata* Ulrich, Hudson River group.

This is the largest and one of the best characterized genera of the *Trepostomata*. Adding the new forms here proposed we have a total of seventeen described species. There are at least six more to be published from the Hudson River Rocks of Ohio and Indiana alone, while as many more are known to me from various Lower Silurian horizons in Tennessee, Illinois, Wisconsin and Minnesota.

The affinities of the genus, as indicated by species like *H. intercalaris*, are with *Homotrypella;* others resemble *Eridotrypa*, while some again are not easily distinguised from erect forms of *Monticulipora* like *M. arborea* and *M. molesta* Nicholson. In this conuection it would be well to read the remarks on pp. 215 aud 216.

HOMOTRYPA MINNESOTENSIS *Ulrich.*

PLATE XIX, FIGS. 1-9.

Homotrypa minnesotensis ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 79.

Zoarium ramose, branches subcylindrical, from 5 to 15 mm. in diameter, generally dividing dichotomously at long intervals, rarely inosculating. In the typical form monticules are not developed, but the clusters of large cells are conspicuous. In a later variety, commonly also of larger size than the typical form, these clusters are often raised into prominent monticules, about 2.5 mm. from center to center. Central part of these groups often appearing subsolid or with shallow mesopore-like depressions in the interspaces. True mesopores wanting. Acanthopores exceedingly small and few, observed only in thin sections. Ordinary zoœcia angular, with thin walls and more or less oblique apertures. In young examples the obliquity is very great, while it is only in the largest that the apertures can be said to be direct. About twelve of the average zoœcia in 3 mm. In the large monticulose variety, already mentioned, and which may be designated as var. *montifera*, there are thirteen apertures in the same space.

Internal characters: In vertical sections the peripheral or "mature" region is very narrow, and the axial region, in which the tubes are long and nearly vertical, correspondingly large. In the latter diaphragms are wanting, and the walls extremely thin and wavy. Near the surface the walls are appreciably thickened, but never enough to be described as otherwise than thin. The curve of the tubes throughout is unusually gentle. Diaphragms and cystiphragms set in abruptly and their arrangement in the tubes is shown better in figs. 1, 5 and 6 than it can be described.

Owing to the obliquity of the zoœcial apertures it is difficult to prepare satisfactory tangential sections of any except large and old examples. The successful ones show that the zoœcial walls are comparatively thin, that a few mesopore-like cells are sometimes interpolated between the zoœcia, and that the acanthopores are so small and few that they are readily overlooked. Nor are the cystiphragms conspicuous in these sections.

Transverse sections are interesting chiefly because they show the unusual narrowness of the peripheral region, and the decrease in size and flattening of the tubes as they enter this part of the zoarium.

This species is distinguished from all the others of the genus known from the Trenton by its oblique zoœcial apertures.

Formation and locality.—Common in the lower third of the Trenton shales, at Minneapolis, St. Paul, Cannon Falls, Preston, Fountain and other localities in the state. It has not been certainly identified in the middle third of the shales, but in the upper third, at St. Paul, a large form of this species occurs associated with the var. *montifera* in considerable abundance. The species is also known from Decorah and other localities in Iowa.

Mus. Reg. Nos. 5970, 5975, 7600.

Homotrypa exilis *Ulrich.*

PLATE XIX, FIGS. 10-16.

Homotrypa exilis Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 80.

Zoarium ramose, branches slender, without monticules, cylindrical, 3 to 5 mm. in diameter (generally 4 mm.), dividing at long intervals. Entire hight of zoarium less than 75 mm. Zoœcia with rounded, direct apertures and moderately thick walls, about twelve in 3 mm. Clusters of cells larger than the average occur, but do not constitute a conspicuous feature. Mesopores comparatively numerous, especially in the clusters just mentioned. Diaphragms wanting in the axial region, but present in the short and rather abruptly bent peripheral region, in which the walls are also thickened and a series of cystiphragms developed.

This clearly is not the young of *H. minnesotensis*. The specimens viewed under a hand lens show more direct and rounder zoœcial apertures, with the mesopores also more abundant, and on the whole have a more matured appearance than many much larger specimens of that species. Furthermore, the zoœcial walls in the larger species never get to be as thick as has been observed in sections of *H. exilis*.

Formation and locality.—Not uncommon in the lower third of the Trenton shales at Minneapolis, Minnesota.

Mus. Reg. Nos. 5976, 7655.

Homotrypa separata, *n. sp.*

PLATE XIX, FIGS. 17-20.

In its growth and, with the exception of one feature, also in its internal characters, this species is very similar to *H. minnesotensis*. As it also occurs in the same beds with that species, a detailed description is unnecessary. A comparison of the two forms brings out that *H. separata* has an abundance of mesopore-like depressions at the angles of junction between the zoœcia, with aggregations of such depressions in the maculæ (see fig. 19), causing the zoœcial apertures to be rounded—commonly subcircular instead of angular. Internally these interspaces give, to tangential sections especially, a very different appearance from those of *H. minnesotensis* (compare figs. 3 and 4 with 17 and 18, plate XIX). Vertical sections of the two species are more alike, the only difference worthy of notice being the numerous presence of mesopores in the one and almost total absence in the other. Despite the obviousness and, in most other cases, the importance of a difference like that existing between these two forms, I cannot doubt that they are in reality closely related.

Formation and locality.—Lower third of the Trenton shales at Minneapolis, Chatfield, and near Preston, Minnesota.

Mus. Reg. Nos. 7667, 8122.

HOMOTRYPA (?) INTERCALARIS, *n. sp.*

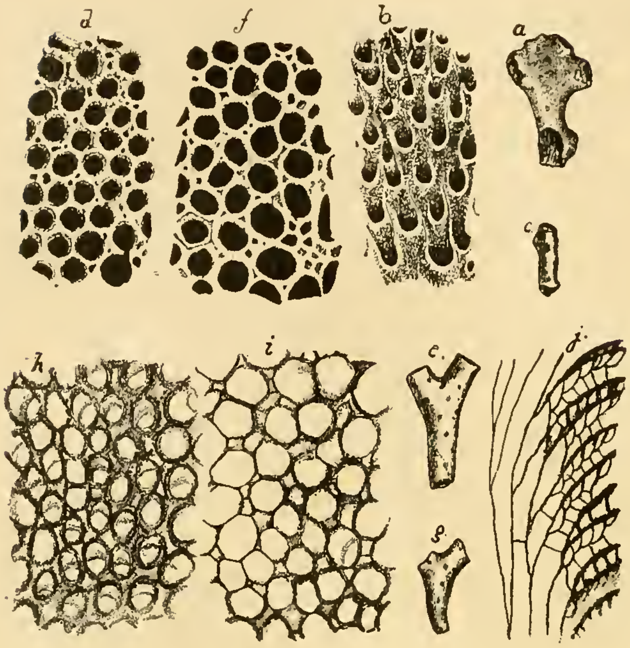


FIG. 13. *Homotrypa* (?) *intercalaris, n. sp.*, middle Trenton shales, Minneapolis, Minnesota. Collection of E. O. Ulrich. *a* and *b*, a specimen of the natural size, and small portion of its surface x18, showing unusually oblique zoœcial apertures; *c* and *d*, similar views of a fragment of a form doubtfully referred to this species, having somewhat smaller zoœcia and mural papillæ; *e* and *f*, similar views of a typical example; *g*, more slender fragment, natural size; *h*, tangential section, x18, showing structure immediately beneath surface of fully matured example; *i*, another portion of same section, showing structure at a deeper level; *j*, vertical section, x18, showing the peripheral region with the mesopores and cystiphragms, and a small part of the untabulated axial region.

Zoarium small, ramose, branches subcylindrical, generally 2.5 to 3.5 mm. in diameter. Surface without monticules but exhibiting distinct clusters of large cells in the centers of which there is often a small aggregation of mesopores. Zoœcial apertures rounded or subangular, commonly direct to the surface, at other times more or less oblique, occasionally so much so (see fig. 13 *b*) that they recall those of *Ceramoporella.* The last condition probably occurred only when a new layer of zoœcial tubes was developed in which the individual cells failed to correspond exactly with those of preceding layers. Typical form with about thirteen zoœcia in 3 mm.; the variety, also figured above, has fifteen in the same distance. Walls or interspaces of moderate thickness, commonly with very few and inconspicuous acanthopores. But in the variety a row of minute papillæ has been observed along the center of the wall. Mesopores rather abundant, occurring at most of the angles of junction between the zoœcia.

The internal structure is brought out sufficiently in the accompanying cut. Figures *h* and *i* show how very similar tangential sections may be to those of the later *Homotrypella* (?) *ovata*, illustrated on plate XVIII. The mesopores are on the whole smaller and do not separate the zoœcia so completely, and sometimes the difference in these respects is greater than is shown in the illustrations. The difference between vertical sections of the two forms is better marked, the cystiphragms being more numerous and diaphragms wanting in the axial region in the present species. *Homotrypa exilis* is another closely allied form, but differs in the opposite manner, the mesopores being fewer (see plate XIX).

This is an important stage in the line of development discussed on page 216.

Formation and locality.—Middle third of the Trenton shales at St. Paul and Minneapolis, Minnesota.

Homotrypa subramosa *Ulrich.*

PLATE XIX, FIGS. 21-28.

Homotrypa subramosa Ulrich, 1886. Fourteenth Rep. Geol. Nat. Hist. Sur. Minn., p. 81.
Homotrypa insignis Ulrich, 1886. Fourteenth Rep. Geol. Nat. Hist. Sur. Minn., p. 82.

Zoarium subramose, frequently though irregularly divided; branches compressed or subcylindrical, their extremities often bulbous. Size of branches varying greatly, the smallest 4 or 5 mm. in diameter, the largest 6 to 9 mm. thick, and as much as 25 mm. wide. Average specimens are about 6 mm. thick and between 8 and 12 mm. wide, with the total hight of zoarium rarely exceeding 60 mm. Surface without monticules, nor are the clusters of large cells very conspicuous. Zoœcia with rather thin walls and polygonal, direct apertures; twelve to fourteen in 3 mm. Zoœcial apertures shallow, exposing the cystiphragms when in a good state of preservation. These structures leave but a small opening, and when the fossil has suffered a little from attrition (a frequent occurrence in the beds holding the species most abundantly) in which case the true walls are obscured or cut away, the appearance is very deceptive, the apertures seeming to be very small and oblique, and much the greater part of the surface occupied by wall-substance. Acanthopores varying in number and size, sometimes as numerous as two to each zoœcium. More commonly the number is little more than half that extreme. In many cases they are large enough to constitute a marked external feature. In others, however, apparently in an equally good state of preservation, they are so small that it is difficult to detect them even with the aid of a good lens.

Internal characters: Vertical sections show that the tubes proceed in a gradually increasing curve from the axial region outward to the peripheral region, in which they are approximately at right angles to the surface; that in the axial region the tubes are rather large, with wavy walls, and crossed by straight or oblique diaphragms, either in zones or occurring at intervals varying from one to three times their diameter; that in the peripheral region the walls are moderately thickened, and the tubes occupied by a gradually crowding series of cystiphragms. The varying appearances of tangential sections are sufficiently exhibited in figs. 22 to 25. The differences so far observed in these sections consist almost entirely of variations in the number and size of the acanthopores.

Greatly increased collections, and the study of numerous sets of thin sections, have convinced me of the specific identity of *H. subramosa* and *H. insignis.* The latter name might be retained in a subordinate sense for the Galena shales variety, in which the clusters of large cells are more conspicuous, the average size of the zoarium smaller, the zoœcial walls thinner, and the acanthopores permanently less numerous and smaller than in the typical middle and upper Trenton shales form of the species.

The tabulated axial region, more numerous and larger cystiphragms, the presence of acanthpores, and the irregular and more compact growth, will distinguish the species from preceding forms of *Homotrypa.* Thin sections will of course separate it at once from outwardly more similar species, belonging to other genera, that are associated in the same beds.

Formation and locality.—H. subramosa is rare in the middle third of the Trenton shales at several localities in St. Paul and Minneapolis, but is much more abundant in the upper third of the shales at St. Paul and localities in Goodhue county, Minnesota. The restricted var. *insignis* is comparatively rare in the Galena shales at localities in Goodhue and Fillmore counties; also in the same beds at St. Paul, and at Decorah, Iowa.

Mus. Reg. Nos. 5977 to 5980, 8030, 8061.

HOMOTRYPA TUBERCULATA, *n. sp.*

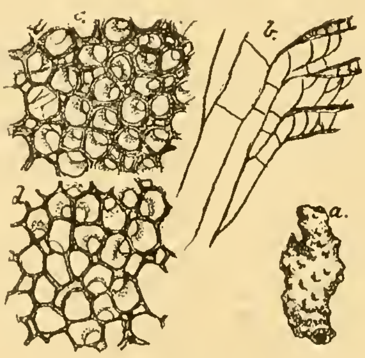


FIG. 14 *Homotrypa tuberculata*, n. sp., upper third Trenton shales, near Cannon Falls, Minnesota. Collection of E. O. Ulrich. *a*, fragment of the natural size; *b*, small portion of a vertical section, x 18, showing two mesopores, the cystiphragms and diaphragms of the peripheral region, all of which are wanting in the axial region; *c* and *d*, two portions of a tangential section of a fully matured example, x 18, the former showing appearance immediately beneath the surface, the latter at a slightly deeper level.

Zoarium small, ramose, branches rounded or flattened, dividing rather frequently, 2.0 to 3.5 mm. thick, and 2.5 to 7.0 mm. wide. Surface more or less strongly tuberculated, the monticules 2 to 2.5 mm. apart, conical, often very prominent. Zoœcial apertures nearly fourteen in 3 mm., angular or rounded, more or less oblique except in the oldest examples, in most specimens exposing the cystiphragms. Walls thin, often separating so as to form considerable interspaces in which a greater or less number of closed mesopores is contained. The extent of these interspaces varies greatly, being sufficient in some instances to cause the zoœcial apertures to be of rounded or ovate form, while in other specimens they are scarcely appreciable. Acanthopores small, about one to each zoœcium.

Internal characters: In vertical sections the tubes are large and without diaphragms in the axial region, the latter, together with short and rather irregular series of cystiphragms, being developed in the narrow peripheral region only. The mesopores appear as shown in the figure. Of tangential sections it would be possible to select small portions differing so much from each other in the number of mesopores that they would scarcely be suspected of belonging to one species. Still, if the sections are large enough each will contain some parts that may be said to be practically the same as those represented in figs. *c* and *d*. The acanthopores, though small and few, are quite distinct in these sections.

This is another of those aberrant forms of the genus like *H. intercalaris*. While its relations seem often to be decidedly suggestive of *Homotrypella* (?) *ovata*, I do not believe that its development resulted in that form. It seems to be an offshoot, perhaps from that line, which latter produced the *H. obliqua* Ulrich, of the Cincinnati group.

The strong monticules distinguish the species from the Trenton forms of the genus. Associated with it there are two really very distinct though dangerously similar species. The first of these is the *Atactoporella ramosa* with its numerous acanthopores and inflected zoœcial apertures, and totally different internal structure. The second, *Callopora persimilis*, differs so widely in its internal structure that it will be sufficient to refer the student to the figures on plate XXII. Other species presenting more or less superficial resemblance might be mentioned, but I cannot regard it as necessary, since with the aid of thin sections the student will have no trouble in distinguishing them.

Formation and locality.—Upper third of the Trenton shales, near Cannon Falls, Minnesota. The species probably occurs in the same beds at St. Paul.

Mus. Reg. No. 8123.

Homotrypa similis *Foord.*

PLATE XX, FIGS. 28-33.

Homotrypa similis Foord, 1883. Contri. Micro-Pal. Cambro-Sil. Rocks, Canada, p. 10.

Zoarium of medium size, ramose, the branches subcylindrical or compressed, 4 to 10 mm. in diameter, dividing at unequal intervals, often irregularly, occasionally even anastomosing. Surface without monticules, but usually exhibiting well marked substellate spots, consisting of aggregations of large, thick-walled cells, in many cases surrounding a minutely granulose central space. Zoœcial apertures more or less oblique, the degree depending upon age, appearing thin-walled and angular when in a good state of preservation, but much smaller and ovate, and seemingly with much thicker walls, when slightly worn; about twelve in 3 mm. Mesopores wanting, acanthopores small, inconspicuous superficially. When perfectly preserved the walls are minutely granulose.

Internal characters: Tangential sections will present a variety of appearances depending upon the age of the specimen sectioned, and the distance from the surface. In the central or deeper parts of a section prepared from an old example (plate XX, fig. 32), the zoœcia have thin walls, each will have a well-defined cystiphragm, or, if too deep to show the end walls distinctly, will be crossed by three or four straight and curved lines, representing both cystiphragms and diaphragms. From this condition we pass gradually into stages in which the walls are thickened, the cystiphragms filled up more or less completely and their ends drawn out and around so as to enclose a comparatively small ovate open space. At the same time the walls assume a minutely granular character, while at many of the angles of junction a larger dark spot (acanthopore) is to be detected. These stages are illustrated in figures 32 and 30. The lower half of the latter represents an unusual condition, in having the original wall undefined. It should be remembered that very few sections will show more than the first stage, and that, on account of the brevity of the peripheral region and the obliquity of the zoœcial tubes, it is at all times rather difficult to prepare really satisfactory tangential sections.

Figures 29 and 31 illustrate vertical sections taken from fully matured examples, the first from Canada, the second from Minnesota. These and other sections show that the tubes bend outward very gradually; that they are tabulated throughout, with the diaphragms from one to three times their diameter apart in the axial region. As they near the periphery the diaphragms become oblique and curved and then pass over into series of cystiphragms and short, crowded diaphragms, with from twelve to sixteen of the latter in 1 mm. The most peculiar feature of the species, perhaps, is the solid filling of the cystiphragms near the surface. This is, however, a peculiarity that is not shown to advantage except in sections of old examples.

Foord's figures of this species (*op. cit.*) are not entirely satisfactory, though sufficiently so to make the identity of the Minnesota examples referred to it a matter of high probability. Still, in making the identification I relied chiefly upon the characters of a Canadian example kindly furnished me by the author of the species.

The obliquity of the zoœcial apertures, and the substellate surface spots will serve to distinguish the species from associated forms, while its peculiar internal structure separates it from all others known to me. The affinities of the species are somewhat doubtful, but it is certainly not related very closely to *H. obliqua* Ulrich, of the Cincinnati group.

Formation and locality.—The types are from the Trenton limestone at Ottawa, Canada. In Minnesota the species is an abundant fossil in the Galena shales, in the upper beds especially, at several localities in Goodhue county, and at St. Paul, Minnesota.

Mus. Reg. Nos. 7636, 8021, 8043, 8058.

Homotrypa callosa, *n. sp.*

PLATE XX, FIGS. 15-21.

Zoarium irregularly ramose, less than 80 mm. high ; branches generally somewhat compressed, 6 to 12 mm. wide, 5 to 10 mm. thick. Surface with moderately distinct clusters of large cells, sometimes raised into low monticules. Zoœcial apertures subangular, nearly or quite direct, enclosed by rather thick, ridge-shaped walls ; thirteen or fourteen in 3 mm. Mesopores wanting. Acanthopores small, inconspicuous superficially.

Internal characters: In tangential sections the most striking features are (1) the thickness and minute structure of the walls (see figs. 16 and 21) and (2) the comparative straightness of the inner edge of the cystiphragms. In the Minnesota specimens the latter seem to project a little farther across the zoœcial cavity, while the walls are uniformly a little heavier and the zoœcia sometimes a trifle larger than in the Kentucky form.

In vertical sections the tubes bend outward gradually, and are tabulated throughout, remotely and irregularly in the axial region, where only diaphragms occur, and more crowded, also consisting chiefly of cystiphragms, in the peripheral region. On plate XX, fig. 19 shows the character of the tubes near the center of the branch, while figs. 17 and 18 illustrate their usual appearance in the outer fourth of the diameter. In other parts of the same sections the short diaphragms crossing the tubes from the series of cystiphragms to the opposite wall, are still preserved almost to the surface. That they are often wanting, as shown in the figures, is probably due to imperfect preservation.

This species is clearly distinct from all the preceding. Its relations seem to be with *H. curvata* of the Cincinnati group. Superficially it resembles *Monticulipora arborea* Ulrich, a form that is associated with it not only in Minnesota but also in Kentucky. That species is separated by its smaller cells and finely granulose walls. Internally they are quite distinct.

Formation and locality.—Galena shales, near Cannon Falls, Minnesota; shales of the Trenton group at Burgin and Frankfort, Kentucky.

Genus PRASOPORA, Nicholson and Ethridge, jun.

Prasopora, Nicholson and Ethridge, jun., 1877, Ann. and Mag. Nat. Hist., ser. 4, vol. xx, p. 38; 1879, Nicholson, Pal. Tab. Corals, p. 324, and 1881, "Genus Monticulipora," pp. 102 and 202; 1882, Ulrich, Jour. Cin. Soc. Nat. Hist., vol. v, p. 153, and 1890, Geol. Surv. Ill., vol. viii, p. 371; 1887, Foerste, Bull. Sci. Lab. Dennison Univ., vol. ii, p. 170.

Zoaria forming conical, hemispheric, discoid or irregular masses; at other times growing in thin expansions; usually free in the adult state, with a wrinkled epithecal covering upon the lower concave or flat side. Zoœcial tubes prismatic or cylindrical, thin-walled, partially separated from each other, occasionally completely isolated by smaller angular mesopores, best seen in young specimens and thin transverse sections, and perhaps always smaller and less readily distinguishable at the surface of mature or old examples. Acanthopores usually present, but in most cases neither numerous nor strong. Cystiphragms in all the zoœcial tubes. Diaphragms crowded in the mesopores.

Type: *P. grayæ* Nicholson and Ethridge.

This is one of the best characterized genera of paleozoic Bryozoa. The species moreover are most of them common fossils and widely distributed, so that the genus is also important in a geological sense. Most of the species are restricted to the Trenton rocks, and only one, *P. parmula* Foerste, of the Clinton of Ohio, is as yet known from strata above the top of the Lower Silurian.

Prasopora simulatrix *Ulrich.*

PLATE XVI. FIGS. 1-10.

Prasopora simulatrix Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p, 85.

Zoarium discoid in the younger stages, becoming hemispheric or subconical with age; occasionally the central part of the upper surface is drawn out, and in a few instances has been observed even to divide into two branch-like lobes. The last conditions, as well as various other irregular developments, are to be considered as abnormal. Base more or less concave, usually with a central cicatrix of attachment beyond which it is covered with a concentrically striated and wrinkled epitheca. Upper surface celluliferous. Hight of zoarium varying from 5 mm. or less to 50 mm. or more; diameter from 10 to over 100 mm. Zoœcia with direct, subcircular apertures, thin walls, those of neighboring cells generally in contact except at the angles of junction, the latter being occupied by angular mesopores of variable though usually small size. In the youngest specimens the zoœcia are the roundest and the interspaces, occupied by the mesopores, the widest, while in the oldest the opposite conditions prevail. More or less conspicuous clusters of cells of larger size than the average occur at intervals of nearly 4 mm., measuring from center to center. Between these cells the mesopores are commonly more numerous than elsewhere, and in nearly all cases constitute aggregations of variable extent and substellate form. These aggregations are unusually large and conspicuous in the var. *orientalis* to be mentioned presently. In many cases, chiefly old examples, the mesopores between the zoœcia occupying the intermacular spaces might be overlooked, although, as shown by thin sections, they are really numerous even there. Diameter of an ordinary zoœcium about 0.25 mm., with an average of eleven in 3 mm. Those forming the clusters vary in size, generally, from 0.25 to 0.38 mm., but in the var. *orientalis* a few in each may attain a diameter of 0.48 mm. Acanthopores wanting.

Internal characters: These, as shown in over one hundred thin sections, are very constant in all the essential parts. In tangential sections the form of the zoœcial tubes varies from perfectly circular to polygonal, their walls in most cases being very thin, and the cavity of each intersected by the crescentic edges of one or more cystiphragms. The opening left by the cystiphragms is generally lateral and of bi-convex shape, occasionally it is subcentrally situated and oval, but more commonly two or more cystiphragms combine to give it a subtriangular form. An abnormality is sometimes met with in the confluence of two zoœcia (see lower right-hand corner of fig. 9). The zoœcia are in contact with each other only in part, perhaps only at limited points, the interspaces left between them being occupied by the small mesopores. These vary somewhat in number, and more so in size, but are always decidedly angular. At intervals they are collected into substellate maculæ of greater or less extent, and in the immediate vicinity of these the zoœcia are of appreciably larger size than elsewhere. No evidence whatever of acanthopores has been detected.

In vertical sections the cystiphragms form continuous series on one or both sides of the tubes, according as they extended all around the circumference or embraced only a portion of same, while an equal number of straight diaphragms crosses the remaining portion of the tube. In the Kentucky, Tennessee, and Minnesota form of the species the tabulation of the tubes is more uniform and crowded than in the Canadian and New York variety, for which the name *orientalis* is proposed. In the former the cystiphragms average sixteen or seventeen in 2 mm., while in the latter the average does not exceed thirteen, and in some cases is not over ten in that space. In the mesopores the diaphragms are simple, and average about eighteen in 1 mm. for the typical form, and twelve for var. *orientalis*.

Variety ORIENTALIS, *n. var.*

PLATE XVI, FIGS. 1, 2, 6, 7.

Monticulipora (Diplotrypa) whiteavesi (part.) Nicholson, 1879. Pal. Tab. Corals, p. 316.

This subordinate name is proposed for the eastern variety of the species. It is distinguished from the typical form by the greater extent and distinctness of the substellate maculæ, the greater size attained by the zoœcia in the immediate vicinity of the maculæ and the less compact tabulation of the zoœcia and the mesopores.

This species may really be the one referred to by Vanuxem in 1842 (Geol. 3d Dist. N. Y. p. 46), when he speaks of "The Puff ball favosite (Favosites lycopodites)" as being highly characteristic and in great numbers in the Trenton limestone of New York. He adds, "it is found also in the lower part of the Utica slate, where it ends," and that "it is equally abundant at Frankfort, Kentucky, where it received the name of *Trianisites cliffordi.*"

The name *Favosites* or *Chætetes lycoperdon* (equivalent to Vanuxem's *Favosites lycopodites*) is generally credited to Say, but no description of the form was ever published by him, and the first known of the so-called species under that name is found in vol. i, Pal. N. Y., 1847, in which Hall devotes nearly two plates to the illustration of its supposed variability. I might point out some of the now only too evident incongruities in the assemblage of forms so placed by that even then experienced observer, but it would be more than useless, since, if such a name has any claim whatever to stand, we must go back to Vanuxem's *lycopodites*, because it has priority not only of publication but also in the matter of illustration.

Professor H. A. Nicholson has given his views on the value of these equivalent names in his work on "The Genus Monticulipora," p. 8, 1881, and as my own conclusions on the points at issue agree thoroughly with his I cannot do better than quote his excellent statement of the facts: "My object in mentioning this in this place is twofold. On the one hand, there are few corals which have been more commonly quoted by American geologists and paleontologists than *Chætetes lycoperdon* Say, or *Chætetes lycopodites* Vanuxem; and it would therefore be very desirable to establish, if possible, the precise nature and characters of the form to be understood by this name, though I am not aware that this has ever been satisfactorily accomplished. On the other hand, I wish to record the opinion that the generally laudable desire of preserving an old name, where this is possible, may sometimes be carried too far, and that this is, in my view, an instance in point. No definition of *Chætetes lycopodites* Vanuxem, which can be regarded as in any sense a definition, was given by its original author, or has since been supplied by any subsequent observer, while it is certain that this name (or the equivalent *C. lycoperdon* Say) has been applied by different writers to wholly different forms."* "Nor, in the case of a genus like *Monticulipora*, where external form goes for so little, can Vanuxem's original *figure*, however good, be regarded as satisfactory proof as to the species upon which he really founded the name in question. Under these circumstances, therefore, I think as I think about such names as *Favosites fibrosa* Goldf., and various other similar titles, that it would be a real gain to science if there could be a general agreement that designations of this kind—published, in the first place, with wholly insufficient definitions, and subsequently employed by others in widely different senses—should be dropped altogether, and that no attempt should be made to revive them."

To show the inadequacy of Vanuxem's figure, which shows absolutely nothing beyond the tubular structure of a hemispheric bryozoan mass, I have drawn the accompanying illustrations of the internal structure of four *hemispheric* species, all of them from the Trenton and supplementing those figured on plates XVI and XVII.

---

*I should like to add here that it would not be difficult to show that since 1842 no less than one hundred distinguishable froms have been included under this indefinite general designation. E. O. U.

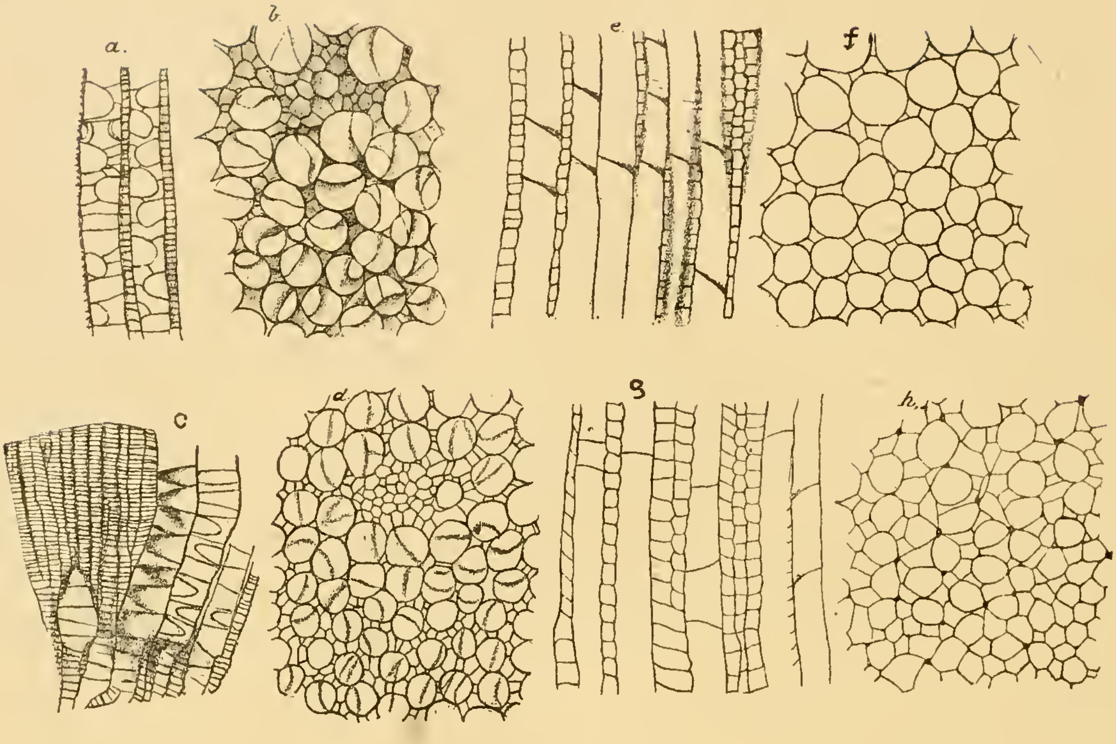


FIG. 15. *a* and *b*, vertical and transverse sections of *Prasopora selwyni* Nicholson, Trenton limestone, Ottawa, Canada; *c* and *d*, similar sections of *Prasopora oculata* Foord, Galena shales, near Cannon Falls, Minnesota; *e* and *f* similar sections of *Mesotrypa quebecensis* Ami, sp., Trenton limestone, Little Falls, N. Y.; *g* and *h*, similar sections of *Mesotrypa whiteavesi* Nicholson, sp., Trenton limestone, Ottawa, Can. All the figures are x18.

Indeed, there are at least ten hemispheric species, to any one of which the orignal of Vanuxem's figure might have belonged. Most of these are species of *Prasopora* and *Mesotrypa*, but I do not in the least doubt that Vanuxem, as well as all the other early workers in geology, would have included under one specific name, and perhaps did, also species of *Leptotrypa*, *Monotrypa*, and even *Crepipora*, having a similar mode of growth. In the absence of his illustrated specimen, and the utter impossibility of deciding permanently to which of these various forms it belonged, it seems to me not only desirable but necessary to drop the names *lycopodites* and *lycoperdon*, so far as their application to fossils of the types in question is concerned.

Formation and locality.--The typical form of the species is one of the most abundant and characteristic fossils of the shaly part of the Trenton group of central Kentucky. It occurs also at Nashville, Tennessee, and in the Galena limestone at Neenah and Oshkosh, Wisconsin, and Decorah, Iowa. In Minnesota it is abundant in the upper third of the Trenton shales at St. Paul, and rather rarely at other localities in the state. Also in the upper part of the Galena shales at Kenyon and other points in Goodhue county. The exact horizon of certain specimens in the state collection labeled Minneapolis, Lanesboro and Mantorville, is somewhat doubtful. The variety *orientalis* is common in the Trenton limestone at Ottawa, Peterboro, and other localities in Canada, and at Trenton Falls, New York.

Mus Reg. Nos. 4041, 5124, 5532, 5986-5988, 6786, 7570, 7571.

Prasopora contigua *Ulrich.*

PLATE XVI. FIGS. 24-26

Prasopora contigua Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 87.

Zoarium hemispheric, base flat or slightly concave, usually less than 30 mm. in diameter. Zoœcia with very thin walls and polygonal apertures, ten or eleven of the average size in 3 mm. Clusters of zoœcia, some of them attaining a diameter of 0.37 mm., occur at intervals of a little less than 4 mm. Mesopores comparatively few, often difficult to detect at the surface.

Internal structure: Tangential sections show that the zoœcial walls are polygonal and very thin, with neighboring cells in contact, except at many of the angles of junction, these being occupied by one or two small mesopores. The latter often form very inconspicuous clusters at the center of the groups of large zoœcia, but in the intermediate spaces not over half of the angles of junction between the ordinary zoœcia are occupied by mesopores. A few very small acanthopores are developed. The opening left by the cystiphragms is generally of ovate form and more often eccentric than central in its position within the tube cavity.

Vertical sections are peculiar chiefly because they exhibit a marked decrease in the number of mesopores when compared with other species of the genus.

This form is closely related to *P. simulatrix*, and perhaps should be classed as a variety of that species. The distinguishing features are (1) the much smaller number of mesopores, (2) thinner walls, (3) the presence of small acanthopores, and (4) a somewhat greater crowding of the cystiphragms, these averaging over twenty in 2 mm. More specimens are necessary before the constancy, and, therefore, value, of these differences can be established fully. The same species, very slightly modified, occurs at Cincinnati, Ohio, about three hundred feet above the Ohio river bed.

Formation and locality.—The Minnesota specimens are believed to have been found either in the upper part of the Trenton shales or in the Galena shales, at localities in Goodhue and Dakota counties.

Mus. Reg. Nos. 5301, 5534, 5989.

Prasopora conoidea *Ulrich.*

PLATE XVI, FIGS. 11-15.

Prasopora conoidea Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 87.

Zoarium generally depressed-conical, with the hight a little more than half the diameter; at other times subhemispherical; hight varying from 4 to 16 mm., the diameter from 8 to 20 mm. Under surface rather deeply concave, wrinkled concentrically, with a small central scar. Upper surface celluliferous and presenting, at intervals of about 3 mm., more or less prominent monticules, whose summits usually appear subsolid or minutely pitted; their slopes are occupied by zoœcia above the average in size. Zoœcial apertures subcircular, eleven or twelve of those of the ordinary size in 3 mm. Mesopores abundant, in most cases readily distinguishable at the surface with the aid of a good lens. Acanthopores small, inconspicuous.

Internal characters: These require no detailed description, being brought out sufficiently in figs. 14 and 15. Compared with those of *P. simulatrix* Ulrich, we find that the zoœcial walls are thinner, the mesopores rather more abundant, and that small acanthopores, one or more to each zoœcium, are present, these structures being absent in *P. simulatrix*. The tabulation of both sets of tubes is also more compact, the average number of diaphragms in the mesopores in 1 mm. being about thirty, and the cystiphragms in the zoœcial tubes over twenty-five in 2 mm. In the latter respect the species is nearer *P. contigua* Ulrich, from which it is distinguished by its smaller size, more conical form, tuberculated surface, and more numerous mesopores. More than five hundred specimens show that the subconical form, more or less developed monticules, the strongly concave base, and the small size of the zoarium are persistent characters, sufficing to distinguish the species almost at a glance from other forms of the genus.

Formation and locality.—Restricted to the upper third of the Trenton shales, occurring rather rarely at St. Paul, but more abundantly at several localities in Goodhue county. The best locality is at Oxford Mills, near Cannon Falls.

Mus. Reg. Nos. 3483, 7622, 8024, 8037.

Prasopora selwyni *Nicholson.*

PLATE XVI. FIGS. 16–17.

Monticulipora (Diplotrypa) whiteavesii (part.) Nicholson, 1879. Pal. Tab. Corals, p. 316.
Monticulipora (Prasopora) selwynii Nicholson, 1881. "The Genus Monticulipora," p. 206.

Zoarium discoid, subconical, or hemispheric, rarely more than 30 mm. high, and in most cases varying between 40 and 90 mm. in diameter. Base flat or gently concave, the epithecal plate striated or wrinkled concentrically. Surface characters of the Minnesota specimens obliterated through weathering, the only one still distinguishable being the substellate maculæ. Their specific characters, however, are clearly determinable by means of thin sections.

Tangential sections are not materially different from those of *P. simulatrix* Ulrich. As a rule the zoœcial walls are a little thinner, and the mesopores of larger size. But vertical sections, as may be seen by comparing figs. 1 to 5 with 16 on plate XVI, are quite different. The tabulation of the tubes is on the whole less compact, but the principal peculiarity is found in the cystiphragms, these appearing as series of semicircular lines, each distinct from the other, on one or both sides of the zoœcial tubes. In the latter case they are arranged alternately. About three cystiphragms occur on each side in 1 mm., while in the same distance six or seven diaphragms cross the space left by them. This is the usual arrangement of the cystiphragms, but in many of the tubes they also form loose connecting series very much as in *P. similatrix*, var. *orientalis* (see plate XVI, fig. 2).

This species is certainly distinct from *P. simulatrix*, the isolated condition of the cystiphragms being too striking a feature to be considered as less than specific. Foord's *P. affinis* and *P. oculata*, the first especially, are closer relatives, having likewise the cystiphragms isolated and not forming continuous series. The first, a smaller species, with no maculæ, and conical instead of semicircular cystiphragms, is known as yet only from Canada.* *P. oculata*, however, has been found in Minnesota, and is described on a succeeding page.

Formation and locality.—Dr. Nicholson's types of the species are from the Trenton limestone of Peterboro'. Ontario. Foord says the species "is very abundant throughout the Trenton formation of Canada." Also that it has been found in the upper beds of the Chazy, at Nepean, near Ottawa. The Minnesota specimens were collected by the author in the upper part of the Galena shales near Cannon Falls. It is there associated with *Monticulipora grandis* Ulrich, another massive but more irregularly growing form, that was at first believed to be restricted to the top of the lower limestone.

Prasopora insularis, *n. sp.*

PLATE XVI, FIGS. 18-23.

Zoarium small, discoid, plano- or concavo-convex, commonly from 15 to 20 mm. in diameter, and 5 or 6 mm. in hight. In a very large example these dimensions are respectively 28 and 12 mm., while in the smallest seen they are 1.5 and 0.5 mm. Under surface with a central scar, and beyond it delicate radiating lines, fine concentric striæ, and, at intervals indicating stages of growth, stronger wrinkles. Very often the zoaria are evidently made up of distinct superimposed layers, but these are not usually distinguishable internally. Upper or convex surface without monticules, but exhibiting, at intervals of about 4 mm., distinct clusters of large zoœcia. Generally, at the center of each of these clusters, the mesopores which are small and in nearly all cases just about numorous enough to isolate the zoœcia, are gathered into groups of varying size. Zoœcial apertures circular, those in the clusters attaining a diameter of 0.4 mm., while those of the smaller size in the inter-macular spaces average about 0.22 mm., with eleven or twelve in 3 mm.

*Since writing this a number of specimens of *P. affinis* were collected near Cannon Falls in the upper part of the Galena shales, associated with species of *Nematopora* and *Arthroclema armatum*.

Internal characters: The first peculiarity to be noticed in tangential sections is the relatively great abundance of the mesopores. In most specimens they form a complete ring around the zoœcia, and it is chiefly the large cells in the clusters that are occasionally in contact at limited points. The zoœcial walls are thin, and in one section have the peculiar tubular structure shown in fig. 21. The cystiphragms are more numerous and extend to a less distance from the walls than in any other American species. The opening left by them is of various shapes, generally subangular, and often removed from the walls. True acanthopores have not been detected.

In vertical sections the abundance of the mesopores, the narrowness of the cystiphragms, and the unusual crowding of the tabulation in both sets of tubes, are the distinctive features. In the mesopores the average number of diaphragms in 1 mm. is over twenty-five, while the cystiphragms may number as high as twenty in 1 mm., though the average is not likely to be over fifteen in that space.

Figures 18 and 19 represent one of two examples that may prove distinct. In tangential sections it differs in the greater size of the mesopores, and in the different appearance of the cystiphragms. In vertical sections the cystiphragms are less crowded and extend farther inward, while the mesopores here and there change into vesicles, a peculiarity that has not been observed in the usual form of the species. Provisionally the doubtful form may be distinguished as var. *filmorensis.*

This species is readily recognized by its small size and discoid shape. When studied by means of thin sections it cannot be confounded with any other known to me.

Formation and locality.—This is probably the commonest and most characteristic fossil of the Galena shales, having been found in greater or less abundance at nearly every locality in the state where that horizon is known to be exposed. The species also occurs in the Galena at the quarries near Neenah, Wisconsin, and at Decorah, Iowa. Var. *filmorensis* seems to have come from a lower horizon at Fountain and Preston, both in Fillmore county.

Mus. Reg. Nos. 310, 5991, 5992, 7569, 7601, 7611, 7628, 7637, 7644, 7666, 8057; var. *filmorensis*, 5990.

PRASOPORA OCULATA *Foord.*

FIG. 15, *c, d*, PAGE 248.

Prasopora oculata FOORD, 1883. Contri. Micro-Pal. Cambro-Sil. Rocks, Can., p. 11.

Zoarium a thin, discoidal expansion, 15 to 30 mm. in diameter, and from 1 to 3 mm. in thickness. Of the Minnesota examples none is thicker than 2 mm., and all are nearly 25 mm. in diameter. Under surface flat or gently concave, and marked with more or less strong wrinkles of growth, and sometimes with very fine radiating lines. Upper surface celluliferous, exhibiting subsolid maculæ (clusters of mesopores) at intervals of about 3 mm., each a mm. or more in diameter. Surrounding these the surface is depressed to a variable degree, and occupied by angular zoœcial apertures of comparatively large size and very few mesopores. The average diameter of these zoœcia is about 0.28 mm. On the rounded ridges between the depressions the zoœcial apertures are circular and smaller, averaging about 0.2 mm. in diameter; here they are also completely surrounded by a row of small mesopores.

Internal characters: The tangential section figured on page 248 shows in the upper half one of the maculæ with the large zoœcia surrounding it and occupying the depressed hexagonal surface spaces. Between these zoœcia the mesopores are very few, but farther out, in spaces representing the ridges (lower third of figure), the mesopores usually completely isolate the, here also smaller, zoœcia from each other. Acanthopores are wanting.

In vertical sections (fig. 15*c*) the maculæ appear as numerous, small, subequal, closely tabulated tubes. One or two similar mesopores occur between many of the zoœcia in the inter-macular spaces. In the zoœcial tubes the transverse partitions are quite different. The appearance of the cystiphragms depends upon the direction in which the section passes through them. When this is at right angles they appear (see the central tube of the three shown in the figure) as narrow loops projecting inward from the walls. Sometimes a complete diaphragm passes between each pair. A variety of appearances, some of them shown in the figure, result when the section passes through the cystiphragms at other than a right angle.

This species is readily distinguished from its associate, *P. insularis* Ulrich, as well as from all the other species of the genus known to me, by the division of the surface into subhexagonal depressed spaces. The zoarium is also unusually thin, while the internal structure is peculiar enough to be distinguished at once, even from its nearest allies, *P. affinis* Foord, and *P. selwyni* Nicholson. Still, I am not fully satisfied that the form is in all cases to be distinguished specifically from *P. affinis*, small specimens of which have recently been found associated with it.

Formation and locality.—Rather rare in the Galena shales at several localities in Goodhue county, Minnesota. The types of the species are from the equivalent Trenton limestone at Ottawa, Canada.

Mus. Reg. No. 7625.

PRASOPORA LENTICULARIS, *n. sp.*

PLATE XVII. FIGS. 22-25.

Zoarium small, lenticular, beginning its growth upon foreign bodies, as far as observed, about 12 mm. in diameter and 1 mm. thick. Zoœcial apertures regularly arranged, oval, twelve or thirteen in 3 mm., each of the smaller or average size 0.18 by 0.23 mm. In the clusters a few of the largest may attain a size of 0.35 by

0.28 mm. Zoœcial walls very thin, in contact at limited points, yet leaving comparatively large and easily distinguished interspaces, which, because the prevailing arrangement of the apertures is quincuncial, are commonly bounded by four concave sides. In most cases each of these spaces is occupied by a single mesopore, averaging 0.1 mm. in width and a little more in length. Mesopores but little if at all more numerous in the clusters than elsewhere. They may be however a little larger and less regular in shape. Acanthopores apparently wanting.

This species may be nearly related to *P. simulatrix* Ulrich, but it is not its young. This is shown best by thin sections, but the smaller size and more oval shape of the zoœcial apertures, the absence of maculæ, and the larger size and different shape of the interspaces, alone are sufficient in discriminating between them. Comparing internal characters these differences are emphasized, while another point is added in the greater separation of the diaphragms in the mesopores. Tangential sections are a little like those of *P. insularis*, var. *filmorensis*, but the zoœcia in that species are completely isolated, and the tabulation of both sets of tubes much more crowded. It seems to me that *Aspidopora parasitica* Ulrich, is more closely related, but differs sufficiently in its parasitic growth, more closely tabulated mesopores, and in possessing small acanthopores.

Formation and locality.—Rare in the upper third of the Trenton shales at St. Paul, Minnesota.

Genus ASPIDOPORA, Ulrich.

Aspidopora, ULRICH, 1882. Jour. Cin. Soc. Nat. Hist., vol. v, p. 155; 1890, Geol. Sur. Ill., vol. viii, p. 373.

Zoarium consisting of one, or two or more superimposed, thin expansions, each 1 mm. or less thick, rarely parasitic, generally free, with an epithecal covering on the concave lower side; typically composed, according to age, of from one to many subequal parts, each gently convex, with the zoœcia increasing in size from their margins to near their centers. Mesopores numerous, largest and best seen externally in the younger stages. Acanthopores usually present, always small. Diaphragms horizontal and closely set in the mesopores, usually wanting in the zoœcial tubes, but one or more cystiphragms occur in most of the latter.

Type: *A. areolata* Ulrich, Utica horizon, Cincinnati group.

This genus is so closely related to *Prasopora*, Nich. and Ethr., jr., that for some time I have considered the propriety of dropping the name in favor of theirs. But, as I could not arrive at a wholly satisfactory conclusion, it seemed best to retain the genus till we can learn more of the developmental history of this section of the *Monticuliporidæ*.

Taking *Aspidopora* in the sense above described, there is only one character (the other peculiarities being dependent upon it) that will distinguish it from *Prasopora*, namely, the thinness of the zoarial expansion and the consequent brevity of the zoœcial tubes. That this is the mature condition of the zoaria is proved by finding hundreds of examples of some of the species, not one of which exceeds 1 mm. in thickness, though many of them may be over 25 mm. in diameter. Some may consist (see plate XVII, fig 17) of several layers in contact at limited points but really quite distinct from each other, and thus showing that, beyond the development of the individual layers, the method of growth is not the same as in *Prasopora*. In that genus the tubes, though perhaps presenting many immature and mature regions or layers, are continuous throught the zoarium, even if it be over 50 mm. in thickness. The tabulation of the two sets of tubes is essentially the same in the two genera, excepting that in *Aspidopora* it is altogether as in the immature regions of a *Prasopora*.* Perhaps some significance is to be attached also to the fact that only a few cystiphragms and no straight diaphragms occur in the zoœcial tubes.

Seven species are referred to *Aspidopora* as now defined. The next described, *A. parasitica*, is the oldest, and occurs in the lower and middle thirds of the Trenton shales. This species is also one of the earliest known phases of the type of structure that at this time was evidently being rapidly differentiated into true *Prasopora* and *Mesotrypa*. Before we can fully understand the relations of these groups of species to each other it is necessary to discover the more primitive forms that are to be expected in the Chazy. The second species, *A. elegantula*, occurs in the Galena shales, and the five remaining, *A. areolata* Ulrich, *A. newberryi* Nicholson, sp., *A. calycula* (James) Nich., sp., *A. eccentrica* James, sp., and an undescribed species, in the lower two hundred feet of strata at Cincinnati, Ohio.

Aspidopora parasitica *Ulrich.*

PLATE XVII, FIGS. 26-32.

Aspidopora parasitica (part.) Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 90.

Zoarium parasitically attached to shells, *Streptelasma profundum* Conrad, and other foreign bodies, upon which it forms very thin, subcircular or irregular patches, 10 to 20 mm. in diameter, and 0.5 mm. or less in thickness. Zoœcial walls very thin, apertures oval or circular, arranged in regular curved series around groups of cells distinctly larger than the average; eleven or twelve of the latter in

*In previous publications on this genus (*loc. cit.*) I did not mention the presence of cystiphragms because these structures seemed to be wanting in the type species. My present opinion is that the supposed diaphragms figured by me for *A. areolata* (*op. cit.*, vol. vi, p. 164), are really cystiphragms, in part incorrectly drawn.

3 mm. Of these the average diameter is 0.2 mm. or a fraction more, but that of the largest in the clusters is commonly about 0.3 mm., though of a few it may by 0.35 mm. Mesopores numerous, readily distinguishable even at the surface, not surrounding the zoœcia entirely. Acanthopores very small and inconspicuous.

Internal characters: These are faithfully and amply illustrated on plate XVII rendering a description unnecessary.

In my original description of the species I included another which is now separated as *Mesotrypa (?) spinosa.* While I still regard them as related forms, the result of a study of larger and better collections is to show that the latter is more intimately connected with *Mesotrypa infida* than with the form to which I propose to restrict the use of the name *A. parasitica.* I found no difficulty in distinguishing specimens of the two species after discovering that they were really distinct. In the *parasitica* the thickness of the zoarium is constantly 0.5 mm. or less, the acanthopores very inconspicuous, and the mesopores readily determinable under a good lens. In the *spinosa*, on the contrary, the zoarium may attain a thickness of over 2 mm., the mesopores are scarcely distinguishable at the surface, and the acanthopores strong. Among associated parasitic species there is another that the beginner may find it troublesome to separate. This is the *Atactoporella insueta*, really a very different species, with more numerous acanthopores and less regularly distributed zoœcial apertures.

Formation and locality.—Rather rare in the lower and middle thirds of the Trenton shales at Minneapolis, St. Paul and Fountain, Minnesota.

Mus. Reg. Nos. 5994, 5995.

Aspidopora elegantula, *n. sp.*

PLATE XVII, FIGS. 13-21.

Zoarium a thin, concavo-convex expansion, 25 to 33 mm. in diameter, and 0.5 mm. or less in thickness; sometimes consisting of two or more of such layers grown loosely over each other. Under surface concave, with a concentrically and radially marked epithecal membrane. Upper or convex surface celluliferous. Zoœcial apertures ovate, their walls thin, in contact only at limited points, the interspaces distinctly occupied by mesopores, all the parts nicely arranged around clusters of large cells. The latter are 3 or 4 mm. apart, and in most cases slightly elevated. Average size of ordinary zoœcial apertures about 0.18 mm, by 0.25 mm., with eleven or twelve in 3 mm.; size of the largest in the clusters rarely exceeding 0.28 mm. by 0.37 mm. Acanthopores wanting.

Internal characters: These are sufficiently illustrated on plate XVII, but it is well to state that a few tubes in both vertical and tangential sections may show a single cystiphragm at the bottom. Diaphragms are wanting, as are acanthopores also.

This beautiful bryozoan is a true *Aspidopora,* and is rather closely related to *A. newberryi* Nicholson, sp., the only reliable or constant difference between them being in the number of cystiphragms. In the present species these structures are so few that they may appear to be wanting entirely, but in Nicholson's species they occur in every zoœcial tube, numbering in each, according to age, from one to ten. Several discoidal forms are to be found in the same beds with *A. elegantula,* but none of them are sufficiently like it to render confusion probable.

Formation and locality.—Rather rare in the Galena shales at St. Paul, and near Kenyon, Goodhue county, Minnesota.

Mus. Reg. No. 8126.

Genus MESOTRYPA, n. gen.

Diplotrypa (part.) NICHOLSON, 1879, Pal. Tab. Cor., p. 312, and 1881. The Gen. Monticulipora, pp. 101 and 155.

Zoaria hemispheric, conical, or discoidal, generally free, with the lower surface covered by an epitheca. Zoœcial tubes prismatic or cylindrical, more or less separated from each other by angular mesopores; internally with oblique and sometimes funnel-shaped diaphragms, that often simulate and probably are to be regarded as peculiarly modified cystiphragms. Mesopores becoming smaller with age, intersected by numerous diaphragms. Acanthopores generally present, sometimes of large size.

Type: *Diplotrypa infida* Ulrich.

This genus is established for a natural group of species heretofore referred, erroneously, I believe, to *Diplotrypa**. These species are *D. regularis* Foord, *D. quebecencis* Ami, *D. whiteavesi* Nicholson, *D. patella* Ulrich, the type *D. infida,* and three new species, *M. discoidea, M. rotunda,* and *M.* (?) *spinosa.* To these might be added the Niagara *D. milleri* Ulrich, but as the position of that species is somewhat in doubt, it had best be left as originally placed till an opportunity offers to rework the type specimens.

The affinities of the proposed genus are not with *Diplotrypa* but with *Prasopora.* Indeed, for some time I considered the propriety of referring the group to *Prasopora,* yet after mature reflection the erection of a new genus was decided upon as serving the purposes of classification better than would have been done by extending the limits of that genus.

*See part ii, Contri. Micro-Pal. Cambro-Sil. Rocks, Can., p. 32, 1890.

Mesotrypa infida *Ulrich.*

PLATE XVII, FIGS. 1-8.

Diplotrypa infida Ulrich, 1886, Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 88.

Zoarium discoid or subhemispheric, with the base flat or concave and partly covered with a concentrically wrinkled epitheca ; or it may be parasitic and conform with the shape of the body grown upon ; hight or thickness from 2 to 7 mm., diameter from 12 to 20 mm. Zoœcial apertures varying from polygonal to subcircular, the shape depending upon the number and size of the mesopores. In some specimens the latter are almost certain to be overlooked, the zoœcia being angular and seemingly in perfect contiguity (pl. XVII, fig. 8). In others they are large enough to constitute an obvious external feature (fig. 7). The latter condition is to be regarded as less mature than the former, since in it the acanthopores are scarcely distinguishable, while they are readily made out where the mesopores are smallest. At intervals of 3 or 4 mm. there are clusters of large zoœcia varying in diameter from the smaller or ordinary sizes of 0.2 to 0.24 mm. to 0.4 or 0.45 mm. An average of eleven of the ordinary size in 3 mm.

Internal structure: In vertical sections the tubes are everywhere perpendicular to the basal membrance. Their walls are a little thicker than usual in species of the genus. In the lower part of the zoarium the mesopores with their numerous diaphragms are very conspicuous. In following them upward they seem to be reduced in diameter, permitting the zoœcial tubes to come in contact with each other. These zones may be repeated several times. Diaphragms are numerous though not regularly distributed in the zoœcial tubes. The appearances presented by them are exceedingly variable. Some appear to be horizontal and straight or slightly bowed down in the middle (figs. 4 and 6), others are obliquely curved and perhaps overlapping (fig. 3), while still others are funnel-shaped (fig. 5). This variability however is not a structural peculiarity, but is due to the varying angles at which the diaphragms are cut by the section.

Tangential sections vary according to the depth from the surface at which they divide the zoarium. In the immature region (fig. 2) we have rounded zoœcia, almost completely surrounded by mesopores, and small acanthopores. In the mature region (fig. 1) the mesopores are much smaller, the zoœcia somewhat larger and subangular, and the acanthopores larger. In most of the zoœcial cavities the oblique and somewhat funnel-shaped diaphragms are represented by curved lines, often closely simulating the appearances of ordinary cystiphragms.

The mesopores are less numerous, and the tabulation of both sets of tubes more crowded than in *M. whiteavesi* Nicholson, sp. In *M. regularis* Foord, sp., the diaphragms are few in the zoœcial tubes. This is likewise true of *M. quebecensis* Ami, sp., in which acanthopores seem to be wanting entirely.

Formation and locality.—In the middle third of the Trenton shales at Minneapolis, St. Paul and localities in Goodhue and Fillmore counties, Minnesota.

Mus. Reg. No. 5993.

Mesotrypa (?) spinosa, *n. sp.*

PLATE XVII, FIGS. 9-12.

Aspidopora parasitica (part.) Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 90.

Zoarium parasitic, 0.5 to 6.0 mm. thick. Zoœcia small, circular, neatly arranged about the clusters, twelve or thirteen of the ordinary size in 3 mm. Interspaces or walls rather thick, but the abundant mesopores shown in thin sections are rarely, if ever, to be made out at the surface. This may be due in part to the large size and prominence of the acanthopores. Internally, with crowded horizontal diaphragms in the mesopores and mostly oblique curved partitions in the zoœcial tubes. Sometimes a few at the bottom of the tubes are precisely like ordinary cystiphragms (fig. 12).

This form seems to hold an intermediate position between *M. infida* and *Aspidopora parasitica*, differing from the first in having smaller zoœcia, thicker walls and stronger acanthopores, and from the second in the greater thickness of the zoarium, much stronger acanthopores, different tabulation of the zoœcial tubes, and in but rarely showing the mesopores at the surface, these being, so far as observed, always distinctly visible at the surface of *A. parasitica*. *Atactoporella insueta*, another associated parasitic species, has larger and less regularly distributed zoœcia, with smaller and more numerous acanthopores.

Formation and locality.—Perhaps the commonest of the parasitic Bryozoa occurring in the middle third of the Trenton shales at St. Paul, Minneapolis and other localities in Minnesota.

Mus. Reg. No. 8127.

Mesotrypa quebecensis *Ami, sp.*

FIG. 15, *e* and *f*, PAGE 248.

Diplotrypa quebecensis Ami, 1892. Canadian Record of Science, p. 101.

Zoarium discoid or subhemispheric, base gently concave, hight 4 to 20 mm., diameter 12 to 45 mm. At Decorah, Iowa, the specimens are generally about 25 mm. in diameter, and 6 or 7 mm. thick. The same is true of the Kentucky examples, but in New York and Canada they are usually nearly again as large.

Mr. Ami's original type is probably a young specimen, being only about 12 mm. in diameter. Zoœcial apertures rounded, the largest of those in the clusters attaining a diameter of 0.4 to 0.45 mm., but those occupying the spaces between the clusters average about 0.24 mm., with eleven or twelve in 3 mm. Walls thin. Mesopores of variable size, not isolating the zoœcia, in most cases readily distinguishable at the surface; internally with diaphragms averaging about ten in 1 mm. Zoœcial tubes intersected by a few oblique curved diaphragms. These are developed chiefly in zones, 3 or 4 mm. apart, in which several occur approximately on the same level in all the tubes. In even these zones the diaphragms are separated but rarely by intervals less than 0.5 mm., while between the zones they may be wanting for a distance of 4 mm., though commonly occurring there at intervals of about 2 mm. Not a sign of acanthopores has been detected on the surface nor in thin sections.

This species is closely related to *M. regularis* Foord, sp., differing therefrom chiefly in wanting acanthopores. The same and other differences will be noticed when thin sections of it are compared with similar sections of *M. infida*, *M. whiteavesi* and *M. patella*, in all of which the zoarium has very nearly the same shape. Young examples are also very much like *Prasopora insularis* and *P. lenticularis*. Indeed, it is a matter of no small difficulty to identify with certainty any of the host of discoidal Bryozoa that are already known from Lower Silurian deposits without the aid of intelligently prepared thin sections.

Formation and locality.—Rather rare in the Galena Shales at Decorah, Iowa, in shales of the Trenton group at Burgin and Danville, Kentucky, and in the Trenton limestone at Trenton Falls, New York. Mr. Ami's type is from rocks supposed to be equivalent at Quebec, Canada.

Mus. Reg. No. 8128.

Mesotrypa discoidea. *n. sp.*

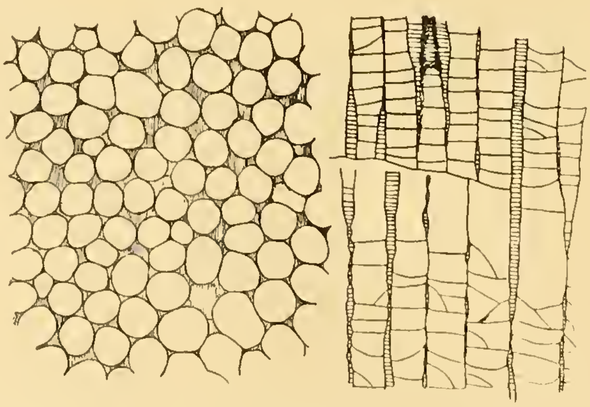


FIG. 16. *Mesotrypa discoidea* Ulrich, upper beds of the Galena shales, Goodhue county, Minnesota. Collection of E. O. Ulrich. Tangential and vertical sections, x 18, the latter consisting in part of two distinct layers.

Zoarium discoid, base flattened, upper surface gently convex; diameter, so far as observed, less than 20 mm.; hight, sometimes divisible into two subequal layers, 4 mm. or less. Upper surface with inconspicuous clusters of zoœcia a little larger than the average. Zoœcial apertures rounded, rather regularly arranged, about eleven in 3 mm. Mesopores numerous, rather small, occupying merely the triangular or quadrangular interspaces left between the adjoining rounded zoœcial walls. The latter are very thin. As usual with species of this and related genera the mesopores are more abundant (in this case completely isolating the zoœcia) in the basal or primitive part of the zoarium than in the fully matured superficial portion. Acanthopores apparently absent.

In vertical sections the chief peculiarity of the species is found in the tabulation of the tubes. In both sets of tubes, namely, diaphragms are present in unusually large numbers, there being a few more or less than thirty-five in 1 mm. in the mesopores, while in the zoœcial tubes the average is eight or nine in the same distance. In the latter the diaphragms, especially in the lower part, are frequently curved or oblique, as shown in the figure, but some of the tubes have practically horizontal diaphragms throughout. The mesopores are quite abundant at the curved basal part of the zoœcial tubes, becoming, however, very much less so soon after these assume an erect position. Many of the zoœcial walls may appear as completely in contact, but the rule is that at intervals, at any rate, they separate, producing the periodic tabulated swellings shown in the figure.

This species, having no acanthopores, belongs near *M. quebecensis* Ami, sp., from which it differs strongly in vertical sections, the diaphragms being much fewer in that species. *M. rotunda*, also without acanthopores, has more numerous and comparatively loosely tabulated mesopores.

Formation and locality.—Rare in the uppper part of the Galena shales (Anastrophia beds) at localities in Goodhue county, Minnesota.

Mesotrypa (?) rotunda, *n. sp.*

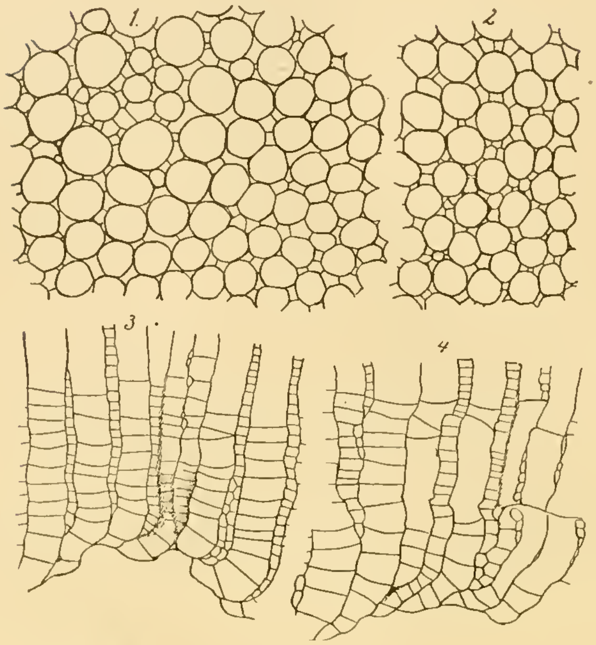


Fig. 17. *Mesotrypa rotunda* Ulrich, upper beds of the Galena shales, Hader, Goodhue county, Minnesota. Collection of E. O. Ulrich. 1, tangential section showing arrangement of cells about one of the clusters. The latter embraces several young zoœcia. 2, another portion of same section, with half of a cluster shown above. 3, vertical section passing through a cluster like the one represented in 1, and showing at center of figure several mesopores that have enlarged and assumed the tabulation of zoœcial tubes. 4, another portion of same section showing a partial break in the continuity of the tubes, and consequent irregularities in their tabulation. All x 18.

Zoarium a small hemispheric mass, 10 mm. in diameter, 6 mm. high, and 4 mm. thick at the middle, the under surface being strongly concave and wrinkled concentrically. Upper surface without monticules, but exhibiting fairly distinct clusters of large cells, rendered in many cases more so by aggregations of mesopores. Zoœcial apertures rounded, about eleven of the average size in 3 mm. Mesopores abundant, but seeming never to separate the zoœcia completely. Acanthopores wanting.

Internal structure as shown in the accompanying figures.

This form is distinguished from the other species of the genus in having all the diaphragms essentially horizontal. This fact casts some doubt upon the propriety of placing the species under *Mesotrypa*, and the uncertainty of the reference is emphasized by undoubted relations with species now classed as *Diplotrypa* (e. g. *D. milleri* Ulrich, and *D.? dubia* Ulrich), having a decided leaning toward *Callopora*.

Formation and locality.—Lower beds of the Galena limestone at Hader, Goodhue county, Minnesota.

Family BATOSTOMELLIDÆ, Ulrich.

Genus BYTHOPORA, Miller and Dyer.

Bythopora, MILLER and DYER, 1878, Contri. to Pal., pt, ii, p. 6; ULRICH, 1890, Geol. Surv. Ill., vol. viii, p. 376.

Zoaria consisting of very slender branches. Zoœcial apertures very small, oblique, lanceolate, narrowing above. Interspaces variable, generally thick, often channeled. Mesopores and diaphragms very few or wanting. Acanthopores usually present, never numerous, rarely more than one to each zoœcium.

Type: *B. fruticosa* Miller and Dyer. Cincinnati group.

The two species found in Minnesota are very similar to the typical species, and, although the latter is not as fully known as we would desire, there can be no reasonable doubt that the three forms are thoroughly congeneric. At least five other species occur in the rocks about Cincinnati, Ohio, but only two of these have been described, both by Nicholson, one as *Chætetes delicatulus*, the other as *Ptilodictya ? arctipora*. Still another form was described by me as *B. striata* from the upper beds of the Hudson River group at Stony Mountain, Manitoba, and Middletown, Ohio.

BYTHOPORA HERRICKI *Ulrich.*

PLATE XXVI, FIGS. 1-6.

Bythopora herricki ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 99.

Zoarium ramose, 20 to 40 mm. high, consisting of slender cylindrical branches, 0.8 to 2.0 mm. in diameter, dividing dichotomously at intervals of from 8 to 12 mm. Zoœcial apertures small, very oblique, narrow, rounded behind, drawn out in front; when perfect with a minutely granulose rim, highest posteriorly. Interspaces depressed, wider than the apertures. In the worn condition in which the species is often found, the ramulets appear to be made of thick-walled tubes with oblique apertures. The arrangement of the apertures is in more or less irregular, longitudinal and diagonal rows, with four in 1 mm. in the latter. Acanthopores small, few, but rarely preserved at the surface. True mesopores wanting.

Internal characters: A number of thin sections were prepared, but in all the finer details of structure are more or less completely destroyed by crystallization. The sections figured were prepared from an unusually old example. I have endeavored to represent the characters shown in these as faithfully as possible, and as I cannot add anything of importance not shown, it is unnecessary to attempt a description of them.

The species is closely related to *B. arctipora* Nicholson, sp., of the Cincinnati rocks, but the zoœcial apertures are narrower and more produced anteriorly than in that species.

Formation and locality.—Fragments of this species are common in the middle third of the Trenton shales at St. Paul and Minneapolis, Minnesota. Good specimens, however, are rare.

Mus. Reg. Nos. 6012, 6013.

BYTHOPORA ALCICORNIS, *n. sp.*

PLATE XXVI, FIGS. 7-9.

In this species the zoarium divides at shorter intervals than in any other of the genus known, the distance between the branches varying between the extremes of 1.5 to 6.0 mm. Compared with *B. herricki*, we find that the average size of the branches is a little less, that they bifurcate at shorter intervals, that the zoœcial apertures are arranged less regularly and on the whole less compactly, the direction of the rows being interrupted and changed by meeting with spots, 2 or 3 mm. apart, in which the interspaces between the apertures are much wider than elsewhere. These subsolid spots distinguish the species from all the others as well, excepting an undescribed larger form occurring in the upper beds of the Hudson River group at Waynesville, Ohio, in which they are of greater extent and constitute a very obvious superficial character.

Formation and locality.—Upper third of the Trenton shales, associated with *Phylloporina corticosa* and *Prasopora conoidea*, near Cannon Falls, Minnesota.

Genus ERIDOTRYPA, n. gen.

Batostomella (part.) ULRICH, 1890. Ill. Geol. Sur., vol. viii, pp. 375, 432.

Zoaria ramose, branches slender. Zoœcia more or less oblique, with thick walls, the tubes intersected by diaphragms only. The latter may be wanting in the axial region, are in most cases absent for a short distance within the apertural edge, but always present and closest together in the turn from the axial into the narrow peripheral region. Mesopores with close-set diaphragms, varying in number, sometimes abundant, at other times very few. Acanthopores small, never numerous, sometimes wanting.

Type: *Eridotrypa mutabilis*, n. sp.

This genus became necessary partly through the restriction of *Batostomella* to its Carboniferous types, and partly for the accommodation of a number of species that could not be disposed of satisfactorily under any of the existing genera.* The

*It is unfortunate that both Hall's recently proposed *Trematella* (Pal. N. Y., vol. vi, p. xiv, 1887) and my *Batostomella* (1882) should have been founded upon practically the same type of structure. In both cases species are included doubtfully that are now to go under *Eridotrypa*.

genus will include beside the following, probably two as yet undescribed species from the Trenton of Kentucky, *Batostomella simulatrix* Ulrich, a widely distributed species from the upper beds of the Hudson River group, *Trematopora echinata* Hall, from the Niagara group of Indiana, *T.? (Trematella ?) corticosa* Hall (see Pal. N. Y., vol. vi, p. 15, pl. X, figs. 1–10), from the Lower Helderberg of New York, and *Batostomella obliqua* Ulrich, from the Hamilton group of Michigan.

The systematic position of the genus, though in a measure doubtful, is probably intermediate between *Homotrypa* (compare *H. similis* Foord) of the *Monticuliporidæ*, and *Bythopora*, Miller and Dyer, of the *Batostomellidæ*. Because of the absence of cystiphragms it will be best to embrace the genus provisionally in the latter family.

Eridotrypa mutabilis, *n. sp.*

PLATE XXVI. FIGS. 20-32.

Zoarium ramose, dividing at rather long but irregular intervals; branches 2 to 6 mm. in diameter, the younger examples slender and nearly cylindrical, the old ones more or less irregular. Considerably over half of the hundreds of specimens seen are from 3.5 to 4.5 mm. in diameter. Zoœcial apertures variable, the changes due chiefly to age, always oblique, the degree decreasing with age; walls thick, generally ridge-shaped and highest posteriorly, sloping gradually down into the apertures. In young examples—also in old ones on which a new layer of zoœcial tubes wàs formed—the apertures may be exceedingly oblique and drawn out anteriorly. With age they became gradually more direct. The arrangement of the apertures is always more or less irregular, some of the short rows having six, others seven, and occasionally eight in 2 mm. Small maculæ, either pitted or irregularly sculptured, commonly present in the older examples. In others the maculæ are represented by clusters of zoœcia which, though a little larger than the average, are distinguished from them chiefly by the greater thickness of the interspaces. The mesopores too are most variable. In some cases, but this is rare, they will appear to be wanting over large portions of the surface (see fig. 24); in others they may be twice as numerous as the zoœcia. As a rule, however, they are to be counted as few, appearing at the surface, except in rare instances, only as occasional shallow depressions between the zoœcial apertures. True acanthopores probably wanting, but small knots at the angles of junction may be noticed.

Internal characters: These are, luckily, fairly constant in all essential features, the principal variations observed being in the number of mesopores. Figs. 26 to 28 represent parts of sections prepared from an average example. Diaphragms occur all through the axial region at intervals, averaging about twice the diameter of a tube. As the tubes are about to open at the surface the diaphragms increase in number, and immediately thereafter the walls are greatly thickened, and mesopores developed. The latter were unusually numerous in the sections drawn in figs. 31 and 32.

Variety MINOR, *n. var.*

PLATE XXVI, FIGS. 20, 21, 29, 30.

This name may be attached to the small form represented by the figures cited. The surface magnified is generally very much as shown in fig. 21, the zoœcial walls being thinner than in typical *mutabilis.* But the principal peculiarities are to be found in the axial region, as shown in vertical sections. First, the central tubes are unusually large and their walls more wavy than in typical *mutabilis;* second, the tubes altogether seem to have been developed more regularly, and their width in the peripheral region somewhat less; and third, diaphragms are wanting throughout the greater part of the axial region. Under ordinary circumstances these differences would be considered as of specific value, but in this instance, knowing the extreme variability of the species, I cannot credit them with more than subordinate importance.

The smaller size of the branches, oblique zoœcial apertures, and the thicker walls or inter-apertural spaces, distinguish the species without much trouble from associated species of *Homotrypa* and *Callopora.* Despite its variability, I have always found it one of the easiest of the numerous Trenton species to identify off-hand.

Formation and locality.—Very common in the Galena shales at many localities in Goodhue, Dakota and Ramsey counties in Minnesota; also at Decorah, Iowa, and in the Galena at Neenah and Oshkosh, Wisconsin; in the shaly portion of the Trenton group at many points in central Kentucky; also at Nashville, Tennessee, and Ottawa, Canada. Specimens referred to the var. *minor* are to be found also in the upper third of the Trenton shales at St. Paul.

Mus. Reg. Nos. 5541, 6009, 7561, 7603, 7623-3, 8034, 8050, 8079.

ERIDOTRYPA EXIGUA, *n. sp.*,

PLATE XXVI, FIGS. 17-18.

Zoarium small, branches very slender, several hundred fragments varying in diameter from 0.6 to 1.0 mm.; bifurcations apparently remote. Some of the fragments are pointed at the lower end, indicating a free condition of the zoarium, or an articulation like that of *Escharopora.* The eastern form of the species is usually a little stronger than the average of the Minnesota types, the specimens seen from

Vermont and New York being mostly 1.0 mm. or a little more in diameter. Considering the small size of the branches, the zoœcia are large. Their apertures are oblique, but not excessively so, subequal, and arranged in both longitudinal and diagonal series, the former with eight in 3 mm., predominating in the small specimens, and the latter in the larger. At the lower end of each aperture the wall is usually raised into a spine-like prominence. In vertical sections the greater part of the branch is seen to consist of comparatively large and nearly or quite vertical tubes, intersected here and there by a diaphragm. The peripheral region is exceedingly short and abrupt.

The small size of the branches might be regarded as indicating *Bythopora* rather than *Eridotrypa*, but the comparatively large zoœcia and the internal characters, so far as known, point to the last genus with considerable certainty. Considered specifically, its branches are so much smaller than those of even the var. *minor* of the preceding species that there is really no likelihood of confusion here. Both *Bythopora herricki* and *B. alcicornis* have smaller zoœcial apertures and impressed, instead of ridge-shaped, interspaces.

Formation and locality.—A large number of fragments were picked from washings of upper Galena shales collected from a locality near Cannon Falls, Minnesota. The eastern form of the species occurs in the Trenton limestone, at Trenton Falls, New York, and Chimney Point, Vermont.

Mus. Reg. No. 8129.

Family HETEROTRYPIDÆ, Ulrich.

Genus HETEROTRYPA, Nicholson.

Heterotrypa (part.) NICHOLSON, 1879, Pal. Tab. Corals, p. 291; NICHOLSON, 1881, Genus Monticulipora, pp. 101 and 103.

Heterotrypa, ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 155; ULRICH, 1882, *idem*, vol. vi, p. 83; FOORD, 1883, Contri. Micro-Pal. Cambro-Sil. Rocks, Can., p. 20; ULRICH, 1890, Geol. Surv. Ill., vol. viii, pp. 371 and 413.

Zoaria frondescent, subramose, or incrusting. Zoœcial tubes prismatic, sometimes subcylindrical. Apertures angular, subcircular, or slightly petaloid. Walls moderately thin. Mesopores varying in number, sometimes abundant, with illy-defined walls. Acanthopores small, usually numerous. Diaphragms well developed, generally horizontal; occasionally a few may be concave or recurved.

Type: *H. frondosa* d'Orbigny, sp., (*H. mammulata* Nicholson, not d'Orbigny).

This genus is not yet known to occur in the rocks of Minnesota, but the two species following are to be looked for in the southern part of the state, being rather common fossils in the Hudson River rocks of Illinois and Wisconsin.

For remarks on this genus see under *Dekayella*.

Heterotrypa prolifica *Ulrich.*

(Not Figured.)

Heterotrypa prolifica Ulrich, 1890. Geol. Surv. Ill., vol. viii, p. 413, pl. xxxvii, fig. 1-1*d*.

Original description: "Zoarium frondescent, or subramose with much flattened branches ranging in thickness from 4 to 12 mm., and at times attaining a hight of 10 cm. Low rounded tuberosities arranged in irregularly intersecting lines, and composed of cells a little larger than the average, commonly surrounding a cluster of mesopores, serve to break up the monotony of an otherwise smooth surface. Zoœcial tubes curving in the axial region, direct throughout the peripheral region, where their walls become considerably thickened. Zoœcial apertures subpolygonal, about eight in 2 mm., and 0.15 to 0.18 mm in diameter. Interspaces occupied by calcareous matter; where very wide by a few mesopores with illy-defined walls. Most of the mesopores are found in the clusters.

A few diaphragms in the axial region; in the transition period they become more numerous; in the cortical region they are close set, a tube diameter or less apart. In the outer portion of this region they are often concave, sometimes tending to the infundibular form. Mesopores more closely tabulated than the zoœcial tubes. Acanthopores a little more than one-third as numerous as the zoœcia; when not situated at the angles, generally inflecting the zoœcial cavity a little."

"This species approaches quite closely to *H. frondosa* d'Orb., having a somewhat similar growth; but in that species the zoœcia are more angular, the walls thinner, mesopores far more numerous, and the acanthopores rather more abundant."

Formation and locality.—A common form in the upper beds of the Hudson river group at many localities in Ohio and Indiana, also at Wilmington, Illinois, and Iron Ridge, Wisconsin.

Heterotrypa singularis *Ulrich.*

(Not Figured.)

Heterotrypa singularis Ulrich, 1890. Geol. Surv. Ill., vol. viii, p. 415, pl. xxxvii, figs. 3-3*e*.

Original description: "Zoarium subramose, at times attaining a thickness of 7 cm. Surface smooth or nearly so, with clusters of cell apertures a little larger than the average. Zoœcia about nine in 2 mm., angular and thin-walled in the axial, subcircular in the mature region. There are commonly two or more successions of immature and mature regions. Mesopores of variable size, very numerous, usually angular or subcircular. Diaphragms developed very irregularly, at times but few in the cortical region and wanting in the axial, at other times about two tube diameters apart in the axial and close-set in the peripheral region. They are commonly horizontal, often concave, sometimes infundibular and occasionally simulate cystiphragms if they are not of that nature. Acanthopores very numerous, inflecting the viscerial cavity so as to give it a petaloid appearance.

"The extremely large size of this species, the remarkable development of acanthopores and mesopores and irregular character of the diaphragms are its leading features. Some points of its structure leave me in doubt as to this being its rightful position, but for the present it seems best to place it with *Heterotrypa*."

Formation and locality.—Upper beds of the Hudson river group at Wilmington, Illinois, and Iron Ridge, Wisconsin.

Genus DEKAYELLA, Ulrich.

Dekayella, ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 155, and vol. vi, p. 90; 1890, Geol. Surv. Ill., vol. viii, p. 372.

Zoaria ramose, branches cylindrical or compressed. Zoœcia angular or rounded, the shape depending upon the number and disposition of the mesopores. Typically, the mesopores are more or less numerously distributed among the zoœcia, and aggregated into irregular clusters. In other cases they may be wanting, except in the clusters, while in some of the earliest forms they are so few as to be practically absent. Acanthopores of two sizes, the large ones, equivalent to those of *Dekayia*, commence in the axial region, the smaller ones more abundant and developed in the peripheral region only. Diaphragms horizontal, numerous.

Type: *D. obscura* Ulrich, Utica horizon of the Cincinnati group.

This genus includes, so far as known, the earliest types of the family *Heterotrypidæ*. In the Trenton or more strictly speaking, the Birdseye shales of Minnesota we have, besides species or varieties that are as typical of *Dekayella* as any occurring in the Cincinnati rocks, two forms that, in having very few mesopores, are more nearly like *Dekayia*, Edwards and Haime. Tangential sections of the one (*Dekayella prænuntia* var. *echinata*) very much resemble those of *Dekayia aspera* Ed. and H., yet when carefully examined, two sets of acanthopores—the one large, the other small—will be noticed. The abundant tabulation of the tubes is also indicative of *Dekayella*. The other form (*D. prænuntia* var. *simplex*) is, as the name implies, of a more simple and perhaps *the* primitive type, with the acanthopores much smaller and scarcely, if at all, separable into two sets.

The relations existing between *Dekayella*, *Dekayia* and *Heterotrypa* are so intimate that I have seriously considered the propriety of throwing them together as one genus. The chief reason for doing so is that with the great abundance of material —specific, varietal and individual—studied, an almost complete chain may be made out connecting one with the other. But, as I have had occasion to state more than once heretofore (*ante* pp. 115, 138, 216), this is not a sufficient reason for uniting two or more genera. The groups of species embraced in each are natural and in a great measure readily distinguished, and therefore must always be recognized in some manner. *Heterotrypa*, as restricted and used by me, includes only frondescent or palmate zoaria, with all the acanthopores small and approximately of one size; *Dekayia*, subcylindrical or flattened stems growing from a large base, with one set of acanthopores, mesopores very few or wanting, and few diaphragms in the tubes; and *Dekayella*, zoaria as in *Dekayia*, but with acanthopores of two sizes, mesopores more or less numerous, and abundantly tabulated tubes.

DEKAYELLA PRÆNUNTIA, *n. sp.;* and VARIETIES.

PLATE XXIII, FIGS. 32-47.

Compare *Heterotrypa ulrichii* NICHOLSON, 1881, "Genus Monticulipora," p. 131.

Typical form: Plate XXIII, fig. 43.

Zoarium ramose; branches subcylindrical, often compressed, dividing at irregular intervals, varying in diameter or width from 4 to 12 mm. Surface without monticules, but in well-preserved specimens minutely spinulose; clusters of large cells inconspicuous. Zoœcial apertures obscurely angular or rounded, enclosed by moderately thin walls, averaging about thirteen in 3 mm. Mesopores not very numerous, generally one to each zoœcium, rather irregularly distributed, often forming small clusters. Acanthopores small, about half the number of zoœcia.

Internal characters: In vertical sections the tubes are nearly vertical in the axial region, and here are crossed by diaphragms at intervals equalling two to four times their diameter. As the tubes bend outward an occasional acanthopore may be detected, while the intervals between the diaphragms become less, until in the fully matured peripheral region, in which the tubes are directed nearly at right angles to the surface, the average distance between them is about one-half their diameter. It is in the latter region that the mesopores are developed. These are distinguished by their smaller size and more crowded diaphragms. An obscurely beaded wall-structure, as shown in fig. 40, with overlapping diaphragms, is of common occurrence.

Tangential sections show that the zoœcia are mostly oval or rounded, their walls of variable thickness, and in part separated by intervening mesopores. The latter vary considerably both in number and size, with medium conditions about as in fig. 43. Acanthopores comparatively small, the principal set comparing in number with the zoœcia about as one is to four ; small set very minute, not often preserved, at any rate, only rarely distinguishable in sections.

Mus. Reg. Nos. 6019, 6020, 8073, 8305.

Var. SIMPLEX, *n. var.*

PLATE XXIII, FIGS. 39-42.

In this form the mesopores are reduced numerically to a minimum. Indeed, they are not distinguishable externally, and only a very few are to be made ont in tangential sections. The zoœcial apertures are polygonal and unusually regular in their arrangement. The walls, too, get to be stronger than in any other form of the genus, with perhaps one exception, while the acanthopores are, if not smaller, at any rate less noticeable in thin sections. From an external examination merely specimens of this species might be regarded, and with good reason, as belonging to the *Amplexoporidæ.* Certainly they would scarcely be suspected of being closely related to *Dekayella prænuntia.* But with the aid of thin sections, vertical ones especially, the true affinities of the form become obvious at once. Excepting that mesopores are practically wanting, there is little or no difference between vertical sections of the typical form of the species and var. *simplex.*

Mus. Reg. No. 8307.

Var. NÆVIGERA, *n. var.*

(Not Figured.)

This form differs from the preceding in having thinner zoœcial walls, and clusters of from five to thirty mesopores at the center of the usual groups of large zoœcia. In the var. *simplex* the zoarium consists generally of but few branches, but in the best examples of the present form they are numerous, strong and divide and inosculate freely, the whole forming a mass over 70 mm. in diameter.

Mus. Reg. Nos. 6018, 7669.

Var. ECHINATA, *n. var.*

PLATE XXIII. FIGS. 32-38.

This variety grows in large compressed branches, that seem never to inosculate. The clusters of large cells are moderately distinct, and frequently enclose small aggregations of mesopores. In having very few mesopores their structure agrees with the two varieties immediately preceding, but specimens are distinguished at once by the much greater size of the acanthopores, these being so large and prominent that they are easily seen by the unassisted eye. An average distance of 0.5 mm. separates them. Internally the walls vary in thickness, very commonly even in the same tangential section. Where they are thinnest the acanthopores are the most distinct, and it is chiefly in such parts that the small set is determinable. Aside from the latter the general appearance of tangential sections is decidedly like that of typical *Dekayia*.

Mus. Reg. Nos. 6016, 7657, 8022, 8098.

Var. MULTIPORA, *n. var.*

PLATE XXIII, FIGS. 44-47.

In this form the acanthopores are likewise very large and, as a rule, are to be seen with the naked eye on the surface of all well preserved specimens. Still there is, as may be seen by comparing figs. 44 and 45, considerable variation in their size, so that the identification of the variety depends chiefly upon the unusually numerous and large mesopores and the rounded shape of the zoœcia. In many cases, however, it is difficult to discriminate positively between the two sets of tubes, as these are shown in tangential sections. As a rule—perhaps the test is reliable at all times—the zoœcia never have any part of their walls convex upon the inner side. In vertical sections the mesopores are distinguished by having the diaphragms more crowded than they are in the zoœcial tubes. A radial arrangement of the cells about the acanthopores, as shown in fig. 45, is frequently noticeable. Both sets of acanthopores about equally numerous, but the smaller set is liable to be overlooked except when the walls are unusually thin.

Mus. Reg. Nos. 6021, 8306.

These species and varieties gave me more trouble than the whole genus *Homotrypa*. It seemed impossible to draw up a thoroughly satisfactory classification of the hundreds of Minnesota specimens of *Dekayella* studied. The separations made were generally recognizable, and some of them are based upon not only obvious, but upon what, as a rule, we may regard as important structural deviations. Extended investigation, however, seemed to show that in the present cases the peculiarities were too inconstant to deserve specific recognition. The var. *simplex* appears to be the best marked and most constant, and should, perhaps, have been called a good species, with var. *nævigera* under it. In that case the var. *echinata* also should be raised to the rank of a species. Variety *multipora*, however, though often very distinct (compare figs. 43 and 45, plate XXIII), is too intimately connected with the typical form of the species to admit of greater than varietal distinction.

My reasons for employing the adopted classification instead of the one just suggested, and which I really believe to be the best, are dominated by the fact that very similar variations are encountered in large collections of *D. ulrichi* Nicholson, sp., an exceedingly common species at Cincinnati, Ohio. This fact makes it, I think, not only desirable but necessary that these Minnesota lower Trenton forms be studied in connection with the various Cincinnati types of the genus. The most important point to be determined by such a study relates to the origin of the Cincinnati varieties mentioned as being similar to those here separated from *prænuntia*. Did the two sets of varieties have a separate origin, or did those above defined continue and develope into the supposed varieties of *D. ulrichi?* Although these questions, whose final solution would require months of careful labor, cannot now be answered definitely, sufficient data have accumulated incidentally to render it more than probable that a separate origin for the two sets is more nearly the truth of the matter. In other words, I believe that future investigation will prove that *D. ulrichi* was developed from some descendant of *D. prænuntia*, that the known varities of the latter became extinct before the close of the Trenton, and that in the Utica and Hudson river eras a new set of forms was developed from the *D. ulrichi* stock.*

Comparing *D. prænuntia* and *D. ulrichi* it is evident that the two species are closely related. In the tabulation of the zoœcial tubes, which is the least variable character in both, they are almost identical. The acanthopores furnish the only reliable point of difference, these structures being much more abundant in *D. ulrichi*.

Formation and locality.—The typical form and var. *multipora* are common in the middle third of the Trenton shales at St. Paul, Minneapolis, and localities in Goodhue and Fillmore counties. Var. *simplex* occurs in the lower and middle thirds at St. Paul and Minneapolis, while var. *nævigera* is as yet known only from Fillmore county, where it was found in the lower third of the shales. The var. *echinata* is rare in the upper part of the middle third of the Trenton shales at Minneapolis, but abundant in the lower part of the upper third at St. Paul, and near Fountain, Minnesota.

---

*It may be well to add that the var. *echinata* will probably prove to be the stock that produced *Heterotrypa* on the one side and true *Dekayia* on the other. Also that the small *Dekayella obscura* of the Cincinnati rocks may be a degenerate descendant of the var. *multipora*.

Genus DEKAYIA Edwards and Haime.

Dekayia, EDWARDS and HAIME, 1851, Mon. Pol. Foss. Terr. Pal., p. 277; NICHOLSON, 1879, Pal. Tab. Corals, p. 291; 1881, "Genus Monticulipora," p. 98; ULRICH, 1882, Jour. Cin. Soc. Nat. Hist. vol. v, p. 155, and vol. vi, p. 148; also 1890, Geol. Sur. Ill., vol. viii, pp. 371 and 415.

Zoaria irregularly ramose; branches subcylindrical or compressed, growing from a broad base. Zoœcia polygonal, walls thin. Mesopores wanting or very few, when present restricted to the maculæ. Acanthopores originating in the outer part of the axial region, in most cases rather widely separated, often of large size; in other cases small, and in one instance equalling the zoœcia in number. Diaphragms straight, in most cases remote, sometimes from one-half to one tube diameter distant in the peripheral region; wanting usually in the axial region. A thin calcareous pellicle often drawn over the zoœcial apertures.

Type: *D. aspera* Ed. and H., Hudson River group.

For remarks see under *Dekayella*, p. 269. For more detailed observations and full descriptions of all the known Lower Silurian species, the reader is referred to my "American Paleozoic Bryozoa."* Beside the following, another as yet undescribed species of *Dekayia*, with fewer diaphragms, thinner walls and smaller acanthopores than *D. trentonensis*, occurs in Minnesota. It is rather rare, and so far known only from the Galena shales of Goodhue county.

DEKAYIA TRENTONENSIS *Ulrich.*

(Not Figured.)

Dekayia trentonensis ULRICH, 1882. Jour. Cin. Soc. Nat. Hist., vol. vi, p. 151.

Zoarium dendroid, branches compressed, dividing frequently and rather irregularly, 4 to 10 mm. in width. Entire hight of zoarium probably not exceeding 8 or 9 cm. Surface even, or with low rounded monticules, 2.5 mm. apart; the latter occupied by clusters of cells a little larger than those in the intermediate spaces, and occasionally have a few mesopores at their summits. Zoœcia with comparatively thick walls, their apertures subangular, about fourteen in 3 mm. Acanthopores rather large, moderately prominent at the surface where six or seven are to be counted in 3 mm.

Internal characters: In the axial region of vertical sections the tubes have very thin and slightly flexuous walls, and are crossed by diaphragms from two to four times their diameter distant from each other. Bending into the peripheral region

*Jour. Cin. Soc. Nat. Hist., vol. vi, pp. 84 and 148-155.

with a gentle curve, the walls become thickened and the diaphragms more abundant, the intervals between the latter varying here from one-fourth to one tube-diameter, with seven in 1 mm. measuring from the surface of a fully developed example. Acanthopores originating in the outer part of the axial region, large and readily distinguished. Tangential sections with the walls rather thick and consisting of a central space, generally of light color, representing the original walls, and a dark ring-like deposit immediately about the zoœcial cavities. On the whole the structure and thickness of the walls is much as in *Dekayella prænuntia*, var. *simplex* (pl. XXIII, figs. 41 and 42). The acanthopores are isolated, occupying the points of junction between every three, four or five zoœcia. Their large size makes them very conspicuous in sections passing through deeper levels in which the walls are thinner than described.

In this species the diagnostic characters of *Dekayia* are not yet fully developed, the diaphragms being too numerous. A revision of the *Heterotrypidæ* would probably remove it to *Dekayella*. A more typical, but undescribed species, with fewer diaphragms and smaller acanthopores, is sometimes associated with *D. trentonensis* in the Galena shales. *Dekayella echinata*, which at first I confounded with the present species, has more numerous diaphragms, thinner walls, and a small set of acanthopores.

Formation and locality.—Rather rare in the upper third of the Trenton shales and in the overlying Galena shales at St. Paul, and near Cannon Falls, Minnesota. The original types are from the shaly portion of the Trenton at Burgin, Kentucky. The species is to be found also at Frankfort and other localities in that state, associated with *Prasopora simulatrix* Ulrich.

Family CALLOPORIDÆ, Ulrich.

Genus CALLOPORA, Hall.

Callopora, HALL, 1852, Pal. N. Y., vol. ii, p. 144, and 1887, Pal. N. Y., vol. vi, p. xv; NICHOLSON, 1874, Pal. Ontario, p. 61, and Geol. Mag., n. s., vol. i, p. 13; ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, pp. 154 and 251; also 1890, Geol. Sur. Ill., vol. viii, pp. 372 and 416; FOERSTE, 1887, Bull. Sci. Lab. Denn. Univ., vol. ii, p. 172.

?*Callopora*, DYBOWSKI, 1877. Die Chætetiden, p. 106.

Zoarium usually ramose, rarely subfrondescent, or pyriform; surface smooth or tuberculated. Zoœcial tubes with thin walls, varying according to the number of mesopores from circular or oval to polygonal in cross-section. Apertures closed in the perfect state by centrally perforated and often radially marked or ornamented plates, which are left behind as growth proceeds to form floors (diaphragms) of succeeding layers. Mesopores angular or rounded, more or less numerous, sometimes surrounding the zoœcia; closely tabulate. Zoœcial tubes attaining their full development slowly, with closely arranged diaphragms in the attenuate proximal ends, and fewer or no diaphragms in the middle part of their length. In the peripheral region these structures commonly increase again in number. Transverse sections show that in the axial region the tubes are of two sizes, the larger ones with six, seven, and most commonly eight sides, the smaller set four- or five-sided.

Type: *C. elegantula* Hall.

Thin sections of *Callopora*, vertical and transverse especially, exhibit a striking uniformity of structure, so that it is often difficult to discriminate between those of closely allied forms. Slight though generally recognizable peculiarities in the tabulation of the zoœcial tubes characterize the various species, but in a general way the distribution of the diaphragms is essentially the same in all. The axial or proximal end of the tubes always has diaphragms--sometimes only one or two (see plate XXII, fig. 15)—while these structures may be wanting in the rest of the tube, excepting one or two in the peripheral region. In other cases they will occur throughout, but in every instance they are less crowded in the central part of the tube than in its inner and outer parts (see plate XXII, fig. 36).

The twenty-five distinguishable forms now known to me of this, one of the best characterized and most easily recognized genera of the *Trepostomata*, are distributed through the various horizons intervening between the Birdseye and the top of the Upper Silurian, one or more species being characteristic of every recognized geological division embraced in the interval. Nearly all the species again are to be numbered among the common fossils, so that they may be said to be of the first importance to the stratigrapher. The described species are distributed as follows: In the Birdseye shales of Minnesota, *C. angularis*, *C. incontroversa*. and *C. undulata;* in the overlying Trenton and Galena shales, *C. dumalis*, *C. ampla*, *C. multitabulata*, *C. goodhuensis*, *C. crenulata*, *C. persimilis*, and *C. pulchella;* in the four horizons of the Cincinnati group going upward (1) *C. nodulosa* (Nicholson), *C. sigillaroidea* (Nich.), (2) *C. subplana* Ulrich, *C. dalei* (Edwards and Haime), *C. andrewsi* (Nich.), *C. ramosa* (d'Orb), (3) *C. subnodosa* Ulrich, (4) *C.* n. sp.; in the Clinton, *C. magnopora* Foerste; in the Niagara, *C. elegantula* Hall; and in the Lower Helderberg, *C. perelegans* Hall.

The affinities of *Callopora* doubtlessly are with the *Diplotrypidæ* and, but for the perforated closures of the zoœcia in *Callopora*, would recommend placing the genus in that family. Aside from the closures, which, though they may really have existed, have not been noticed in any member of that family, and a difference in the method of growth, the zoaria of the one being ramose, of the other massive, *Callopora* and *Diplotrypa* (in the restricted sense recently employed by me*) are very similar. It

*Contri. to the Micro.-Pal. of the Cambro-Sil. Rocks of Canada, pt. ii, p. 32, 1889.

s true the zoœcial tubes of the latter are larger than is usual in *Callopora*, yet even in this respect the genera are brought together by *C. magnopora* Foerste, of the Clinton rocks of Ohio. In the remaining features the agreement is marked, both having more or less numerous mesopores and no acanthopores, while the tabulation of the tubes is essentially the same in the two genera, the proximal ends of the tubes being crossed by numerous diaphragms.

Batostoma, another genus of that family, also agrees closely with *Callopora*, the principal differences being the abundant presence of acanthopores, an irregularity in the tabulation and walls of the axial portion of the tubes, and the more ring-like character of the peripheral part of the zoœcial investment in *Batostoma*. These differences, however, are less obvious when we compare some of the earlier species referred to the two genera. Take, for instance, *B. decipiens* and *B. winchelli*, and *C. angularis*, of the Birdseye shales of Minnesota. In these species the mesopores are very few, the tabulation of the tubes alike in essential respects, and the axial region in transverse sections made up of large and small tubes. As differences we note that the *Batostomæ* have the walls more irregular in the axial region and thicker in the peripheral, and possess acanthopores, which are wanting in the *Callopora*.

Simple forms of the genus like *C. angularis* and *C. multitabulata* also remind one, especially in tangential sections, of *Monotrypella*, but it is more than doubtful that this resemblance indicates relationship. In any event I am now satisfied that I was in error in placing *C. multitabulata* with *Monotrypella*. This species differs from ordinary *Calloporæ* only in having fewer mesopores and more diaphragms, both points of slight importance. True *Monotrypella* is distinguished at once from *Callopora* by the subequal size of the tubes in the axial region of transverse sections.

CALLOPORA ANGULARIS, *n. sp.*

PLATE XXII, FIGS. 37-41.

Zoarium small or of medium size; branches 3 to 5 mm. in diameter. Zoœcial apertures angular, subequal, about nine and a half in 3 mm. Mesopores very few, occurring chiefly in small clusters. Walls rather thin, ridge-shaped.

Internal characters: Vertical sections show numerous diaphragms, whose distribution in the outer third of the section is shown in fig. 38 better than can be described. In the central third the proximal ends of the tubes increase very slowly in size. Here the diaphragms are also closer together than higher up in the tube. The axial region therefore appears as made up of two sets of tubes, one large with diaphragms averaging 0.25 mm. apart, the other small with diaphragms from 0.1 to

0.2 mm. apart. In tangential sections of fully matured examples (fig. 39) the zoœcia are decidedly angular, subequal, most of them in contact on all sides, the mesopores being small, very few, and sometimes restricted to certain spots where limited clusters may be found.

Both the mesopores and diaphragms are less numerous than in *C. multitabulata;* the angular shape of the zoœcial aperture will distinguish the species from other forms of the genus. I found it difficult to separate slightly abraded specimens of a small form of *Batostoma*, near *B. winchelli*, from those of the present species. When unworn the *Batostoma* has distinct acanthopores which are a sufficient mark, and when these have been removed by abrasion the student may succeed in separating them by measurement, the latter having eleven or twelve zoœcia where *C. angularis* has nine or ten.

Formation and locality.—Rather rare in the lower third of the Trenton shales at Minneapolis, Chatfield, and near Fountain, Minnesota.

Mus. Reg. Nos. 8088, 8097.

Callopora incontroversa *Ulrich.*

PLATE XXII, FIGS. 33-36.

Callopora incontroversa Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 96.

Zoarium ramose; branches smooth, subcylindrical, 4.5 to 6 or 7 mm. in diameter, dividing dichotomously at intervals of 12 or more mm. Zoœcia with walls comparatively thin; apertures oval or subcircular, rarely polygonal; small, inconspicuous, and rather irregularly distributed clusters consisting of openings slightly larger than the average occasionally present; about ten apertures in 3 mm. Closures occasionally preserved; central perforation larger than usual, 0.07 to 0.08 mm. in diameter, enclosed by a thickened rim; apparently not radially marked. Mesopores numerous, small, scarcely gathered into clusters, usually occupying only the spaces left between the contiguous rounded walls of the zoœcia.

Internal characters: Tangential sections show that the zoœcia are broadly elliptical, rather thin-walled, and usually in contact with each other at as many points as their rounded form will admit. Interspaces occupied by the mesopores. At unequal intervals the latter may be more numerous and the zoœcia a little larger than usual, but these clusters are never conspicuous. In vertical sections the tubes form a gradual but rather short curve to the surface. In their tabulation and general appearance the proximal ends of the zoœcial tubes are so much like the true mesopores of the peripheral region that we cannot escape the conviction that their functions also were alike. From the point of origin till it has attained nearly its mature size, the tube is crossed by from ten to twenty or more closely and regularly arranged diaphragms. After this the diaphragms are much farther apart, and in many tubes may be wanting entirely until they enter the peripheral region when they once more come close together.

This species is distinguished from *C. undulata* by its slightly larger size, smooth surface, and slight differences in the tabulation of the tubes. In tangential sections the zoœcia of that species are less rounded. *C. goodhuensis* and *C. ampla* have fewer mesopores and more abundant diaphragms.

Formation and locality.—Rather rare in the lower third of the Trenton shales at Minneapolis, St. Paul and Preston, Minnesota.

Mus. Reg. No. 7653.

Callopora undulata *Ulrich.*

PLATE XXII, FIGS. 24-31.

Callopora undulata ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 95.

Zoarium ramose, branches slender, averaging about 2.5 or 3.0 mm. in diameter, dividing dichotomously at intervals of 10 mm. or more. Surface with rather large, rounded monticules, that usually coalesce laterally, forming transverse ridges, or more or less complete annulations, five in ten mm. In some fragments and portions of others the monticules are separate, while in a few they are nearly obsolete. Zoœcia with moderately thin walls, subangular or ovate apertures, of nearly equal size over all portions of the surface; ten or eleven in 3 mm. Mesopores comparatively few, small, not readily distinguished externally, their mouths usually closed. Zoœcial covers not observed.

Internal characters: These are sufficiently shown in the illustrations, and, as they are also very similar to those of the preceding species, I shall only point out the differences. The walls in tangential sections are thicker than in *C. incontroversa*, the divisional line between adjoining zoœcia more distinct, and the mesopores less numerous.

C. angularis has a smooth surface, fewer mesopores, and more crowded diaphragms. *C. ampla* is distinguished in like manner, and *C. incontroversa*, externally, by its smooth surface and more rounded zoœcial apertures.

Formation and locality.—Not uncommon in the upper part of the middle third of the Trenton shales at Minneapolis and St. Paul, Minnesota.

Mus. Reg. No. 8113.

CALLOPORA MULTITABULATA *Ulrich.*

PLATE XXIII, FIGS. 11, 12, 16, 17, 24, 25, 26, 30, 31.

Monotrypella multitabulata ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 100.

Zoarium consisting of more or less irregularly divided, subcylindrical branches, their diameter averaging 7 or 8 but varying between the extremes of 3 and 10 mm. Surface generally with more or less strongly elevated, conical or rounded monticules, 2.5 mm. from center to center. The typical form of the species occurs in the Trenton of Kentucky and Tennessee, and in the upper third of the Trenton shales of Minnesota. In this monticules are always present, and they are occupied by zoœcia but little if at all larger than the average. Mesopores are exceedingly few at the surface, the zoœcia being angular, in contact with each other, their walls thin; apertures direct, with an average of eleven in 3 mm. Closures preserved in a few specimens, ornamented as shown in fig. 26. In the underlying middle third of the shales and in the overlying Galena shales there is a form, rare in the first, exceedingly common in the second, that varies in having the monticules lower and even quite inconspicuous, the zoœcia a little larger (ten in 3 mm), and the cells occupying the low monticules usually well distinguished by their size. Very frequently too a sprinkling of mesopores is detectable at the surface, as shown in fig. 31, but it is rare to find them as numerous as in fig. 30.

Internal characters: In tangential sections of the typical form the zoœcia are regularly polygonal, generally in contact with each other on all sides, and provided with moderately thickened walls, in which the original boundary line between the zoœcia is preserved as a sharp dark line. Mesopores are very few. Because of a lack of room no section of this form was illustrated, but a good idea of its appearance may be gathered from fig. 39 on plate XXII, and the upper third of fig. 17 on plate XXIII. In the Galena shales variety the appearance of tangential sections is generally as in the mentioned fig. 17.

In vertical sections (pl. XXIII, fig. 24) the peripheral region is comparatively wider than in other species of this type. Diaphragms exceedingly abundant throughout the tubes, the average distance between them in the axial region being about equal to their diameter; in the peripheral region twelve to sixteen occur in 1 mm. Here many of them may be slightly curved or joined to one another. An occasional mesopore is met with in these sections. These are very closely tabulated, the average number in 0.5 mm. being ten. Now and then one of the mesopores may widen and assume the characters of a true zoœcium.

In the central part of transverse sections the size of the tubes and the appearance in general is intermediate between figs. 20 and 21 of plate XXIII.

The diaphragms are more numerous in this species than in any other known to me. Very closely allied, however, are *C. angularis*, *C. ampla* and *C. goodhuensis*. The first is distinguished by its smaller size, smooth branches and somewhat less crowded diaphragms, especially in the mesopores; the second by its smooth branches, narrower peripheral region, slightly larger zoœcia and more numerous mesopores; the third is smaller, with smaller zoœcia and more abundant mesopores.

Formation and locality.—In Minnesota the species is rare in the middle third of the Trenton shales at Minneapolis, rather abundant in the upper third at St. Paul and in the vicinity of Cannon Falls, and exceedingly abundant in the Galena shales at many localities in Ramsey, Goodhue and Fillmore counties. Also a common fossil of the Trenton at several localities in central Kentucky, and near Nashville, Tennessee. The same species apparently occurs at Ottawa, Canada.

Mus. Reg. Nos. 3485, 7652.

Callopora ampla, *n. sp.*

PLATE XXIII, FIGS. 15, 18-20, 22, 23, 27, 28.

This form is very closely related to *C. multitabulata*, and doubtlessly belongs to the same line of development. Under the circumstances it will be sufficient to point out its peculiarities. The growth is less compact, the branches, though fully as large as in that species, being, as a rule, less frequently divided. Except in rare cases the surface is without monticules, and while there are clusters of zoœcia appreciably larger than the average they are never conspicuous except when elevated into monticules. The zoœcia are larger, with an average of nine in 3 mm., the apertures a little oblique, drawn out lengthwise and apparently more shallow, while the occasionally preserved closures seem to be without ornamentation. The form of the apertures may be oval or angular, the first when mesopores are comparatively abundant, the second when they are few and very small. In both cases, however, thin sections are generally required to demonstrate the existence of the latter. In most instances the mesopores are fewer than in fig. 18, and as a rule they occupy the angles of junction between the zoœcia where, when the surface is a little weathered, they often appear as acanthopore-like elevations.

Comparing internal characters we find that in *C. ampla* the tubes in the axial region are generally of larger size, and that they curve to the surface more slowly. The fully developed peripheral region is much narrower than in specimens of the same size of *C. multitabulata* (compare figs. 19 and 22 with 24 of plate XXIII), the superficial crowding of the diaphragms more sudden, and the intervals between them throughout the axial region a little greater. The last difference, however, does not apply when we compare the Galena shales varieties of the two species. These often agree so closely in every other respect as well that a rigid distinction between them is almost if not quite impossible. How else can we explain this fact than by assuming that the two forms gradually and by almost equal concessions approximated in structure?

Compared with other species *C. angularis* will be found to be smaller, with smaller and more equal-sided zoœcia and fewer mesopores. *C. goodhuensis* is smaller in every respect.

Formation and locality.—Rather abundant in the upper layers of the middle and in the lower part of the upper third of the Trenton shales at various localities in Ramsey, Goodhue and Fillmore counties, Minnesota. Common also at many localities in the state where the Galena shales are exposed, and in equivalent beds at Decorah, Iowa.

Mus. Reg. Nos. 7640, 7659, 8067.

Callopora goodhuensis, *n. sp.*

PLATE. XXIII, FIGS. 9, 10, 21, 29.

This also is closely related to *C. multitabulata.* As a rule the surface is without monticules, and they are never prominent, while the average size of the branches is less, the average diameter being between 4 and 5 mm. The zoœcia are smaller especially at the center of transverse sections, their apertures subangular, rather oblique in young examples, nearly direct in those full-grown, with twelve or thirteen in 3 mm. Internal characters very similar, excepting that the peripheral region is comparatively narrower, being in this respect more like *C. ampla.*

Mesopores more numerous and more closely tabulated than in *C. angularis.* The zoœcial apertures, on the other hand, are more direct in that earlier species.

Formation and locality.—Common in the Galena shales at St. Paul and near Cannon Falls, Minnesota.

Mus. Reg. No. 8111.

Callopora dumalis, *n. sp.*

PLATE XXIII, FIGS. 1-8.

Zoarium bushy, attaining a width of 50 mm. or more, consisting of numerous small inosculating branches, varying between 1 and 2.5 mm. in diameter, but with 1.5 mm. by far the most common size. In young stages the zoœcial apertures are more or less oblique and ovate, the mesopores rather numerous and some of them of large size. In old fragments the latter are fewer and of small size, and the zoœcial apertures more direct and polygonal. Closures with faint radiating lines; central perforation rather small. Measuring diagonally about six zoœcia in 1.5 mm.

Internal characters as shown in figs. 7 and 8. Vertical sections show that while diaphragms are rather abundant in all parts they are not excessively crowded in the peripheral region. In this respect the species differs from the species grouped about *C. multitabulata.*

The small size of the branches and bushy habit of growth distinguish the species from all the other known Minnesota species of the genus. Externally its zoaria are exceedingly like those of an undescribed form occurring in the Cincinnati quarries associated with *C. dalei* Ed. and H.

Formation and locality.—Very abundant in the upper third of the Trenton shales, rare in the Galena shales, at St. Paul and Cannon Falls, Minnesota.

Mus. Reg. No. 8112.

Callopora pulchella, *n. sp.*

PLATE XXII, FIGS. 1-12.

Zoarium dendroid, branches averaging 5 mm. in diameter, tapering slightly, the oldest parts sometimes attaining a diameter of 7 mm., the young extremities only 3 or 4 mm. The branches divide dichotomously at average intervals of 12 mm., and never, so far as observed, inosculate. Surface exhibiting small conical monticules, 2.0 to 2.5 mm. apart, their summits generally with small aggregations of mesopores. As shown in the figures, the hight of the monticules varies in different examples, and in some they are to be described as rounded rather than conical. Zoœcial apertures small, subcircular, enclosed by rather thick, ridge-shaped walls, regularly arranged, subequal, thirteen or fourteen in 3 mm. Mesopores very small and, though numerous, often difficult to distinguish externally with an ordinary pocket lens. This difficulty is greatest in old examples in which they are partially filled by calcareous deposits.

Internal characters: Vertical sections show that in the axial region the proximal end of the tubes is crossed by from two to four diaphragms, beyond which these structures are absent till we reach the middle of the comparatively wide peripheral region when each zoœcial tube is again intersected by one or two. Mesopores are abundant and closely tabulated. In tangential sections the zoœcia are subcircular, their walls somewhat ring-like and in contact with each other in only a limited degree, the interspaces being occupied by more or less numerous mesopores varying considerably in size and shape. Just beneath the surface of a fully matured example the walls are thickened by internal deposit, the mesopores small and approximately of uniform size. At deeper levels the walls are thinner and the mesopores larger and more irregular in shape and size. In transverse sections the axial region is made up of decidedly angular tubes of which those of the larger set are also comparatively small, while those of the minor set are less regularly distributed than usual.

This form is to be compared with the *C. dalei* Edwards and Haime, of the Cincinnati group, from which it differs chiefly in having fewer diaphragms and slightly smaller zoœcia. Excepting the following variety there is no Minnesota species of *Callopora* known that is likely to be confounded with *C. pulchella*, but care is required in separating it from the associated *Homotrypa tuberculata*.

Formation and locality.—Common in the upper third of the Trenton shales at St. Paul and near Cannon Falls, Minnesota.

Mus. Reg. Nos. 8033, 8114.

Callopora pulchella, *var.* persimilis, *n. var.*

PLATE XXII, FIGS. 13-17.

This variety differs from the typical form of the species in having more prominent tubercles, thinner zoœcial walls (causing the apertures to be correspondingly larger), more readily distinguished and, as a rule, more numerous mesopores, even fewer diaphragms, and in the greater size of the tubes in the axial region. The growth of the zoarium and the number of zoœcial apertures in 3 mm. (thirteen or fourteen) is the same. Indeed, the points of difference even are not constant. We cannot, therefore, doubt the propriety of referring the form to *C. pulchella*. On the other hand it is impossible to distinguish var. *persimilis*, by external comparison of fragmentary material alone, from the later *C. ramosa* d'Orbigny, one of the most common Bryozoa of the Cincinnati rocks. It is true the zoaria of the Trenton form never grew to such a size nor do the branches inosculate as in the Cincinnati species, but such differences the student will find of little practical use when, as usual, fragments are to be identified. Luckily, the interior furnishes us with a guide in the relative number of diaphragms, these being much more abundantly developed in the Cincinnati species than in the Trenton variety. For further remarks relating to this subject see *ante*. p. 215.

Formation and locality.—Associated with *Phylloporina corticosa*, *Trigonodictya conciliatrix* and *Prasopora conoidea*, all characteristic species of the upper third of the Trenton shales, at Poe's farm, near Cannon Falls, Minnesota.

Mus. Reg. No. 8115.

Callopora crenulata, *n. sp.*

PLATE XXII, FIGS. 18-23.

Zoaria forming rather large, compactly interwoven, bushy masses, consisting of strong branches that divide and inosculate most irregularly and frequently; average thickness of branches 7 or 8 mm., but some may be over 10 mm., and as many only 4 or 5 mm. Surface generally with rounded monticules, occupied by clusters of zoœcia larger than the average, and by greater or less aggregations of small mesopores. Zoœcial apertures rounded, mostly subcircular, regular, twelve or thirteen in 3 mm. Closures preserved in one out of about forty specimens, slightly concave, apparently smooth and without a raised rim about the central perforation. Walls of moderate thickness, ridge-shaped. Mesopores numerous, rather small, but distinctly visible under a good pocket lens.

Internal characters: These are remarkable chiefly in vertical sections, tangential and transverse sections being very much like those of *C. pulchella* and *C. ramosa*. In vertical sections namely there seems to be a total absence of diaphragms, not only in the zoœcial tubes but in the mesopores as well. Another peculiarity is the crenulated or wavy character of the walls in the axial region that has suggested the specific name. This crenulation is shown very distinctly when the tubes are exposed by vertical fractures.

The two peculiarities mentioned in the preceding paragraph distinguish the species from all the others now referred to the genus. In other respects we are reminded of its associate *C. pulchella*, yet they ought in no case to be confounded, since in that species the branches are more slender and do not inosculate, and the zoœcial apertures are appreciably smaller.

Formation and locality.—Not uncommon in the upper third of the Trenton shales at St. Paul and near Cannon Falls, Minnesota. Rare in the Galena shales (here almost invariably without monticules) at the same localities, and at Decorah, Iowa, and Neenah, Wisconsin.

Mus. Reg. Nos. 8019, 8038, 8068, 8082.

Family DIPLOTRYPIDÆ, Ulrich.

For remarks on this family see pp. 276 and 290.

Genus DIPLOTRYPA, Nicholson.

Zoaria massive or discoid, generally free. Zoœcial tubes comparatively large, with thin prismatic walls, and horizontal diaphragms. Mesopores few to numerous, varying in size, many of them enlarging gradually and assuming the characters of true zoœcia. Acanthopores wanting.

Type: *D. petropolitana* Pander, sp.

The relations of this genus are with *Batostoma* on the one hand and *Monotrypa* and *Callopora* on the other. Species are few and, so far as known, all belong to Lower Silurian rocks. The two about to be described are aberrant in having very few mesopores.

DIPLOTRYPA LIMITARIS, *n. sp.*

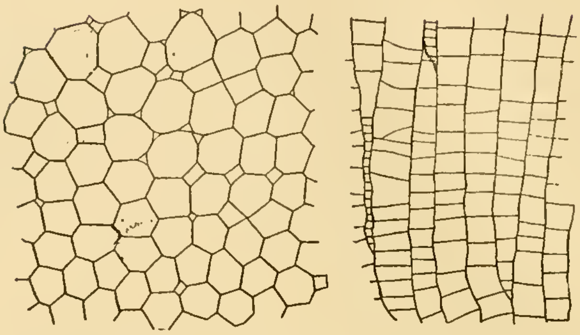


FIG. 18. *Diplotrypa limitaris* Ulrich, upper beds of the Galena shales, Goodhue county, Minnesota. Collection of E. O. Ulrich. Transverse and vertical sections, x 18, showing the tabulation of the tubes and the great reduction in the number of mesopores characterizing the species.

Zoarium, as seen in four specimens, small, hemispherical, 12 mm. or less in diameter, and 3 to 7 mm. in hight. Under surface concentrically wrinkled; upper surface without monticules but presenting rather conspicuous clusters of large cells among which the mesopores are commonly more numerous than elsewhere. Walls very thin; zoœcial apertures polygonal, 0.25 to 0.4 mm. in diameter, with ten to twelve in 3 mm. Mesopores of variable size, not as numerous as the zoœcia. Tabulation of tubes comparatively regular and uniform; in the mesopores there are nine or ten diphragms in 0.5 mm., in the zoœcial tubes six to nine in 1 mm. As shown at the margin of the vertical section figured above, the tabulation of the mesopores changes suddenly (? always) into that of the zoœcia.

The unusually small number of mesopores distinguishes this species from *D. petropolitana* and *D. westoni* (Ulrich). In those species the zoœcia are also somewhat larger, and the tabulation less uniform.

Compared with associated and other discoidal Bryozoa, the species of *Mesotrypa* are separated by their rounded zoœcia and much more abundant mesopores, those of *Prasopora* by the cystiphragms, those of *Leptotrypa* by their acanthopores, while those of *Monotrypa* are entirely without mesopores.

Formation and locality.—Upper beds of the Galena shales at localities in Goodhue county, Minnesota. The best exposure of these beds is in a bluff about thirteen miles south of Cannon Falls.

DIPLOTRYPA NEGLECTA, *n. sp.*

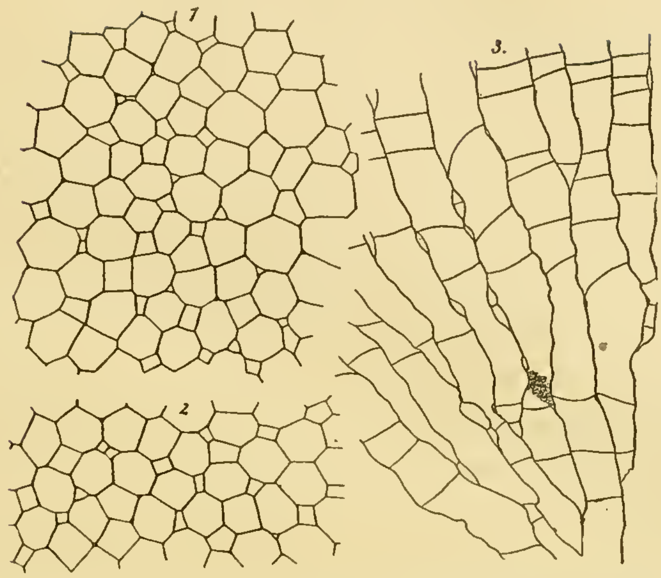


FIG. 19. *Diplotrypa neglecta* Ulrich, base of Galena limestone, Hader, Goodhue county, Minnesota. Collection of E. O. Ulrich. 1 and 2, two tangential sections, x 18, and 3, a vertical section, similarly enlarged.

Zoarium a small subconical or hemispheric mass, about 12 mm. in diameter and 8 mm. in hight. Tube walls thin, transversely rugose, appearing quite irregular and rough in longitudinal fractures. Zoœcia about nine in 3 mm., not regularly arranged, polygonal, largely in contact with each other, the mesopores being few in number and variable in size and distribution. Clusters of large zoœcia occur and among these the mesopores may be more abundant than in the intermediate spaces.

In transverse sections we see cells of all sizes up to 0.45 mm., and not infrequently it is difficult to discriminate between the smaller zoœcia and the mesopores. As is shown by vertical sections the two sets of tubes are not totally distinct, the mesopores being in many cases clearly superseded by zoœcia. Perhaps on account of the rugosities of the walls the mesopores often appear as developed periodically. The diaphragms are irregularly distributed, from one-half to four times their diameter distant in the large tubes and averaging about 0.15 mm. apart in the mesopores.

Though possessing all the essential characters of the genus, the internal irregularly and other peculiarities of the species are so obvious that comparisons are unnecessary.

Formation and locality.—Lower part of the Galena limestone, at Hader, Goodhue county, Minnesota. It is here associated with *Mesotrypa* (?) *rotunda* Ulrich, *Plectambonites gibbosus* W .and S., *Pleurocystites angulatus* Ulrich, *Fusispira ventricosa* Hall, and other fossils described in this volume.

Genus BATOSTOMA, Ulrich.

Batostoma ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 154; 1890, Geol. Sur. Ill., vol. viii, pp. 379, 459; FOORD, 1883, Contri. Micro-Pal. Cam.-Sil. rocks Can., p. 17.

Zoaria irregularly ramose, with a large basal expansion. Zoœcial walls thin, and irregularly flexuous in the axial region, more or less thickened in the peripheral. In the most typical species the walls are irregularly ovate, thick and ring-like in tangential sections, with neighboring zoœcia in contact only at limited points, the mesopores numerous, closed at the surface, and irregular in shape and size, and the acanthopores abundant and with a larger central cavity than usual. Species vary from these to forms having polygonal, thin-walled zoœcia and very few mesopores and acanthopores. Diaphragms strong, horizontal, complete, few or wanting in the axial, more or less abundant in the peripheral region. In the axial region of transverse sections the tubes are divisible into two sets, one larger than the other.

Type: *B. implicatum* Nicholson, sp.

Beginning in the Birdseye limestone and shales of Minnesota with *B. fertile*, *B. magnopora*, and an undescribed species, it is evident that, the same as with *Callopora* and *Dekayella*, the primitive stock of the genus was of the simplest type. Mesopores were few, the zoœcia angular and thin-walled, and acanthopores both few and very small. And yet the first of these species varies by most gentle degrees to forms (*B. fertile* var. *circulare*) having numerous mesopores, circular zoœcial apertures, and thick walls—in short to a form that approximates the most typical and fully developed species of the genus.

In *B. implicata* and *B. jamesi* Nich. sp., of the lower half of the Cincinnati group, the zoœcia are characterized by thick ring-like walls, irregularly oval apertures, numerous mesopores and acanthopores. Although closely allied, *B. variabile* differs conspicuously from them in having few mesopores and polygonal zoœcia. Being a later species, and one that doubtlessly is a direct descendant of those forms, we are justified in assuming that a reversion in structure toward the primitive type took place during the closing times of the Lower Silurian. While such a tendency seems to have been general it was by no means universal, since at certain localities (Stony Mountain, Manitoba, Iron Ridge and Delafield, Wisconsin) where the conditions for the development of these Bryozoa seems still to have been eminently favorable, the genus is represented by species with abundant mesopores.

A similar reversion had already taken place during the deposition of the Utica, in which two of the species, both as yet undescribed, are so simple in their structure that their really intimate relations to *B. jamesi* might not be suspected. It is only by making large collections that the affinities of such species can be determined. When this can be done we find that some specimens exhibit, perhaps over limited areas only, the full characters of the genus in an indubitable manner.

The mesopores, therefore, are to be considered as the most unstable feature of *Batostoma.* Though they can never be said to be wanting entirely, it is nevertheless true that an inexperienced student might occasionally come to such a conclusion. Even in the same species great differences in their number may be encountered. Take *B. fertile*, for instance, in which such deviations are more strikingly expressed than in any other species (compare figs. 4 and 7 with 8 and 9 on plate XXV). On the other hand the peculiar irregularity of the tubes in the axial region seems always to be present, thus assuring us of a clue to the generic affinities of forms that, because of the almost total lack of mesopores and practical absence of acanthopores may appear to have relations with types differing widely from *Batostoma.*

Respecting the affinities of the species of *Batostoma* and the systematic position of the genus, I have always been in some doubt. At first the *Heterotrypidæ* seemed the most likely family to receive them, but I soon satisfied myself that their relations did not lie in that direction. Next the *Calloporidæ* were suggested, and finally, as vol. viii of the reports of the Geological Survey of Illinois was going through the press, I decided to place them with the *Diplotrypidæ,* and it is with this family that I have since arranged them. To-day another arrangement would suit me better. The fact is that most of my time since the printing of the Illinois work has been spent on the Bryozoa, and the last six months were devoted to the *Trepostomata* exclusively. Innumerable comparisons were drawn, many of them resulting in important genealogical discoveries. But as is intimated on p. 216, the changes in classification that would be necessary, if the results of my comparative studies were carried to a logical conclusion, seemed too numerous and great for the present state of published knowledge. Indeed, I feared that under the prevailing circumstances it would be difficult to substantiate my claims. It should be remembered that I work from a basis, or rather with a knowledge of paleozoic bryozoan forms that exceeds the published lists by several hundred species. Even with the conservative plan adopted by me, I am obliged continually to draw upon unpublished matter to prove my points, so that only too often they narrowly escape standing as mere assertions. Among other changes that I should have liked to make in the scheme of classification on pp. 105–107, is a reconstruction of the families *Calloporidæ*, *Diplotrypidæ* and *Trematoporidæ*. In the first place it was a mistake to make *Trematopora* the type of the family as defined, because the relationship to *Constellaria,* which more truly expresses the characters of the family intended, is remote compared with the affinities existing between *Trematopora* and *Batostoma.* The latter, I am now fully satisfied, embraces the progenitors of *Trematopora*, and as the relationship seems to be very intimate it may be well to consider the advisability of dropping *Batostoma* in favor of Hall's older name. The *Calloporidæ*, with *Aspidopora* removed to the *Monticuliporidæ*, might be united with the *Diplotrypidæ*, from which, in that case, it would be well to remove *Batostoma*.* But for the reasons stated it was deemed inexpedient to carry out sweeping innovations in the present work, and the only excuse for their mention here is that it seemed necessary to publish some idea of the lines in which progressing knowledge is likely to modify the present classification. Perhaps also to show how well we are acquainted with its imperfections.

Batostoma fertile *Ulrich.*

PLATE XXV. FIGS. 1-11.

Batostoma fertile Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 92.

Zoarium attaining a large size, 50 to 100 mm. in hight, consisting of strong, irregularly thickened, more or less compressed branches that divide without regularity; thickness of branches 5 to 25 mm., width 8 to 30 mm. Zoœcial apertures varying according to the size and number of the mesopores and the thickness of the walls, from polygonal to circular. In some specimens and portions of others mesopores are exceedingly few and the zoœcial walls thin and generally in contact at all sides; in the majority of examples mesopores are moderately abundant and the walls thicker, but the zoœcial apertures are still polygonal or at any rate most of them subangular. From this, the typical form, we can trace the variations by small degrees into a form which, for the sake of reference, may be designated as var. *circulare*. In this the zoœcial apertures are almost perfectly circular, enclosed by a raised rim or peristome, and largely separated from each other by depressed interspaces. Often the peristomes are thicker and more distinctly separated from each other than is shown in fig. 6. Interspaces occupied by mesopores varying considerably in size and shape. Their mouths are commonly closed by a calcareous plate in which a variously situated rounded opening may be observed. When the preservation is unusually favorable the surface of the plate is studded with very minute papillæ representing the terminations of exceedingly small foramina. Acanthopores between one and two to each zoœcium, but very small and only in rare instances distinguishable at the surface. At intervals of 3 or 4 mm. occur clusters of zoœcia a little larger than the average, and in the center of these usually small substellate maculæ. Between eight and nine of the average zoœcia in 3 mm.

*The families reconstructed in accordance with the above suggestions would be as follows: Calloporidæ, *Calíopora*, *Diplotrypa*, *Monotrypa*, ? *Callopora*; Trematoporidæ, *Trematopora*, *Batostoma*,? *Hemiphragma*, ? *Stromatotrypa*; Constellaridæ, *Constellaria*, *Stellipora*, *Nicholsonella*, ? *Idiotrypa*.

Internal characters: In vertical sections the tubes have thin and somewhat irregularly fluctuating walls in the axial region. Their course to the surface is gently curved throughout, and as they near the same their walls are appreciably thickened, while mesopores, whose number varies greatly in different specimens, are abruptly developed. The mesopores may be constricted at the points where they are intersected by the diaphragms. The latter are often thickened circumferentially, and vary somewhat in the number occurring in a given space, seven and eleven in 1 mm. being the extremes so far noticed. In the axial region diaphragms are very far apart or are wanting entirely, but in the peripheral portion the average distance between them is about equal to half their diameter. Specimens more than 12 mm. thick consist of two or more layers of tubes.

The four tangential sections figured on plate XXV, fully illustrate the characters of the species as brought out in this kind of section. Fig. 7 is from a specimen with very thin walls, few mesopores, and scarcely distinguishable acanthopores, the latter being in the angles of junction. Fig. 4 represents a small portion of a section prepared from the original of fig. 2. In this, which is an average example, the walls are thicker, mesopores more abundant, and the acanthopores, though small, more readily distinguished. Minute foramina are shown in the diaphragms of some of the mesopores. Figures 8 and 9 are from specimens of the variety *circulare*, the first with thick zoœcial walls, the second with them thin as in fig. 6.

In a general way this species reminds one more of upper Hudson river species than of Trenton forms. Variety *circulare* resembles *B. manitobense* Ulrich,* very closely, but the clusters of large zoœcia are more conspicuous in that species. The typical variety on the other hand is more like *B. variabile*, differing from it chiefly in the smaller size of the acanthopores. Compared with associated Bryozoa none save *Anolotichia impolita* have as large zoœcia.

Formation and locality.—Abundant in the lower third of the Trenton shales at Minneapolis and St. Paul, Minnesota.

Mus. Reg. No. 8136; var. *circulare*, 8137.

Batostoma magnopora, *n. sp.*

PLATE XXV, FIGS. 12-15.

Zoarium ramose; branches large, subcylindrical, 8 to 15 mm. wide; surface elevated at irregular intervals into low monticules, the latter broad and occupied by zoœcia a little larger than the average. Zoœcia unusually large, about eight in 3 mm., their apertures polygonal, the walls thin, with one or two small acanthopores

*Contr. Micro-Pal. Cambro-Sil. rocks of Canada, pt. II, p. 33, 1889.

to each zoœcium rising generally from the wall at some point between the angles of junction. Many of the latter are occupied by small mesopores, but these are to be regarded as comparatively very few and at all times difficult to distinguish externally.

Internal characters: In tangential sections the tubes are polygonal and have rather thin walls in which the line of contact between adjoining tubes is distinctly preserved. Mesopores few, small, chiefly at the angles of junction. Acanthopores small, inconspicuous. In vertical sections the tubes proceed toward the surface in a very gentle curve until they enter the unusually narrow peripheral region, where the curve is sufficiently accelerated to enable them to open at the surface with nearly direct apertures. Diaphragms are very remote or wanting in the axial region, and not numerous even in the peripheral portion. Here each tube presents from one to five, separated by intervals of from one-half to one tube-diameter. In the mesopores, which appear to be very short, the diaphragms are much closer with three or four in 0.5 mm. In the central part of transverse sections (fig. 14) the tubes are conspicuously divided into a large and small set, both having very thin walls.

The large size of the zoœcia distinguishes this species not only from all the other forms of the genus known but from all the associated bryozoans as well. *Anolotichia impolita*, restricted to the bed of shales immediately beneath ("Stictoporella beds"), has zoœcia fully equalling those of the present species in size, but they are each provided with a lunarium and are commonly of either rhomboidal or hexagonal shape, while the surface is without monticules and the growth of the zoarium decidedly irregular.

Formation and locality.—Four specimens were found in the middle third of the Trenton shales, three at Minneapolis, the fourth at West St. Paul.

Batostoma varium, *n. sp.*

PLATE XXV, FIGS. 16-25.

Zoarium growing from a large basal attachment into erect branches. These vary in width from 7 to 20 mm. but average from 10 to 15 mm., are generally a little compressed and divide most irregularly. In some cases the basal expansion consists of several distinct layers, varying from 1 to 3 mm. in thickness. Surface without monticules, but exhibiting instead clusters of orifices larger than the average and separated by interspaces wider than usual. Not infrequently the center of these clusters is marked by a small substellate solid macula. Superficial characters variable, the walls in some cases being thin, with the zoœcial apertures subangular, the zoœcial walls seemingly in contact in most cases, the mesopores few, and the acanthopores indistinct. This condition, which is to be counted as rare, corresponds to fig. 18. From it the usual deviation consists in the rounding and constriction of the zoœcial apertures, and widening of the interspaces. When carried to the extreme we have subcircular apertures enclosed by a thin peristome, separated by depressed interspaces in which the mouths of a few mesopores may be noticed. In all these conditions (corresponding to figs. 16, 19, 20 and 21) the average number of zoœcial apertures in 3 mm. is nine or ten. The acanthopores also are rarely very conspicuous for size, though they are numerous enough and may be distinctly visible on well preserved examples. But in a variety, or rather an occasionally observed condition of the species, the acanthopores are much larger and situated three or four in the now thin walls of each zoœcium, causing their apertures to be more or less indented at the points occupied by them.

Internal characters: The extreme variability of tangential sections is well shown in the seven figures on plate XXV. And yet the species is an easy one to identify by means of thin sections. Each tangential section will show from two to four of the conditions illustrated, and although I used five specimens and six sections I might have obtained an equal range of variation with two of them. The greater part of them vary between the appearances represented in figs. 16, 19 and 21. Vertical sections are more constant, having numerous diaphragms—about four in the zoœcial tubes and six in the mesopores in 0.5 mm.—in the peripheral region, and none in the axial. The usual irregularity of the tubes in the axial region is noticeable. Also a peculiar moniliform structure of the walls in the peripheral region is the probable cause of some of the variations noticed in tangential sections.

The zoarial growth is less robust and the average size of the zoœcia less than in *B. fertile.* The opposite is the case when compared with *B. winchelli,* which, like *B. minnesotensis,* has also much fewer mesopores. The species is evidently a forerunner of *B. humile* of the Galena shales and *B. jamesi* Nich. sp. of the Cincinnati rocks.

Formation and locality.—Moderately abundant in the middle third of the Trenton shales at Minneapolis and St. Paul, Minnesota.

Mus. Reg. No. 8135.

Batostoma montuosum, *n. sp.*

PLATE XXV, FIGS. 26-28.

Zoarium ramose, small, branches dividing rapidly, 5 to 10 mm. in diameter; surface with more or less conspicuous monticules, 2.0 or 2.5 mm. apart, occupied by apertures of the same size as those in the depressions; the summit of the monticules occasionally appearing subsolid. Acanthopores numerous, rather small, often indenting the zoœcial apertures. Interspaces variable, occupied by closed mesopores, often thinner and the zoœcial walls more in contact with each other than shown in fig. 27. About ten zoœcial apertures in 3 mm.

None of the specimens at hand have preserved the internal characters in a fully satisfactory manner. The sections prepared, however, are sufficiently clear to make the generic reference of the species unquestionable. They point, furthermore, to close relationship with *B. varium*, differing from that species in having the peripheral region narrower and diaphragms less abundant. Of external peculiarities the possession of well marked monticules distinguishes the species from all related forms. For comparisons with associated monticulose species belonging to other genera see p. 227.

Formation and locality.—Not uncommon in the upper third of the Trenton shales at Poe's farm, near Cannon Falls, Minnesota.

Mus. Reg. No. 8134.

Batostoma humile, *n. sp.*

PLATE XXV, FIGS. 29-36.

Zoarium rather small, consisting of comparatively slender, compressed or subcylindrical branches, 4 to 11 mm., commonly 5 to 7 mm., in width; bifurcations few, less frequent than usual with species of this genus; surface without monticules, but more or less strongly spinulose in the older stages. Zoœcial apertures subovate, varying in size according to thickness of walls and interspaces, generally with a thickened rim; apertures subequal, eight or nine in 3 mm. Interspaces variable, depressed, the zoœcial walls sometimes in contact at as many points as the rounded form of the tubes will admit; more commonly their walls are completely separated. At intervals the interspaces may widen and form subsolid spots. Acanthopores numerous, situated in the interspaces or on the outer side of the walls, small and often difficult to distinguish on young examples, but conspicuous enough on well matured specimens and very much so on several apparently old fragments. In the latter the interspaces may be solidified and raised instead of depressed, and the size of the zoœcial apertures 0.15 by 0.2 mm. against 0.2 by 0.3 mm. in young specimens.

Internal characters: Good tangential sections cannot be prepared except from fully matured or old examples, because of the brevity of the peripheral region. Young specimens give tangential sections like the upper half of fig. 33, with thin walls and angular zoœcia. With age the walls become thickened, ring-like and more or less separated by partially filled mesopores. The acanthopores also increase in size and distinctness but, being situated either in the interspaces or on the outer side of the zoœcial walls, never encroach upon the zoœcial cavities. In the axial region of vertical sections the tubes have irregularly undulating thin walls and no diaphragms. Nor are these structures developed except in the unusually narrow peripheral region, where from one to three have been observed in each tube. The mesopores are very short and provided with two or three thick diaphragms; or they may appear to be filled with solid tissue.

The oval zoœcial apertures, more slender growth, and absence of monticules are the most striking differences between the present species and *B. montuosum.* The zoarium is smaller, the branches more slender, and the peripheral region much narrower than in *B. varium.* An undescribed variety of *B. jamesi* Nich. sp., occurring in the Utica horizon at Cincinnati, Ohio, corresponds more nearly than any of the known Minnesota species of the genus.

Formation and locality.—Moderately abundant in the Galena shales at St. Paul and near Cannon Falls, Minnesota. Also at Decorah, Iowa. A similar, perhaps identical, species occurs in the Trenton of central Kentucky.

Mus. Reg. Nos. 7613, 8063.

Batostoma winchelli *Ulrich.*

PLATE XXVI, FIGS. 33-37; PLATE XXVII, FIGS. 1-6.

Amplexopora winchelli Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 91.

Zoarium irregularly ramose; branches subcylindrical or a little compressed, varying in diameter from 4 to 10 mm., but in nine-tenths of the fragments seen from 5 to 7 mm. In the typical and common form of the species monticules are wanting, nor are the clusters of apertures of larger size than the average, which sometimes take their place, ever a conspicuous feature. Occasionally they are rendered more distinct than usual by a thickening of the interspaces and an aggregation of the mesopores. In a variety that may be distinguished as *nodosa*, the surface is thrown up into more or less strongly marked monticules. Zoœcial apertures rounded or subangular, rather irregularly arranged, ten to twelve in 3 mm.; walls moderately thick in most specimens, comparatively thin in young, very thick in worn old ones, ridge-shaped when perfect, and with acanthopore spines at nearly all angles of junction. Mesopores sparingly developed, never as numerous as the zoœcia, occurring chiefly in small straggling clusters, their mouths open, of various sizes, some of them apparently developing into zoœcia.

Internal characters: Being an exceedingly common and superficially variable species, over thirty sets of thin sections were prepared. These prove the species constant in most of the characters shown in vertical sections, and decidedly variable in tangential sections. It should, however, be stated that many of the specimens sectioned exhibited some external peculiarity or deviation from the ordinary types of the species. In the axial region of vertical sections the tubes are thin-walled and crossed by diaphragms from one to three times their diameter distant from each other. But in the attenuate proximal ends of the tubes the diaphragms are always closer than after the tubes have attained their full size. In entering the peripheral region, the width of which depends upon age, the tubes bend outward rather abruptly, proceeding thereafter directly to the surface. In the turn the diaphragms become more numerous and, though generally straight and complete, not infrequently exhibit a tendency to coalesce with each other. In the mesopores, which sometimes evidently changed into zoœcial tubes, the diaphragms occur regularly seven in 0.5 mm.

In figs. 4 to 8 on plate XXVII, I have endeavored to represent the principal variations noticed in tangential sections. The most of them are as in fig. 6, and figs. 4 and 5 represent what I regard as a condition of extreme age, differing from the usual condition merely in having an extra internal deposit of hard tissue. Figs. 7 and 8, however, deviate in a more important respect in having stronger and more abundant acanthopores. Many of these, furthermore, are developed between the angles, causing an inbending of the tube-walls. The average size of the zoœcia in this form, which may receive the provisional name of var. *spinulosum*, is also a trifle greater than usual.

The systematic position of this and the two species following is somewhat doubtful, but after careful reflection I have selected *Batostoma* as more fitting to receive them than *Amplexopora*. The closer tabulation of the proximal ends of the tubes, the irregularity of the tubes in the axial region, and their division there (as seen in the central part of transverse sections) into a large and small series, are characters so far unknown in *Amplexopora*. But my chief reason for placing the species with *Batostoma* is found in the marked resemblance exhibited by fig. 8 to similar views of *B. implicata* and *B. jamesi* of the Cincinnati rocks.

Formation and locality.—Very abundant in the middle third of the Trenton shales at St. Paul, Minneapolis, and localities in Goodhue and Fillmore counties, Minnesota.

Mus. Reg. Nos. 5999-6001, 8092, 8095.

Batostoma minnesotense, *n. sp.*

PLATE XXVI, FIGS. 38-40; PLATE XXVII, FIGS. 9-15.

Amplexopora superba Ulrich, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 92. (Not Foord, 1883, Contri. Micro-Pal. Cambro-Sil. Rocks, Can., p. 16.)

Zoarium ramose, above the medium size for the genus; branches without monticules, subcylindrical, bifurcating at rather long intervals, averaging 9 or 10 mm. in diameter, but varying between the extremes of 7 and 15 mm. Zoœcial apertures subangular, with walls of moderate thickness, arranged in regular curving series about clusters of orifices that are in most cases decidedly larger than the average; of the latter sometimes nine, more often ten, occur in 3 mm. Prominent acanthopores at all the angles of junction, and in many cases another is placed between the angles. These at all times occupy the summit or center of the walls and in no case cause irregularities in the form of the zoœcial apertures. Mesopores very few, scattered at random among the larger apertures.

Internal characters: In tangential sections the walls are nearly uniformly thick, with the angles of junction often appearing as open (pl. XXVII, fig. 15). In other cases the angles are occupied by dark spaces looking more like the usual appearance of acanthopores. A more typical phase of the species is shown in figs. 9 and 10, representing parts of a section of an excellently preserved example. In this we have more abundant acanthopores and the cavity in these is unusually large, while many of the angles are occupied by open spaces similar to those shown in fig. 15.

In vertical sections the tubes are provided with thin wavy walls in the axial region, where they are also a little irregular and generally entirely without diaphragms, the latter first making their appearance as the tubes bend into the peripheral region. In the outer region the walls are much thickened and in places distinctly traversed longitudinally by acanthopores. The mesopores are but seldom observed, have few diaphragms and appear to be in part filled with solid tissue. The arrangement of the diaphragms in the zoœcial tubes varies somewhat in different sections. Figures 11 and 13 represent extremes in this respect.

This species, though closely related to *B. winchelli*, is readily distinguished externally by its larger size and slightly larger and more regularly arranged zoœcial apertures; internally by the wavy walls and the absence of diaphragms in the axial region. Foord's *Amplexopora superba*, to which I at first referred this species, is probably congeneric, but distinguished specifically by having nearly straight instead of wavy walls to the axial tubes, and a tuberculated surface.

Formation and locality.—Not rare in the middle third of the Trenton shales at Minneapolis, St. Paul and other localities in Minnesota.

Mus. Reg. Nos. 5996, 5998, 7592, 7668, 8093.

Batostoma? decipiens, *n. sp.*

PLATE XXVII, FIGS. 16-19.

Zoarium ramose, branches smooth, 5 to 12 mm. in diameter. Zoœcia with moderately thick walls; apertures polygonal, subequal, about eleven in 3 mm. When in a good state of preservation the walls are sharply ridge-shaped, appearing thinner than usual. Clusters of large cells scarcely distinguishable. Mesopores very few, acanthopores not observed at the surface.

Internal characters: Vertical sections show that in the axial region the proximal end of the tubes is crossed by four to six diaphragms, 0.2 mm. or less apart. Above these the distance between them is from two to four times as great until the tubes are about to turn into the well defined peripheral region, when their number is greatly increased. In the outer part of the tubes, where the diaphragms also exhibit a tendency to coalesce, the number varies in different sections from seven to twelve in 0.5 mm.

In tangential sections the walls are thick, though some difference in this respect is noticeable in the ten sets of sections prepared. This is owing to the varying thickness of the internal concentrically laminated deposit. The divisional line between adjoining tubes is sharply marked, and sometimes contains a small, acanthopore-like dot midway or thereabout between the angles of junction. The mesopores, which are scattered very sparingly among the zoœcia, and sometimes gathered into clusters of three or four, look very much as though they might be merely young or perhaps aborted zoœcia, differing from them, so far as can be seen in these sections, solely in the matter of size.

The systematic position of this species cannot be determined finally until we know more of the Chazy *Trepostomata*. Without that knowledge its affinities appear to lie as closely with *B. winchelli* on the one hand as with *Callopora angularis* on the other. I thought much of classing the species with *Callopora*, but at last concluded that the occasional presence of acanthopores and greater thickness of the walls would not now admit of such an arrangement. *Callopora angularis*, which of all the associated species is probably the most like *B.? decipiens*, has smaller branches and thinner zoœcial walls.

Formation and locality.—Rather rare in the lower and middle third of the Trenton shales at Minneapolis, Minnesota.

Genus HEMIPHRAGMA, n. gen.

Batostoma (part.) ULRICH, 1890. Geol. Surv. Ill., vol. viii, p. 379.

Zoaria like those of *Batostoma* save in this, that the diaphragms in the peripheral part of the zoœcial tubes are incomplete.

Type: *Batostoma irrasum* Ulrich.

The discovery of a fourth species having incomplete diaphragms has decided me in giving the character generic rank. What may prove to be a fifth species, occurs among my material from the upper beds of the Hudson river group at Delafield and Iron Ridge, Wisconsin. Unfortunately, the Bryozoa which occur so abundantly at those localities do not preserve the internal characters, so that in cases like this it is impossible to verify the generic affinities of the species by means of thin sections. It is possible that the natural relations of *Hemiphragma* are not with *Batostoma*, but in the absence of data showing the value of the difference between the two genera, we are obliged to place them together because of their marked agreement in all other respects.

HEMIPHRAGMA IRRASUM *Ulrich.*

PLATE XXIV, FIGS. 5-19.

Batostoma irrasa ULRICH, 1886. Fourteenth Ann. Rept. Geo. Nat. Hist. Sur. Minn., p. 94.

Zoarium consisting of small, subcylindrical, frequently and rather irregularly dividing branches, commonly 5 or 6 mm. in diameter, but varying from 4 to 8 mm., the latter extreme probably only when an extra layer of tubes has grown over the original branch. Monticules wanting, but under fully matured conditions the surface is abundantly spinulose. Zoœcia with subangular apertures and thin walls when young, and with smaller, subcircular or oval apertures and more or less thick walls in fully matured examples; arrangement of apertures rather regular in rows about small solid spots, in the immediate vicinity of which the zoœcia may be of larger size than elsewhere; seven to nine in 3 mm. Interspaces apparently solid and generally with shallow irregular depressions in most specimens, but in very young stages a variable number of irregular mesopores may be recognized. Acanthopores numerous, two or more to each zoœcium, situated in the angles of junction and interspaces, and increasing in size with age. They are large and a conspicuous external feature of well preserved mature examples.

Internal characters: In the axial region of vertical sections the tubes have thin and irregularly fluctuating walls, and few or no diaphragms. The latter are complete here and the proximal end of the tube expands to full size with unusual rapidity. In the peripheral region, which is narrow and abruptly distinguished from the axial, the walls are more or less thickened, and the tubes intersected by semi-diaphragms, about four in 0.5 mm. I have satisfied myself that all the transverse partitions in this outer part of the zoœcial tubes are really incomplete. That many may appear entire in sections is only because their inner edge happens to be vertical instead of horizontal. Mesopores are difficult to make out in these sections, being short and usually filled, in part at least, with solid tissue. Tangential sections require no description, all the essential characters being shown in figs. 6, 7, 9 and 14. In the axial part of transverse sections the tubes are unusually irregular and their walls comparatively thick.

This is a common and well marked species, but proves to be nearer *H. ottawense* Foord sp., than I thought at first. Perhaps the only reliable difference, and that may in part be due to the greater size of Foord's species, is the much smaller number of diaphragms in *H. irrasum.* The largest specimens of the latter even do not approach *H. ottawense* in the width of the closely tabulated peripheral region.

Formation and locality.—Common in the lower third and rare in the middle and upper thirds of the Trenton shales at Minneapolis, St. Paul, and Preston. In the overlying Galena shales it is again common at St. Paul and at various localities in Goodhue county. Also at Decorah, Iowa.

Mus. Reg. Nos. 7618, 7627, 8033, 8041, 8051, 8078.

HEMIPHRAGMA OTTAWENSE *Foord.*

PLATE XXIV, FIGS. 1-4.

Batostoma ottawense FOORD, 1883. Contri. to Micro-Pal. Cambro-Sil. Rocks, Can., p. 18.

This species is so much like the preceding that it is sufficient to merely point out the differences between them. In the first place *H. ottawense* is always of larger size than *H. irrasum*, the width of its branches, which in some cases are strongly compressed, varying from 9 to over 30 mm., and their thickness from 8 to 12 mm. Internally, the axial region is comparatively smaller and the tubes here have diaphragms which, though sometimes wanting for short distances, are yet more abundant throughout the region than in *H. irrasum.* In the latter the peripheral region is narrow and the number of semi-diaphragms correspondingly limited. In the present species, however, this region is wide and the number of cross-partitions often great. The difference in these respects is generally quite as marked as in figures 3 and 5 on plate XXIV.

Foord says of the Canadian form of the species (*loc. cit.*) that the surface exhibits "small and inconspicuous monticules placed at variable distances apart and occupied by from ten to fifteen cells slightly larger than the average." The monticules are wanting in the specimens collected by me at Ottawa and in the Minnesota form, but smooth spots, consisting of clusters of mesopores, are present instead, and in the immediate vicinity of the spots the zoœcial apertures are larger than midway between them. It is possible that Mr. Foord was mistaken in crediting the species with monticules, since these spots, being more solid than the rest of the zoarium, are likely to withstand weathering better and thus to appear gradually as elevated points.

Formation and locality.—In Minnesota the species is rather rare and restricted to the upper part of the Galena shales at Kenyon, Berne and Mantorville. The same horizon contains *Fusispira ventricosa* Hall, *Orthis germana* W. and S., *Pachydictya pumila*, *Homotrypa similis*, *Monotrypa* (*? Chætetes*) *cumulata*, and other highly characteristic fossils.

Mus. Reg. No. 6002.

Hemiphragma tenuimurale, *n. sp.*

PLATE XXIV, FIGS 20-23.

In its growth and general aspect this species is precisely like *H. irrasum.* Under a hand lens, however, they are immediately distinguished by the much thinner walls, fewer mesopores, and seeming total absence of acanthopores in the present species. In *H. irrasum* the zoœcial apertures also are always of rounded form, in *H. tenuimurale* angular. These differences, as may be seen from figs. 5 to 8 and 20 to 22 of plate XXIV, are no less obvious when we compare the internal characters of the two species. It is true, perhaps, that we may occasionally see faint evidence of very small acanthopores at the angles of junction in tangential sections, yet they are too indistinct and small to compare with the acanthopores of *H. irrasum.* In tangential sections the species is much more like *H. imperfectum* (*Batostoma imperfectum* Ulrich) of the Hudson river group of Illinois and Wisconsin. But that species grows to a much greater size and has rather conspicuous clusters of mesopores. *H. ottawense,* besides being much larger and having more abundant semi-diaphragms, differs in the same manner as *H. irrasum.*

Formation and locality.—Not uncommon in the Galena shales at various localities in Goodhue county, Minnesota.

Mus. Reg. Nos. 8032, 8042, 8052.

Genus STROMATOTRYPA, n. gen.

Zoarium consisting of one or several superimposed thin layers growing upon foreign bodies. Zoœcial tubes short, with few diaphragms, the proximal end scarcely prostrate, oval in cross-section; walls thin, containing periodically constricted, bead-like tubuli (? modified acanthopores), one or more to each zoœcium.

Apertures oval, separated by depressed interspaces, the peristomes minutely papillose. Mesopores abundant, beginning on the basal lamina, decreasing in size with age, closely tabulated, the diaphragms finely punctured; mouths rarely visible, closed by a common dermal sheet. True acanthopores wanting.

Type: *Stromatotrypa ovata*, n. sp.

The species upon which this genus is based has much to remind us of the Devonian *Pinacotrypa*, Ulrich. But as that genus is clearly a branch of the *Fistuliporidæ*, and *Stromatotrypa* most likely not far removed from *Batostoma* and *Trematopora*, it is evident that there can be no real affinity with *Pinacotrypa*. The arrangement with the *Diplotrypidæ*, though provisional, is strongly suggested by the dimorphic character of the zoarium and the supposed relationship to *Bastostoma*.

STROMATOTRYPA OVATA, *n. sp.*

PLATE XXIV, FIGS. 24-31.

Zoarium consisting of one or more exceedingly thin layers, varying in thickness from 0.5 to 2.0 mm., occasionally attached to shells, but more commonly encrusting other Bryozoa. Sometimes the attachment is incomplete, and in a few cases the zoarium is free, with the underside wrinkled. Surface without monticules, but exhibiting at irregular intervals smooth spots of greater or less extent on which the zoœcia are generally farther apart than usual and the apertures of some of them closed. Zoœcial apertures oval, peristomes thin, in contact at limited points or more or less widely separated, the arrangement inclining to be irregular, with six to eight, commonly seven, in 3 mm.; length of apertures varying from 0.3 to 0.45 mm., the average about 0.28 by 0.38 mm. Interspaces depressed, of variable width, apparently smooth in the youngest stages, minutely granulose in the aged conditions. Small acanthopore-like elevations generally where peristomes come into contact. The best preserved specimens exhibit also a row of minute papillæ crowning the peristomes.

Internal characters: In tangential sections the zoœcial walls are thin and in contact at one or more points, or they may be completely isolated by mesopores varying considerably in shape and size. Attached to the walls, or more frequently occupying the angles of junction, are minute rounded and thin-walled cells that are perhaps to be regarded as peculiarly modified acanthopores. Good sections show besides a large number of smaller dots in the interspaces and zoœcial walls. In vertical sections both sets of tubes rise abruptly from the basal lamina, and the mesopores decrease more or less conspicuously in size in nearing the surface.

Diaphragms are few in the zoœcial tubes, but in the mesopores, which are usually constricted at the point of crossing, they are abundant. Here and there the zoœcial walls seem to diverge periodically so as to produce minute beaded tubuli.

There is no parasitic bryozoan known to me from Lower Silurian rocks with which this species could be confounded. Ramose Bryozoa coated with it might be mistaken for certain varieties of *Batostoma fertile*, but the crusts are rarely complete enough to render such a difficulty common. A greater superficial resemblance even is sometimes presented to young examples of *Pachydicta foliata*, a truly bifoliate species, with very different internal structure and really so distinct that no one ought ever to confuse them.

Formation and locality.—Not uncommon in the lower and middle thirds of the Trenton shales at Minneapolis and St. Paul, Minnesota. Occurs also in the "Lower Blue" at Beloit, Wisconsin.

Genus MONOTRYPA, Nicholson.

Monotrypa (part.), NICHOLSON, 1879, Pal. Tab. Cor., p. 293; 1881, Genus Monticulipora, pp. 102 and 168; ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 153; FOORD, 1883, Contri. Micro-Pal. Can., p. 14.
Monotrypa, ULRICH, 1890. Geol. Surv. Ill., vol. viii, p. 379.
Ptychonema, HALL, 1887. Pal. N. Y., vol. vi, p. xiii.

Zoaria irregularly massive, discoid, or subglobose, apparently not divisible into mature and immature regions. Zoœcia comparatively large, prismatic, with very thin, straight or transversely wrinkled walls; diaphragms complete, remotely placed in the tubes. Both mesopores and acanthopores wanting.

Type: *M. undulata* Nicholson.

We are satisfied that the position of this genus is near *Diplotrypa* (*sensu stricto*) and the simple section of the genus *Batostoma*. In the last we have only the ramose habit of growth, and few and small mesopores and acanthopores to distinguish it from *Monotrypa*, the structure of the walls and the character of all the other points being precisely the same in the two groups. In *Diplotrypa* diaphragms are perhaps always more abundant, but in all other respects, excepting that the tapering proximal ends of the zoœcial tubes are closely tabulated like mesopores, the structure is essentially the same as in *Monotrypa*. There is a largeness and a certain looseness of arrangement that distinguishes the whole family *Diplotrypidæ* from the *Amplexoporidæ*, a family including (under *Leptotrypa*) a number of simple species agreeing otherwise closely with *Monotrypa*. These species of *Leptotrypa* (*e. g. L. filiosa* d'Orb. sp., and *L. petasiformis* Nich. sp.) belong, I am convinced, to a different line of development than that of true *Monotrypa*.

The genus as restricted embraces but few species. Besides the type, which occurs in the Trenton of Canada and New York, we have *M. subglobosa* Ulrich, in the Utica horizon at Cincinnati, *M. rectimuralis* Ulrich, in the Trenton of southern Illinois and probably in the Cincinnati group of Ohio, *M. intabulata*, n. sp., and *M.* (*? Chætetes*) *cumulata*, n. sp., in the Galena of Minnesota, *M. magna*, n. sp., in the Birdseye limestone of the northwest, *M. colliculata* (*Chætetes colliculatus* Hall,) in the Lower Helderberg of New York, and *M. tabulata* (*Ptychonema tabulatum* Hall,) in the Upper Helderberg of New York. A small undescribed species occurs in the Niagara of Indiana, while another, apparently belonging here, I found in the Corniferous limestone at Columbus, Ohio.

MONOTRYPA MAGNA, *n. sp.*

PLATE XXVII, FIGS. 28 and 29.

Zoarium growing in large expanded masses, sometimes consisting of superposed layers, the whole perhaps 20 to 40 mm. high and 100 mm. wide; under side generally with a wrinkled epitheca, the upper celluliferous and without monticules. Zoœcia large, polygonal, thin-walled, with clusters of larger size than the average at intervals of about 6 mm., measuring from center to center; about nine in 5 mm.; size of largest in the clusters about 0.8 mm., average diameter of these in the spaces between the clusters about 0.5 mm.

Internal characters: In vertical sections the zoœcial walls are strongly undulating and very thin throughout, and the tubes crossed by complete horizontal diaphragms at intervals varying between one and three times the diameter of a tube. Transverse sections exhibit thin structureless walls, an occasional small (young) cell, and a total absence of mesopores and acanthopores.

The larger size of the zoœcia distinguishes the species from *M. undulata* Nicholson. Excepting the *Crepipora perampla* of the present work, they are larger than in any paleozoic bryozoan known to me. The zoaria of that species are comparatively higher and less expanded, and their zoœcia provided with lunaria.

Formation and locality.—Not uncommon in the "Lower Blue" limestone at Dixon, Illinois; also at Mineral Point and Beloit in Wisconsin. A small fragment from the equivalent limestone at Minneapolis is provisionally identified with it.

Monotrypa intabulata, *n. sp.*

Compare *Monotrypa rectimuralis* Ulrich, 1890, Geol. Sur. Ill., vol. viii, p. 462.

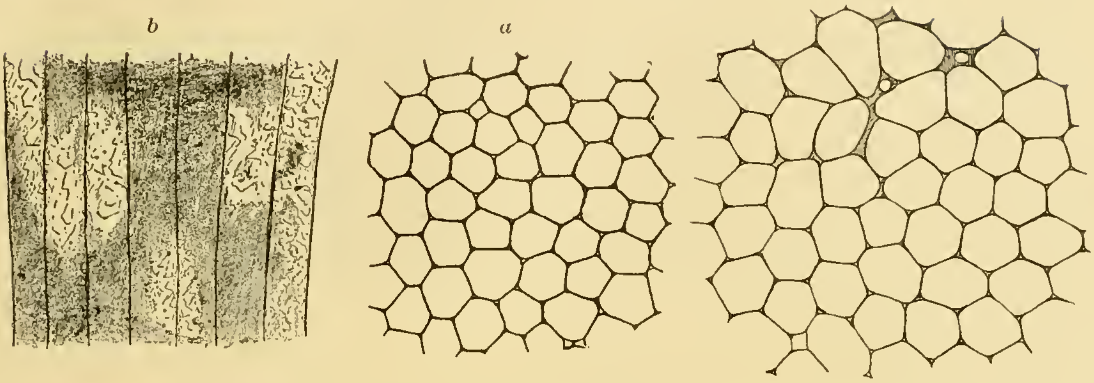


Fig. 20. *Monotrypa intabulata, n. sp.* Upper half of Galena shales, Goodhue and Fillmore counties, Minnesota. Collection of E. O. Ulrich. *a*, transverse section, x18, showing subequal size of tubes, their thin walls, and the lucid spot in the angles of junction; *b*, vertical section, x18, the tubes filled chiefly with clayey matrix; c, transverse section, x18, of a variety from Fountain, Minnesota, provisionally referred to this species. It has larger zoœcia than usual, while the size of the latter seems also to be rather less equal.

Zoarium forming subhemispherical or depressed-spherical masses, generally between 30 and 60 mm. in diameter and 15 to 30 mm. in hight; lower surface usually less convex than the upper and sometimes partly covered by an epitheca. Celluliferous surface even, covered with subequal, thin walled, polygonal zoœcial apertures, of which the usual number in 3 mm. is between eight and nine. In several small examples found near Fountain, the number is between seven and eight. Conspicuous and regularly arranged clusters of large cells are wanting, though here and there one or several zoœcia may be of unusual dimensions.

Internal characters: In transverse sections the walls are exceedingly thin, but where well preserved their duplex character is determined by minute triangular, seemingly open spaces at the angles of junction, formed by the separation of the walls of adjoining tubes. Here and there a young zoœcium is met with, but true mesopores and acanthopores as well, are unquestionably wanting. In vertical sections the walls form nearly straight lines (merely curving to adapt themselves to the growth of the zoarium) being entirely without the crenulations so characteristic of the typical species of the genus. Diaphragms also seem to be wanting, and most of the tubes of specimens from shaly strata are in great part filled with the matrix.

At first I believed this species must be the same as the *M. rectimuralis* Ulrich, the types of which were collected from nearly equivalent beds in southern Illinois. The absence of diaphragms was explained by the supposition that they had been destroyed during the process of fossilization. But the study of new material, and other sets of thin sections shows that this explanation is inadequate, since, while the diaphragms are always absent in this form they are present in all associated Bryozoa; and it stands to reason that the conditions under which the two sets of specimens were preserved must necessarily have been identical. I am obliged therefore to consider their absence in the *Monotrypa* as normal, and to give these peculiar Minnesota specimens a new name.

M. intabulata agrees with *M. rectimuralis** not only in the external appearance of the zoarium but in having straight walls and minute triangular open spaces at the angles of junction as well. As differences we have diaphragms two to four times their diameter apart, and rather conspicuous clusters of large cells in the latter and none in the former.

Among associated forms only *Monticulipora grandis* and *Bythotrypa laxata* have a similar growth, the species of *Prasopora* and *Mesotrypa* forming discoidal zoaria. Both of these species however are too widely different structurally from *Monotrypa* to be confounded.

Formation and locality.—Not uncommon in the upper part of the Galena shales (Fusispira beds) at several localities in Goodhue and Fillmore counties, Minnesota.

Mus. Reg. No. 8379.

Monotrypa nodosa, *n. sp.*

(Not Figured.)

Monticulipora (?) *ortoni* Whitfield, 1882. Geol. Wis., vol. iv, p. 251. (Not *Chætetes ortoni* Nicholson, 1875. Pal. Ohio, vol. ii, p. 211.)

Zoarium commonly beginning its growth upon shells over and beyond which it spreads till it forms large discoidal or hemispheric masses, often over 5 or 6 cm. in diameter. Sometimes the masses are shapeless, but as a rule the base is concave, and, where it projects beyond the covered shell, clothed with a wrinkled epitheca. Upper surface with more or less prominent subconical monticules, averaging about 3.4 mm. from summit to summit. Zoœcia with thin walls, polygonal and rather regularly arranged apertures, nine or ten in 3 mm.; apertures occupying the monticules but little if at all larger than those in the intermediate spaces. Summits of monticules occasionally appearing solid. Not a trace of either mesopores or acanthopores has been observed. Internal characters unknown, none of the specimens seen being fit for sectioning.

*In the original description of the species I included, erroneously, a hemispheric or lenticular, tuberculated form that is very common in the Hudson river rocks at Savannah, Illinois, and Delafield and Iron Ridge, Wisconsin. As it may justly be expected to occur in the southern part of Minnesota, the next brief description of its known characters may be of advantage to students of the palæontology of the State.

In the absence of any knowledge of the interior the generic position of the species is necessarily a little doubtful. In a general way, *M. nodosa* resembles *Leptrotypa filiosa* d'Orb. sp., of a lower horizon in the Hudson river rocks, very closely, and the principal difference that can now be pointed out is in the size of the zoœcia, that species having eleven or twelve apertures where the present form has nine or ten. But *Atactoporella ortoni* Nich. sp., to which Whitfield referred the Wisconsin specimens, is a delicate parasitic form totally distinct.

Formation and locality.—Common in the upper beds of the Hudson river group at Iron Ridge and Delafield, Wisconsin, and Savannah, Illinois.

Mus. Reg. No. 7574.

Monotrypa (? Chætetes) cumulata, *n. sp.*

PLATE XXVII, FIGS. 26 and 27.

Zoarium forming small subglobular or irregular masses, generally consisting distinctly of irregularly superposed layers; average sizes between 15 and 20 mm. in diameter, anything under or over those extremes being rare; no monticules. Zoœcial walls thin; apertures polygonal, of unequal sizes, sometimes forming at long but irregular intervals large clusters in which they are conspicuously larger than elsewhere; in most cases however the apertures are subequal, with an average of six and one-half or seven in 3 mm. Mesopores and acanthopores wanting.

Internal characters: In vertical sections the tubes diverge rapidly and rather irregularly, and their walls present an obscure longitudinal lineation. Diaphragms occur at intervals varying from one to four times their diameter, but their position in neighboring tubes corresponds approximately. In transverse sections the principal interest attaches to the structure of the walls. In most sections the wall is comparatively thick and seems to be composed of minute columns which, being cut transversely, appear as alternately dark and lighter parts. In this respect the structure of the walls is essentially the same as in true *Chætetes*, and I would unhesitatingly have placed the species into that genus had I been able to satisfy myself that the phenomena observed were not the result of secondary causes. Namely, in some sections the appearance is very different, the wall itself being more sharply defined and thinner than usual (especially where the tubes are filled with matrix instead of calcite) and without the alternating light and dark spots. But where the tubes are filled with calcite the latter for some distance inward from the wall is of a darker color than at the center, and exhibits, strange to say, a spotting not unlike that pertaining to the wall itself in other sections.

The external form, though smaller, is much the same as in *M. intabulata* and other species of the genus, but the zoœcia are larger, and none of them have a wall-structure as described above.

Formation and locality.—Upper part of the Galena shales (Fusispira beds) at various localities in Goodhue county, Minnesota. Also in the Trenton limestone of Canada.

Mus. Reg. Nos. 7629, 7635, 8025.

Family TREMATOPORIDÆ, Ulrich.

For remarks on this family see p. 289.

Genus TREMATOPORA, Hall.

Trematopora, HALL, 1852, Pal. N. Y., vol. ii, p. 149; DYBOWSKI, 1877, Die Chætetiden, p. 69; ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 241; 1883, *idem.*, vol. vi, p. 257; HALL, 1887, Pal. N. Y., vol. vi, p. xiv; ULRICH, 1890, Geol. Surv. Ill., vol. viii, pp. 373, 418.
Not *Trematopora*, ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 153.

Zoaria ramose, branches solid, even or montiferous. Zoœcia with oval or sub-circular apertures, surrounded by more or less elevated peristome. Interspaces depressed, sometimes exhibiting the closed mouths of the abundant mesopores. Zoœcial tubes with thin walls and few diaphragms. Mesopores irregularly angular, generally exhibiting an obscurely beaded appearance in vertical sections, with a diaphragm at the constriction. Acanthopores superficial, of moderate or small size, one or more to each zoœcium.

Type: *T. tuberculosa* Hall, Niagara group.

The really essential characters of this genus have been most persistently misinterpreted and overlooked. Even now I am not satisfied that they are fully brought out in the above diagnosis, which is practically the same as the one in volume viii of the Illinois reports. The truth is that more study, especially genealogical, is required before it will be possible to delineate even approximately the limits of the genus. Thus, while almost certain that most of the Lower Silurian species placed here by me (*e. g. T. primigenia* and *T.? nitida*) are not really related to *T. tuberculosa*, I find myself unable as yet to justify their placement elesewhere.

As stated on a preceding page (289) the type of the genus presents many points of agreement with *Batostoma* and is probably to be viewed as a later expression of the same type of structure. Not so, however, with *T.? primigenia* and allied species, these being much more like *Leioclema*, *Bythopora* and *Batostomella*, on the one hand,

and *Nicholsonella* and *Constellaria* on the other. And yet, above all, there are peculiarities that postpone the determination of the systematic position of the next following species till we can learn something of their ancestors. In the meantime they can remain under *Trematopora* and their doubtful affinities be indicated by the usual sign.

As regards *Trematella* and *Orthopora*, two subgeneric names proposed by Hall,* the first is clearly a synonym for *Batostomella,* Ulrich, the second for *Rhombopora,* Meek. Both groups are widely different from true *Trematopora.*

TREMATOPORA? PRIMIGENIA *Ulrich.*

PLATE XXI, FIGS. 23-40.

Trematopora primigenia ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 97.

Zoarium loosely bushy, consisting of small slender ramulets, dividing dichotomously at varying intervals; branches cylindrical or compressed, commonly about 2 mm. in diameter, but varying from 1.5 to 4.0 mm., arising in greater or lesser numbers from a large basal expansion that is thinly spread over some cylindrical body like a crinoid column. Not infrequently the branches inosculate freely. Entire zoaria varying in diameter probably between 20 and 60 mm. Superficial aspect of zoœcia varying with age. In young stages or examples the apertures are more or less oblique, with only the posterior border elevated and the interspaces in a varying degree narrower than the apertures. With age the apertures become somewhat smaller, ovate or subcircular and direct, and the peristome or rim equally elevated all around, while the interspaces were widened till in some examples they are often equal to twice the width of the zoœcial orifices. At the same time the interspaces, which as a rule exhibit no sign of the really very numerous mesopores, are roughened, as are also the peristomes, by the development of acanthopores. These vary greatly in size and number. The arrangement of the zoœcial apertures is only moderately regular, there being here and there spots in which they are of larger size and more widely separated than usual. An average of twelve or thirteen in 3 mm., but the number in that distance may vary from eleven to fifteen.

Internal characters: In vertical sections the tubes have thin walls, are not entirely vertical, and without diaphragms in the axial region. Near the surface they bend outward rather abruptly when one and sometimes two diaphragms were in most cases thrown across each tube. At the same time an abundant series of mesopores was developed. These are crossed by from two to six diaphragms, the

*Pal. N. Y., vol. vi, p. xiv, 1887.

outer ones of which are much thicker and separated by shorter intervals than the inner pair. This gradual thickening of the diaphragms is more decided in the branches than in the basal expansion, part of a vertical section of which is represented in fig. 40. The walls of the mesopores where two or more occupy an interspace are strongly zigzag, in some instances appearing not unlike vesicular tissue. In tangential sections the zoœcial walls may be thin and occasionally even inflected by the acanthopores (fig. 37), but as a rule they are ring-like, as in figs. 38 and 39, and generally completely separated from each other by a series of unequal and irregularly shaped mesopores. The acanthopores are distinct, nearly uniform in size, usually attached to the outer side of the zoœcial walls, and number from one to three or four to each zoœcium.

Var. ORNATA *Ulrich.*

PLATE XXI, FIGS. 26, 28, 33, 34.

Trematopora ornata ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Surv. Minn., p. 98.

Increased collections have convinced me that this is merely an uncommon variety of *T.? primigenia*, differing from the typical form of the species, as above described, in having the zoœcial apertures a little more elongate and rather more regularly arranged, and in having the peristomes crowned by a crowded row of small papillæ. Larger spines, as shown in fig. 34, are sometimes present.

Var. SPINOSA, *n. var.*

PLATE XXI, FIGS. 29, 30, 35, 36.

Of this form, which, if it proves permanent, should be called a species, I have seen only a few specimens. Though evidently mature they are a trifle smaller than typical *T.? primigenia*, and differ in a number of other minor points from that form. But their principal peculiarity, and the only one that in the present state of our knowedge deserves mention, is the presence of a considerable number of strong spines in the interspaces. A few smaller acanthopores are scattered among the larger ones, but unless searched for they are likely to be overlooked.

The large basal expansion, small branches, rounded zoœcial apertures and depressed interspaces are features that serve to distinguish this species and varieties at once from all associated ramose Bryozoa.

Formation and locality.—The typical form is an abundant fossil in the middle third of the Trenton shales at St. Paul and Minneapolis, while it is not uncommon in the same beds at other localities in the State, notably near Fountain and Preston in Fillmore county. The two varieties are rare and associated with the typical form at St. Paul and vicinity.

Mus. Reg. Nos. 6010, 6011, 7654, 7661.

Genus CONSTELLARIA, Dana.

Constellaria, DANA, 1848, Zoophytes, p. 537; NICHOLSON, 1879, Pal. Tab. Corals, p. 292; 1881, Genus Monticulipora, p. 97; ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 156; 1883, *idem*, vol. vi, p. 265; 1890, Geol. Surv. Ill , vol. viii, pp. 374, 423; JAMES and JAMES, (part.) 1888, Jour. Cin. Soc. Nat. Hist., vol. xi, p. 29.*

Stellipora, DYBOWSKI, 1877. Die Chætetiden d.Ostb. Silur. form., p. 42.

Zoaria subramose or frondescent, growing erect from a basal expansion which is attached to foreign bodies. Surface with stellate maculæ, the spaces between the rays more or less elevated and occupied by two or three short rows or clusters of closely approximated zoœcial apertures. Zoœcia with rather thin walls, small circular apertures enclosed by an elevated rim, equally distributed and partly in contact with each other in the spaces between the maculæ. Interspaces depressed; mesopores abundant, aggregated in the maculæ, always closed at the surface, with gradually crowding horizontal diaphragms. Zoœcial tubes with fewer diaphragms. True acanthopores wanting, but exceedinly minute tubuli, increasing in number with age, are to be detected in the interspaces by means of tangential sections.

Type: *C. florida* Ulrich.

Of this genus I am now acquainted with eight good species and three or four varieties that group themselves around *C. florida*. The earliest known occurs in the Pierce limestone of Tennessee. This is very much like the Minnesota Trenton species next described, but as it has not yet been critically studied it may prove quite distinct. A variety of *C. florida* occurs in the upper Trenton beds at Nashville, Tennessee, and in Canada, and other varieties occur abundantly with the typical form of the species in the lower half of the Cincinnati rocks. *C. fischeri* Ulrich, is a Kentucky form from about the same horizon. In the upper part of the Hudson river group in Ohio, Indiana, Illinois and Wisconsin, we meet with *C. polystomella* Nicholson, and *C. limitaris* Ulrich, and with two undescribed species at Wilmington, Illinois. This locality furnished also the types of *C. parva* Ulrich. These species are all separated easily from each other by means of intelligently prepared thin sections.

CONSTELLARIA VARIA, *n. sp.*

PLATE XXI. FIGS .1-7.

Zoarium consisting of one or more irregularly dividing branches arising from a broad basal expansion. Branches usually compressed, generally from 8 to 10 mm. wide, but varying between the extremes of 3 and 15 mm. Maculæ large, irregularly

* I consider the work of James and James referred to above as unworthy of such quotation, and that its citation among reputable works on the Bryozoa is to dignify it with an attention far beyond its deserts. But the possibility that others may be able to discover merits which I cannot may be sufficient excuse for its inclusion in the bibliography.

stellate, very slightly depressed or on a level with the general plane of the surface. The small clusters of zoœcial apertures (four to ten in each) occupying the angles between the rays may be elevated a little above the level of the maculæ, but as a rule the entire surface may be said to be even. In a few cases however the maculæ themselves are higher than the spaces separating them. Zoœcial apertures subcircular, inclosed by a very thin rim, and varying considerably in size, though approximately equal on each fragment. Width of interspaces varying correspondingly so that about the same number of apertures occur in a given space in all specimens. Ten or eleven occur in 3 mm. in the intermacular spaces, while the diameter of the apertures varies between the extremes of 0.15 and 0.25 mm. Figure 1 represents the surface of a specimen (x9) with small apertures and wide interspaces; fig. 2 a small part of another (x18) having comparatively large zoœcial apertures and correspondingly narrow interspaces. The latter are always a little depressed, and, like the maculæ, occupied by the shallow yet distinct mouths of angular mesopores.

Internal characters: Figure 4 represents a portion of a tangential section where it divides a mature zoarium immediately beneath the surface. In most sections the walls will be thinner and probably not show the minute tubuli in them as drawn in fig. 4. Series of sections prove that the relative width of the zoœcial tubes and interspaces depends largely upon age, the width of the zoœcia decreasing with maturity. Figure 5 is from a good vertical section, and shows that diaphragms occur in all the tubes throughout the zoarium, in the axial region generally about twice their diameter apart, the distance between them becoming less as the zoœcial tubes bend to the surface. In the mesopores, which are very abundant, especially when the section passes through one of the maculæ, the diaphragms are at first rather far apart, but gradually become almost crowded at the surface.

This species is nearer *C. limitaris* Ulrich, of the upper part of the Hudson river group, than any other. The superficial resemblance between them is very decided, but when we compare thin sections we find that the later species has smaller and much more abundantly tabulated mesopores. Indeed, the diaphragms are more numerous in both sets of tubes. All the other described species of the genus have smaller zoœcia, and most of them differ in having no diaphragms in the axial region.

None of the associated species are likely to be confused, none of them having stellate maculæ.

Formation and locality.—Rather rare in the upper beds of the Galena shales near Cannon Falls, Minnesota. It is here associated with *Orthis germana* W and S., *Homotrypa similis* Foord, and several species of *Nematopora.*

Mus. Reg. No. 8044, 8130.

Genus NICHOLSONELLA, *Ulrich.*

Nicholsonella, ULRICH, 1890, Geol. Sur. Ill., vol. viii, pp. 374 and 421.

Zoaria consisting of irregularly intertwining flattened branches or fronds growing from an expanded base; or of laminar, free or parasitic, expansions only. Zoœcial tubes subcylindrical, with diaphragms only moderately numerous; apertures circular, enclosed by a slightly elevated papillose peristome. Interspaces wide, occupied by numerous angular mesopores more or less completely isolating the zoœcia; minutely granulose in fully matured examples. Walls of both sets of tubes thin, and in the peripheral region traversed longitudinally by minute tubuli. With age a perforated calcareous deposit fills the interzoœcial spaces in which the walls of the mesopores become unrecognizable. Mesopores with thicker and generally more numerous diaphragms than the zoœcial tubes. In the axial region of transverse sections of the erect forms the tubes are very unequal.

Type: *N. ponderosa* Ulrich, Geol. Sur. Ill., vol. viii, p. 422, 1890.

This is a Lower Silurian genus with rather uncertain affinities. So far as our knowledge goes the position of the genus in classification seems to be in a measure intermediate between *Constellaria* and *Leioclema*. In another direction we note considerable resemblance to *Heterotrypa*. The type is one of the earliest as well as one of the most complicated and interesting of the *Trepostomata*, and on the whole appears to occupy a rather isolated position with respect to contemporaneous types of structure. It is therefore unfortunate that the preservation of the most typical species of the genus is almost invariably unfavorable for microscopic determination of their internal peculiarities. Indeed, it is a noteworthy fact, that Trenton specimens of *Nicholsonella* are but rarely as well preserved as are associated Bryozoa of other genera.

N. ponderosa was described from the "Lower Blue" or sponge beds at Dixon, Illinois. A nearly related species occurs at Beloit, Wisconsin, and in the middle third of the Trenton shales of Minnesota. Associated with the latter is the laminar species, *N. laminata*, about to be described. *N. pulchra* is a fourth species from the "Pierce" limestone of Tennessee. *N. vaupeli** is abundant in the quarries at Cincinnati, Ohio, as is an undescribed and closely related form occurring higher in the series at several localities in Ohio and Indiana. Finally, *N. cumulata* is described in my Illinois work from the upper beds of the Hudson river group at Wilmington, Illinois.

**Heterotrypa vaupeli* Ulrich, 1883, Jour. Cin. Soc. Nat. Hist., vol. vi, p. 85.

NICHOLSONELLA PULCHRA, *n. sp.*

PLATE XXI. FIGS. 8-12.

Zoarium forming a bushy mass, consisting of irregularly divided, sometimes anastomosing flattened branches, 6 to 10 mm. thick and 8 to 20 mm. wide. Surface with small conical or rounded menticules, subsolid at their apices, and frequently uniting on the rounded edges of the branches to form short ridges. In some specimens the monticules are very slightly developed. Zoœcial apertures rounded, small, subequal, regularly arranged, about eleven in 3 mm., separated by interspaces nearly equalling their diameter—about 0.15 mm. Interspaces minutely papillose, generally depressed midway so that a rather irregular ring of papillæ surrounds each aperture. Mesopores, though completely isolating the zoœcia, are to be detected at the surface only in young and weathered examples.

Internal characters: In vertical sections the tubes diverge with comparative rapidity and uniformity of curvature. Their walls are thin, though not excessively so, and exhibit that lack of sharpness which characterizes especially the Trenton species of the genus. Young zoœcial tubes arise in the axial region mainly and expand very gradually. Diaphragms occur throughout, two or three times their diameter apart in the axial region, and averaging nearly twice as many in a given space in the peripheral region. In young examples it is not easy to distinguish the mesopores from the true zoœcial tubes, but the solid deposit which more or less completely fills up the outer part of the mesopores in the fully matured stages then renders the task an easy one. This deposit is lined vertically with rows of dots, and in many cases is divided up into two or more layers with light intervals between them. The two halves of fig. 10 show, in the upper, the structure of a matured example just beneath the surface. Here the zoœcia are as usual not sharply defined and the interspaces completely filled with solid tissue in which a great number of small dots (representing the superficial papillæ) are to be observed. At a deeper level in the zoarium (see lower half of fig. 10) the large angular mesopores are open. Here even some dots (? acanthopores) are to be made out in the walls, chiefly at the angles of junction.

Transverse sections show that in the axial region the tubes are of all sizes and variously angular. No dots like those seen in tangential sections are to be detected, but one of my sections exhibits fairly conclusive evidence of an intermittent structure of the walls not unlike fig. 26 on plate 27.

There is very little likelihood of confusion between the present species and any other referred to the same genus, and thin sections will of course distinguish it at once from species of other genera. Among the latter *Monticulopora arborea,* from higher rocks, is strikingly like *N. pulchra* superficially.

Formation and locality.—Not uncommon in the "Pierce limestone" at Murfreesboro, Tennessee, where it is associated with an abundance of fossils, chiefly Bryozoa.

Mus. Reg. No. 8131.

Nicholsonella laminata, *n. sp.*

PLATE XXI, FIGS 15-19 and 21.

Zoarium laminar, several mm. thick, the under side strongly wrinkled concentrically. Upper surface even, but exhibiting rather indistinct maculæ or areas in which the interspaces between the zoœcia are wider than usual. Zoœcial apertures circular, regularly arranged, nine or ten in 3 mm., averaging 0.2 mm. in diameter and 0.13 mm. apart. Peristome thin, very minutely papillose. Interspaces occupied by angular mesopores forming a complete series between the zoœcia. Mouths of mesopores closed or open. When closed the interspaces are slightly roughened by small granules among which a few of larger size (? acanthopores) have been detected. Internal characters as shown in figures.

I have taken great pains to illustrate the internal characters just as they appeared to me under the camera lucida, and I refer the student to figs. 15, 16 and 17, rather than attempt a description. I will however admit at once that I do not understand the purpose of the system of dots lining the walls and radiating from the center of one of the zoœcia. The latter may represent perforations in the diaphragms.*

The surface and growth of this species remind one of species of *Fistulipora* with small zoœcia. The laminar form of the zoaria will, it is believed, effectually distinguish it from other forms of *Nicholsonella.* I know of no associated bryozoan with which it might be confounded, and the mere mention of caution should deter the student from carelessly classifying the *Nicholsonella* with the very different discoidal species of *Prasopora* and *Mesotrypa.*

Formation and locality.—Rare in the middle third of the Trenton shales at St. Paul and Minneapolis.

---

*Such pore-like "dots" and other minute unexplained structures have been drawn carefully on a number of the plates attached to this work. Some day perhaps we may be able to appreciate their significance. In the meantime we must gather *facts* and I shall continue to delineate them as faithfully as I can. In this connection it may be well to mention what many microscopists have long observed with dismay. Namely, that minute structures like those in question are gradually obliterated by some insidious action of the Canada balsam in which the preparations are mounted. It is therefore desirable, indeed necessary, to make the drawings as soon as possible after mounting the sections.

NICHOLSONELLA PONDEROSA ? *Ulrich.*

PLATE XXI, FIGS. 13, 14, 20 and 22.

?*Nicholsonella ponderosa* ULRICH, 1890. Geol. Sur. Ill., vol. viii, p. 422, pl. XXXIV, figs. 5-5*d*.

Two specimens only of this form were found by the author at Minneapolis in the lower third or "Stictoporella beds" of the Trenton shales. One is an irregular mass, 65 mm. long by 30 to 40 mm. in thickness, presenting the bases of several large branches. The surface is not well preserved, but seems to have been considerably like that of *N. laminata.* The interior likewise is but illy preserved, and the illustrations (figs. 13 and 20) may be objected to on the ground that they are much more distinct than the sections. The "dots" in the interspaces have most probably been drawn too small and too numerous. It seems that two or three should have been united into one, giving an appearance more like fig. 10 of the same plate. Still, enough of the internal characters are to be made out to render the generic reference almost beyond dispute. On protected spots the surface is decidedly spinulose. Here about nine zoœcial apertures occur in 3 mm.

The other specimen is a fragment of a branch, about 11 mm. thick and 14 to 19 mm. wide. In the shape of the zoœcia, their number in a given space, and in the charcter of the interspaces and interior, this specimen is apparently precisely like the first.

There is nothing decidedly opposing the placing of these specimens with *N. ponderosa*, the types of which are from the sponge-layer of the "Lower Blue" limestone at Dixon, Illinois. Still, better preserved material is desirable before much confidence is to be placed in the identification.

Family AMPLEXOPORIDÆ, Ulrich.

Genus LEPTOTRYPA, Ulrich.

Zoaria varying from thin incrustations to free forms of discoidal, spiral, or elongate conical shape; subglobose and irregularly massive species occur also. Zoœcial tubes polygonal, with thin walls just appreciably thickened in the mature regions, and a variable number of diaphragms. Acanthopores small, more or less numerous, but almost invariably restricted to the angles of junction between the zoœcial tubes. Mesopores wanting.

Type: *L. minima* Ulrich, of the Cincinnati group.

This genus includes forms essentially like those of *Amplexopora*, Ulrich, only they arise into erect branching zoaria while the species of *Leptotrypa* never depart from the types of growth mentioned in the description. Numerous species of both genera are known and several of *Leptotrypa* from the Trenton beds of Minnesota. True *Amplexopora*, however, is first met with in the Utica.*

Leptotrypa hexagonalis *Ulrich.*

(Not Figured.)

Leptotrypa hexagonalis, Ulrich, 1890. Geol. Surv. Ill., vol. viii, p. 455.

Original description: "Zoarium forming parasitic expansions less than 1 mm. in thickness, spread upon *Orthoceras* and *Hyolithes.* Surface smooth. Clusters of cell apertures of almost twice the usual size are arranged in diagonally intersecting rows; these clusters are about 3 mm. apart, measuring from center to center. Zoœcia regularly hexagonal in shape, sometimes a little elongated, seven, measuring longitudinally, almost nine, diagonally, in 2 mm.; diameter of the smaller 0.2, of the larger 0.35 mm. Acanthopores prominent on the surface when well preserved."

This species occurs almost invariably as a delicate lace-like expansion upon *Hyolithes baconi* Whitfield. This fact, together with the markedly hexagonal shape of the zoœcial apertures, renders it an easily recognized species.

Formation and locality.—Rather rare in the limestone at Minneapolis, Minnesota. The types are from equivalent beds ("Lower Blue") at Mineral Point, Wisconsin, and Calhoun county, Illinois. Other localities are Janesville and Beloit, Wisconsin.

Mus. Reg. Nos. 7551, 7557, 7595.

Leptotrypa informis, *n. sp.*

PLATE XXVII, FIGS. 22 and 23.

Zoarium forming parasitic patches or lump-like growths upon foreign bodies, varying considerably in size and from 1 to 5 mm. in thickness. At other times apparently free, with a wrinkled epitheca beneath. Surface without monticules, nor are the clusters of large cells very conspicuous except in a few cases where the zoœcia forming them are separated by a limited number of small cells. Zoœcial apertures polygonal, thirteen or fourteen of the average size in 3 mm. Walls very thin, in vertical sections sometimes appearing as though made up of alternating horizontal bands of light and dark shades. Acanthopores more or less prominent at the surface, varying some in size, restricted to the angles of junction, one-half of which are occupied by them. Diaphragms complete, on the whole rather remote and irregularly distributed, the intervals between them varying from one to four times their diameter.

*Trenton species have been placed under *Amplexopora* by both Mr. A. H. Foord and myself, but a re-examination has convinced me that the species in question are more likely aberrant types of *Batostoma*, where I would now place them.

In many respects like *L. semipilaris* Ulrich, of the Cincinnati rocks, the most striking difference appearing in the number of the diaphragms, these being almost totally absent in that species. An undescribed species, differing chiefly in having much smaller and fewer acanthopores, occurs in the Galena shales.

Formation and locality.—In the lower and perhaps also in the middle third of the Trenton shales at Minneapolis and St. Paul.

Mus. Reg. No. 6024.

Leptotrypa acervulosa, *n. sp.*

PLATE XXVII, FIGS. 24 and 25.

Zoarium occurring as small, irregular or subglobular masses, generally between 15 and 20 mm. in diameter and somewhat less in hight. Surface approximately even, but clusters of cells are conspicuously larger than the average, and in one case these are elevated into low monticlues. Zoœcia angular, thin-walled, thirteen to fifteen, commonly fourteen of the usual size in 3 mm.; average diameter of apertures in the spaces between the clusters about 0.21 mm., of the largest in the clusters 0.35 to 0.4 mm. New tubes are interpolated in a great measure at corresponding levels through the zoarium, so that immediately above and beneath such a level there may be considerable difference in the average size of the tubes. Diaphragms from one to one and a half times their length apart except in the mature regions where they are separated by intervals about half as long. Acanthopores very small, in the angles, developed at intervals only, no trace of them being visible in some of the transverse sections. At the surface they are but rarely to be distinguished. In a single example, however, many of the angles of junction are prominent and the walls between them crowned with a closely arranged row of minute papillæ.

L. acervulosa agrees in most respects very closely with an undescribed species occurring at Clarksville, Ohio, in the upper beds of the Hudson river group. Smooth examples of *L.* (*Monotrypa*) *irregularis* Ulrich, also from Ohio, are likewise simulated, but that species is distinguished by having tubes practically without diaphragms. Two other species from the Cincinnati exposures, *L. filiosa* d'Orb., sp. and *L. petasiformis* Nich., sp., are probably the nearest among described species. The first grows in large masses and has well developed monticules, while the second forms hat-shaped or hemispheric zoaria like *Prasopora simulatrix.*

Formation and locality.—Not uncommon in the Galena shales at Decorah, Iowa. A single specimen from the same horizon in Goodhue county, Minnesota. Also in the shaly part of the Trenton at Burgin and Frankfort, Kentucky.

Mus. Reg. No. 8060.

Leptotrypa claviformis, *n. sp.*

PLATE XXVII, FIGS. 20 and 21.

Zoarium growing around and beyond one or more segments of *Arthroclema* and *Helopora* into simple club-shaped forms varying from the smallest figured to one that is 23 mm. long and 1.5 to 2.5 mm. in diameter. Some of the specimens have one or two short lateral branches, in which cases the supporting body was a twig of *Arthroclema* with lateral segments in place. Zoœcial tubes growing about the axial body very much as in ordinary ramose forms they grow about an imaginary center; diaphragms abundant except in the outer or direct portion; walls thin. Zoœcial apertures subangular, nearly uniform in size, there being no *appreciable* clusters of large cells; without apparent arrangement, about fourteen in 3 mm. What may be mesopores, but more likely are merely young zoœcia, are scattered among the ordinary tubes. At intervals, however, they seem to be more numerous than usual. Many, perhaps the majority, of the angles of junction are thickened and occupied by projecting acanthopores.

In a general way, this species may be said to fall under *Leptotrypa*, but I am more than inclined to doubt that it belongs there. The interior of the specimens sectioned is but illy preserved, the finer details of structure being quite obscure. Some of the specimens remind of *Petigopora*, Ulrich, and it is here that better sections will probably cause us to refer them.

Formation and locality.—Rather common in the middle and upper thirds of the Trenton shales at St. Paul and Minneapolis.

Mus. Reg. No. 8132.

Family CERAMOPORIDÆ, Ulrich.

Genus SPATIOPORA, Ulrich.

Spatiopora, Ulrich, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 155, and 1883, vol. vi, p. 166; Foord, 1883, Contri. Micro-Pal. Cambro-Sil. Rocks, Can., p. 20; Ulrich, 1890, Geol. Surv. Ill., vol. viii, p. 381.

Zoaria forming thin parasitic crusts upon foreign bodies, the shells of *Orthoceras* being the most favored. Surface even or with monticules. Zoœcia short, with direct and more or less irregularly shaped apertures. Lunarium scarcely perceptible even in thin sections. Mesopores very few, usually absent, when present occurring chiefly as "maculæ." Interspaces often with large blunt spines (? acanthopores). Walls of zoœcia moderately thin, with the characteristic structure pertaining to the family.

Type: *S. aspera* Ulrich.

Two Trenton species, *S. areolata* Foord, and *S. labeculosa* Ulrich, are referred to the genus with doubt.* The type, together with four or five other species, is found in the Cincinnati or Utica and Hudson river groups, above which the genus is not known to pass.

Spatiopora labeculosa, *n. sp.*

PLATE XXVIII, FIGS. 1 and 2.

Zoarium forming large and very thin expansions generally upon *Orthoceras* or *Endoceras*. Surface even, but conforming with the irregularities of the body grown upon. At intervals of 4 or 5 mm., measuring from center to center, there are clusters of cells decidedly larger than the average. These large apertures—they vary from 0.25 to 0.50 mm. in diameter—are arranged in each case about a substellate or irregular, apparently solid, spot, which on closer examination proves to consist of closed mesopores. The extent of these spots varies greatly, some being almost 2 mm. wide, while in others the center is scarcely more than 0.5 mm. wide. Zoœcial apertures subangular, usually a little oblong, with the margin on one side generally a little higher and more rounded than on the other. The last is true more particularly of the large cells which are not infrequently decidedly oblique and directed away from the center of the maculæ. In very young examples all of the apertures may be quite as oblique as in some species of *Ceramoporella*, but the lunarium is ever an inconspicuous feature. Many of the large cells again may preserve peculiar convex closures. Of the smaller or average zoœcia eleven to thirteen occur in 3 mm. Mesopores varying in number and distribution, but something like the following rule seems to prevail. When the maculæ are large the mesoposes are few and of small size elsewhere (see figs. 1 and 2); when small they are comparatively more abundant in the inter-macular spaces.

Internal characters: Figure 2 is a faithful copy of a portion of a tangential section prepared from a specimen (fig. 1 is an enlargement of its surface) having large maculæ. It will be noticed that the side of the zoœcia nearest the macula is nearly always less angular than the opposite side. This fact is good evidence of the possession of an incipient or undeveloped lunarium. The minute structure of the walls, which is not the same as in *Leptotrypa*, is likewise indicative of ceramoporoid affinities. In vertical sections the prostrate part of the tubes is rather short, and the erect part, forming an angle of about 80° with the line of the surface, perhaps

*Since this report was placed in the hands of the printer, two specimens of a typical species of this genus were collected by the author in the upper part of the middle third of the Trenton shales at Chatfield, Minn. The specific characters of these specimens, which grew over the shells of a small *Orthoceras*, are very similar to those of *S. maculosa* and *S. lineata* Ulrich, of the Cincinnati rocks. As a provisional designation for the form I would propose the name *S. maculosa*, var. *incepta*.

never exceeds 1 mm. Diaphragms are wanting in most of the tubes, but here and there the sections pass through one or several adjoining tubes having one diaphragm about midway up and sometimes another at the mouth.

This is an interesting and easily recognized species. Of associated parasitic forms only two need be compared; one, *Stromatotrypa ovalis* of this work, has oval and much larger zoœcia; the other is a rare and as yet undetermined form with circular and smaller zoœcia, numerous mesopores, and more uneven zoarium. *S. labeculosa* differs from both in the greater size and distinctness of its maculæ, and in the slight obliquity of its zoœcial apertures. The maculæ will distinguish the species at once from all the other species of the genus.

Formation and locality.—In the middle third of the Trenton shales at Minneapolis and St. Paul. *Mus. Reg.* No. 5026.

Spatiopora iowensis, *n. sp.*

(Not figured.)

Zoarium spread as an exceedingly thin crust over the cones of *Orthoceras sociale* Hall. Monticules wanting, but unusually distinct clusters of large cells are distributed over the surface at intervals of about 5 mm., measuring from center to center. Zoœcia larger than in other species of the genus, their walls thin, the apertures nearly or quite direct, angular, often of hexagonal or rhombic shapes, with three of those in the clusters in 2 mm. and an average of nine of those in the spaces between the clusters in 3 mm. Mesopores wanting except in the clusters mentioned where a few may be wedged in among the large cells. Many of the angles of junction between the apertures are raised into sometimes small, at other times large, acanthopore-like prominences.

In the dark shales at Graf, Iowa, this bryozoan is preserved as a thin gladiolus leaf-like film, the *Orthoceras* grown upon being compressed to such a degree that its original presence may not be suspected.

This species is in every respect a true *Spatiopora*. The affinities are nearer *S. maculosa* Ulrich, of the Cincinnati rocks, than to any of the others, and it is with that species that I first thought to place it. On comparison however *S. iowensis* proved to have larger zoœcia, with eight to ten where the Ohio species has eleven or twelve.

Formation and locality.—Maquoketa shales of the Hudson River group at Graf, Iowa. *Mus. Reg.* Nos. 7586, 7587.

Genus CREPIPORA, Ulrich.

Crepipora, ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 157; 1890, Geol. Surv. Ill., vol. viii, pp. 380, 469.

Zoaria incrusting, massive, or hemispherical; in one case forming regular hollow branches. Surface, especially in the first and last styles of growth, exhibiting at regular intervals maculæ of mesopores, appearing as minutely porous or subsolid elevations or depressions. In the massive forms these maculæ, to which the mesopores are usually restricted, are very small. Zoœcial tubes erect, their apertures very slightly oblique and varying from rhomboidal to subpyriform in shape. Lunarium small and easily overlooked except in well preserved examples; best shown in tangential sections. Thin diaphragms are developed in moderate numbers.

Type: *C. simulans* Ulrich.

Eleven or twelve species, several as yet undescribed, are known to me having the characters ascribed to this genus. Three of these are Trenton, the rest, save an Upper Silurian species from Gotland, are Utica or Hudson River group forms.

Crepipora differs from *Ceramporella* in having much fewer mesopores (typically none) in the inter-macular spaces, longer tubes, and less oblique apertures. *C. epidermata* Ulrich, from the Hudson River group of Illinois, is closely related to the new genus *Bythotrypa*, and ought perhaps to be referred to that genus, but it has seemed the wiser course to leave the species as originally described until special investigations into the inter-relations of the *Ceramoporidæ* can be taken up.

CREPIPORA SUBÆQUATA, *n. sp.*

PLATE XXVIII, FIGS. 26-28.

Zoarium a small laminar or incrusting expansion, 1 to 3 mm. thick. Zoœcial apertures approximately direct, angular, often quadrate or pentagonal, of nearly uniform sizes on all parts of the surface, no distinguishable clusters of cells larger than the average having been developed; ten in 3 mm. Lunarium very slightly developed, the zoœcial apertures and walls appearing much more like those of species of *Monotrypa* than of a ceramoporoid. Tangential sections, however, (see figs. 26 and 27) afford more or less clear evidence of its presence, but it is rare to find more than one of the ends of the lunarium projecting inward from the wall. Many of the angles of junction are thickened and include an acanthopore-like structure.

Mesopores very few. In vertical sections the walls are thin, with faint transverse lineation, and somewhat irregular. Diaphragms occur sparingly and at unequal intervals in the zoœcial tubes, but in the mesopores which, being few, are not often seen, they are numerous.

The absence of clusters of large cells and the greater average size of the ordinary zoœcia will distinguish this peculiar species from associated Bryozoa having a similar mode of growth.

Formation and locality.—Rare in the upper third of the Trenton shales at St. Paul, Minnesota.

Crepipora spatiosa, *n. sp.*

(Not figured.)

This name is proposed for a massive or heavy lamellate form that occurs in the Bryozoa layers at the top of the Trenton near Harrodsburg and Frankfort, Kentucky. It is closely related to *C. hemispherica* Ulrich (upper beds of Hudson River group in Illinois), on the one side, and *C. perampla* on the other. From the first it differs in the greater size and different shape of its zoarium, in having thinner walls and fewer diaphragms, and less distinct lunarium. The second has larger zoœcia and even less developed lunarium, but in other respects is very similar to the Kentucky species.

Specimens of this species may attain a diameter of 300 mm. with a thickness of from 50 to 100 mm. Of the ordinary zoœcia twelve occur in 5 mm. Diaphragms 0.4 to 1.0 mm. apart.

Crepipora perampla, *n. sp.*

PLATE XXVIII, FIGS. 29-32.

Three specimens have been seen of this. One, about 70 mm. in diameter and 33 high, is hemispheric, with the base concave and the margin flaring slightly. The others are larger (about 95 mm. in diameter) and, though worn, the basal part of the zoarium seems to have been convex instead of concave. Zoœcia large, with very thin walls, generally of angular shapes, the pentagonal and hexagonal more common than the subrhomboidal; those of the average size about 0.5 mm. in diameter, with nine or ten in 5 mm. At intervals of 5 or 6 mm. clusters of tubes of more or less decidedly larger size than the ordinary are to be observed. Some of these may attain a width of 0.9 mm., but as a rule their size varies between 0.6 and 0.8 mm. Mesopores very few.

The appearance of thin sections is shown in the figures on plate XXVIII. In figs. 30 and 31 the presence of the lunarium is shown in an unmistakable manner, but fig. 32 is more like the usual appearance. Indeed, the lunarium is often so difficult to distinguish in transverse sections, that it is in order to caution the student against confusing the species with *Monotrypa.* In vertical sections the walls are often minutely crenulated, and in most cases exhibit the transverse lineation so common among the ceramoporoids. Exceedingly thin diaphragms occur in all the tubes at intervals varying from one to two tube-diameters.

The great size of the zoœcial tubes separates this species from all the other forms of *Crepipora* known. In this respect the species is approached by but one other paleozoic bryozoan, the *Monotrypa magna* of the present work, and both are believed to occur in nearly the same geological horizon. These two forms also present some points of resemblance in vertical sections, but so far as I can see there is really no relationship between them. In the *Monotrypa* the zoœcia are much more regularly angular, their walls without the transverse lineation and more coarsely wavy, while a lunarium is of course never present. The *C. hemispherica* Ulrich, which seems to occur in the shales of the Hudson River group at Granger and near Spring Valley, differs chiefly in the smaller size of the zoœcial tubes.

Formation and locality.—Trenton limestone at Chatfield and two miles northeast of Spring Valley, Minnesota.

Mus. Reg. Nos. 151, 170, 211.

Genus BYTHOTRYPA, n. gen.

Zoaria massive or lamellate. Zoœcia forming long continuous tubes, intersected by thin diaphragms, their walls minutely crenulate and with the structure characterizing the ceramoporoids. Lunarium well defined, large, projecting above the rest of the aperture margin. Mesopores numerous, open at the surface, interiorly forming a species of vesicular tissue unusually loose and irregular in construction.

Type: *Fistulipora laxata* Ulrich.

Largely increased collections of the type of this genus have convinced me that the species really belongs to the *Ceramoporidæ.* As none of the established genera of that family would include it, a new generic division became necessary. *Bythotrypa* is probably, as I regarded it at first, a type of structure that culminated in true *Fistuliporidæ*, but the lines along which the development progressed we are as yet unable to define. Still, it is more than possible that we have here merely a foreshadowing of that family—in other words, a premature evolution of the fistuliporoid type—that became extinct or was reabsorbed into the parent stock, failing to establish a permanent line of development. In that case *Crepipora? epidermata* Ulrich, from the Hudson River rocks of Illinois, would seem to be the earliest known point in the direct line to *Fistulipora*.

Bythotrypa laxata *Ulrich*.

PLATE XXVIII, FIGS. 21-25.

Fistulipora? laxata Ulrich, 1889. Contri. Micro-Pal. Cambro-Sil. Rocks. Can., pt. ii, p. 37.

Zoarium irregularly massive, usually beginning its growth upon some foreign body, the exposed under side strongly wrinkled and covered with an epithecal membrane. Specimens vary greatly in size, the smallest seen being about 12 mm. in diameter and 5 mm. or less high, while the largest is an oval mass 150 mm. long, 120 mm. wide, and about 70 mm. high. In the lower third of the Trenton shales they are all small, none observed exceeding 50 mm. in diameter. In the middle and upper thirds specimens between 75 and 100 mm. wide are not rare, but masses exceeding that size have been met with only in the upper part of the Galena shales.

Zoœcial apertures subovate, nearly equal, direct or a little oblique, the lunarium broad, sharply elevated, sometimes seeming to arch slightly over the aperture; their arrangement appearing more irregular than it is, with nine or ten in 5 mm. Mesopores abundant, varying greatly in size, a few quite as large as the zoœcia from which they are distinguished by their more angular and irregular form and in being without a lunarium. Mesopores forming larger or smaller clusters at irregular intervals from which the zoœcial apertures are turned in a radial manner. These clusters are most inconspicuous—even difficult to make out under the glass—except under certain conditions of weathering when they stand out as subsolid spots. Under ordinary circumstances the whole surface seems to be occupied uniformly by an irregular network of cells.

Internal characters: In transverse sections the appearance, aside from an unusual irregularity and looseness of arrangement, is much as in species of *Fistulipora*. The zoœcia are irregularly pyriform or ovate in cross section, and have thin walls. The lunarium, though often not a very marked feature, is still always determinable by the more regularly curved semi-circular form of the lunarial side of the circumference of the zoœcium, the opposite side being, if not angular, at any rate always drawn to a circle of greater diameter than the lunarial side. Occasionally one or both ends of the lunarium may project into the zoœcial cavity (see fig. 25). Not infrequently also the lunarial side is thickened by a light-colored deposit upon the outer side in which very fine transverse lines may be noticed. Dimensions of zoœcium of average size, about 0.3 by 0.4 mm. Interstitial cells varying greatly in size and distribution, some being very small, others as large and even larger than the zoœcia. They form generally but a single series between the zoœcia, yet it is not uncommon to notice a double row for a short distance. An obscure radial arrangement, with the zoœcia in contact lengthwise, is noticeable about certain points, 6 mm. or more apart, where the interstitial cells are more numerous than elsewhere, without, however, at any time being in sufficient numbers to justify being called "maculæ."

Vertical sections are even more characteristic, since in these the *loose construction* mentioned is very striking. The zoœcia appear as long irregular tubes crossed at variable intervals by exceedingly delicate horizontal diaphragms. The average distance between the diaphragms depends somewhat upon the horizon from which the specimen was collected. In zoaria from the lower and middle thirds of the Trenton shales, the average is between 0.5 and 0.9 mm., but in those from the Galena shales it is between 0.8 and 1.2 mm. The interstitial cells assume all sorts of shapes, but are always extremely high. A tendency to arrange themselves in vertical series is usually manifest, but they cannot be said to form tabulated tubes, their walls being on the whole quite irregular and the end partitions more or less oblique and in many cases overlapping. All the walls have that peculiar granular structure noticed, in paleozoic Bryozoa, only among the *Ceramoporidæ* and *Fistuliporidæ*.

Both the external and internal characters of this species are so distinctive that there is little or no danger of confusing it with associate massive forms.

Formation and locality.—Not rare in the three divisions of the Trenton shales at Minneapolis, St. Paul and Cannon Falls. It reappears, larger than ever, in the upper part of the Galena shales at several localities in Goodhue county, Minnesota, and at Decorah, Iowa. The original Manitoba type of the species I now believe to have come from strata equivalent to the last. It was collected at St. Andrews.

Mus. Reg. Nos. 5963, 7602.

Genus ANOLOTICHIA, Ulrich.

Anolotichia, Ulrich, 1890. Geol. Sur. Ill., vol. viii, pp. 381 and 473.

Zoaria large, irregularly ramose or digitate. Zoœcia comparatively large, forming long prismatic tubes, intersected by complete diaphragms more or less remotely situated. Walls thin, appearing transversely lineate in vertical sections. Apertures angular or subovate, direct, with a distinctly elevated lunarium. Thin sections show the lunarium to be traversed lengthwise by from two to seven minute, closely tabulated tubes. Mesopores very few in *A. impolita*, but moderately abundant, rather equally distributed among the zoœcia, and of irregular form, in the type species.

Type: *A. ponderosa* Ulrich, Hudson River group, Wilmington, Illinois.

Only two species, the type and the one next described, are as yet known of this remarkable genus. Aside from the lunarial tubuli, which constitute the principal distinctive character, the genus corresponds rather closely on the one hand, through *A. impolita,* with *Crepipora,* and fully as well on the other, through *A. ponderosa* with *Chiloporella.* In the absence of any positive knowledge concerning the functions and classificatory value of the lunarial tubuli, the relationships noted must provisionally determine the systematic position of *Anolotichia* as intermediate between those genera.

ANOLOTICHIA IMPOLITA *Ulrich.*

PLATE XXVIII, FIGS. 15-20.

Crepipora impolita ULRICH, 1886. Fourteenth Ann. Rep. Geol. Nat. Hist. Sur. Minn., p. 77.

Zoarium large, bushy, consisting of abundantly and irregularly divided solid branches, the latter varying from 5 to over 20 mm. in diameter. At the base the branches may coalesce, and here they are always stronger than at their terminations. Rarely the zoarium is not branched but occurs as an irregular mass with lobe-like excrescences. Zoœcia large, with moderately thin walls, direct, hexagonal or subrhomboidal apertures. The latter are subequal (there being no distinguishable clusters of large ones), are arranged in rather regular series with eleven in 5 mm. Lunarium well developed, appearing as a small crescentic elevation usually in one of the angles. Mesopores few, sometimes appearing to be absent entirely; occasionally forming small clusters of from two to six.

Internal characters: In tangential sections the walls of contiguous zoœcia appear to be thoroughly amalgamated; the lunarium is represented by two or three small lucid spots (lunarial tubuli) on one side of the tube, the end ones projecting slightly into its cavity. In vertical sections the tubes are scarcely to be called vertical even in the axial region, curving outward with a uniform curve from the beginning. Their walls are composed of rapidly alternating dark and lighter shades of schlerenchyma, so that they appear more or less distinctly lineate transversely. The cause of these lines, which are closest in the peripheral part of the zoarium, is unknown, unless the light ones, which are of uniform width and, especially in the axial region, narrower than the dark bands, represent rows of perforations. Exceedingly delicate diaphragms, their diameter or more apart, occur chiefly in the outer and middle parts of the tubes. The axial portion of transverse sections is very nearly like tangential, the only difference being that the walls are a little thinner and small tubes comparatively more abundant.

The much smaller number of mesopores is the most obvious external difference between the present species and *A. ponderosa* Ulrich. The lunarial tubuli also are about twice as numerous in that species. Of Minnesota species, I know of only one that is likely to be confounded. This is the *Batostoma magnopora*, a rare species of the middle third of the shales (Rhinidictya beds), having, if not always monticules, at least conspicuous clusters of large cells. The absence of such clusters in the *Anolotichia* renders the separation of the two forms comparatively easy after all.

Formation and locality.—This is a very abundant and highly characteristic fossil of the lower third of the Trenton shales at St. Paul, Minneapolis, Cannon Falls, Chatfield, Lanesboro and Fountain.

Mus. Reg. Nos. 5958, 5962, 7660.

Genus CERAMOPORELLA, Ulrich.

Ceramoporella, ULRICH, 1882, Jour. Cin. Soc. Nat. Hist., vol. v, p. 156; Geol. Surv. Ill., vol. viii, pp. 380, 464.

Zoaria incrusting, often becoming massive by the superposition of numerous thin layers. Zoœcial tubes short, their walls thin. Apertures more or less oblique, hooded, commonly of oval shape. The hoods are directed away from the centers of small maculæ marking the surface at rythmical intervals. Mesopores abundant, often completely isolating the zoœcia, their apertures usually open, sometimes closed by a thin membrane. Diaphragms only rarely present.

Type: *C. distincta* Ulrich, Cincinnati group, Ohio.

This genus embraces all the parasitic Lower Silurian ceramoporoids. The species, with few exceptions, are all closely related, and some of them seem also to have an unusually extended vertical range. Thus the first of the following Minnesota species, which occurs here in the lowest member of the shales, is so much like the Cincinnati types of the genus that I cannot distinguish them. *C. inclusa* is a well marked species, and unknown above the upper third of the Trenton shales, but the Galena shales species, *C. interporosa*, n. sp., is likewise a common form throughout the lower 300 feet of the rocks at Cincinnati, Ohio.

CERAMOPORELLA DISTINCTA *Ulrich.*

PLATE XXVIII, FIG. 13.

Ceramoporella distincta ULRICH, 1890. Geol. Surv. Ill., vol. viii, p. 464.

Zoarium forming thin parasitic patches upon other Bryozoa, the Minnesota specimens seen consisting of but a single layer less than 0.7 mm. thick. Zoœcia small, radially arranged about certain small maculæ, nine to eleven, measuring obliquely, in 3 mm. Apertures very oblique, with an overhanging hood, highest posteriorly. Mesopores numerous, small, usually forming a single linear series between the sides of the zoœcia.

This species is much rarer than the associated *C. inclusa* from which it is at once distinguished by its smaller and differently shaped zoœcial apertures. In *C. interporosa* the apertures are larger and more direct.

Formation and locality.—Lower third of the Trenton shales at Minneapolis and St. Paul. It is met with next in the Cincinnati rocks, being an abundant species at that locality.

Ceramoporella inclusa, *n. sp.*

PLATE XXVIII, FIGS. 8-11.

Zoarium forming thin crusts over foreign bodies, not observed to consist of more than a single layer, less than 1 mm. thick, generally 20 mm. or more in diameter. The customary maculæ, about which the zoœcial apertures are arranged in a radial manner, are represented, but less distinctly than usual. Nor is the radial disposition of the apertures as marked a feature as usual. Indeed, it is common to find, as shown in figure 8, all of them turned toward the nearest margin of the zoarium. Zoœcial apertures oval, occupying, with three mesopores, the bottom of subtriangular or rhomboidal, obliquely depressed spaces. One of these mesopore-pits is in front, the second and third on the sides of the true aperture, the posterior side of the latter being formed by the strongly elevated lunarium which in this species is an unusually prominent feature. Arrangement of apertures only moderately regular, eight or nine in 3 mm.

Numerous deviations from the above described normal characters of this species are shown in the abundant material before me. Most of them are due to imperfect preservation and irregularities of growth, and all of them are of a nature that can be interpreted successfully only by extended study of specimens.

The inclusion of each zoœcial aperture and mesopores in a subtriangular enclosed space, and the strong development of the lunarium are distinctive for the species. These features are less constant in what I presume to be a mutation of the species (toward the Cincinnati group *C. ohioensis* Nicholson) occurring in the upper third of the Trenton shales.

Formation and locality.—Common in the lower and middle thirds of the Trenton shales at Minneapolis, St. Paul, and various localities in Goodhue and Fillmore counties. Rare and less typical in the upper third of the shales at St. Paul and Cannon Falls.

Mus. Reg. Nos. 7624, 7656, 7661, 7662, 8380.

CERAMOPORELLA INTERPOROSA, *n. sp.*

PLATE, XXVIII, FIG. 12.

All the Minnesota examples seen are thin crusts upon foreign bodies, but in the Cincinnati rocks the species often forms large masses by superposition of numerous layers. The zoœcial apertures are larger, more direct, and comparatively wider than in *C. distincta* Ulrich, with an average of nine in 3 mm. Fig. 12 represents the usual appearance of the surface. Sometimes the lunarium is better distinguished from the rest of the posterior hood than shown in the figure. The mesopores are always numerous and generally more equally distributed around the zoœcia than in other species of the genus.

Formation and locality.—In Minnesota the species has been noticed only in the Galena shales of Goodhue county. At Cincinnati, Ohio, the same species apparently is not uncommon in the lower 300 feet of strata.

Mus. Reg. No. 7647.

Genus DIAMESOPORA, Hall.

Diamesopera, HALL, 1852, Pal. N. Y., vol. ii, p. 158 (not defined); Pal. N. Y., vol. vi, p. xv, 1887: ULRICH, 1890, Geol. Surv. Ill., vol. viii, pp, 380, 467.
Cœloclema, ULRICH, 1882. Jour. Cin. Soc. Nat. Hist., vol. v (not defined).

Zoaria ramose, branches hollow, lined internally with a striated epitheca. In other respects very much like *Ceramoporella* and *Ceramophylla*.

This name stands for an easily recognized division of the *Ceramoporidæ*. The genus may be more convenient than natural, yet I must confess that the evidence so far gathered points rather to an opposite conclusion. The species next described is the earliest known. Several occur in the Cincinnati rocks, but it is not till we come to the Niagara that the genus has its greatest development, both in the way of species and individuals.

DIAMESOPORA TRENTONENSIS, *n. sp.*

PLATE XXVIII, FIG. 14.

Zoarium consisting of small hollow branches varying from 1.5 to 3.5 mm. in diameter; thickness of zoarium 0.4 to 0.8 mm.; axial tube varying in diameter, the epithecal lining not observed. Small maculæ sometimes present. Zoœcial apertures oval, about their diameters apart, arranged sometimes regularly in diagonally intersecting rows, at other times as shown in fig. 14; averaging nine in 3 mm. When regularly arranged they are set into obliquely depressed subrhomboidal areas, reminding of *Ceramoporella inclusa* (see pl. XXVIII, figs. 8-11). The lunarium, however, is never prominent as in that species, nor is the posterior border of the aperture elevated as much as is usual among Lower Silurian ceramoporoids. Mesopores two or three to each zoœcium, placed indiscriminately among the larger apertures or one on each side and a third in front of the zoœcial orifice.

This species is closely related to both *D. vaupeli* and *communis* Ulrich, of the Cincinnati group of Ohio, but it is clearly not identical with either. In the first place the Trenton form is always smaller, so that they may be distinguished at once by the matter of size alone. Then the lunarial rim is not so high and the arrangement of the mesopores and other superficial parts generally a little different.

Formation and locality.—In the upper third of the Trenton shales, and in the Galena shales at St. Paul and Cannon Falls. Also in the Trenton limestone at Trenton Falls, New York, and Ottawa, Canada.

Genus CERAMOPHYLLA, *n. gen.*

Zoaria erect, bifoliate, the two layers grown together back to back; in other respects like *Ceramoporella* and *Diamesopora*.

Type: *C. frondosa*, n. sp.

The leaf-like zoarium of the only species of this genus known, is in many respects very much like that of *Rhinopora*, Hall. Still they are very different structurally, and I am satisfied that the relationship between them must be quite remote. On the other hand, *Ceramophylla* may be justly called a bifoliate *Ceramoporella*, just as *Diamesopora* would be a ramose one.

Ceramophylla frondosa, *n. sp.*

PLATE XXVIII, FIGS. 3-7.

Zoarium arising from a small basal expansion into erect, leaf-like, undulating fronds, celluliferous on both sides; thickness varying from 0.5 to 2.0 mm., but averaging less than 1 mm.; largest frond seen about 40 mm. high; margins rounded, exposing the mesial laminæ. At intervals of about 3 mm. the surface exhibits more or less conspicuous, substellate maculæ of mesopores. Zoœcial apertures ovate, oblique, the posterior margin well elevated, arranged more or less regularly in transverse and diagonally intersecting series, with about eight in 3 mm. Mesopores one, two, or three to each zoœcium, variously arranged, often irregularly distributed. In the most regular and normally developed examples the zoœcial apertures are ovate or pyriform and narrowest and highest behind, while in front of the depressed anterior side of each there is either one large triangular mesopore or three small ones, the whole in each case being contained in an obliquely concave rhomboidal space.

Of internal characters it is sufficient to say that diaphragms are wanting, the primitive or prostrate part of the tubes thin-walled and in most cases longer than the erect portion. In the latter the interspaces are very thick and, in vertical sections, crossed obliquely by dark lines.

Of associated bifoliate Bryozoa only *Eurydictya multipora* grows into broad fronds. But the merest tyro in the science must find the task of identifying the *Ceramophylla* an easy one.

Formation and locality.—Over one hundred examples were collected at St. Paul in the upper third (Phylloporina beds) of the Trenton shales. It is rarely met with in the same beds in Goodhue county.

Mus. Reg. No. 8381.

NOTE:—In the preceding report on the Bryozoa the author has adopted a merely provisional nomenclature of the divisons or beds into which the Trenton formation of Minnesota is divisible, partly upon lithological, but more especially upon paleontological grounds. This is in accordance with an agreement among the several authors at work on the paleontology of the Lower Silurian rocks of Minnesota. We believed, namely, that it was best to defer the adoption of permanent names for the faunal zones till the study of all the classes had been completed. The subject, therefore, will be found treated in a comprehensive manner in the introductory chapter to the volume. In that chapter a full list of the Trenton and Hudson River fossils found in the state is given, and each is referred to its proper horizon in the series.

PLATE I.

PAGE.

Fig. 1 to 5. VINELLA REPENS Ulrich... 114

1. Two colonies attached to the inner side of a ventral valve of Strophomena septata W. and S.; natural size.
2. Portion of one of the colonies magnified ×18. The pores are absent, probably not having been preserved.
3. Another portion of same zoarium ×18, showing a nucleus with five divisions of the tubular stolon radiating from it. This portion of the specimen also preserves some of the pores marking the points where the zoœcia were attached.
4. Another specimen attached to a fragment of shell; natural size.
5. Small portion of same, ×18, with three tubes lying parallel with each other. The longitudinal lines are stronger than usual.

Upper third of the Trenton shales at St. Paul.*

Figs. 6 and 7. STOMATOPORA TENUISSIMA Ulrich. 116

6. Portion of zoarium, ×9, showing its slender zoœcia and mode of growth, Utica horizon, Cincinnati group, Cincinnati, O.
7. Several zoœcia of same ×25, to show their apertures and form more clearly.

Figs. 8 to 12. STOMATOPORA PROUTANA S. A. Miller.. 117

8 and 9. Zoarium natural size and portion ×9.

10. Several zoœcia of same, ×25.

11. Several zoœcia of same colony, a little more slender than usual, ×25.

12. Several cells of a form of this species in which they are unusually large, ×25. (Survey Museum. Reg. No. 5926.)

Middle third of the Trenton shales at Minneapolis and St. Paul.

Figs. 13 to 21. STOMATOPORA INFLATA Hall..... 117

13 and 14. A colony attached to inner side of a fragment of shell, natural size, and a portion of same ×9.

15 and 16. Another colony, natural size and a portion ×9.

17. Three zoœcia of same, ×18, one of them preserving traces of the minute pores that pierce the wall.

18. Vertical section of one cell, ×18. Upper third of the Trenton shales at Cannon Falls, Minn.

19. Small portion of a large colony, ×9, growing upon the concave side of *Leptæna alternata;* Cincinnati hills.

20. Two zoœcia of same, ×18. In the Cincinnati form of this species the zoœcia are more inflated, and the whole zoarium more compact, and the growth more luxuriant than in the typical Trenton form.

21. Several zoœcia of another Cincinnati specimen, in outline, ×18, showing the unusual condition of three "gems" springing from one parent cell.

Figs. 22 and 23. STOMATOPORA TURGIDA Ulrich............ 118

An example of this species growing upon *Pachydictya splendens* Ulr., natural size and same ×9. Upper beds of the Hudson River gr., Wilmington, Ill. This species was recently discovered in the lower part of these beds in Fillmore county, Minn.

Fig. 24. PROBOSCINA TUMULOSA, n sp.............. 119

An example of this species, natural size and portion ×9. Upper third of the Trenton shales, St. Paul, Minn.

Figs. 25 to 27. BERENICEA MINNESOTENSIS Ulrich... 120

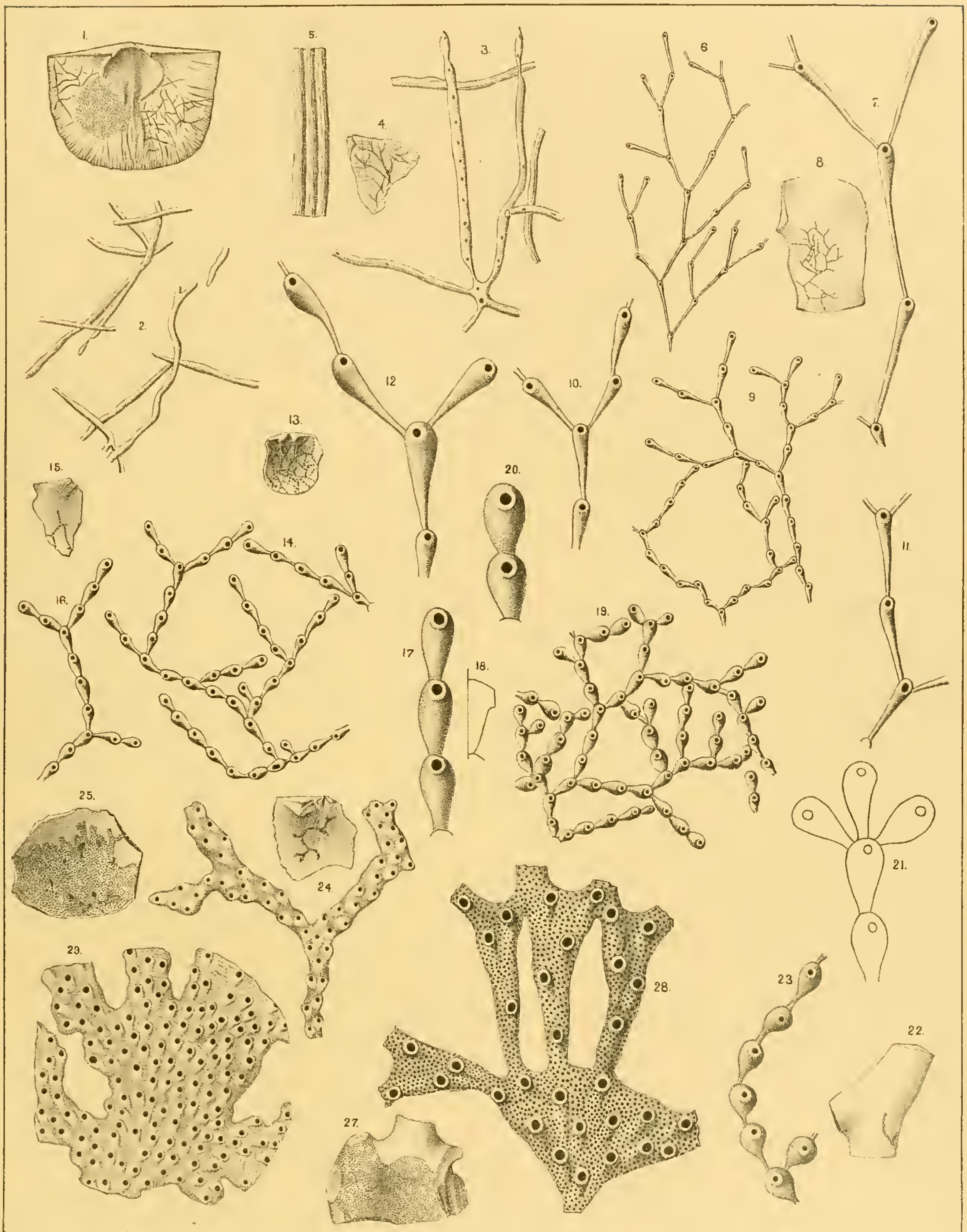
25 and 27. Two specimens of the natural size. Near Minneapolis, Minn. The original of fig. 27 belongs to the Survey Museum. Reg. No. 5925.

26. (29 on plate) Portion of original of fig. 25, ×9. (See also Plate II).

Fig. 28. PROBOSCINA FRONDOSA (Nicholson).. 119

Portion of specimen showing mural perforations very clearly, ×18. Cincinnati gr., Cincinnati, O.

*It is to be understood that when the collection containing the specimens illustrated on this and all of the following plates of Bryozoa is not mentioned, they belong to the author.



E. C. E. & C. S. del. et Lith.

The Henderson Achert Lith. Co. Cin. O.

PLATE II.

PAGE.

Fig. 1. BERENICEA MINNESOTENSIS Ulr.. 120
Small portion of the original of plate I, fig. 27, ×18, showing zoœcial apertures less constricted than usual, and portions of two non-celluliferous spots.

Figs. 2 and 3. DIASTOPORINA FLABELLATA Ulr.. 122
A complete zoarium of this species, of the natural size and ×7, showing arrangement of zoœcial apertures, fine interstitial striæ, and obscure concentric wrinkles. A small tubiculous annelid is attached to the frond. Upper part of the Galena shales at Cannon Falls, Minn.
3. Portion of same ×18, to show the characters of the species more clearly.

Figs. 4 to 6. MITOCLEMA (?) MUNDULUM Ulr.. 123
4 and 5. Two fragments, nat. size and ×9.
6. Original of fig. 5, ×18.
Upper part of the Galena shales at Cannon Falls, Minn.

Fig. 7. ARTHROCLEMA BILLINGSI Ulr.. 197
View of the type of this species, natural size. (Introduced to show mode of growth prevailing in this genus.)
Trenton limestone, Ottawa, Can.

Figs. 8 to 11, 25, and 28 to 33. ARTHROCLEMA ARMATUM Ulr.. 201
8. Large segment of the primary series, showing a sharply defined articulating socket: natural size and ×18. This figure was inadvertently placed upside down.
9. Opposite side of another segment of the primary set, ×18. This and the preceding specimen is as thick as any noticed but not as long.
10. Complete segment of the secondary set, ×18.
11. Upper three fifths of another secondary segment, finely preserved, ×18. Upper part of the Galena shales near Cannon Falls, Minn.
25. Vertical section, ×25, of a primary segment somewhat doubtfully referred to this species. Upper third of the Trenton shales, St. Paul, Minn.
28. Transverse section of a small segment (?secondary) ×25. Cannon Falls, Minn.
29 and 30. Transverse and vertical sections of small segments found associated with the original of fig. 25.
31 and 32. A transverse, and the lower half of a vertical section, ×25, of full-grown primary segments. Cannon Falls, Minn.
33. Vertical section of a secondary segment, eqally enlarged and from the same horizon and locality as the preceding.

Figs. 12 to 15. ARTHROCLEMA PULCHELLUM Billings.. 198
12. Vertical section of secondary segment, ×25.
13. Transverse section of primary segment, ×25.
14 and 15 Transverse sections, ×25, of two secondary segments, one with six, the other with seven rows of zoœcia. These sections were prepared from authentic examples collected at Ottawa, Can., from the Trenton limestone.

Figs. 16 to 21 and 23. ARTHROCLEMA CORNUTUM Ulr.. 200
16. A continuous series of four primary segments, natural size, and three of them ×7, showing the articulating sockets near the base of each.
17. A similar series of segments, consisting of seven of the secondary order, natural size, with flive of them ×7.
18 and 19. Two segments of the secondary order, ×18, one with three cycles of zoœcial apertures, the other with four. They differ also in the ornamentation.
20 and 21. Opposite sides of rather small but very perfect primary segment, natural size and ×18. (See also plate III.)
23. Transverse section of primary segment, ×18, showing five rows of zoœcia.
Middle third of the Trenton shales at Minneapolis, Minn.

Figs. 22 and 24. ARTHROCLEMA STRIATUM, n. sp.. 198
Tangential section, ×28, and tranverse section, ×18. (See also plate III.)

Figs. 26 and 27. ARTHROCLEMA sp. undet.. 203
Two segments, the first incomplete, showing slight differences in ornamentation; ×18.
Trenton shales near Fountain, Minn.

E.O.U. & C.S. del et Lith. The Henderson Achert Lith. Co. Cin. O.

PLATE III.

PAGE.

Figs. 1 to 3. HELOPORA DIVARICATA Ulr 191
1. A segment of the natural size and ×7, Minneapolis, Minn.
2. Portion of same, ×18. Only three of the four rows of zoœcia to be seen in this view have been drawn.
3. Transeverse section, ×18, showing a spiral development of the zoœcia.
Lower third of the Trenton shales at Minneapolis, Minn.

Figs. 4 to 6. HELOPORA SPINIFORMIS Ulr 190
4. A segment natural size, and lower portion of same ×18.
5 and 6. Vertical and transverse sections, ×18.
"Glade" limestone at Lavergue, Tenn.

Fig. 7. ARTHROCLEMA ARMATUM Ulr 201
A small segment supposed to belong to the tertiary set of this species, ×18. Cannon Falls, Minn. (See also plate II.)

Fig. 8. HELOPORA (?) sp. undet 196
Nearly entire segment, ×18. Upper part of Galena shales, near Cannon Falls, Minn.

Fig 9. HELOPORA ALTERNATA Ulr 192
About three fourths of a segment of this species, ×18. Middle third of the Trenton shales, Minneapolis, Minn. It is within the possibilities that these segments may belong to the tertiary set of *Arthroclema striatum* Ulr.

Fig. 10. HELOPORA MUCRONATA Ulr 193
A segment of this form natural size, and the greater part of it ×18. The specimens upon which this species is found may prove to belong to *Arthroclema armatum* Ulr.
Upper part of Galena shales, near Cannon Falls, Minn.

Figs. 11 to 12. HELOPORA HARRISI James 195
11 and 12. Two segments, natural size and ×18.
11*a*. Portion of original of fig. 11, ×50.
11*b*. Transverse section of a segment, ×50.
Hudson River group, Waynesville, Ohio.

Figs. 13 and 14. ARTHROSYLUS CONJUNCTUS Ulr 188
13. Lateral view of the central portion of a segment, ×18.
14. View of small portion of non-celluliferous side of same, ×18.
Trenton shales, near Fountain, Minn.

Figs. 15 and 16. ARTHROSTYLUS OBLIQUUS Ulr 188
Two views of a segment of this species, ×18, in the first showing the non-celluliferous side with the upper extremity and about three-fourths of the length, in the second the central portion turned so as to show the lateral aspect.
Lower third of the Trenton shales at Minneapolis, Minn.
Beneath fig. 15 a small figure is erroneously marked with the number 16. This represents a transverse section of the type of the genus *A. tenuis* (James), from the lower part of the rocks at Cincinnati, Ohio.

Figs. 17 to 20. NEMATOPORA GRANOSA Ulr 205
17. Portion of unbranched fragment, ×18, showing the granulose angles and interspaces, and narrow zoœcial apertures; the latter in five rows.
18. Bifurcating fragment, ×18, with the rows of granules slightly flexuous.
19 and 20. Portion of slightly worn fragment, and end view of same, ×18. This has only four rows of zoœcia.
Upper part of Galena shales, near Cannon Falls, Minn.

Figs. 21 to 23. NEMATOPORA CONFERTA Ulr 206
Zoarium of this species, natural size, ×9, and portion of same ×18. Upper part of Galena shales, near Cannon Falls, Minn.

Figs. 24 and 25. NEMATOPORA OVALIS Ulr 204
Two fragments of this opecies, natural size and ×18, the first with four rows of zoœcia, the other with five. Upper part of Galena shales, near Cannon Falls, Minn.

Figs. 26 and 27 NEMATOPORA DELICATULA Ulr 206
Two fragments of the exceedingly delicate zoarium of this species, natural size and ×18. Upper part of Galena shales, near Cannon Falls, Minn.

Figs. 28 to 33. ARTHROCLEMA STRIATUM, n. sp 198
28. Primary segment, natural size and ×12, with a large articulating socket and expanding ends.
29. Lower end of same, ×18.
30 and 31. Lateral and end views of a large and strongly striated primary segment, natural size and ×18. The zoœcial apertures are incorrectly represented in this figure. (See correction p. 199, sixth line from top.)
32 and 33. Two segments of the secondary set, natural size and ×18. One has five cycles of zoœcia and an articulating socket, the other six cycles and no distinguishable socket. (See also plate II.)
Middle third of the Trenton shales, Minneapolis, Minn.

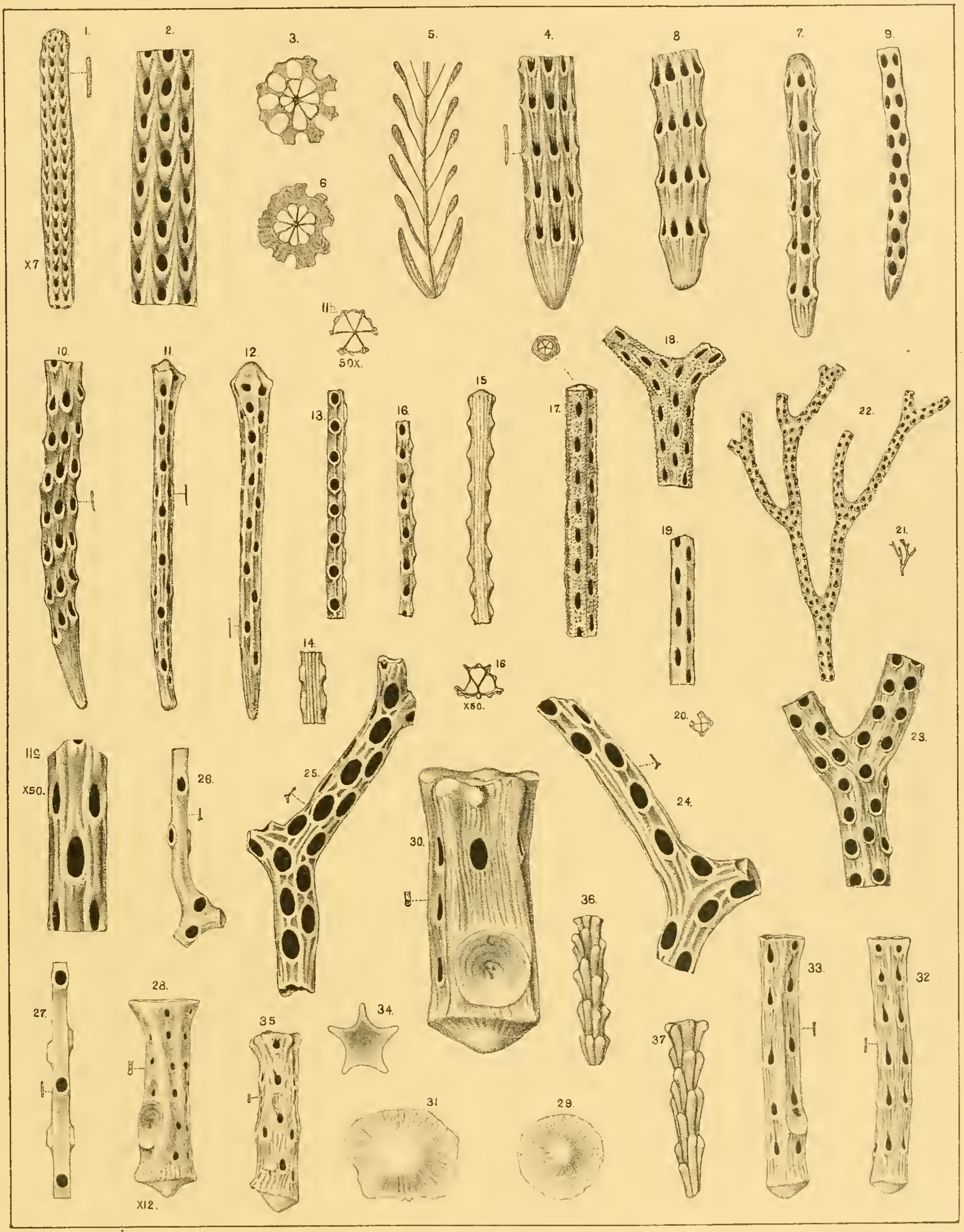
Fig. 34. ARTHROCLEMA CORNUTUM Ulr 200
View of upper end of the segment represented by fig. 18 on plate II; ×18.

Figs. 35 to 37. ARTHROCLEMA, sp. undet 203
35. Slightly abraded segment, natural size and ×18. An obscure, subcentrally situated, articulating socket is distinguishable.
36 and 37. Two internal casts of the zoœcia, ×18, showing their spiral arrangement in the segments.
Upper third of the Trenton shales, St. Paul, Minn.

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA.

Silurian Bryozoa I

Vol. III. Pl. III.



E. O. U. & C. S. del et Lith. The Henderson Achert Lith. Co. Cin. O.

PLATE IV.

PAGE.

Figs. 1 to 7. PHYLLOPORINA SUBLAXA, Ulr. ... 209

1 and 2. Reverse side of small fragment, natural size and portion of same ×9, showing striated character of this side in young or exfoliated examples. Lower Trenton limestone, Minneapolis, Minn. Survey Museum. Reg. No. 5954.

3 and 4. Another fragment from the same locality, exposing the obverse side, natural size, and portion of same ×9.

5. Tangential section, ×18, showing appearance of zoœcia at varying depths.

6. Two transverse sections of branches, ×18.

7. A rather loosely woven frond from the "Glade" limestone at Lavergne, Tenn.; natural size.

Figs. 8 to 14. PHYLLOPORINA RETICULATA (Hall) ... 210

8. A frond exposing the reverse side, natural size, Minneapolis, Minn.

9. Portion of same, ×9.

10 and 11. Another fragment from the same locality, natural size and ×9.

12. Small fragment, likewise from Minneapolis, exposing the obverse face, ×18.

13 and 14. Obverse and reverse sides of two fragments obtained from washings of Galena shale at Cannon Falls, Minn.; ×18.

15. Tangential section, ×18, of an example from Trenton Falls, N. Y.

Figs. 16 to 21. PHYLLOPORINA HALLI Ulr. ... 211

16. Reverse side of a specimen, natural size, showing irregular arrangement of fenestrules.

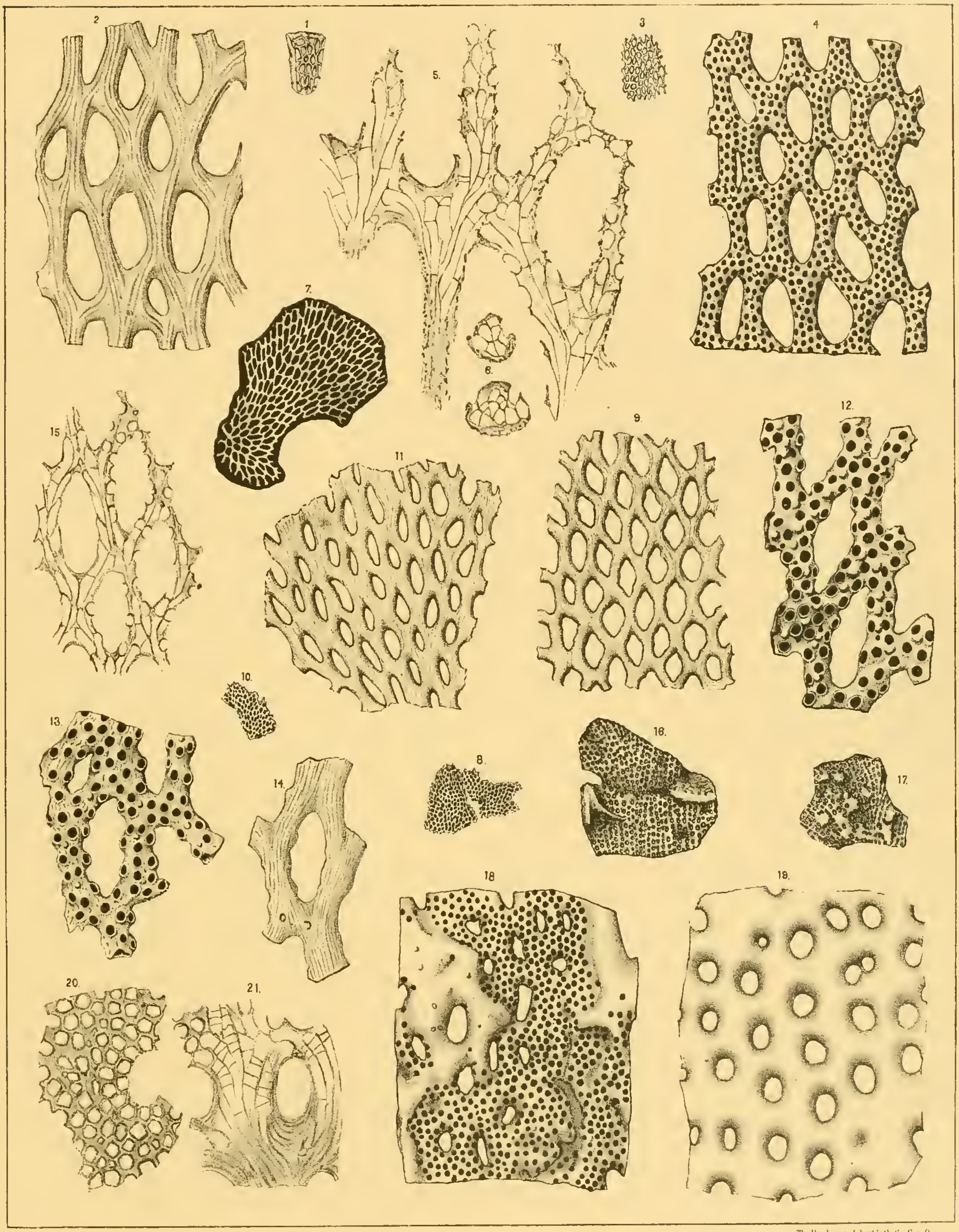
17. Celluliferous side of another fragment, natural size, showing the irregular solid swellings.

18. Surface of same, ×9.

19. Reverse side of same, ×9.

20. Tangential section, ×18, cutting the zoœcia just beneath their mouths.

21. Another portion of same section, ×18, where it divides the zoarium at a deeper level.
Upper third of the Trenton shales at St. Paul, Minn.



E O U & C S del et Lith

The Henderson Achert Lith Co Cin O

PLATE V.

PAGE.

Figs. 1 to 10. PHYLLOPORINA CORTICOSA Ulr. 212

1. A frond of this species exposing the poriferous or obverse side; natural size.

2 and 6. Reverse side of a fragment, natural size and a portion ×9.

3 and 7. Obverse side of another fragment, natural size and a portion ×9.

4 and 5. Two specimens of the basal portion of the zoarium, natural size.

8. Tangential section, ×18, cutting the zoœcial tubes at varying depths from the surface.

9. Transverse section of several branches, ×15.

10. Vertical section of a branch, ×18.

Upper third of the Trenton shales, near Cannon Falls, Minn.

Figs 11 and 12. RHINIDICTYA GRANDIS, n. sp. 136

A fine example from the "Lower Blue" limestone at Dixon Ill., natural size and a portion ×9. (See also Plate VI.)

Figs. 13 to 18. RHINIDICTYA MINIMA Ulr. 132

13. Three fragments of the natural size.

14 and 15. One of them ×9, and a portion of same ×18, showing the small zoœcial apertures and grano-striate character of the interspaces.

17. Tangential section of the variety MODESTA, ×18, showing the appearences of the zoœcia at various depths beneath the surface.

18. Tangential section of the typical form of the species, ×18.

Upper part of the Galena shales, near Cannon Falls, Minn.

Figs. 19 to 21. RHINIDICTYA PAUPERA Ulr. 129

19. A nearly complete specimen, natural size.

20 and 21. A fragment, natural size ×9 and ×18.

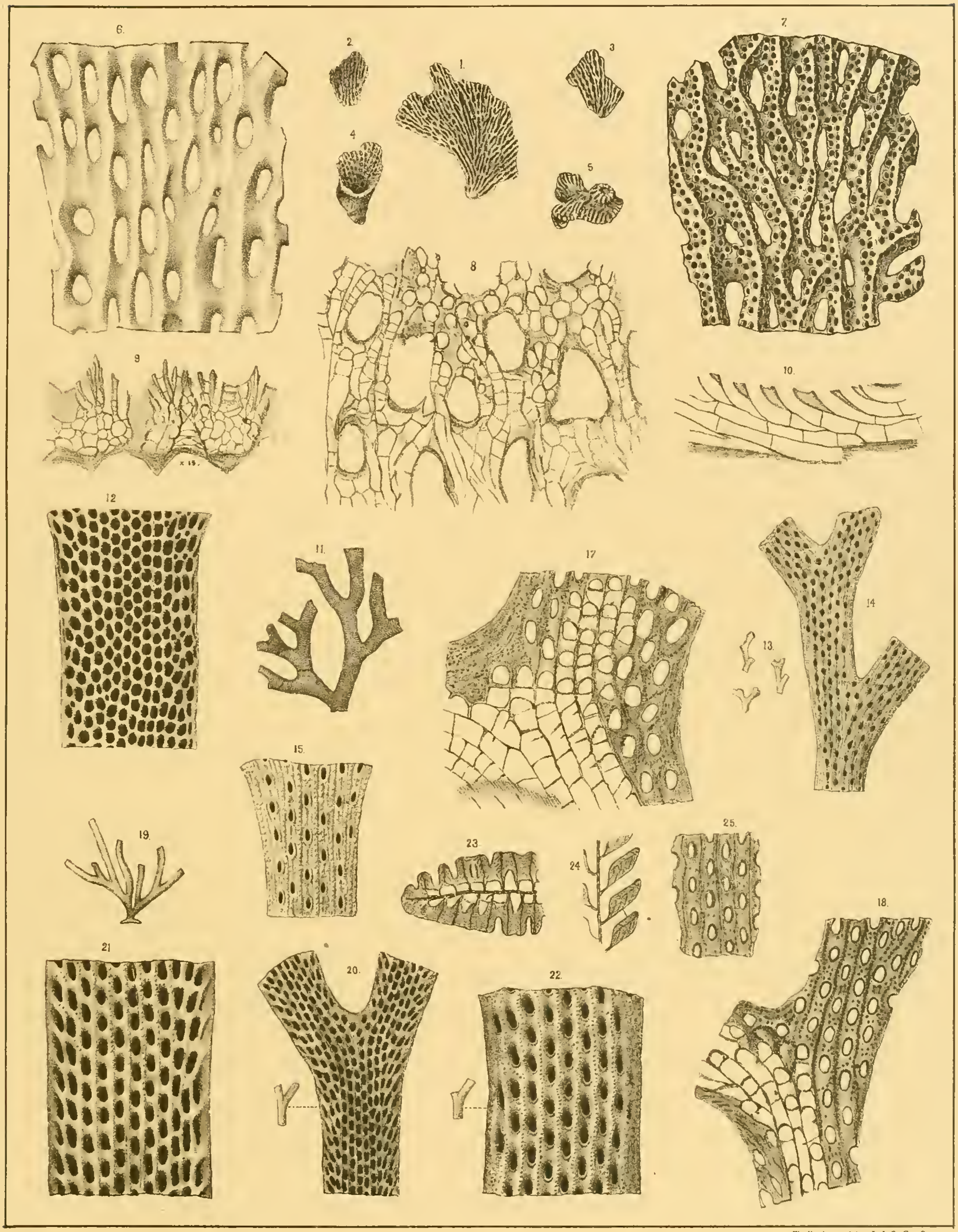
Upper third of the Trenton shales, St. Paul, Minn.

Figs. 22 to 25. RHINIDICTYA NEGLECTA n. sp. 130

22. A fragment of the natural size and a portion ×18, showing the usual characters of the species.

23, 24 and 25. Respectively, trarsverse, vertical, and tangential sections of a specimen wider than the original of fig. 22, but agreeing in all other respects with it.

Trenton limestone near Danville, Ky.



E O U & C.S del et Lith

The Henderson Achert Lith Co Cin O

PLATE VI.

PAGE.

All the figurers on this plate except No. 18 are ×18.

Figs. 1 to 6, 12 and 13. RHINIDICTYA MUTABILIS Ulr..... 125

1. Tangential section of an old and thick example of the usual form of this species. Figs. 6 and 12 represent transverse and vertical sections of same.

2 and 3. Tangential and vertical sections of a fragment of the var. SENILIS (see p. 127), showing the great abundance of the median tubuli and the structure of one of the solid spots.

4 and 5. Tangential and vertical sections of a well preserved and typical example.

6. Small portion of a transverse section prepared from the same specimen that furnished the originals of figs. 1 and 12.

12. Vertical section of a thick specimen. (See figs. 1 and 6). Only one side of the zoarium is entirely represented.

13. Tangential section of a young example.

For the external characters of this species see plate VII.

Middle third of the Trenton shales at Minneapolis and St. Paul.

Figs. 7 and 8. RHINIDICTYA FIDELIS Ulr.. 134

7. Tangential section, showing structure immediately beneath the surface; 7*a*, small portion of same section showing appearances at the bottom of the vestibular region; 7*b*, another portion of same, showing the form of the primitive portion of the zoœcia and the minutely tubular character of the walls and mesial laminæ.

8. Vertical section of same specimen, showing well developed superior hemisepta.

Middle third of the Trenton shales at Minneapolis.

Figs. 9 to 11. EURYDICTYA MULTIPORA Hall (?)... 139

Tangential, transverse, and vertical sections of a narrow frond from the upper third of the Trenton shales at St. Paul. (See also plates VII and XIV.)

Figs. 14 to 18. RHINIDICTYA TRENTONENSIS Ulr..................... 135

14 and 15. Transverse and vertical sections of a young example.

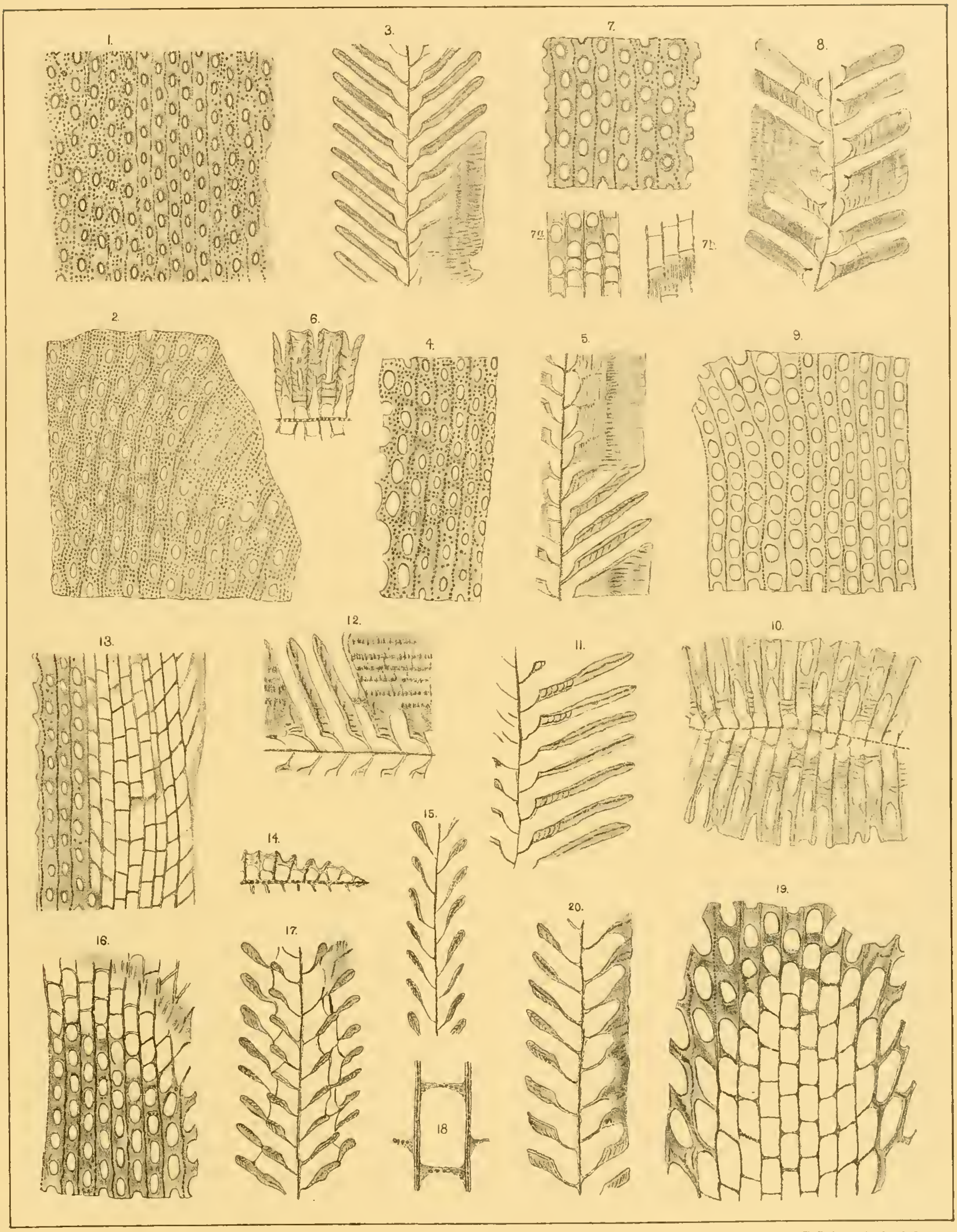
16 and 17. Vertical and tangential sections of a thicker specimen. In this each side is in part composed of two distinct layers of zoœcia.

18. Primitive or prostrate portion of one zoœcium of fig. 16, more highly magnified (×50). See also plate VII.

Lower third of the Trenton shales, Minneapolis, Minn.

Figs. 19 and 20. RHINIDICTYA GRANDIS, n. sp.. 136

Vertical and tangential sections of a specimen from the "Lower Blue" limestone at Dixon, Ill.



E O U & C S del et Lith

The Henderson Achert Lith. Co. Cin. O.

PLATE VII.

PAGE.

Figs. 1 to 5. RHINIDICTYA PEDICULATA, n. sp. 137

1 to 4. Four specimens of the natural size, showing the mode of growth prevailing in this species. Three of the specimens preserve the footstalk.

5. Surface of a slightly weathered example ×9. In better preserved examples the nonporiferous margins are much wider. (See description.)

Lower limestone of the Trenton formation, Minneapolis, Minn.

Figs. 6 to 9. RHINIDICTYA TRENTONENSIS Ulr. 135

6 to 8. Three fragments of the natural size.

9. A well preserved fragment of the natural size and ×9. (See also plate VI.)

Lower third of the Trenton shales, Minneapolis, Minn.

Figs. 10 to 15 and 18 to 21. RHINIDICTYA MUTABILIS Ulr. 125

10. Surface of an old and excellently preserved fragment, ×9.

11 to 14. Four representative specimens of the natural size. The original of fig. 11 belongs to the Survey Museum; Reg. No. 5939. It is from the upper third of the Trenton shales at St. Paul.

15. Portion of original of fig. 13, ×9, illustrating the appearance of a large number of specimens.

18. A finely preserved fragment, natural size and a portion ×9. In this specimen the zoœcia are unusually small.

19 to 21. A very young specimen (var. *minor* of my preliminary report,) natural size, a portion ×9, and several zoœcial apertures ×35. The margins are wide and sharp, the outer zoœcial apertures large and oblique, and the walls in the central part very delicately granulose. (See also plates VI and VIII.)

Middle third of the Trenton shales, Minneapolis and St. Paul, Minn.

Figs. 16 and 17. RHINIDICTYA MUTABILIS, var. SENILIS, n. var. 127

A specimen of the natural size and a portion ×9.

Middle third of the Trenton shales, St. Paul, Minn.

Figs. 22, 23, 25 to 28, and 32. RHINIDICTYA MALTABILIS, var. MAJOR Ulr. 127

22 and 23. A well preserved but narrow stipe of this variety of the natural size, and a few zoœcial apertures, with a portion of one of the solid spots or maculæ, ×18.

25 to 28. Four specimens of the natural size.

32. Small portion of the surface of the original of fig. 28, ×9. (See also plate VI.)

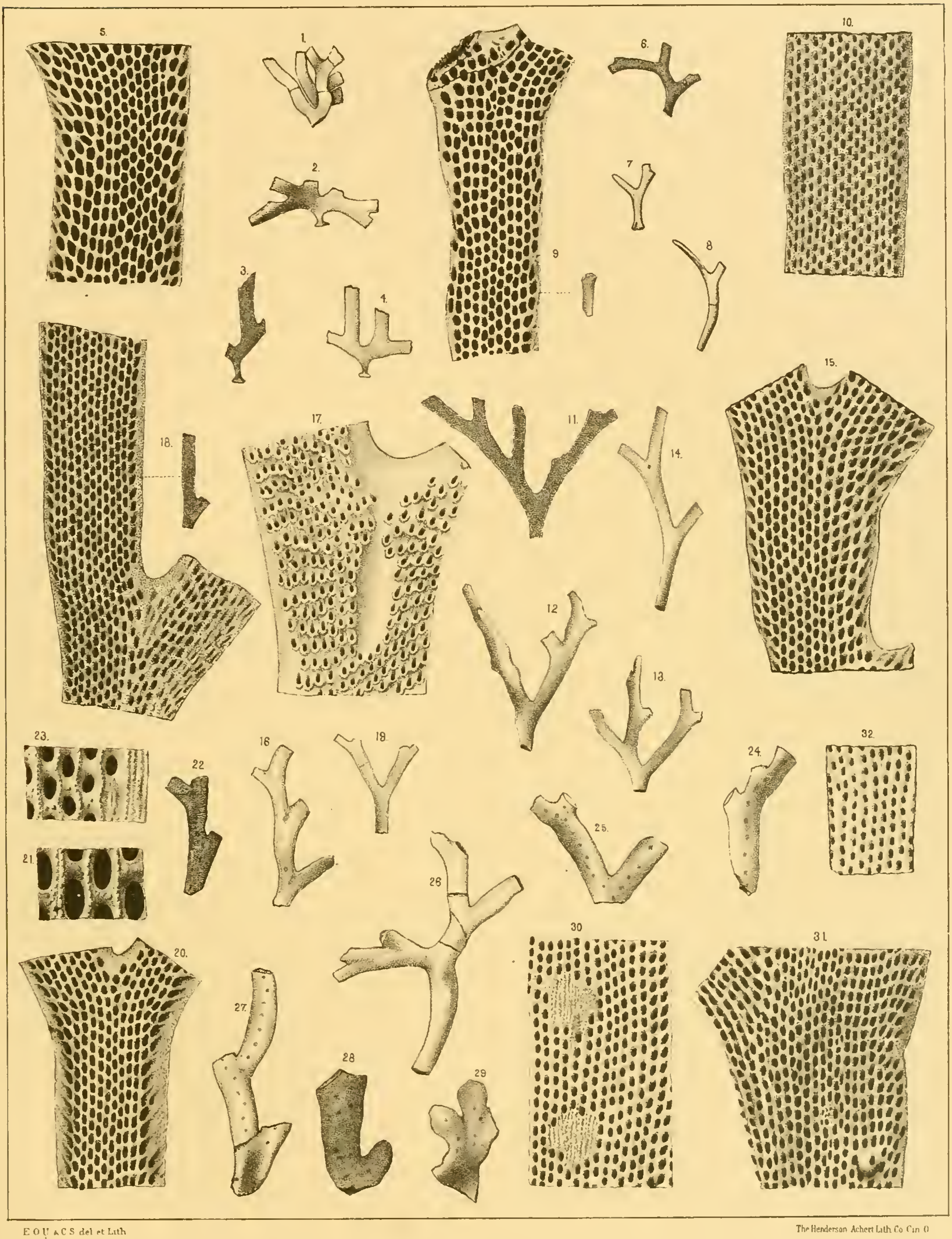
Middle third of the Trenton shales, St. Paul and Minneapolis.

Figs. 24 and 29 to 31. EURYDICTYA MULTIPORA (?Hall) 139

24 and 30. A narrow, parallel-margined example of the natural size and a portion ×9. This resembles *Rhinidictya mutabilis*, var. *major* to such a degree that it was at first regarded as belonging to that variety.

29 and 31. A small, irregularly divided frond, natural size and a portion ×9. This specimen is evidently young, being thin and but inconspicuously maculose. (See also plates VI. and XIV.)

Upper third of the Trenton shales at St. Paul, Minn.



E O U & C S del et Lith

The Henderson Achert Lith. Co. Cin. O

PLATE VIII.

PAGE.

Figs. 1 to 3. RHINIDICTYA MUTABILIS Ulr.. 125

Three portions of an old example of this species ×9, showing, in 1, the thick, rounded and granulose margin, in 2, the shape of the zoœcial apertures at the upper extremity of the specimen, and in 3, their form near the lower end of same. (See also plates VI and VII.)

Figs. 4 and 5. PACHYDICTYA PUMILA Ulr.. 157

Two fragments of the natural size, and one of them representing the basal part of the zoarium, ×9. (See also plate X, and remarks on p. 158.)

Figs. 6 to 10. RHINIDICTYA EXIGUA Ulr.. 131

6 and 7. The basal part of a specimen of the natural size and ×9. One of the branches has three, the rest of the zoarium four rows of zoœcia.

8. A delicate fragment with only three rows of zoœcia.

9 and 10. A branching fragment of the natural size and the lower half ×9. This has from five to seven rows of apertures.

Lower third of the Trenton shales at Minneapolis.

Figs. 11 to 17. PACHYDICTYA ACUTA (Hall) and varieties.. 155

Figs. 11 and 12. A specimen of the natural size and a portion ×9. Trenton limestone, Trenton Falls, N. Y.

13. A very small specimen, with only six and seven rows of zoœcia, from the Galena limestone near Fountain, Minn.

14 to 16. Three specimens from the Galena shales near Cannon Falls, Minn.

17. Surface, ×9, of a well preserved fragment from the same horizon and locality as the preceding. (See also plate IX.)

Figs. 18 and 19. PACHYDICTYA ELEGANS, n. sp.. 154

18. A very nearly perfect zoarium of this species, natural size, from the lower part of the Galena shales at St. Paul. Later collections show that this species is exceedingly abundant at that locality and that the specimen here figured divides with greater frequency than usual.

19. Enlargement of the beautifully ornamented surface of same, ×18. (See also plate IX.)

Figs. 20 to 27. PACHYDICTYA OCCIDENTALIS Ulr.. 151

20 to 24. Five specimens of the natural size, illustrating the variable character of the zoaria.

25. Surface of fig. 24, ×9.

26 and 27. A frond of the natural size and a portion of its surface ×9, traversed by irregular grooves caused by interruptions in the development of the zoœcia. (See also plate IX.)

Upper third of the Trenton shales at St. Paul.

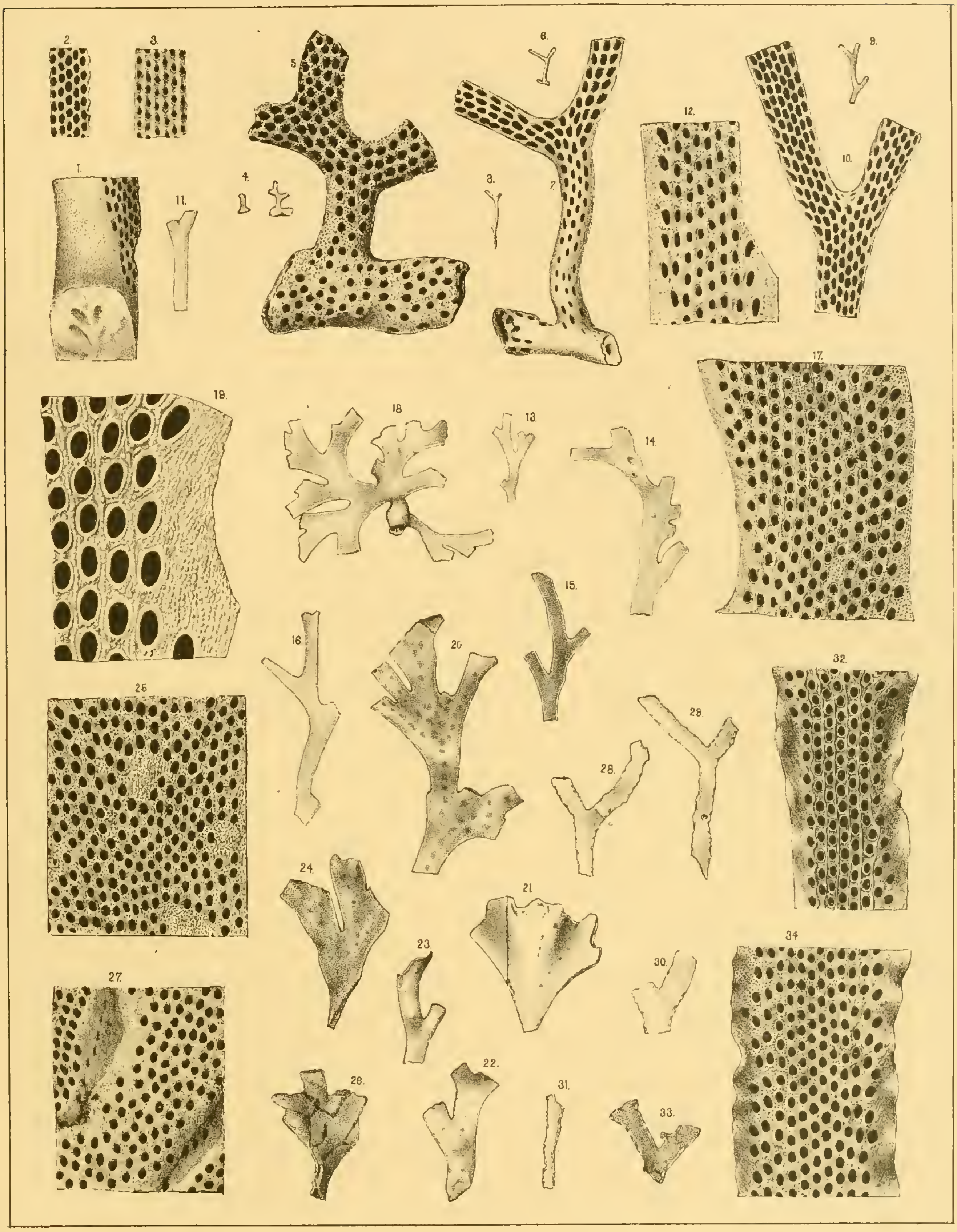
Figs. 28 to 34. PACHYDICTYA FIMBRIATA Ulr.. 152

28 to 30. Three specimens of the natural size, the last one the widest seen.

31 and 32. A very narrow and seemingly young example, natural size and the upper part ×9.

33 and 34. An excellently preserved fragment of the natural size and a portion ×9. This presents the fully matured condition of the species. (See also plate IX.)

Middle third of the Trenton shales at Minneapolis and St. Paul.



E. O. U. & C. S. del et Lith. The Henderson Achert Lith. Co. Cin. O.

PLATE IX.

PAGE

Figs. 1 to 5. PACHYDICTYA FOLIATA Ulr. 149

1. Tangential section, ×18, cutting the zoarium a little obliquely. The figure which was inadvertently placed upside down on the stone represents a spot of the section where inequality of level caused the zoarium to be divided in such a manner that it brings into rapid review the various changes from the base of the zoœcial tubes to the surface. The shaded and vertically lineate zone in the lower part of the figure represents the median tubuli and laminæ.
2. Tangential section ×18, showing structure in the outer half of one of the layers of zoœcial tubes in a well preserved specimen.
3. Small portion of same ×35, to show the minutely tubular character of the zoœcial walls.
4. Vertical section, ×18.
5. About two thirds of the width of a transverse section, ×18, showing median tubuli very distinctly. (See also plate X.)

Lower third of the Trenton shales, St. Paul and Minneapolis.

Figs. 6 and 10. PACHYDICTYA OCCIDENTALIS Ulr. 151

6. Represents a small portion of a tangential section just beneath a bifurcation of the zoarium, ×18. At this point it is common to find, as in the present case, that the longitudinal interspaces are wider and with more lines of median tubuli than usual.
10. Vertical section ×18. (See also plate VIII).

Upper third of the Trenton shales at St. Paul.

Fig. 7. PACHYDICTYA ACUTA (Hall) 155

Tangential section of a specimen from Cannon Falls, Minn. (See also plate VIII).

Figs. 8 and 9. PACHYDICTYA ELEGANS, n. sp. 154

8. Tangential section, ×18, cut obliquely so as to show parts of both sides of the zoarium. This specimen was very old and thick and in the outer part (upper third of figure) developed two extra lines of median tubuli in each longitudinal interspace. The end spaces are also unusually long.
9. Small portion of same section, ×35. (See also plate VIII).

Base of Galena shales, St. Paul, Minn.

Figs. 11 and 12. TRIGONODICTYA CONCILIATRIX Ulr. 160

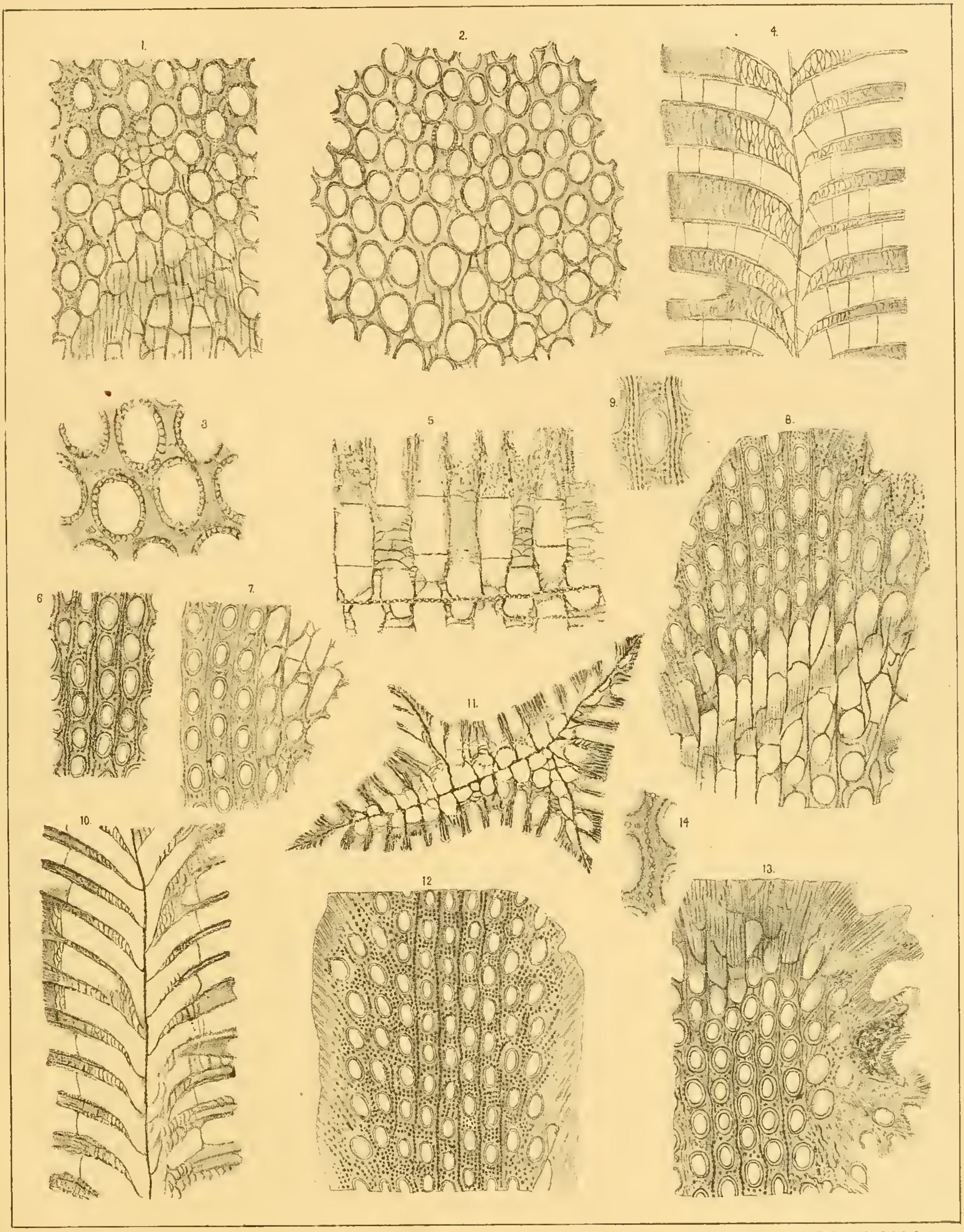
11. Transverse section, ×18.
12. Tangential section, ×18, from a specimen in an unusually good state of preservation. (See also plate X).

Upper third of the Trenton shales near Cannon Falls, Minn.

Figs. 13 and 14. PACHYDICTYA FIMBRIATA Ulr. 152

13. Tangential section, ×18. At the upper end of the figure the section sinks to the level of the median laminæ.
14. Small portion of one of the longitudinal interspaces and adjoining walls of several zoœcia, ×35. (See also plate VIII).

Middle third of the Trenton shales, St. Paul and Minneapolis.



E O U & C S del et Lith

The Henderson-Achert Lith Co. Cin. O

PLATE X

PAGE.

Figs 1 to 4. PACHYDICTYA PUMILA Ulr. 157

1. A group of specimens of the natural size.

2 and 3. Two fragments, natural size and ×9, with some of the zoœcial apertures closed.

4. The basal part of a rather young example, natural size and ×9. (See also plate VIII).

Upper part of the Galena shales, near Cannon Falls, Minn.

Figs. 5 to 10. PACHYDICTYA FOLIATA Ulr. 149

5 to 8. Four specimens of the natural size. Fig. 6 presents the unusual condition of raised maculæ.

9. Surface of fully matured example, ×9.

10. Surface of a young zoarium, ×18. (See also plate IX).

Figs. 11 to 14. PACHYDICTYA TRISERIALIS Ulr. 159

11. Portion of a block of limestone with a group of the slender ramulets of this species, natural size.

12. Surface of an old example, ×18, on which many of the zoœcial apertures preserve the closures.

13 and 14. Two transverse sections, ×25, the first prepared from a young example, the second from one like the original of fig. 12.

Trenton limestone, Montreal, Can.

Figs. 15 to 20. TRIGONODICTYA CONCILIATRIX Ulr. 160

15 to 19. Five specimens of the natural size, illustrating the zoarial variability of the species.

20. Surface of well preserved example ×9. (See also plate IX.)

Upper third of the Trenton shales near Cannon Falls, Minn.

Figs. 21 to 25. STICTOPORELLA CRIBROSA Ulr. 184

21. Nearly complete zoarium of the prevailing type of this species, natural size.

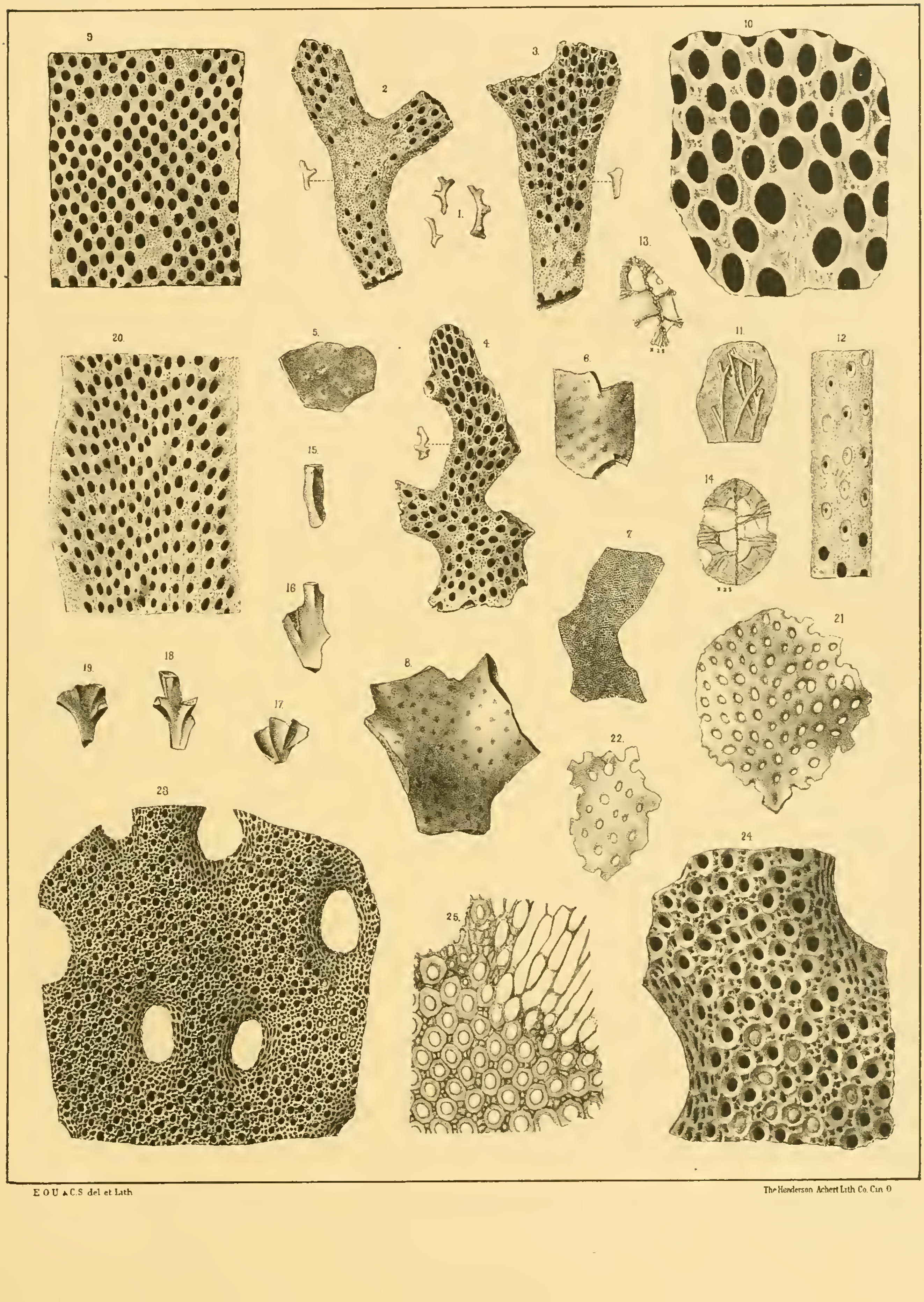
22. A thin fragment less regularly developed than usual.

23. Surface of an excellently preserved example, ×9.

24. Another portion of same ×18. In this specimen the mesopores are very numerous.

25. Tangential section of an average specimen, ×18. In the upper part of the figure the section descends to the level of the prostrate portion of the zoœcial tubes. (See also plate XI.)

Middle third of the Trenton shales at Minneapolis.



E O U & C.S del et Lith

The Henderson Achert Lith. Co. Cin. O.

PLATE XI.

PAGE.

Figs 1 to 3, 6, and 8 to 11. STICTOPORELLA ANGULARIS Ulr.. 182

1 to 3. Three specimens of the usual form of this species, natural size.

6. Surface of an average example, ×9.

8, 10 and 11. Tangential, transverse, and vertical sections, ×18, prepared from the oldest example at hand.

9. Small portion of a tangential section ×50, showing the minutely tubular character of the divisional line between adjoining zoœcial walls.

Lower third of the Trenton shales at St. Paul and Minneapolis.

Figs. 4, 5 and 7. STICTOPORELLA ANGULARIS, var. INTERMEDIA, n. var........................... 183

4. A small subfrondescent example from the base of the shales at Minneapolis.

5. A fragment of the usual form of the variety from the same horizon in Fillmore county.

7. Surface of same ×18, showing the extreme paucity of mesopores and in the upper left corner a portion of one of the clusters of thin-walled zoœcia.

Figs 12 to 19. STICTOPORELLA FRONDIFERA Ulr.. 183

12 to 14. Three specimens of this species, natural size. The original of fig. 14 belongs to the Survey Museum. It is one of a number bearing the register number 5946.

15. Surface of original of fig. 12 ×9.

16. Tangential section of an average specimen, ×18.

17. Small portion of same section ×50, to show the structure of the inter-zoœcial lines.

18. The basal or prostrate portion of several zoœcial tubes as shown in another tangential section, ×18.

19. Vertical section, ×18.

Lower third of the Trenton shales at Minneapolis.

Figs. 20 and 21. STICTOPORELLA RIGIDA Ulr................ 180

20. A fragment of the natural size and the greater part of it ×9.

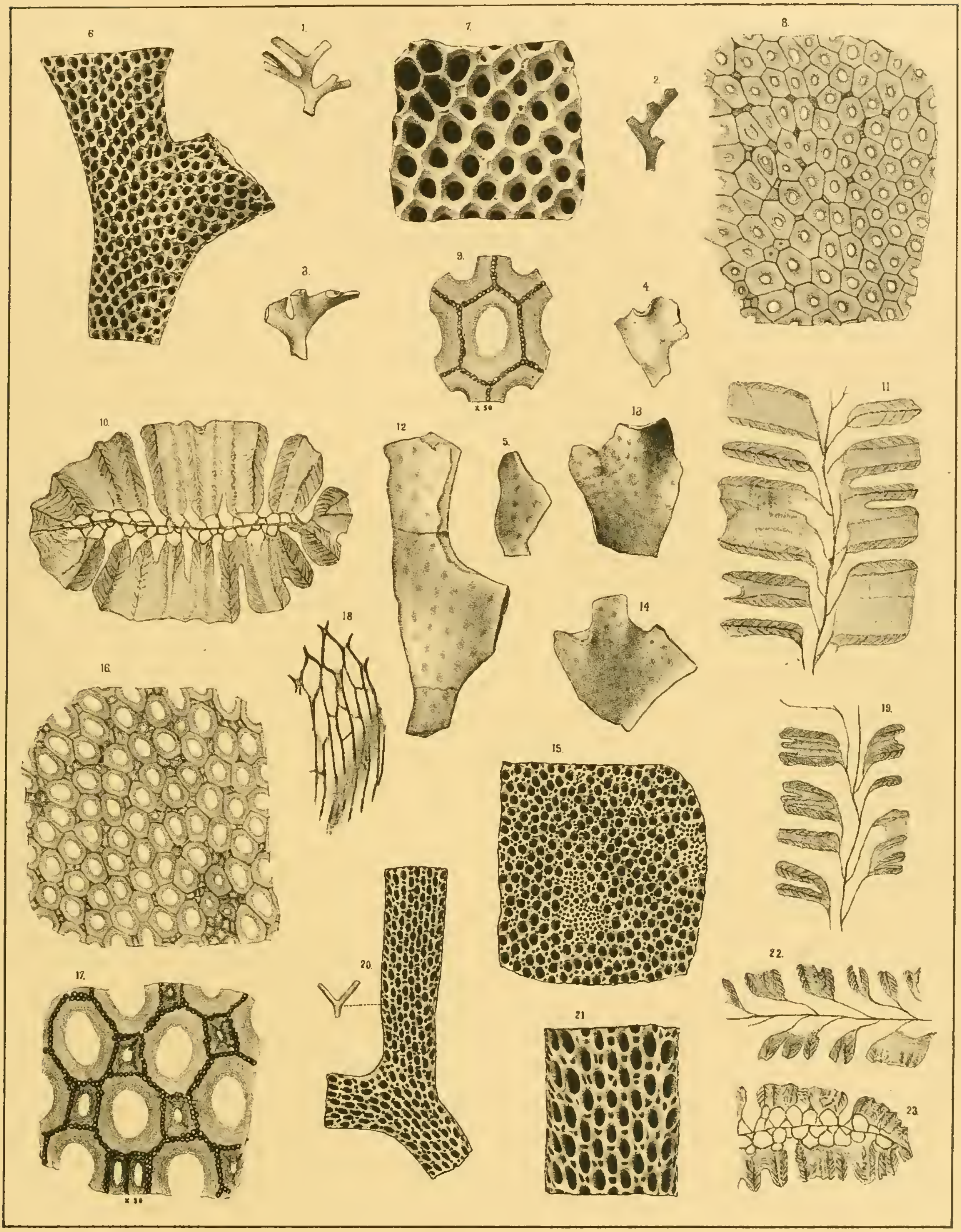
21. Portion of same, ×18.

Lower part of the upper third of the Trenton shales at Fountain, Minn.

Figs. 22 and 23. STICTOPORELLA CRIBROSA Ulr.. 184

22. Vertical section, ×18.

23. Transverse section, ×18. (See also plate X).



E. O. U. & C. S. del et Lith.
The Henderson Achert Lith. Co. Cin. O.

PLATE XII.

1 and 2. A small specimen of natural size and the greater portion of it ×9.

3 and 4. A large specimen of the natural size and a portion of the upper half of its surface ×18.

30 and 31. Vertical and tangential sections, ×18.

Trenton limestone, Minneapolis.

5 to 17. A series of specimens, most of them above the average in size and the four last with from one to three rows of monticules.

18 and 19. The central and basal portions of the original of fig. 9, ×9.

20. Part of same, ×18. The characters as shown in this specimen are to be regarded as typical for the species in its younger stages.

21. Surface of another small example, ×18, with the marginal rows of zoœcia unusually conspicuous.

22. Surface of the basal third of the original of fig. 15, ×18. The features here presented are unusual.

23. Surface of the upper part of the original of fig. 16, ×18.

24. Surface of the original of fig. 17, ×18. In the specimen the zoœcial apertures manifest a tendency to arrange themselves in an obscurely pinnate manner.

25. Tangential section of an example corresponding to fig. 9; ×18.

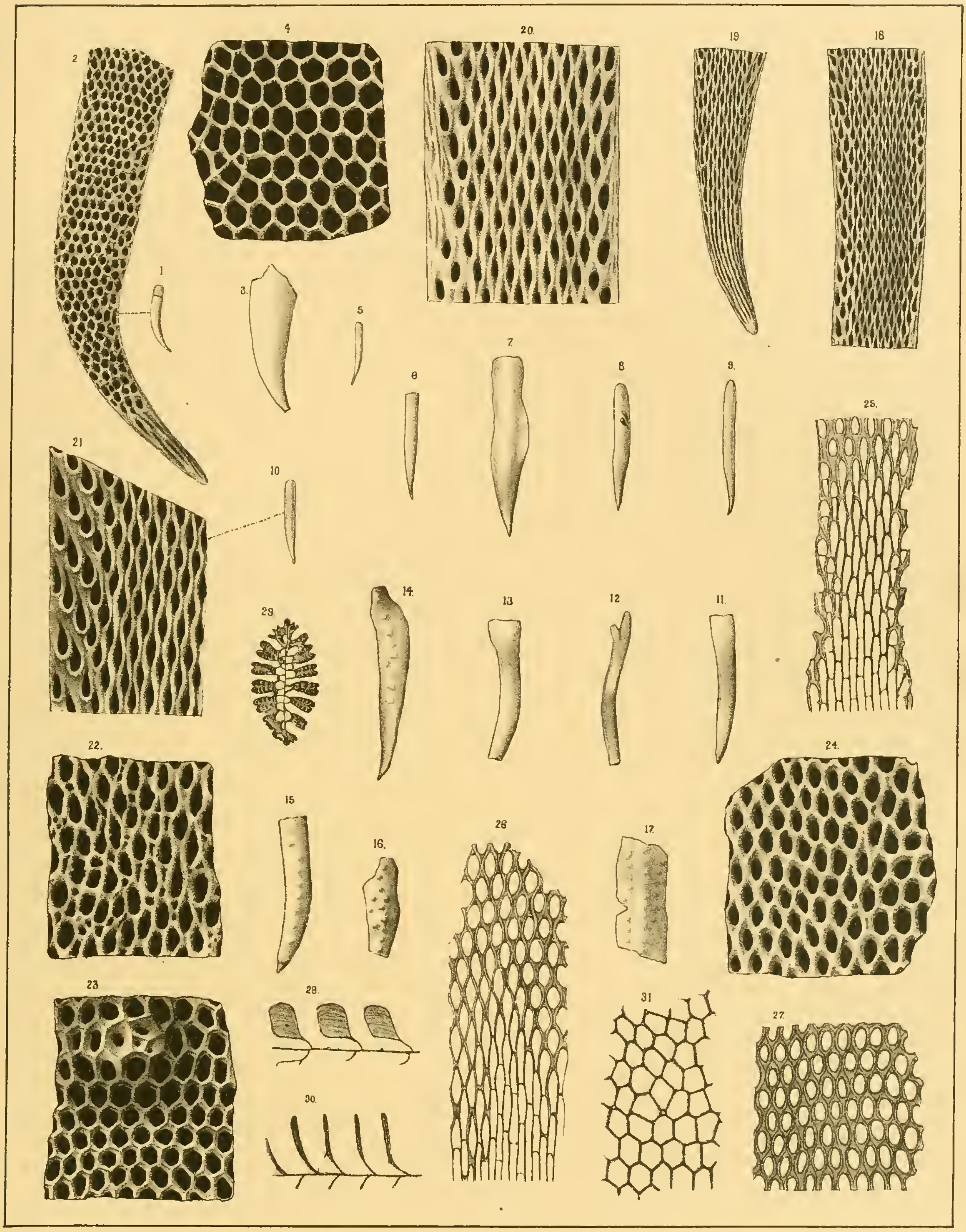
26. Tangential section of a specimen of the size of fig. 8, or a trifle larger; ×18.

27. Tangential section, ×18, showing the appearance just beneath the surface of an old example.

28. Vertical section of several zoœcia prepared from an average specimen, ×18.

29. Transverse section of same ×12.

Middle third of the Trenton shales at St. Paul and Minneapolis.



E. O. U. & C. S. del. et Lith.

The Henderson Achert Lith. Co. Cin. O.

PLATE XIII.

PAGE.

Figs. 1 to 11. ESCHAROPORA CONFLUENS, n sp.. 171

1. A specimen that preserves the pointed articulating base; natural size.
2. Well preserved fragment, the surface of which is enlarged in fig. 5.
3. Portion of a large specimen with comparatively remote bifurcations and obscure monticules; natural size.
4. Incomplete basal part of another large zoarium; natural size.
5. Surface of the original of fig. 2, ×9. The line above indicates the contour of the surface in a transverse section.
6. Tangential section, ×18, of a well preserved example. The figure embraces about two-thirds of the width of the branch, the right side being marginal.
7. Several zoœcia of the same section, ×35, showing the mural lineation.
8. Another portion of the same section, ×18, showing the prostrate part of the zoœcia.
9. Left half of another section, ×18, prepared from a specimen in a less favorable (the usual) state of preservation. In this example the marginal zoœcia were uncommonly large

10 and 11. Transverse and vertical sections ×18.

Middle third of the Trenton shales at Minneapolis.

Figs. 12 and 13. ESCHAROPORA (?) LIMITARIS, n sp. or var 172

12. A very large specimen, provisionally referred to this species; natural size. Middle third of the Trenton shales at Minneapolis. Survey Museum. Reg. No. 5930.
13. A specimen of the average size of the species as it occurs in the lower third of the shales at Minneapolis. (For internal structure see figure 9 on page 172.)

Figs. 14 to 17. PHÆNOPORA INCIPIENS, n. sp.. 174

14. A fragment of the natural size and a part of it ×18. Trenton limestone, Montreal, Can.
15. The basal part of a zoarium from the Trenton limestone at Chimney Point, Vermont.
16. Tangential section, ×18, of a specimen from Montreal.
17. Tangential section of another specimen from Montreal, ×28, showing structure immediately beneath the surface.

Figs. 18 to 21. STICTOPORELLA EXIGUA, n. sp.*

18. Portion of the delicate zoarium of this species, natural size.
19. Surface of one of the branches ×18.
20. Tangential section ×28.
21. Transverse section ×18.

Trenton limestone, Montreal, Can.

Figs. 22 to 26. PHÆNOPORA WILMINGTONENSIS, n sp.. 175

22. Fragmentary example of the natural size.
23. Surface of same ×9.
24. Two portions of a tangential section, ×18, the upper showing the appearance just beneath the surface, the lower just over the prostrate part of the zoœcial tubes.
25. One of the zoœcia and portions of the adjoining ones ×35 to show the minute structure of the walls.
26. Vertical section, ×18.

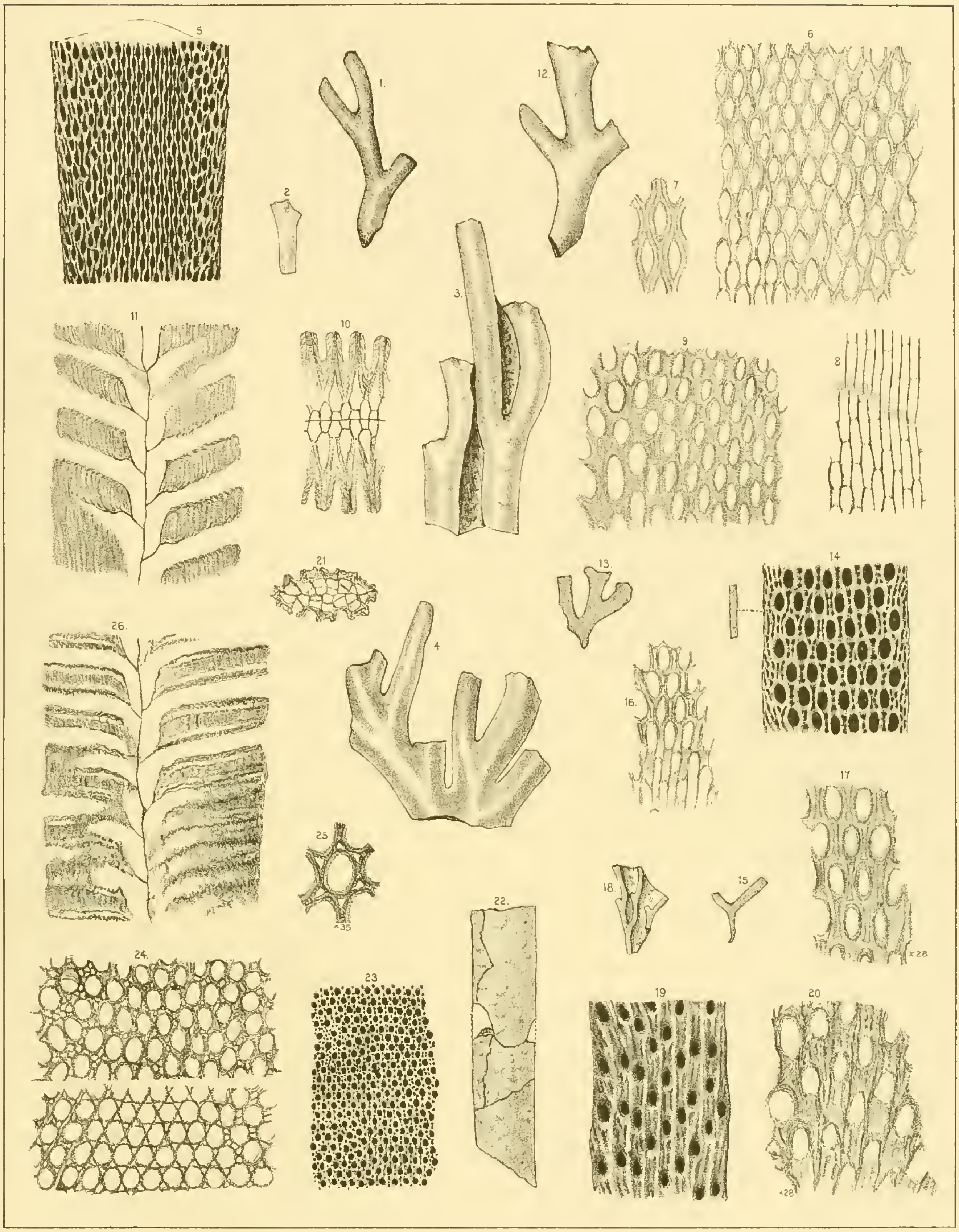
---

*The description of this interesting species having unfortunately been omitted from its proper place in the text, the following brief diagnosis of its peculiarities is added here:

Zoarium consisting of slender and frequently dividing branches, not exceeding 1.5 mm. in width; margins parallel, scarcely sharp. Zoœcial apertures oval, more or less oblique, arranged in eight or nine longitudinal rows, six or seven in 3 mm., between longitudinal ridges; diagonally three or four in 1 mm. End interspaces two or three times as long as the width of the space between the ridges, rsiing distally, usually with two elongate shallow pits or furrows.

All that is known of the interior is shown in the figures.

The types were collected at Montreal, Canada, in the Trenton limestone, by Mr. T. C. Curry, for the Peter Redpath Museum, from which institution they were obtained by the author in exchange for other fossils.



E. O. U. del et lith.
THE HENDERSON ACHERT KREBS LITH. CO. CINCINNATI

PLATE XIV.

PAGE.

Figs. 1 to 8. PHYLLODICTYA VARIA, n. sp. 144

1. A fragment with subparallel margins, natural size.
2. Surface of same ×9.
3. Two rows of apertures ×18; shows the papillose character of the ridges.
4. Vertical section, ×18. By an oversight the diaphragms are wanting in this figure. Each tube should have one crossing it at right angles at a point about midway between its aperture and the mesial line.
5. Tangential section ×18. The internal characters are but illy preserved in even the best of the specimens sectioned.

6 and 7. Old zoarium of the natural size with a portion of its surface ×9. With age the maculæ become more distinct and the longitudinal arrangement of the zoœcial apertures less obvious.

8. Portion of a zoarium larger and wider than usual; natural size.

Middle third of the Trenton shales at Minneapolis.

Figs. 9 to 11. EURYDICTYA MULTIPORA (?Hall, sp.) 139

9. Fragment of a slightly undulating expansion, natural size.
10. Surface of same, ×9.
11. Small portion of same, ×18.

Upper third of the Trenton shales, St. Paul. Survey Museum, Reg. No. 5942.

Figs. 12 to 21. ARTHROPORA SIMPLEX Ulr. 177

12. Two segments of the usual size.

13 and 14. Two bifurcating segments, probably abnormal; natural size.

15. Several segments preserved in their natural positions, natural size.
16. Surface of a well preserved fragment, ×18.
17. Several zoœcial apertures of same, ×35. In many specimens the longitudinal prolongations from the ends of the inner ring of papillæ are longer, in some cases even joining.
18. Irregularly divided basal joint, natural size.
19. The lower part of same, ×9. It is difficult to make out the apertures, the whole surface appearing to be covered with closely intertwining striæ.
20. Vertical section, ×18. showing the form of the zoœcia, the hemisepta, and other features.
21. Three portions of a tangential section, ×35. In *a* the right hand third shows the structure just beneath the surface. In the middle third the section sinks to the level of the prostrate part of the zoœcia and in some of them both kinds of hemisepta are shown. On the left side the dark band represents the noncelluliferous margin. In c we have only the prostrate part of the zoœcia and the dense margin.

Middle third of the Trenton shales at Minneapolis.

Figs. 22 to 25. ARTHROPORA BIFURCATA, n. sp. 178

22. A small segment natural size and its upper part ×18.

23 and 24. Two old segments, the last one probably the basal, of the natural size.

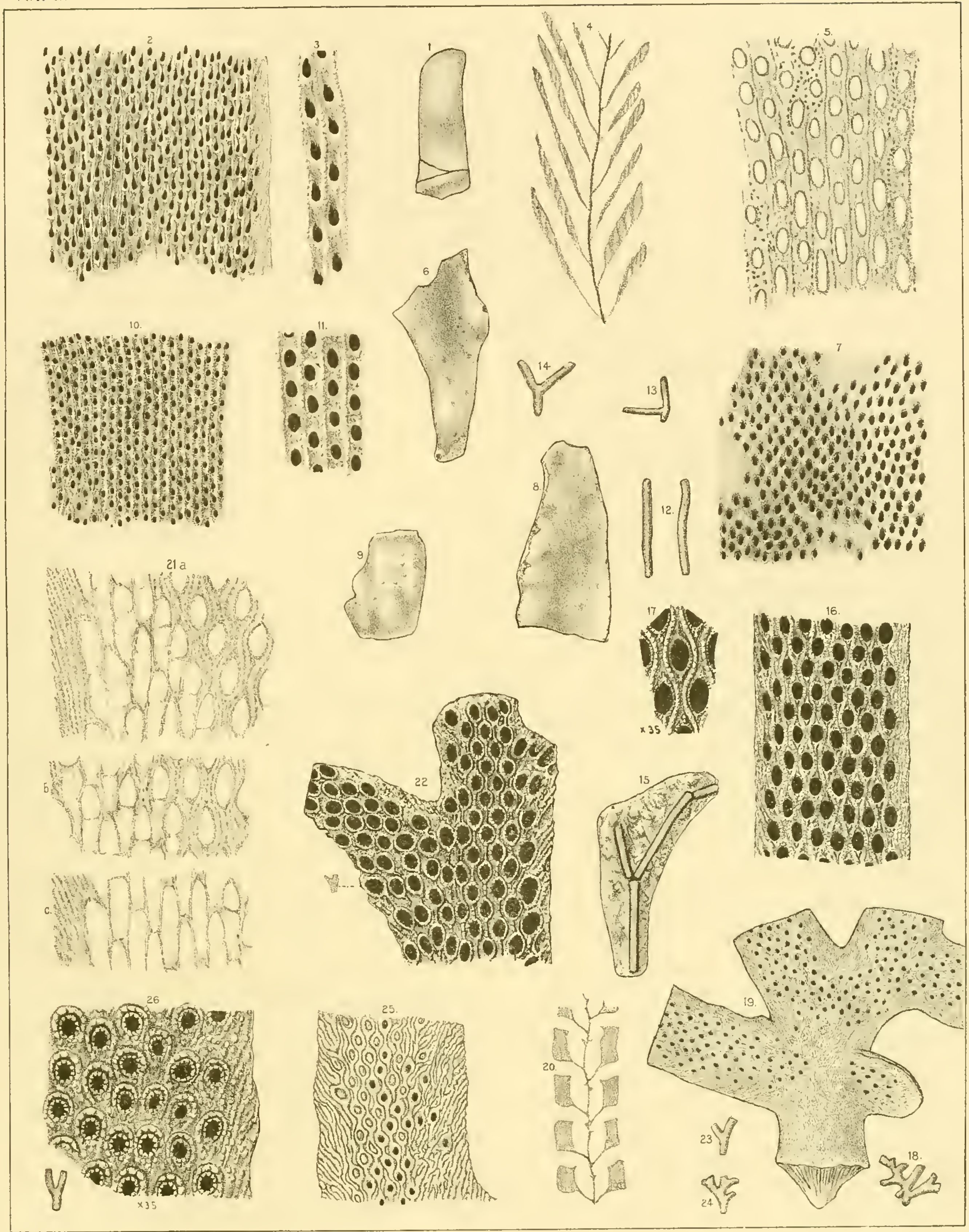
25. Surface of the original of fig. 23, ×18, illustrating the aged condition in contrast with the youthful stage represented in fig. 22.

Upper third of the Trenton shales, St. Paul.

Fig. 26. ARTHROPORA REVERSA, n. sp. 178

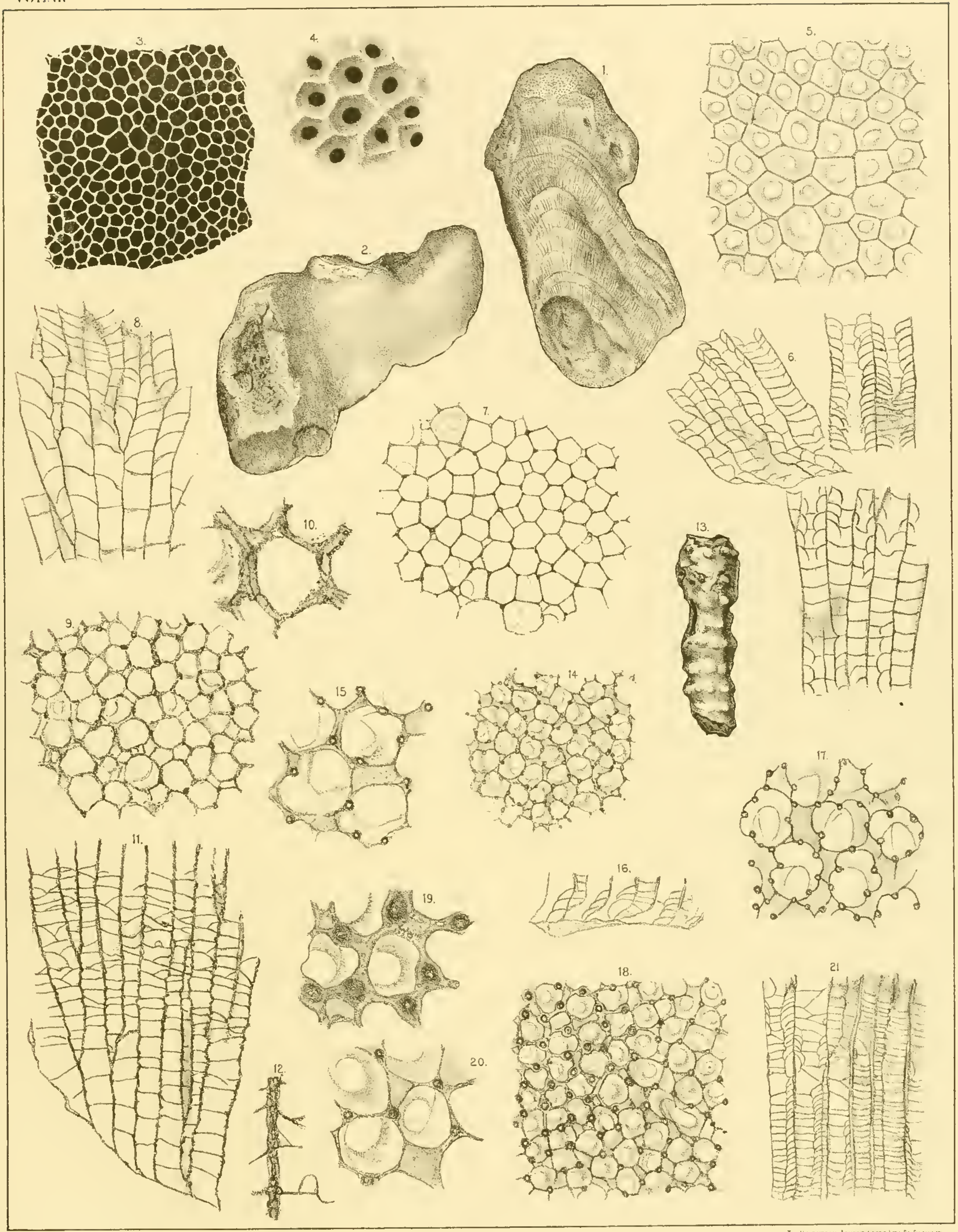
Natural size view of an average segment, and a portion of its surface ×35.

Base of the Galena shales at St. Paul.



E. O. U. del et lith. — The Henderson Achert-Krebs Lith. Co. Cincinnati

PLATE XV.



E O U del et lith.

THE HENDERSON-ACHERT-KREBS LITH. Co. CINCINNATI

PLATE XVI

PAGE.

Figs. 1 to 10. PRASOPORA SIMULATRIX Ulr 245

1 and 6. Vertical and tangential sections, ×18, of a specimen of the var. *orientalis* from Trenton Falls, N. Y.

2 and 7. Similar sections of a Canadian (Ottawa) example of the same variety.

3 and 8. Similar sections of a Kentucky specimen of the western or typical form of the species.

4 and 9. Vertical and tangential sections of a specimen from the lower part of the Galena limestone at Mantorville, Minn. Mus. Reg. No. 5986.

5 and 10. Similar sections of another example of the typical form of the species from the upper third of the Trenton shales at St. Paul.

Figs. 11 to 15. PRASOPORA CONOIDEA Ulr 249

11 to 13. Lateral, basal, and one sectional view of three specimens of this species, natural size.

14. Tangential section ×18, showing the thin walls and minute acanthopores which are characteristic of the species.

15. Vertical section, ×18. The abundant tabulation of the tubes is the chief peculiarity brought out by this kind of section.

Upper third of the Trenton shales near Cannon Falls, Minn.

Figs 16 and 17. PRASOPORA SELWYNI Nicholson 250

16. Vertical section ×18, showing the isolation and semi-circular form of the cystiphragms.

17. Transverse section of same ×18.

Upper part of the Galena shales near Cannon Falls, Minn.

Figs. 18 and 19. PRASOPORA INSULARIS, var. FILLMORENSIS, n. var.. 252

18. A tangential section ×18, showing the different appearance of the inter-zoœcial spaces when compared with typical *P. insularis.*

19. Small portion of a vertical section ×18, showing the vesicular character of the interspaces to which is due the difference referred to in the preceding paragraph.

Probably from the Trenton shales near Fountain, Minn.

Figs. 20 to 23. PRASOPORA INSULARIS, n. sp 251

20. Tangential section of an excellently preserved specimen. ×18.

21. Small portion of same ×50 to show the minutely cellulose character of the walls.

22. One zoœcial tube with adjacent mesopores and one wall with adjoining cystiphragms and diaphragms, ×18. In showing the much greater abundance of the cystiphragms and diaphragms when compared with other species of the genus, this figure, though small, is sufficient for the identification of the present species.

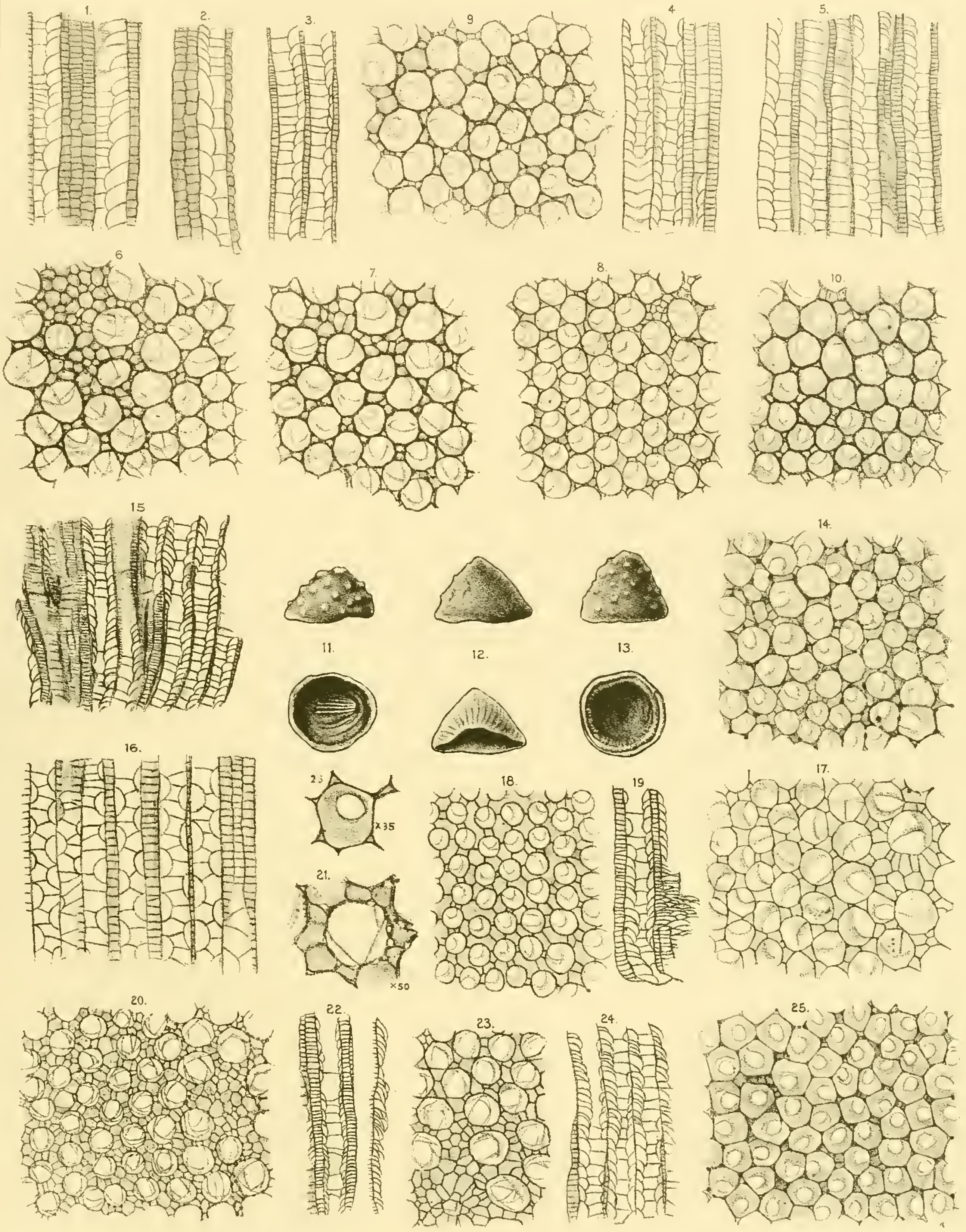
23. Small portion of another tangential section, ×18, in which the zoœcial tubes are more frequently in contact than in fig. 20.

Galena shales near Cannon Falls, Minn.

Figs. 24 to 26. PRASOPORA CONTIGUA Ulr 249

24 and 25. Vertical and tangential sections, ×18, of a specimen from the upper part of the Trenton shales of Goodhue county, Minn.

26. One zoœcium and adjoining mesopores of same ×35. Mus. Reg. No. 5989.



E.O.U del et lith.

Th. Henderson-Achert-Krebs Lith. Co. Cincinnati

PLATE XVII.

PAGE.

Figs. 1 to 8. MESOTRYPA INFIDA Ulr. 258

1 and 2. Two tangential sections prepared from the same example, ×18. The first illustrates the fully matured condition, the second an earlier level in the zoarium. Trenton shales near Fountain, Minn.

3 to 5. Three portions of a large vertical section of the same, ×18, showing the variable disposition and appearance of zoœcial diaphragms.

6. Portion of another vertical section of same ×18. Mus. Reg. No. 5993.

7. Surface of same, ×9, showing a condition approximately intermediate between figs. 1 and 2.

8. Surface of a parasitic specimen in a condition corresponding with fig. 1. Middle third of the Trenton shales, Minneapolis.

Figs. 9 to 12. MESOTRYPA (?) SPINOSA, n. sp. 259

9. Surface of well preserved example, showing the round form and regular arrangement of the zoœcial apertures, and the strong acanthopores; ×9.

10 and 11. Tangential section, ×18, and parts of several zoœcia ×50.

12. Small portion of a vertical section, ×18, showing unmistakable cystiphragms in the lower half. Other parts of the same section are like figs. 3 and 4 of this plate.

Middle third of the Trenton shales at St. Paul and Minneapolis.

Figs. 13 to 21. ASPIDOPORA ELEGANTULA, n. sp. 256

13. A fine example of this species on the surface of which an intermittent second layer of zoœcia was forming; natural size.

14. One of the areas of the secondary layer, ×9.

15. Tangential section prepared from the primary layer of same. ×18.

16 and 17. Views of the upper and lower sides of a specimen that consists of at least four distinct layers grown loosely over each other; natural size.

18. Upper surface of same, ×9.

19. Tangential section of one of the layers of same, ×18.

20. Parts of several zoœcia of a tangential section, ×50.

21. Several zoœcia and mesopores as seen in a vertical section of one of the layers, ×18.

Galena shales, Kenyon, Minn. These two specimens were collected by W. H. Scofield and kindly presented by him to the author.

Figs. 22 to 25. PRASOPORA LENTICULARIS, n. sp. 253

22. Upper surface and sectional view of an example of this species; natural size.

23. Two portions of a tangential section of same, ×18, the upper half representing the appearance in the upper third, the lower half that in the basal third of the zoarium.

24. One of the zoœcia and adjoining parts of same, ×50.

25. Vertical section of same, ×18, showing the comparatively loose tabulation of the two sets of tubes.

Upper third of the Trenton shales at St. Paul.

Figs. 26 to 32. ASPIDOPORA PARASITICA Ulr. 255

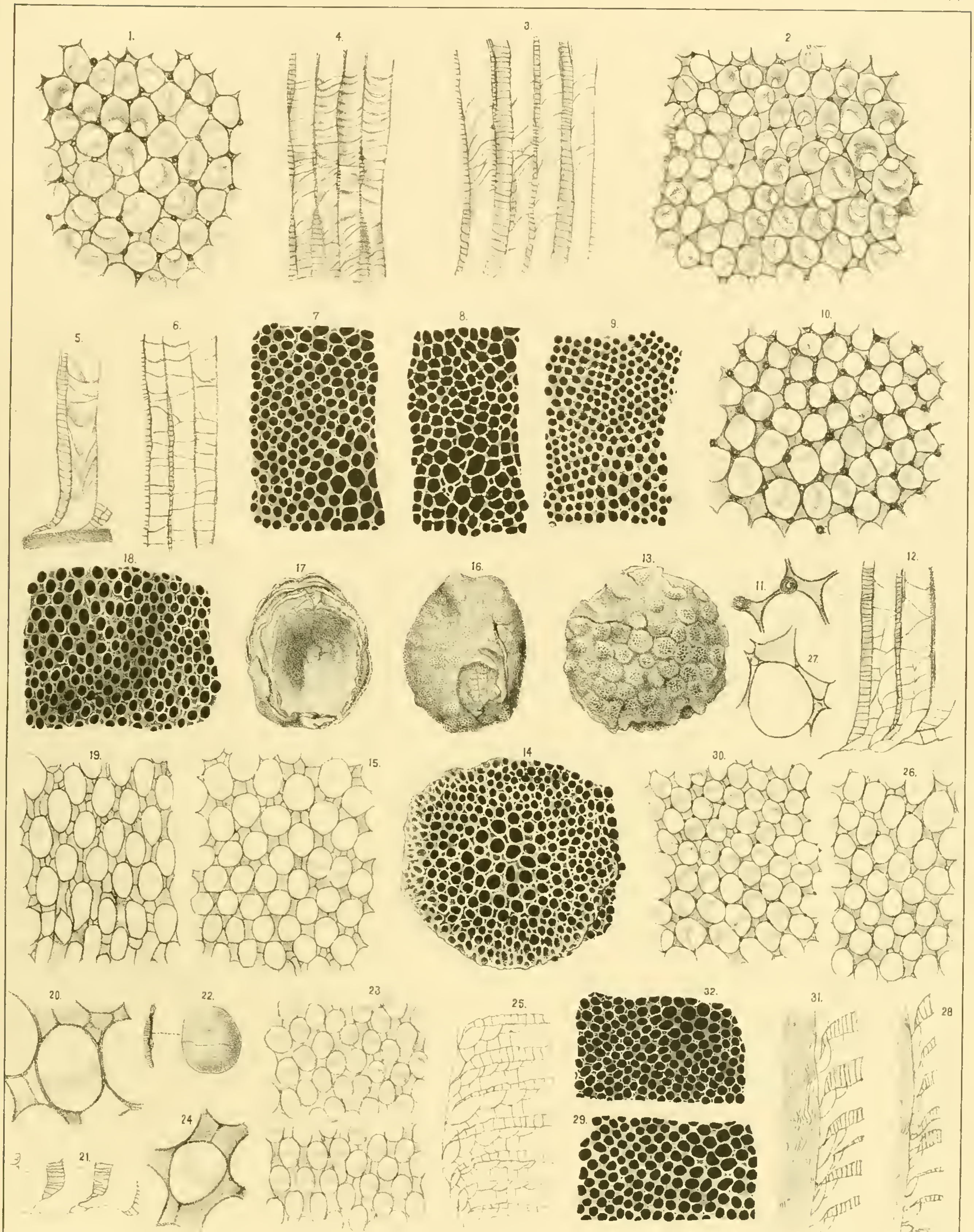
26 add 27. Portions of a tangential section, ×18 and ×50, with few cystiphragms and zoœcia very slightly larger than usual.

28. Vertical section of same specimen, ×18, showing entire thickness.

29. Surface of same, ×9.

30 to 32. Tangential and vertical sections, ×18, and the surface ×9, of a thicker zoarium.

Lower third of the Trenton shales, Minneapolis and near Fountain, Minn.



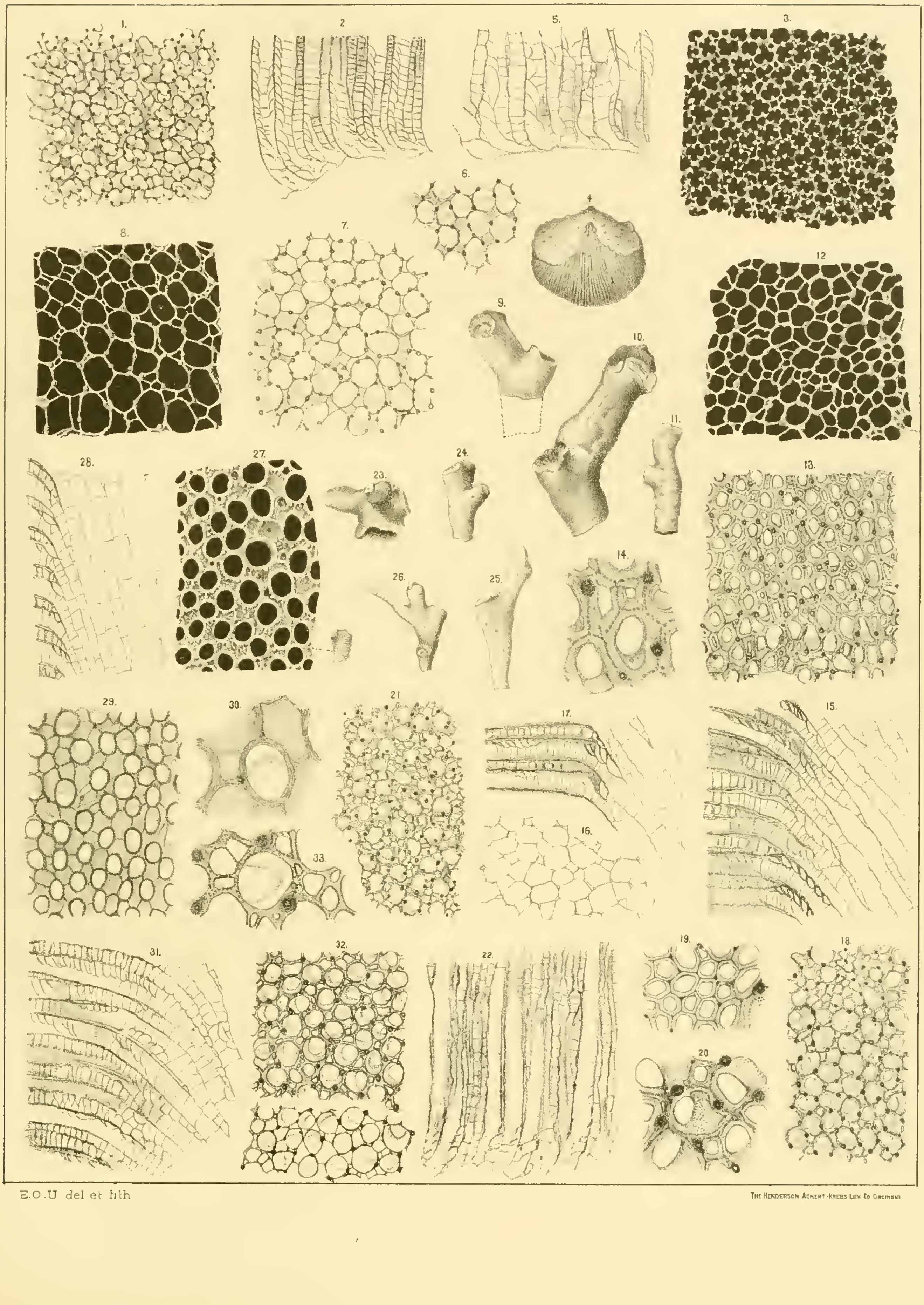
E. O. U. del et lith.

THE HENDERSON ACHERT KREBS LITH. CO. CINCINNATI

PLATE XVIII.

VOL. III

Plate XVIII



E.O.U. del et lith

The Henderson Achert-Krebs Lith Co Cincinnati

PLATE XIX.

PAGE.

Figs. 1 to 9. HOMOTRYPA MINNESOTENSIS Ulr.... 235

1 to 3. Vertical, transverse and tangential sections ×18, of a specimen having the walls in the peripheral region thicker than usual. Mus. Reg. No. 5970.

3*a*. Small portion of a tangential section of an example of the var. *montifera*, ×50. Base of the upper third of the Trenton shales at St. Paul.

4 and 5. Tangential and vertical sections of an average specimen, ×18.

6. The peripheral part of two zoœcial tubes, ×18, more closely tabulated than usual. Mus. Reg. No. 5970*b*.

7 and 8. Two examples of the natural size. The end view under the latter shows the exceeding narrowness of the peripheral region.

9. Surface of the original of fig. 7, ×9.

Lower third of the Trenton shales, Minneapolis.

Figs 10 to 16. HOMOTRYPA EXILIS Ulr.. 236

10 and 11. Two fragments of the natural size.

12. Vertical section ×18.

13. Tangential section in a pre-mature condition, ×18.

14. Tangential section showing fully matured characters, ×18.

15. Portion of fig. 14 more highly magnified.

16. Portion of fig. 13 more highly magnified.

Lower third of the Trenton shales at Minneapolis.

Figs. 17 to 20. HOMOTRYPA SEPARATA, n sp.................. 237

17 and 18. Tangential section of this peculiar species, ×18, and a portion of same ×50.

19. Surface of a well marked specimen ×9.

20. Vertical section ×18. Attention is to be directed to the tabulated interstitial spaces.

Lower third of the Trenton shales, Minneapolis.

Figs. 21 to 28. HOMOTRYPA SUBRAMOSA Ulr............. 239

21. View of a characteristic specimen showing the irregular division of the branches.

22, 24 and 25. A series of three tangential sections ×18, agreeing in all respects except that while in the first the acanthopores are numerous and well developed they are fewer in the second and quite inconspicuous in the third. Original of fig. 24 belongs to Survey Museum, Reg. No. 5980*a*.

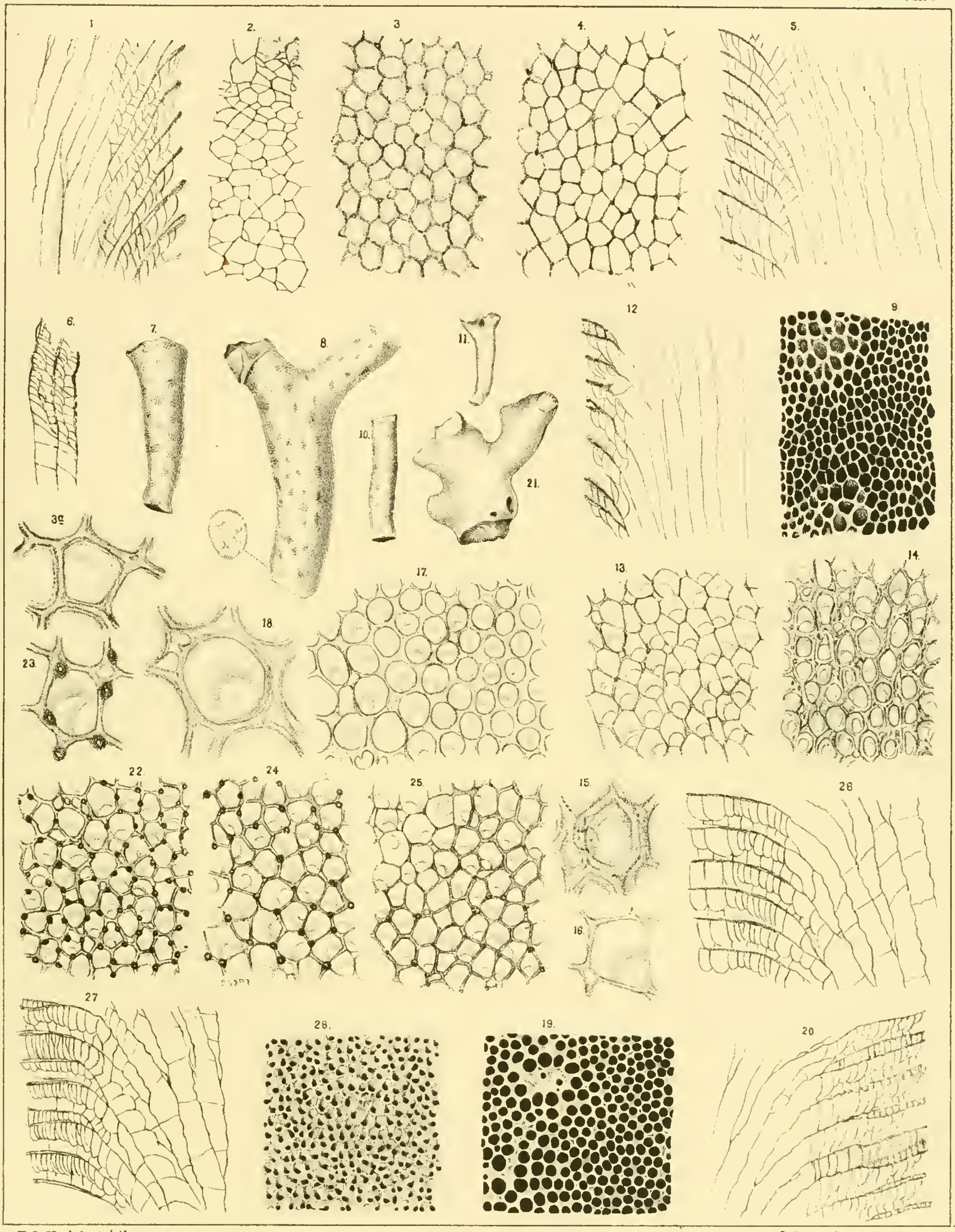
23. Small portion of fig. 22 more highly magnified.

26. Vertical section ×18, of a specimen having the outermost region loosely tabulated; very unusual. Mus. Reg. No. 5980*b*.

27. Vertical section of a typical example, ×18.

28. Surface of an average example, showing the cystiphragms in the zoœcial apertures, ×9.

Upper third of the Trenton shales, St. Paul and near Cannon Falls.



E.O U del et lith.

The Henderson Achert-Krebs Lith. Co. Cincinnati

PLATE XX.

PAGE.

Figs. 1 to 9, 13 and 14. MONTICULIPORA ARBOREA, n. sp. 220

1. Peripheral part of a vertical section ×18.
2. Several tubes from the axial region of same ×18, showing the presence of cystiphragms in even this portion of the zoarium.
3. Transverse section from the center to the periphery of a branch ×18, proving the presence of cystiphragms throughout.

4 and 5. Fully matured portion of a tangential section ×18 and a small part of same ×50.

6. Shows the appearance at a slightly lower level than fig. 4.
7. Small portion of the surface of the specimen represented by fig. 8; ×9.

8 and 9. Two fragments of the natural size exhibiting a difference in the prominence of the monticules.

Galena shales near Cannon Falls, Minn.

13 and 14. Tangential and vertical sections of a form of the species from the Trenton at Burgin, Ky.; ×18.

Figs. 10 to 12. MONTICULIPORA (?) CANNONENSIS, n. sp. 221

10 and 11. Vertical and tangential sections ×18.

12. One zoœcium ×50.

Galena shales near Cannon Falls, Minn.

Figs. 15 to 21. HOMOTRYPA CALLOSA, n. sp. 243

15 and 16. Tangential section×18 and a small portion of same ×50, of a specimen from the Galena shales near Cannon Falls.

17. Vertical section of same ×18.

18 and 19. Peripheral and axial portions of a vertical section ×18, prepared from a specimen from the Trenton at Burgin, Ky.

20 and 21. Tangential section of same ×18 and ×50, differing slightly from that of the Minnesota form.

Figs. 22 to 27. ATACTOPORELLA RAMOSA, n. sp. 226

22. Two portions of a tangential section ×18, exhibiting differences that depend upon the varying depth at which the section passes through the zoarium.
23. Small portion of same more highly magnified.
24. Axial region of a transverse section ×18.
25. Vertical section ×18, showing the continuance of the series of cystiphragms into the axial region.

26 and 27. Two specimens of the natural size.

Upper third of the Trenton shales near Cannon Falls, Minn.

Figs 28 to 33. HOMOTRYPA SIMILIS Foord*.......... 242

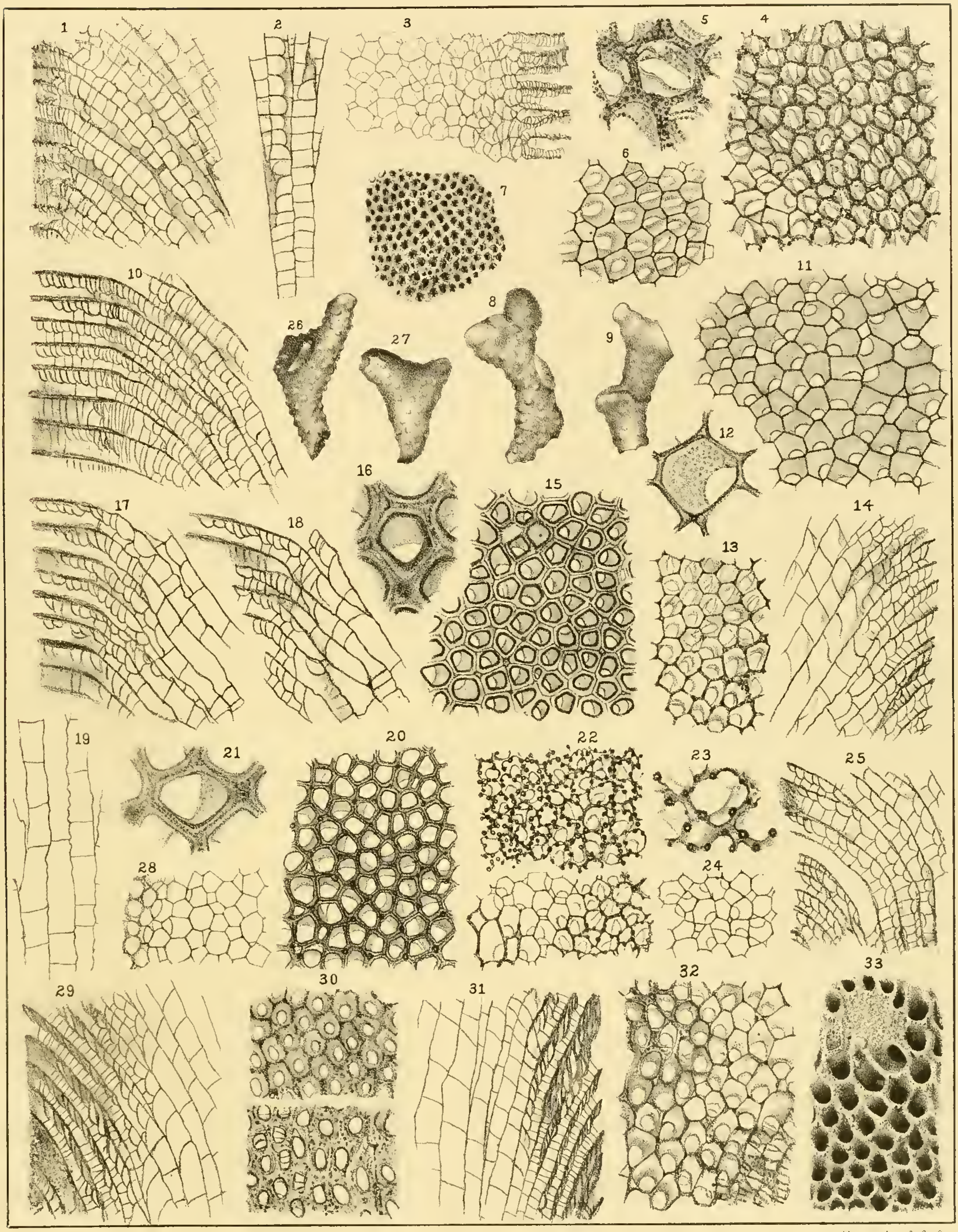
28. Portion of the peripheral third of a transverse section ×18, Cannon Falls.
29. Vertical section of an authentic Canadian example of the species ×18.
30. Two portions of a tangential section of same ×18.

31 and 32. Vertical and tangential sections of a Minnesota specimen, ×18.

33. Surface of another specimen from this state ×18.

Trenton limestone Ottawa, Can., and upper part of the Galena shales near Cannon Falls, Minn.

*The systematic position of this species is doubtful. Though falling in a loose way under *Homotrypa* some of its characters are so peculiar that it can in no wise be regarded as a true representative of the genus. Thin sections are suggestively like those of *Homotrypella instabilis* and in some features also simulate those of *Eridotrypa mutabilis*.



E.O.U. del. et lith.

MACBRAIR LITH. CO. CIN. O.

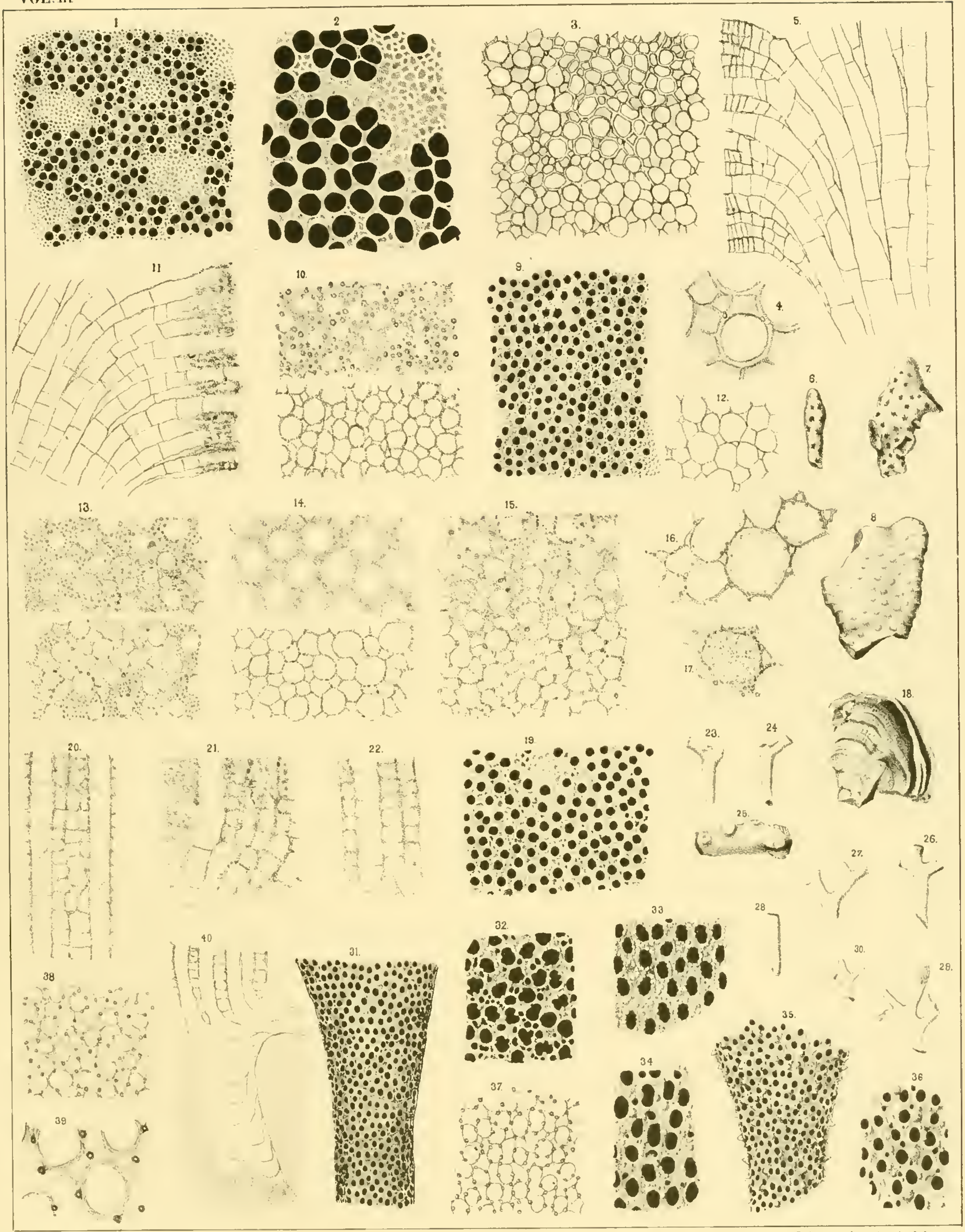
PLATE XXI.

GEOL. AND NAT. HIST. SURVEY OF MINNESOTA.

(Bryozoa)

VOL. III

Plate XXI



E O U del et lith.

The Henderson Achert-Krebs Lith Co. Cincinnati

PLATE XXII.

PAGE.

Figs. 1 to 12. CALLOPORA PULCHELLA, n. sp. 283

1 to 3. Three typical specimens of the natural size.

4. Surface of the original of fig. 3 ×9.

5. One of the depressed spaces of same ×18.

6 and 7. Two fragments, one unusually slender the other thicker than usual.

8. Portion of the original of fig. 7 where the walls are thinner and the mesopores larger than usual, ×18. Other parts of its surface more as shown in fig. 5.

9. Vertical section ×18.

10 and 11. Average tangential section ×18 and small portion of same ×50.

12. Transverse section, natural size and one fifth of it ×18. Note comparatively small size of the tubes in the axial region and wide peripheral region.

Upper third of the Trenton shales, St. Paul.

Figs. 13 to 17. CALLOPORA PULCHELLA, var. PERSIMILIS, n. var. 284

13. Two fragments showing the exceeding prominence of the monticules.

14. Portion of the surface between the monticules ×18.

15 and 16. Vertical and tangential sections ×18.

17. A transverse section, natural size and portion of same ×18.

Upper third of the Trenton shales near Cannon Falls.

Figs. 18 to 23. CALLOPORA CRENULATA, n. sp. 284

18. A fragment of the zoarium of this species, natural size.

19. Surface of same ×9.

20. Average tangential section ×18. Another, representing a more matured condition, rather closely resembles fig. 10.

21. Vertical section ×18.

22. Several tubes from the axial region of same ×18, showing the wavy character of the walls.

23. Portion of one of the maculæ and adjacent parts of a specimen that preserves the centrally perforated zoœcial closures, ×18.

Upper third of the Trenton shales, St. Paul.

Figs. 24 to 31. CALLOPORA UNDULATA Ulr. 279

24 and 25. Typical specimens of the natural size.

26. A fragment with rounded monticules. These are too prominent in the figure.

27. Nearly smooth fragment, in this respect approaching *C. incontroversa*.

28. Surface of the original of fig. 25, ×9.

29. Tangential section ×18.

30. Portion of a transverse section ×18.

31. Vertical section ×18.

Middle third of the Trenton shales, St. Paul and Minneapolis.

Figs. 33 to 36. CALLOPORA INCONTROVERSA Ulr. 278

33. Tangential section ×18, representing part of one of the clusters of large zoœcia and a few of those of the ordinary size. Compared with *C. undulata* (fig. 29) it will be noticed that they are of more rounded shape.

34. The central part of a transverse section ×18

35. The axial part of a vertical section ×18. At the right upper corner one of the tubes is drawn to its aperture.

36. An entire but rather short zoœcial tube ×18, showing the distribution of the diaphragms.

Lower third of the trenton shales, Minneapolis.

Figs. 37 to 41. CALLOPORA ANGULARIS, n. sp. 277

37. Fragment of the natural size.

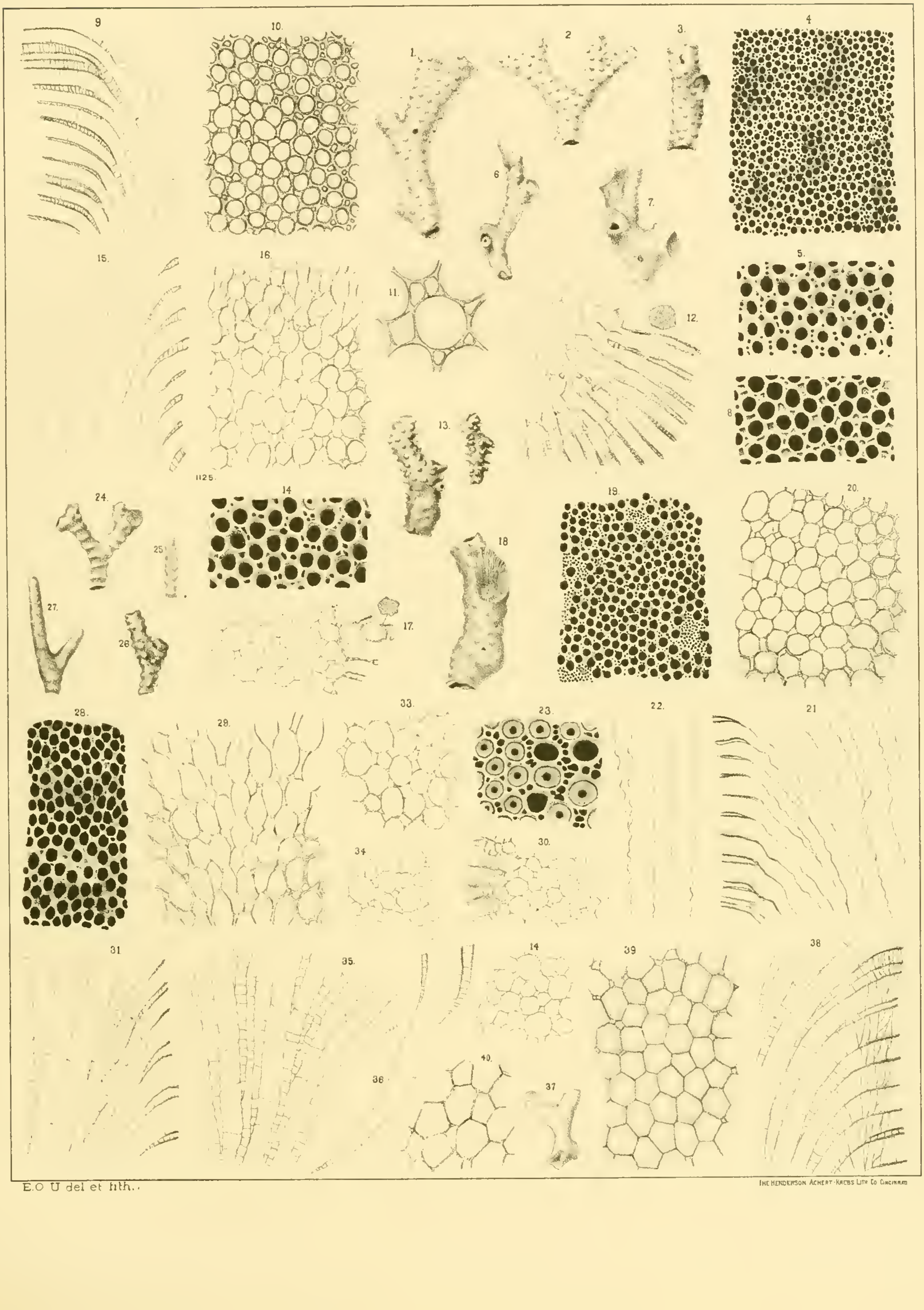
38. Vertical section ×18.

39. Tangential section showing fully matured characters, ×18.

40. Small portion of another tangential section ×18 showing the slightly irregular character of the cells at a deeper level in the zoarium than that represented in fig. 39.

41. (14 on some of the plates.) Axial region of a transverse section ×18.

Lower third of the Trenton shales, Minneapolis.



E. O. U. del et lith.

THE HENDERSON ACHERT-KREBS LITH. CO. CINCINNATI

PLATE XXIII.

PAGE.

Figs. 1 to 8. CALLOPORA DUMALIS, n. sp. 282

1 to 4. Representative fragments of the natural size.

5. Surface of the slender piece ×9.

6. Surface of another that preserves the zoœcial closures, ×18.

7 and 8. Vertical and tangential sections ×18.

Upper third of the Trenton shales, St. Paul.

Figs. 9, 10, 21 and 29. CALLOPORA GOODHUENSIS, n. sp. 282

9 and 10. Two fragments of the natural size.

21. Axial region of a transverse section ×18.

29. Surface of a specimen ×9.

Galena shales near Cannon Falls, Minn.

Figs. 11, 12, 16, 17, 24-26, 30, 31. CALLOPORA MULTITABULATA Ulr 280

11 and 12. Montiferous examples, the latter but slightly, from the Galena shales at Cannon Falls.

16. Typical specimen from the upper third of the Trenton shales at St. Paul.

17. Tangential section ×18, of the Galena shales form.

24. Vertical section of a specimen like fig 16, ×9.

25. Surface of the original of fig. 16, ×9.

26. Surface of a very finely preserved specimen ×18, showing the ornamental zoœcial closures. Upper third of the Trenton shales, St. Paul.

30. Surface of a specimen like the one from which the illustrated tangential section (fig 17) was prepared, ×9. The figure includes one of the clusters of large zoœcia.

31. Surface of a typical specimen ×9.

Figs. 13-15, 18-20, 22, 23, 27, 28. CALLOPORA AMPLA, n. sp. 281

13. A large irregular specimen from the Galena shales at Cannon Falls.

14 and 15. Two typical examples from the base of the upper third of the Trenton shales near Fountain, Minn.

18. Tangential section ×18, of another specimen from the same horizon and locality as the preceding.

19. Vertical section of the same ×9.

20. The axial region of a transverse section of the same ×18.

22 and 23 Portion of one zoœcial tube of a vertical section and a tangential section, ×18, of a specimen like figs. 13 and 28. Galena shales, Cannon Falls.

27. Surface of the original of fig. 14, ×9.

28. Surface of the original of fig. 13, ×9.

Figs. 32 to 47. DEKAYELLA PRÆNUNTIA, n. sp , and varieties.

Figs. 32 to 38. Var. ECHINATA, n. var. 271

32. Typical example of this variety.

33 and 34. A less compressed fragment of the natural size and a portion of its surface ×9.

35 and 36. Two portions of a tangential section ×18.

37. Vertical section of the same specimen ×9.

Lower part of the upper third of the Trenton shales near Fountain, Minn.

38. Portion of a tangential section of a specimen from the upper part of the middle third of the Trenton shales at Minneapolis; ×18. Other parts of this section are precisely as in fig. 36, but in the portion figured the mesopores are larger and more abundant than usual for this variety. The vertical section of this specimen is indistinguishable from fig. 37.

Figs. 39 to 42. Var. SIMPLEX, n, var. 271

39. Tangential section ×18, of a specimen with thick walls.

40. Very small portion of the superficial region of a vertical section magnified 50 diameters to show the minute structure of the walls and the method of depositing the diaphragms.

41 and 42. Small portions of two tangential sections ×50, the first with walls as in figs. 39 and 40, the second with thinner walls, parts of which are marked transversely.

Lower third of the Trenton shales, Minneapolis.

Fig. 43. The TYPICAL FORM of the species 270

An average tangential section ×18. Middle third of the Trenton shales at Minneapolis.

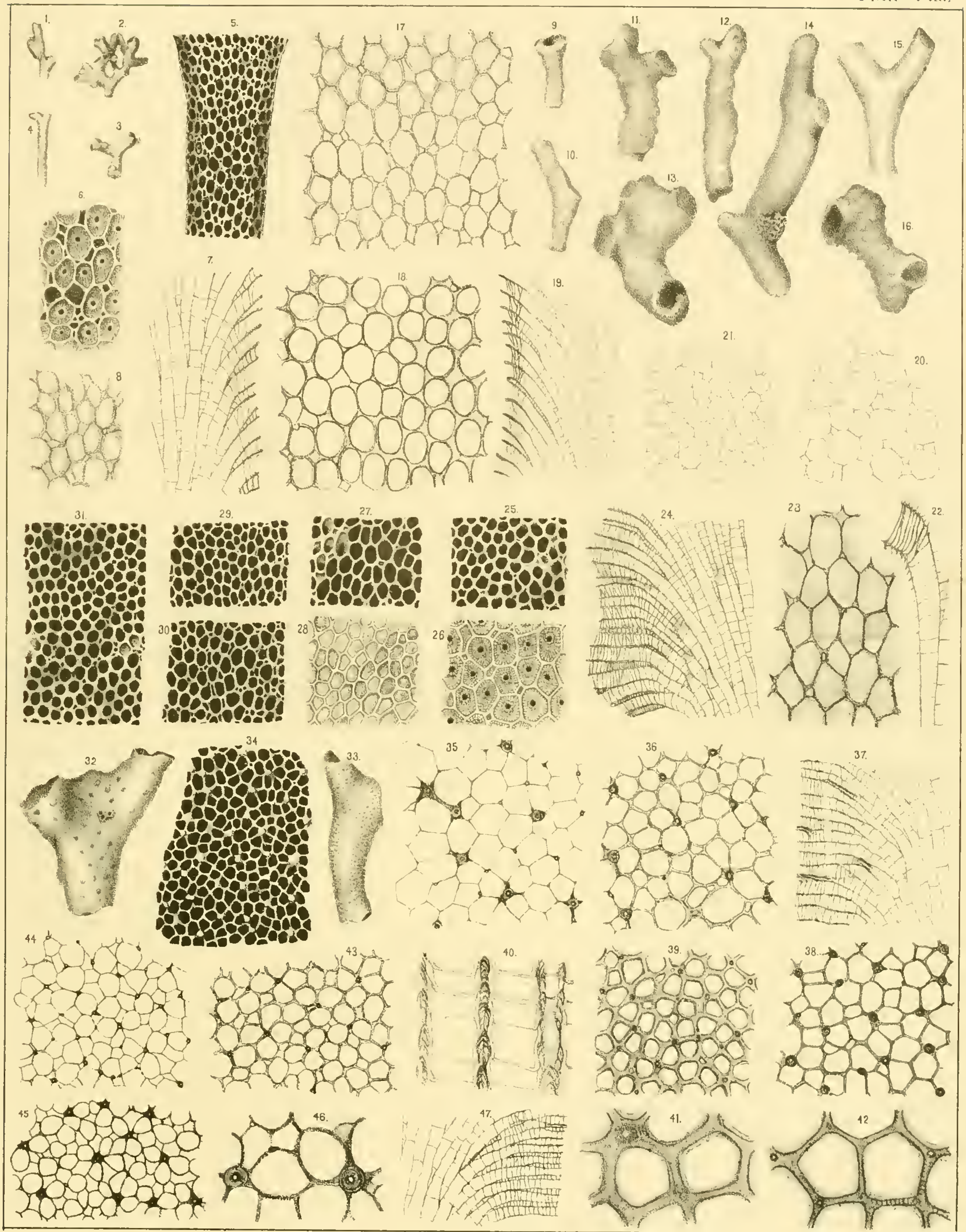
Figs. 44 to 47. Var. MULTIPORA, n. var. 272

44. A tangential section ×18, with very thin walls and small acanthopores.

45 and 46. Another tangential section with stronger walls and large acanthopores, ×18, and several cells ×50.

47. Vertical section ×18.

Middle third of the Trenton shales, Minneapolis.



E O U del et lith.

The Henderson Achert-Krebs Lith Co. Cincinnati

PLATE XXIV.

PAGE.

Fig. 1 to 4. HEMIPHRAGMA OTTAWENSE (Foord) 300

1 and 2. Two portions of a tangential section ×18, showing differences due to age.

3. Vertical section ×9.

4. Small portion of the peripheral region of the same ×35.

Upper part of the Galena shales, Mantorville, Minn. Survey Museum, Reg. No. 6002.

Figs. 5 to 19. HEMIPHRAGMA IRRASUM Ulr. 299

5. Vertical section ×9.

6, 7, 9 and 14. Four tangential sections ×18, exhibiting individual variations.

8. Small part of a transverse section ×18.

10 to 13. The surfaces of four specimens ×9, fig. 10 representing a good average, fig. 12 the appearance of young examples, and figs. 11 and 13 the fully matured conditions.

15 to 19. A group of five specimens, three of them of the average size, while 17 is the largest and 18 one of the smallest seen.

Lower third of the Trenton shales at Minneapolis, and the Galena shales near Cannon Falls, Minn.

Figs. 20 to 23. HEMIPHRAGMA TENUIMURALE, n. sp. 301

20. Vertical section ×18.

21 and 22. Tangential sections ×18, the first showing the fully matured condition, the second a younger stage in the development of the zoarium.

23. Surface of a well preserved example showing the incomplete diaphragms in the zoœcial cavities, ×9.

Galena shales near Cannon Falls.

Figs. 24 to 31. STROMATOTRYPA OVATA, n. sp. 302

24. Surface of an old example ×9.

25, Well preserved specimen consisting of several layers, natural size.

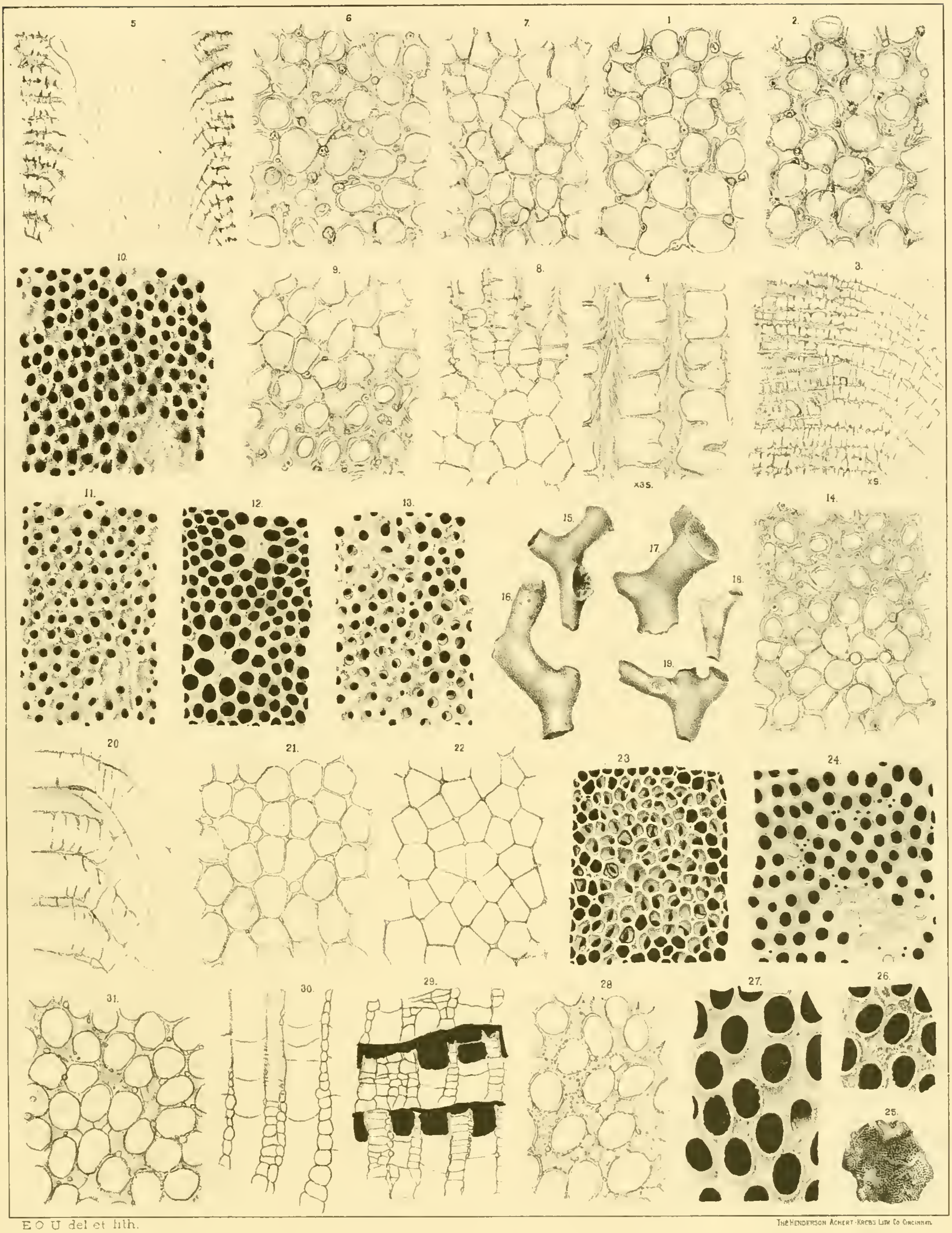
26. Small portion of one of the first layers of same ×18, showing an aged condition.

27. Part of the last layer of same ×18, showing appearance of surface in the youngest stage observed.

28 and 29. Tangential and vertical sections ×18, of an example consisting of three distinct layers of zoœcia

30 and 31. Another pair of sections, vertical and tangential, the latter illustrating a more aged condition than is shown in fig. 28; ×18.

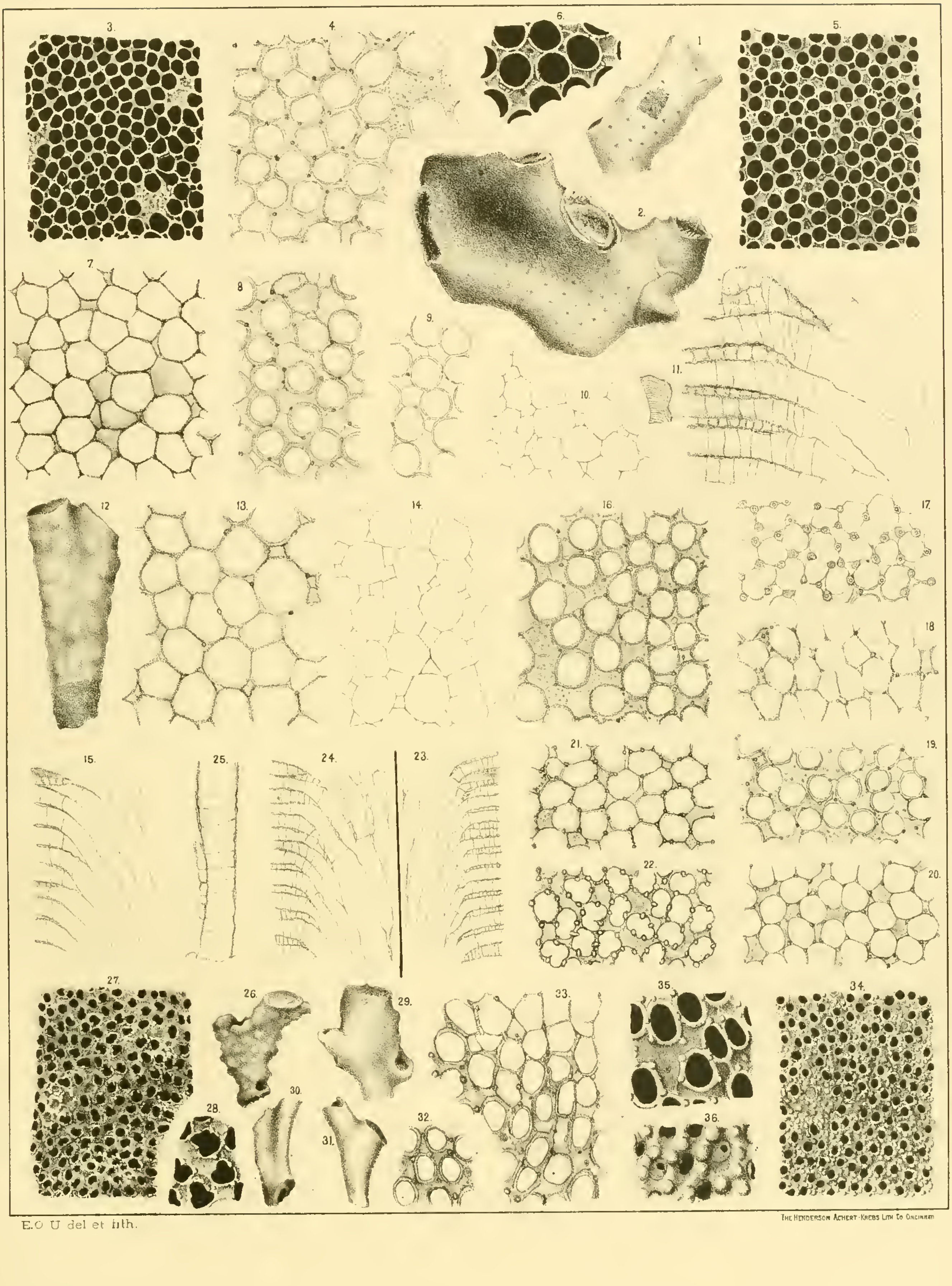
Middle third of the Trenton shales, St. Paul and Minneapolis.



E O U del et lith.

The Henderson Achert-Krebs Lith Co. Cincinnati.

PLATE XXV.



E.O U del et lith. THE HENDERSON ACHERT-KREBS LITH CO CINCINNATI

PLATE XXVI.

PAGE.

Figs. 1 to 6. BYTHOPORA HERRICKI Ulr 263

1. Vertical section ×18, showing slight irregularity in the growth.

2 and 3. Tangential section ×18 and a portion of same ×50.

4 and 5. A large and an average sized specimen.

6. Surface of the smaller ×9.

Middle third of the Trenton shales at Minneapolis.

Figs. 7 to 9. BYTHOPORA ALCICORNIS, n. sp........ 264

7 and 8. Two specimens of the natural size.

9. Surface of the larger one ×9.

Upper third of the Trenton shales near Cannon Falls.

Figs. 10 to 16. HOMOTRYPELLA (?) SUBGRACILIS, n. sp........ 230

10 and 11. Two tangential sections ×18, showing slight differences.

12. Vertical section ×18.. The structure is almost entirely destroyed and only the direction of the tubes is to be made out with any certainty.

13 and 14. Two specimens, the second a little above the average in size.

15 and 16. Surface of the larger specimen ×9 and ×18.

Middle third of the Trenton shales. St. Paul.

Figs. 17 to 19. ERIDOTRYPA EXIGUA, n. sp........ 266

17. A group of fragments as they appear mounted on a slide.

18 and 19. Two of them ×9.

Upper part of the Galena shales near Cannon Falls.

Figs. 20, 21. 29 and 30. ERIDOTRYPA MUTABILIS, var. MINOR, n. var........ 266

20. Three fragments of the natural size.

21. Surface of one of them ×9.

29 and 30. Vertical and tangential sections ×18.

Galena shales near Cannon Falls.

Figs. 22 to 28, 31, 32. ERIDOTRYPA MUTABILIS, n. sp........ 265

22. A specimen of the average size.

23. Large example.

24. Surface of an old example presenting an unusual appearance, ×18.

25. Surface of the original of fig. 23, ×18. The figure includes one of the maculæ and exhibits the most common appearance of these.

26 and 27. Tangential section ×18 and a portion of same ×50; represents an average fully matured condition.

28. Vertical section of the same specimen ×18: shows a superficial layer of zoœcia growing in a direction opposite to the first set.

31 and 32. Vertical and tangential sections ×18, of an old specimen which has grown irregularly causing many interspaces aud thus unusually numerous and large mesopores.

Galena shales, Goodhue county, Minn.

Figs 33 to 37. BATOSTOMA WINCHELLI Ulr........ 295

33. A specimen of the usual diameter.

34. Another, of large though not uncommon size.

35. An average example of the var. *nodosa*.

36. Surface of a fully matured example ×9.

37. Surface of the original of fig. 33 ×9 and ×18. (See also plate 27.)

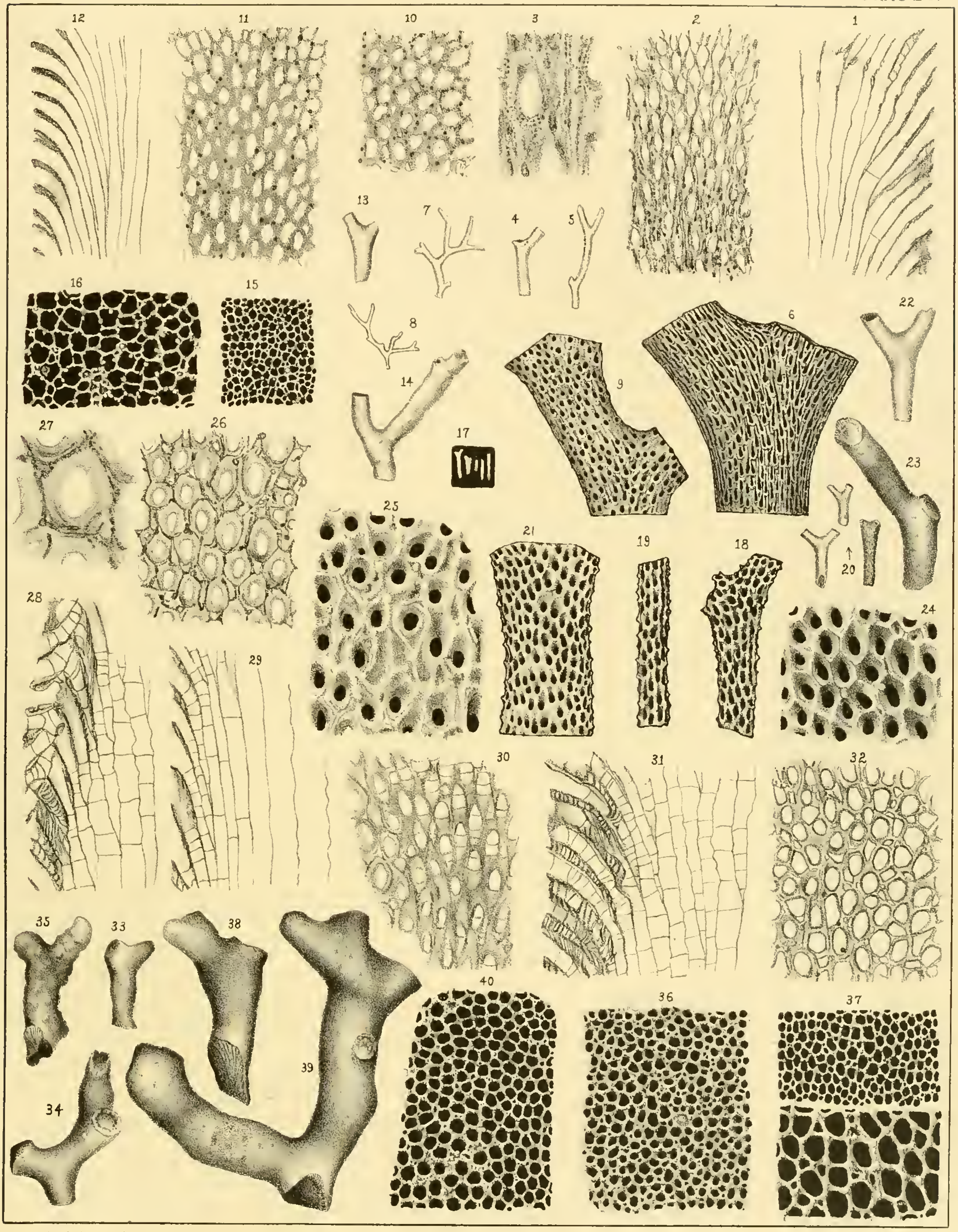
Middle third of the Trenton shales, Minneapolis and St. Paul.

Figs. 38 to 40, BATOSTOMA MINNESOTENSE, n. sp........ 297

38 and 39. Two specimens, the first small, the other of the average size.

40. Surface of the larger specimen, which is in an excellent state of preservation, ×9, showing the granulose walls. (See also plate 27.)

Middle third of the Trenton shales, Minneapolis.



E.O.U del et lith.

MACBRAIR LITH.

PLATE XXVII.

PAGE.

Figs. 1 to 8. BATOSTOMA WINCHELLI Ulr. 295

1, 2 and 3. Vertical sections ×18, of a young, medium, and an old specimen.

4 and 5. Tangential section, ×18 and ×50, of the same specimen from which was prepared the vertical section shown in fig. 3.

6. Tangential section of a young specimen ×18.

7 and 8. Tangential section of the var *spinulosum* ×18 and ×50. (See also plate 26.)

Middle third of the Trenton shales, Minneapolis and St. Paul.

Figs. 9 to 15. BATOSTOMA MINNESOTENSE, n. sp. 297

9 and 10. Portions of a tangential section ×18 and ×50.

11 and 12. Peripheral and axial regions of a vertical section prepared from the same specimen as the preceding, ×18.

13. The peripheral part of a zoœcial tube with fewer diaphragms than usual, ×18. The true average for the species is intermediate between this and fig. 11.

14 and 15. Portions of two tangential sections, ×18 and ×50, in a different state of preservation than figs. 9 and 10. (See also plate 26.)

Middle third of the Trenton shales, St. Paul and Minneapolis.

Figs. 16 to 19. BATOSTOMA (?) DECIPIENS, n. sp. 298

16. Small portion of a vertical section ×18.

17 and 18. Tangential section ×18 and ×50. In some parts of this section certain small acanthopore-like dots are distinguishable usually about midway between the angles. They are dark and scarcely half the size of the smallest shown in fig. 10.

19. From the axial region of a transverse section ×18.

Lower half of the Trenton shales, Minneapolis.

Figs. 20 and 21. LEPTOTRYPA CLAVIFORMIS, n. sp. 319

20. Tangential section ×18. In this section the cells here drawn as open are filled with matrix, while those shaded are occupied by clear calcite. The smaller of the latter have the appearance of mesopores; on the other hand, since the preservation of the fossil is not favorable, it is possible that they represent acanthopores.

21. Vertical section of the upper extremity of same beyond the foreign body, ×18.

Middle third of the Trenton shales, St. Paul.

Figs. 22 and 23. LEPTOTRYPA INFORMIS, n. sp. 317

Tangential and vertical sections ×18.

Lower third of the Trenton shales, Minneapolis.

Figs. 24 and 25. LEPTOTRYPA ACERVULOSA, n. sp. 318

Tangential and vertical sections ×18.

Galena shales, Decorah, Iowa.

Figs. 26 and 27. MONOTRYPA (?CHÆTETES) CUMULATA, n. sp. 307

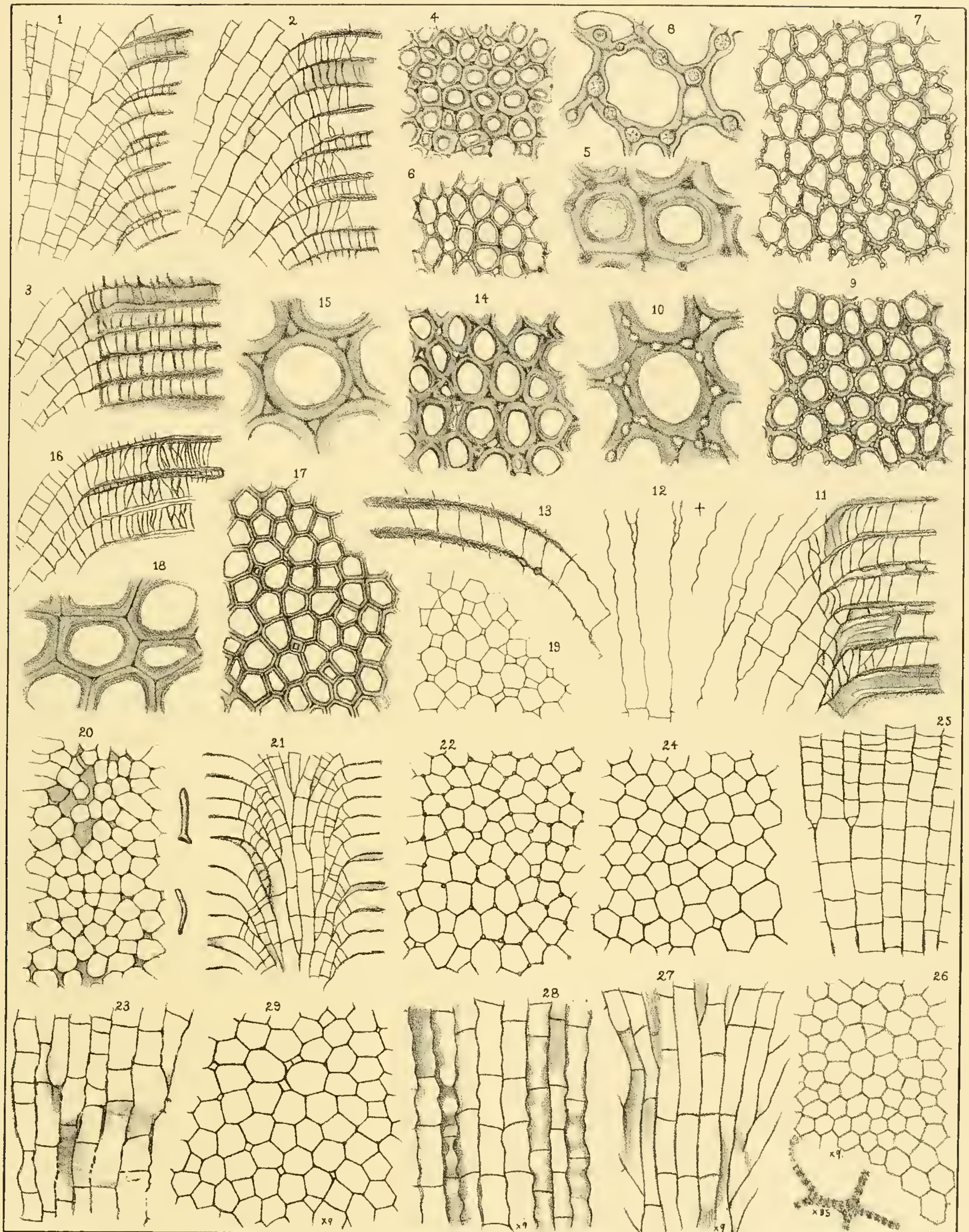
Tangential and vertical sections ×9. Beneath the first the structure of the wall is shown ×35.

Upper part of the Galena shales, Goodhue county, Minn.

Figs. 28 and 29. MONOTRYPA MAGNA, n. sp. 304

Vertical and tangential sections ×9.

"Lower Blue" limestone at Dixon, Ill.



E.O.U. del. et lith.

MACBRAIR LITH. CO. CIN. O.

PLATE XXVIII.

PAGE.

Figs. 1 and 2. SPATIOPORA LABECULOSA, n. sp. 320

1. Surface, ×9, of a specimen with maculæ of the usual size. Others may have smaller maculæ and more numerous mesopores between the zoœcia.
2. Tangential section of same, ×18.

Middle third of the Trenton shales, Minneapolis, Minn.

Figs. 3 to 7. CERAMOPHYLLA FRONDOSA, n. gen. et sp. 331

3. Nearly complete frond of this species, nat. size.
4. Small portion of its surface, ×9, showing in the lower left hand corner the greater part of one of the maculæ.

5 and 6. Small parts of two tangential sections, ×18, the former illustrating the normal development, the latter an old and more irregular arrangement, and greater width of interspaces due to proximity to a macula.

7. Half of a vertical section, ×18; the tubes are divided somewhat obliquely and therefore do not show the full length of the prostrate portion.

Upper third of the Trenton shales, St. Paul, Minn.

Figs. 8 to 11. CERAMOPORELLA INCLUSA, n. sp. 329

8. Surface, ×9, of an example having the apertures filled with the clayey matrix.
9. Small portion of another example, ×18.
10. Larger part of the surface of the original of fig. 9, ×9.
11. Selected normally developed zoœcium, ×40.

Lower and middle thirds of the Trenton shales, Minneapolis, Minn.

Fig. 12. CERAMOPORELLA INTERPOROSA, n. sp. 330

Surface of an average specimen of this species ×18.

Galena Shales near Cannon Falls, Minn.

Fig. 13. CERAMOPORELLA DISTINCTA, Ulr. 328

Surface of a small specimen of this species from the lower third of the Trenton shales at Minneapolis; ×18.

Fig. 14. DIAMESOPORA TRENTONENSIS, n. sp. 330

Two specimens of the natural size and the surface of the upper ×9. The form and arrangement of the zoœcia is a little irregular in this specimen. In others their shape approximates fig. 11.

Galena shales near Cannon Falls, Minn.

Figs. 15 to 20. ANOLOTICHIA IMPOLITA Ulr. 327

15 and 16. Surface ×9 and ×18.

17. From the axial region of a transverse section ×18.
18. Small portion of a tangential section ×18, of a specimen in which many of the lunaria have only two tubuli.
19. Portion of a typical section ×18.
20. Vertical section ×9.

Lower third of the Trenton shales, St. Paul and Minneapolis.

Figs. 21 to 25. BYTHOTRYPA LAXATA Ulr. 325

21 and 22. Surface of a well preserved specimen ×9 and ×18.

23 and 24. Vertical and tangential sections ×9.

25. Portion of the tangential section ×18.

Trenton shales, Minneapolis and St. Paul.

Figs. 26 to 28. CREPIPORA SUBÆQUATA, n. sp. 322

26 and 27. Tangential section ×9 and ×18.

28. Vertical section ×9, the entire thickness of the zoarium being shown in the right half of the figure.

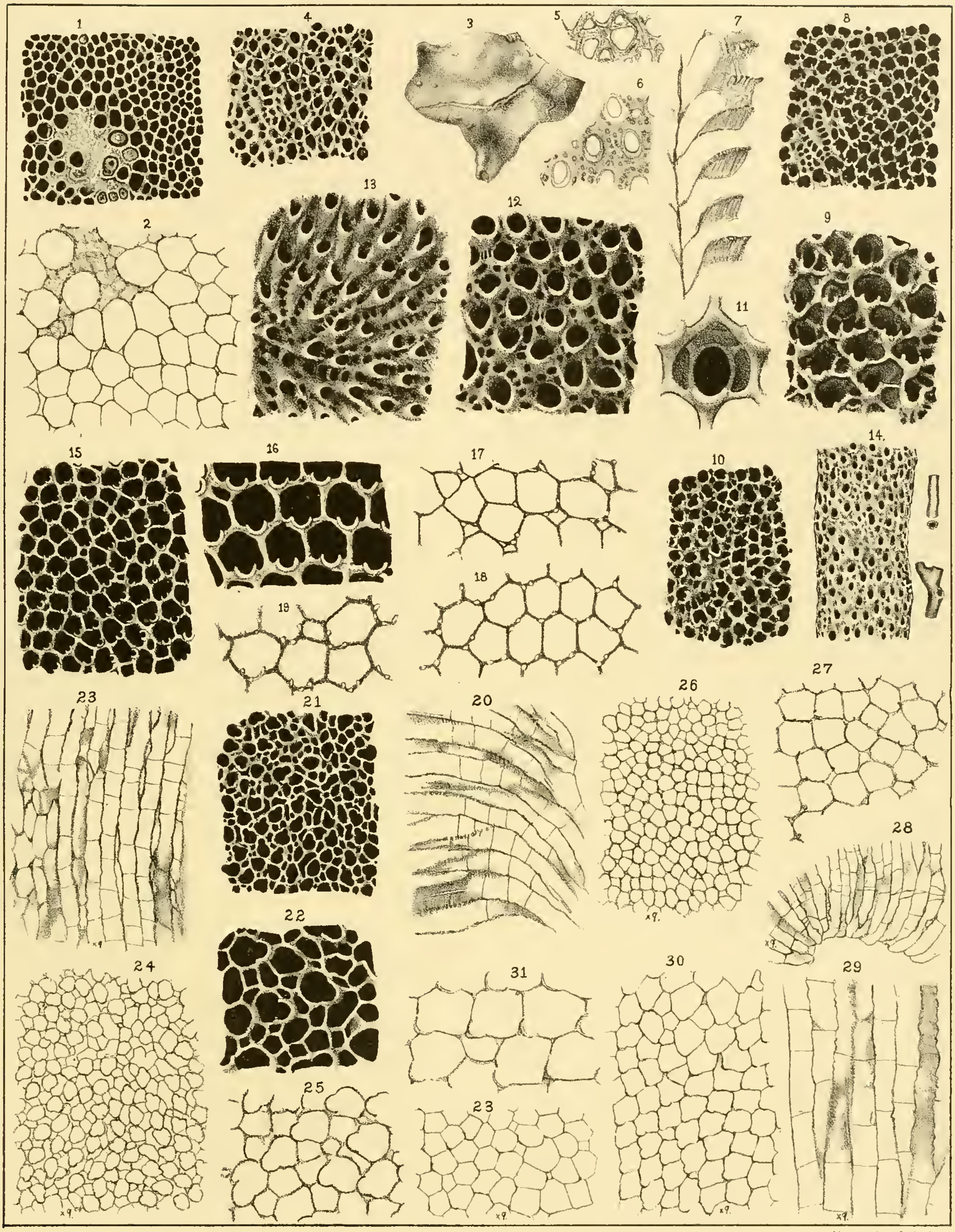
Upper third of the Trenton shales, St. Paul.

Figs. 29 to 32. CREPIPORA PERAMPLA, n. sp. 323

29 and 30. Vertical and tangential sections ×9, the latter with the lunaria unusually distinct.

31. Portion of the tangential section ×18.
32. Another tangential section ×9, with the lunaria scarcely distinguishable.

Top of the Trenton limestone, Fillmore county, Minn.



E.O.U. del. et lith.

MACBRAIR LITH. CO. CIN. O.

CHAPTER V.

THE LOWER SILURIAN BRACHIOPODA OF MINNESOTA.

BY N. H. WINCHELL AND CHARLES SCHUCHERT

PRESERVATION AND DISTRIBUTION.

In the upper third of the Trenton limestone in the vicinity of Minneapolis, brachiopods are numerous, but usually not very well preserved. This is due mainly to the dolomitic nature of the rock, and the frequent small crystals of calcite and pyrite lining the cavities of the casts. In some of the shaly layers, slabs are found, containing very fine specimens of *Rhynchotrema inæquivalvis*, *Orthis deflecta*, *O. subæquata* var. *conradi*, *Scenidium anthonensis* and *Rafinesquina minnesotensis*. With a few exceptions, all the species of this division also occur in the Trenton shales above.

In the Trenton shales, a great abundance and variety of forms of well preserved fossils can be gathered readily in the immediate vicinity of St. Paul and Minneapolis. The greatest thickness of the shales is about seventy feet, but towards the southern part of the state they rapidly diminish, so that at Preston, which is near the state line in Fillmore county, they are not more than fifteen feet thick. The predominating fossils of this horizon are bryozoans, and next in abundance are the brachiopods. The latter are beautifully preserved, either as entire specimens or separated valves, so that the external and internal structure of nearly all the species can be understood satisfactorily. Much can also be accomplished in the discovery of young specimens 1 mm. in size up to maturity. These small specimens cannot be picked up on the hill sides, nor on the quarry dumps, but usually where adult examples of a species are abundant, there, also, will be found all individuals from the youngest to the mature shells. Collectors discovering such localities should not fail to carry away a small sample of the shale to be washed carefully in a pan until the water is colored no longer by the residuum. After drying, what remains should be sifted into various sizes to facilitate examination with the hand lens. If the sample proves to contain young specimens, it will be only a matter of washing and picking to secure of a species a complete series of specimens from less than 1 mm. in length to the adult size. Such series are of great value in classification, and much yet remains to be done in this direction.* A great deal can also be learned by local collectors, in regard to the evolution, introduction and disappearance of the species in these shales.

Near the top of the Trenton shales, new forms are introduced gradually, so that in the overlying Galena deposits the brachiopod fauna is changed. With the introduction of shales containing *Clitambonites diversa*, the marking species of this horizon, the fauna is noticed to disagree more or less in specific expression with that of the underlying Trenton shales. A number of forms are common to both horizons, but there is a perceptible difference in them. Ascending towards the middle Galena, the older species drop out, and new ones take their places more and more rapidly. In connection with this faunal change, there is also a lithological one. The Trenton shales are greenish in color, but change easily to a yellow with a coarser texture, before the *Clitambonites* horizon is introduced. The strata then become more and more sandy in the northern exposures of the Galena, which towards the south is altered into a compact, thin-layered limestone series.

Near the middle of the Galena there is another brachiopod horizon quite distinct from any below it. At some localities the species found here are preserved as casts while in others the shell remains. The characteristic species of this horizon are *Orthis meedsi* var. *germana*, *Rafinesquina deltoidea*, *Strophomena trilobata*, *Plectambonites gibbosa*, *Zygospira uphami*, *Cyclospira bisulcata*, *Schizötreta pelopea*, and *Lingulasma galenensis*. From these beds to the Hudson River group above, the fauna is rather meager, and little collecting has been accomplished.

In the upper member of the Hudson River deposits, the brachiopods are again numerous in individuals and species. Its fauna agrees with that of the upper portion of the Cincinnati group of the Ohio valley. The fossils are preserved in a semi-siliceous condition. Numerous outcrops of this formation occur in the southern portion of the state, but the fauna appears to be localized, and not well preserved nor abundant except in the region of Spring Valley.

Below the Trenton limestone, but one brachiopod (*Lingula morsii*) is known in the St. Peter sandstone; none in the Shakopee formation; but several, as yet unstudied, in the Lower Magnesian. In the St. Croix formation, however, brachiopods are abundant but mainly of inarticulate species.

* See "The Development of some Silurian Brachiopoda," by Beecher and Clarke; Mem. N. Y. State Mus., vol. i. no. 1. 1889: "Development of the Brachiopoda," pt. i, by C. E. Beecher, Am. Jour. Sci., vol. xli, 1891: and "Development of Bilobites," by C. E. Beecher, Am. Jour. Sci., vol. xli, 1891.

TERMINOLOGY.

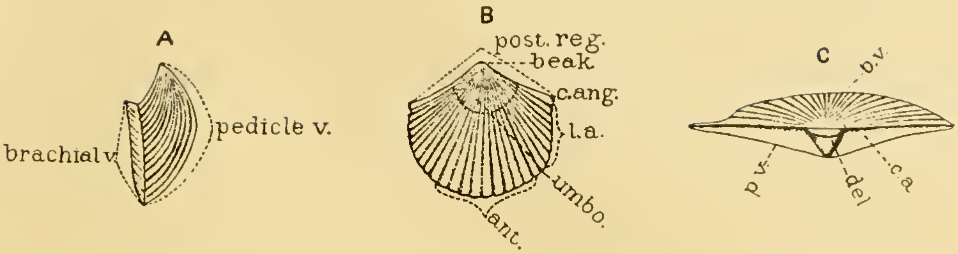


FIG. 21. *a*, profile view of *Orthis tricenaria* Conrad; *b*, ventral view of *Orthis tricenaria* Conrad; *c*, cardinal view of *Strophomena incurvata* Castelnau.

Pedicle=Ventral valve. The valve always situated on the ventral side of the animal and having the foramen or pedicle opening, except in *Lingula*, *Obolella*, etc., where the pedicle protrudes between the valves. When the shell is cemented to foreign bodies it is always by the ventral valve. It is usually the larger and deeper of the two valves in which the animal is contained. It was called the "dorsal valve" by Hall, from 1847 to about 1861; since which time "ventral valve" has been used by him. "Pedicle", "neural" and "receiving" valves, are synonymous terms.

Brachial=Dorsal valve. The valve to which the arms or the calcified brachial supports are attached. "Ventral valve" of Hall, from 1847 to about 1861. "Brachial," "hæmal" and "entering" valves, are other terms more rarely employed.

post. reg., posterior region ; applies to both valves.

beaks, the apexes of valves.

umbo, the elevated portion of the valve immediately in front or anterior to the beaks.

c. ang., cardinal angle, or angle formed by the cardinal plane with the lateral margin.

l. a., lateral margin, or lateral area.

ant., anterior region or margin.

b. v., dorsal valve. *p. v.*, ventral valve.

c. a., cardinal area of the ventral valve.

del., *deltidium.* A plate of one piece which grows over the delthyrium of the *Strophomenidæ*, and is rudimentary in some species of *Orthis*. This plate begins, in the early larval stage of *Thecidium*, as a secretion from the dorsal side of the body segment, and becomes anchylosed to the ventral valve in the phylembryonic stage, subsequent additions being secreted by the body wall and pedicle. A plate similar in appearance, the "chilidium" of Dr. Beecher,* is often present in the dorsal valve covering the cardinal process, but its development does not begin until early nealogic or later growth, and is probably secreted by the dorsal mantle lobe. When the delthyrium of the ventral valve contains two pieces growing out from its walls, more or less uniting medially, they are called "*deltidial plates*", and are deposited by the extensions from the ventral mantle lobe (see d. p., fig. 23*b*). These plates are seen in the rhynchonelloids, spire and loop bearing genera. The pedicle opening in these forms is always situated above the deltidium or deltidial plates.

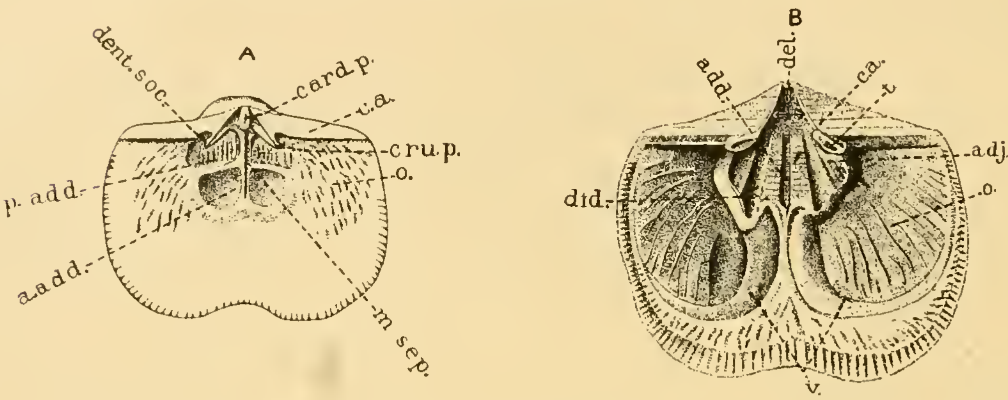


FIG. 22. *a*, interior view of the dorsal valve of *Orthis occidentalis* Hall; *b*, interior view of the ventral valve of *Orthis insculpta* Hall.

c. a., cardinal area.

card. p., cardinal process ; this may be a thin, simple plate, or thickened and trilobed, or separated in two processes, as in the strophomenoids.

dent. s., dental sockets ; the cavities into which the teeth of the ventral valve enter.

cru. p., crural plates, usually forming the inner walls of the dental sockets, to which the brachia are attached.

p. add. and *a. add.*, posterior and anterior adductor scars.

o., genital [ovarian] spaces.

m. sep., median septum separating the two pairs of adductor scars.

del., delthyrium, a term introduced by Hall (Pal. N. Y. vol. viii) for the triangular space usually covered by the deltidium or deltidial plates; "fissure" and "foramen" have also been used.

c. a., cardinal area.

o., genital [ovarian] spaces.

t., teeth ; when they are supported by thin plates, the latter are termed "dental plates."

* For a synopsis of the early embryology of the brachiopods, and a complete discussion of the development of the deltidium and deltidial plates, and on the term chilidium, see "Development of the Brachiopoda, part II, On the Stages of Growth and Decline." American Jour. of Science, August, 1892.

v., vascular sinuses.

add., adductor muscle scars.

did., diductor muscle scars.

adj., adjustor muscle scars. When the *pedicle muscular* scar is present, it appears in the apex of the rostral cavity, posterior to the other scars, and is indicated by transverse striæ.

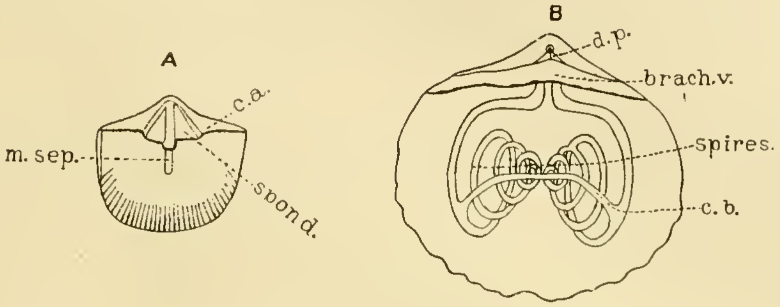


FIG. 23. *a*, interior view of the ventral valve of *Clitambonites diversa* Shaler; *b*, dorsal view of *Zygospira modesta* (Say) Hall, from which the greater portion of the dorsal valve has been removed to show the calcified brachial supports.

spond., spondylium, a plate formed by the junction of the dental plates, to the upper surface of which were attached the adductor, diductor, and adjustor muscles. This plate is also present in the *Pentameridæ*.

m. sep., median septum supporting the spondylium.

d. p., deltidial plates. See *deltidium*.

spire, the spiral cones or calcified brachial supports. The spires may be directed toward the center of the dorsal valve or with their apices toward the lateral margins. The lamellæ are usually single, but a number of genera have two bands in each spiral cone. The brachial supports also may be short or long hooks or crura to which the fleshy arms are attached, as in *Rhynchonella*, or they may form a more or less complicated "loop," as in the terebratuloids. For an illustration of a loop, see the species of *Hallina* of this report.

c. b., connecting band or loop; it is variously disposed, and of a great variety of forms growing out from each spiral cone, and may or may not join medially. In *Atrypa* and *Spirifer*, the band is represented by two prongs.

Protegulum, Beecher. The initial shell of brachiopods. It is smooth and of microscopic size, in outline semicircular or semielliptical, with a straight or arcuate hinge line and without a hinge area. Homologous to the "protoconch" of Owen in cephalopods, and to the "prodissoconch" of Jackson in lamellibranchs.

Nepionic, Hyatt.* The smooth shell stage succeeding the protegulum.

Nealogic, Hyatt. Youthfulness, or the stage in which specific characters begin to develope.

Ephebolic, Hyatt. The mature shell.

Geratologic, Hyatt. Old age. It is indicated in many species of brachiopods by extreme thickness of the valves, obesity, or by numerous, crowded growth lines near the anterior margin, a condition which sometimes produces truncation and absence of striæ at the margin.

Class BRACHIOPODA, (Cuvier) Dumeril.

Subclass LYOPOMATA, Owen.

Order ATREMATA, Beecher.

Family LINGULIDÆ, Gray.

Genus LINGULA, Bruguière.

1789. *Lingula*, BRUGIERE. Histoire naturelle des Vers Testacés.
1892. *Lingula*, HALL. Palæontology of New York, vol. viii, pt. i, p. 2.

Description: "Shells subequivalve, equilateral; elongate-ovate, subquadrate or subtriangular in outline; broad over the pallial region, cardinal slopes more or less conspicuous; slightly gaping at both extremities. Brachial or dorsal valve somewhat the shorter, and with a slightly thickened hinge-line. Surface of the shell smooth, or concentrically and radiately striated. Animal attached by a long, muscular pedicle protruding from between the beaks of the two valves.

"Muscular impressions numerous, but usually indistinct. In the recent species they are twelve in number upon each valve, and are somewhat unsymmetrical in their arrangement. They may be designated as follows: The *umbonal* impressions, produced by a single muscular band passing directly across the cavity of the shell near the beaks, and by their contraction opening the valves; the *lateral* impressions, which are produced by three pairs of muscles, the *anteriors* passing from near the lateral boundaries of the visceral area on the pedicle [ventral] valve, forward to the anterior extremity of this tract on the brachial [dorsal] valve; the *middles* passing in just the opposite direction, from the anterior region of the pedicle-valve to the lateral region of the brachial; the *externals* passing from the ante-lateral region of the pedicle valve to the post-lateral region of the brachial valve; these muscles serving to move the valves forward and backward. The *central* impressions are

* Values in classification of the stages of growth and decline, with propositions for a new nomenclature," by Alpheus Hyatt; Am. Nat., vol. xxii, p. 872, 1888. Also "Genesis of the Arietidæ." Mem. Mus. Comp. Zool., vol. xvi, no. 3, 1889.

produced by a single pair of muscles extending across the ante-lateral region of the visceral area, and by the contraction of these, the valves are closed. The *transmedian* impressions, are made by a triple muscle, one band of which is on one side of the visceral area, the other two on the other side, the two lateral components crossing each other in passing from the posterior region of the pedicle-valve to the medio-lateral region of the opposite valve. By the action of these muscles the animal is able to slide apart the anterior and posterior extremities of its valves. The muscular region in each valve is surrounded by the *parietal* bands, which leave more or less distinct impressions upon the shell.

"The anterior internal surface of each valve bears traces of two strong pallial sinuses, which nearly meet in the axial line before reaching the anterior margin. In front and behind are radiating vascular markings.

"Shell substance composed of alternating lamellæ of chitinous and calcareous material.

"Type *Lingula anatina* Lamarck." (Hall, *op. cit.*)

Species of this genus had their origin in the St. Croix formation,* and thence lived through all geologic times. Several species are still living, usually in shallow water, of which *L. anatina*, the type of the genus, is the most abundant and widely distributed.

LINGULA ELDERI *Whitfield.*

PLATE XXIX, FIGS. 1-4

1875-77. *Lingula quadrata* WINCHELL (non EICHWALD). Fourth Annual Report of the Geological and Natural History Survey of Minnesota, p. 49.

1880, June. *Lingula elderi* WHITFIELD. American Journal of Science, third ser., vol. xix, p. 472, figs. 1, 2.

1880, July. *Lingula minnesotensis* N. H. WINCHELL. Eighth Annual Report of the Geol. and Natural History Survey of Minnesota, p. 61.

1882. *Lingula elderi* WHITFIELD. Geology of Wisconsin, vol. iv, p. 345, pl. XXVII, figs. 1-5.

1892. *Lingula elderi* HALL. Palæontology of New York, vol. viii, pt. i, p. 11, pl. L, figs. 21, 22.

Original description.—"Shell oblong and subquadrangular in outline, with nearly or quite parallel lateral margins, which are but very slightly curved; anterior and posterior extremities subequal, the upper end being slightly angular at the apex and on the shoulders, while the front or posterior end is broadly rounded. Valves rather strongly convex, the dorsal or shorter valve being a little the more convex and the valve, as shown by the cast, frequently marked by a slight flattening, or even by a depressed longitudinal line along the middle of the front half." Surface of the shell nearly smooth and glossy, marked by fine concentric lines of growth

* This statement is based largely on professor James Hall's late investigations as given on p. 6, Paleontology of New York, vol. viii. 1892.

and still finer radiating lines. These give to the surface a minutely crenulated appearance; also several distinct radiating lines over the anterior half of the valves which interfere somewhat with the rounding of the concentric lines.

"In the dorsal valve the impressions of the pallial sinuses [vs] are deeply marked and are widely separated, leaving the area within them very considerable; the central or inner ramifications [v] are very distinct, and the outer ones also for a short distance from the main branches, while the posterior branches show the lateral ramifications only on the outer side. The divaricator [umbonal] muscular scar of the dorsal valve [g] is very large and curved forward at the sides, being situated well back near the apex of the valve. It cannot be positively traced on the ventral side, most of the specimens being imperfect at this point. The anterior adductor [anterior laterals] scars [j] are small and situated near the center of the valve, while the posterior adductors [h, central scars] are large and situated outside of and posterior to them so as to inclose their posterior ends. The adjustor [lateral, middle and transmedian] muscles [l i k] are distant from each other, and placed just within the posterior third of the length of the shell. Two elements can be detected in each scar on some individuals, but they are usually obscure.

"On the ventral valve the lines of the pallial sinuses are nearer together on the anterior half of the shell than on the dorsal, the same as shown in *L. anatina*, but spread out rapidly toward the middle, and, on the posterior half, occupy nearly the same relative position as on the other side. Near the center of the valve are seen a pair of large [central] scars [h], which have advanced from behind their track, forming a strong feature on the cast, as it originates just in front of the position of the divaricator [umbonal] muscular scar [g], and gradually widens as it advances until it occupies fully one-half of the width of the cast near the middle of its length. In the central line of these scars there is an elevated ridge, which terminates in a slightly prolonged tongue, and seems to represent the central adjustors [middle laterals, k]. The large scars outside of these are probably the posterior adductors and external adjustors combined. Posterior to these and distant from the median line are other scars, which are long and narrow, which have also left their track as they have advanced. Two elements are represented on each side, and mark the place of the posterior adjustors and anterior adductors [anterior, laterals and transmedians, j i]. Between the lines formed by the advance of the scars of the adjustor muscles and those of the central area, on each valve, there is a narrow smooth impressed space which unites with the line of the pallial sinuses at the junction of the anterior and posterior branches, seen on all the specimens, and for which I have not been able to satisfactorily account, as it lies within the area of the muscular scar, and consequently within the walls of the perivisceral chamber. The areas of attachment of the muscular walls of the perivisceral chamber has not been detected, unless it be combined with the scar of the posterior branches of the pallial sinuses, which really seems to be the case. If this is so, the posterior branches of the sinuses can have had ramifications on but one side instead of on both, as in the case of *L. anatina*. This would be a marked specific but not a generic character."

There is considerable variation in the outline of this species, some being short and wide, while others are long and comparatively narrow. Specimens with the shell adhering to the limestone show that the valves near the edges are considerably flattened, giving the shell a greater width than the casts of the interior indicate. These specimens greatly resemble *L. quadrata*, as figured by professor Hall (Pal. New York, vol. i, pl. LXXIX, figs. 1*a*. 1*b*), and in several cases we have seen the species labeled in this way. *L. elderi* can be distinguished readily from that species by the absence of a well-developed median septum in the interior of the dorsal valve. In *L. quadrata* Hall=*L. rectilateralis* Emmons, the septum is usually indicated externally by a strong central depression. By washing and picking away the adhering portion of the shell, casts of the interior of *L. elderi* Whitfield, can be made to show the muscular scars, and the delicate detail of the ramification of the vascular trunks.

Formation and locality.—Common in the Trenton limestone at Minneapolis, Wanamingo, Oxford Mills, Fountain, and Rochester, Minnesota; Beloit, Wisconsin. A single example of this species was also found near the base of the Galena* shales on St. Anthony Hill, in the city of St. Paul, Minnesota. In the Salmon River or Cincinnati group at Cincinnati, Ohio, and at Covington, Kentucky.

Collectors—W. D. Hurlbut, Wm. Howling, C. L. Herrick, H. V. Winchell, W. H. Scofield, and the writers.

Mus. Reg. Nos. 291, 786, 3499-3503, 5009, 5010, 5061, 5133, 5668.

LINGULA EVA *Billings.*

PLATE XXIX, FIGS 5 and 6.

1861. *Lingula eva* BILLINGS. Canadian Naturalist and Geologist, vol. vi, p. 150.
1863. *Lingula eva* BILLINGS. Geology of Canada, p. 141, fig. 73.

Original description: "Shell from one to one and a half inches in length, greatest width near the front margin, thence gradually tapering with nearly straight sides until within one-fourth of the length from the beak, from which point the sides rapidly converge to the beak; apical angle about 90°; both valves rather convex along the middle, thence descending with a flat or gently convex slope to the sides and front margin. Surface with distinct sub-imbricating concentric ridges and fine striæ, and when partially exfoliated obscure longitudinal striæ are visible.

* For a definition of this and other stratigraphic terms consult the introductory chapter.

"The width at one-fourth the length from the beak is usually one-fourth less than it is at one-sixth the length from the front margin. The following are the measurements of a specimen of the ordinary form:

"Length, 12¼ lines; width at 3 lines from beak, 6½ lines; width at 2 lines from front, 9 lines.

"The largest specimen found measures nearly one inch and a half in length."

The surfaces of the valves from the mid-length to the anterior margin are marked by a few prominent radiating, continuous, or intermittent striations. The concentric growth lines in passing the radiating striæ are more or less reflexed posteriorly.

Of this species we have seen but a single example in a good state of preservation. It was discovered some years ago by Mr. W. H. Shelton, and is from the Trenton Shales near St. Charles in Winona county, Minnesota. The rather strongly convex valves without indications of a median depression, and the gradually diverging lateral outline, will readily separate it from *Lingula quadrata* Hall,=*L. rectilateralis* Emmons.

Formation and locality.—From the Trenton shales, in section six, Fremont, Winona county, Minnenesota. Also in the Black River formation of Murray bay, lower St. Lawrence river, Canada.

Mus. Reg. No. 4973.

Lingula philomela *Billings.*

PLATE XXIX, FIGS. 7, 8.

1862. *Lingula philomela* Billings. Palæozoic Fossils, vol. i, p. 49, fig. 53.
1863. *Lingula philomela* Billings. Geology of Canada, p. 161, fig. 133.
1892. *Lingula philomela* Hall. Palæontology of New York, vol. viii, pt. i, pl. i, fig. 8.

Original description.—"Very elongate oval; width a little less than half the length; front margin rather narrowly rounded with a small space in the middle straight or sinuate; sides for about two-thirds the length straight or very gently convex; the apical extremity appears to be obtusely angular, but this still remains doubtful, as no specimens with this part perfect have been collected. The shell is rather strongly convex, most prominent at or about the mid-length. There is a shallow concave sinus extending all along the median line from near the apex to the front margin. Surface with fine crowded imbricating striæ of variable size, the smaller just visible to the naked eye, and the larger partaking of the nature of squamose interruptions of growth. Color in the black limestone black. A specimen in gray limestone showing the interior in a state of exfoliation is light grayish-brown, but this may be owing to some circumstance in the fossilization of the shell.

"Length 16 lines; width 7 lines."

The figure of this species, as given by Billings, shows a strong median sinus, which does not reach the anterior margin, but in the description, it is said that the "shallow sinus extends all along the median line from near the apex to the front margin," and that the latter is "straight or slightly sinuate" in the middle. Since the example before us agrees with the original description, we do not hesitate to identify this species as occurring in the Northwest. This example and the one figured by professor Hall, like the Canadian specimens, are broken along the cardinal line, and must have been "obtusely angular," as the earlier lines of growth are semicircular in outline, or *Paterina*-shaped, and not much crowded laterally. The shell substance is thick, and composed of many corneous and calcareous layers, with the surface glossy.

Formation and locality.—From the lower portion of the Hudson River group, or Loraine shales, in a small quarry on the north side of the Upper Iowa river, about two miles west of Granger, Minnesota. Mr. E. O. Ulrich reports the species from the same horizon near Wykoff. The original specimens were found in the Trenton limestone, at Montmorenci falls, and Island of Montreal, Canada.

Collector.—The specimen here figured was found by Mr. R. H. Hasse, and kindly donated by him to the survey collection.

Mus. Reg. No. 7671.

LINGULA RICINIFORMIS *Hall.*

PLATE XXIX. FIG. 9.

1847. *Lingula riciniformis* HALL. Palæontology of New York, vol. i, p. 95, pl. XXX, figs. 2*a*, 2*b*, 2*c*.
1892. *Lingula* (*Glossina*) *riciniformis* HALL. Ibidem, vol. viii, pt. i, pl. I, fig. 3.

Original description.—"Oval, convex, slightly attenuated towards the beak, which is obtuse; surface nearly smooth, or with fine nearly obsolete concentric lines. Fine radiating striæ are sometimes visible; and the surface is sometimes slightly ridged, as if from elevated lines beneath the outer lamina of the shell."

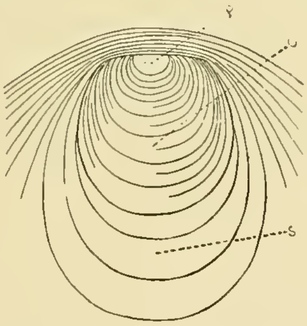


FIG. 24. Stages of *Lingula riciniformis*. *p.* protegulum; *o.* obolella: *s.* nealogic.

Our specimens of this species show three distinct stages of development; the first shelled condition, or "protegulum,"* which is not distinct, owing to its very

*For a definition of this term, and description of the earlier stages of growth in Brachiopoda and their importance in classification, see Dr. C. E. Beecher's valuable papers on "Development of the Brachiopoda," American Journal of Science, April, 1892.

small size; second, a very sharply defined circular stage, which is of a lighter color than the shell surrounding it. This second growth has been appropriately called the *Obolella* stage, and around it the shell begins to assume its specific form, growing most rapidly in the anterior region, and but comparatively little laterally and posteriorly. At maturity, the apex is no longer marginal, as in the *Obolella* stage, but has become submarginal through the addition of shell substance posterior to the protegulum. These stages of growth indicate that the course of development of *Lingula* is through *Paterina—Obolella—Lingula.*

This species can be separated readily from *Lingula attenuata* Hall (non Sowerby) =*L. daphne* Billings=*L.* (*Glossina*) *trentonensis* Conrad, sp., by its oval form and obtuse beaks. The latter is also more attenuated towards the apex, and is now referred to the sub-genus *Glossina,* Phillips. *L. elongata* Hall differs in being twice the size of *L. riciniformis.*

Formation and locality.—Near the base of the Galena shales, associated with *Zygospira recurvirostris* Hall. A single example has been discovered at Minneapolis, while from St. Anthony Hill, a suburb of St. Paul, Minnesota, a number of specimens have been procured. Also in the Trenton at Middleville, New York, and Charlesbourg, Canada.

Collector.—C. L. Herrick.

Mus. Reg. No. 785.

Lingula riciniformis, var. galenensis *W.* and *S.*

PLATE XXIX, FIGS. 10 and 11.

1892, April 1. *Lingula riciniformis,* var. *galenensis* W. and S. American Geologist, vol. ix, p 284.

The conspicuous differences between *L. riciniformis* Hall and this variety are that the former is constantly two-thirds the size of the latter, and that the greatest width is across the center of the length of the valves, while the variety is widest in the anterior third. In the Galena horizon at Oshkosh, Wisconsin, this variety is not rare, and attains twice the size of *L. riciniformis* Hall.

Formation and locality.—From the Galena shales of the north branch of the Zumbro river, at the upper bridge, near Kenyon, and near Fountain, Minnesota. Also from the Galena horizon at Neenah and Oshkosh, Wisconsin.

Collectors.—W. H. Scofield and Charles Schuchert.

Mus. Reg. Nos. 7672, 7673.

Lingula modesta *Ulrich.*

PLATE XXIX, FIG. 41.

1889. *Lingula modesta* Ulrich. American Geologist, vol. iii, p. 382, figs. 4–4*b*.

Original description: "Shell small, subovate, widest in the anterior half, the width and length, respectively, in four representative cases, 3.5 to 5.2, 5.5 to 8, 7 to 10 and 7 to 11, the figures representing the dimensions in millimeters. Both valves with exceedingly little convexity, appearing in most cases, perfectly flat. Anterior third or half usually uniformly rounded. Front margin occasionally somewhat straightened. Sides gently convex to near the beak which, in none of the numerous specimens examined, seems ever to have formed an acute termination. Surface with only very faint concentric undulations; even these are quite obsolete, when the shell is preserved in a shaly or impure limestone matrix."

Formation and locality.—Rather rare near the base of the Hudson River group near Granger and Wykoff, Minnesota. It also occurs at Graf, Iowa, and Cincinnati, Ohio. Also in the middle and upper portion of the Trenton at Frankfort and Paris, Kentucky.

Collectors.—E. O. Ulrich and C. Schuchert.

Lingula clathrata, *n. sp.*

PLATE XXIX, FIGS. 42.

This little *Lingula* is, in form and convexity of valves, much like *L. riciniformis* Hall, except that it is somewhat wider posteriorly. Like that species, this one also shows plainly the Obolella stage of growth. It is, however, much smaller than that species, besides differing from it and all associated species of *Lingula* in having from twenty-two to twenty-eight wavy, imbricating, transverse lines crossing the marks of growth and restricted to the external shell layer. These lines begin to appear on the medial portion of the valves quite close to the apex, or during early nealogic growth. They are closely arranged and gradually become more distant and extend across the valve from side to side. Those which are continuous from one margin to the other occupy but a small portion of the shell, becoming disunited medially at about one-third the length of the valve from the apex and cease to be developed a short distance beyond mid-length or may be continued to near the anterior margin.

Interior characters not defined beyond a low median septum extending for two-thirds of the length of the shell from the apex.

Length and breadth of an ordinary specimen 4.5 mm. and 2.5 respectively.

The transverse surface lines appear in a number of other forms occurring in older and younger formations. The earliest species with it known to us is *Lingulella stoneana* Whitfield* of the St. Croix formation. The next younger one is the species here described followed by *Lingula tæniola* Hall and Clarke† of the New York Clinton. The latter species possesses this feature very strongly developed, obscuring the concentric growth lines, and "are equally visible on the inner side of the shell, a character not seen in the other forms. Of precisely the same character is the ornamentation in *L. zebra* Barrande from the Bohemian Etage E."‡ *L. spathata* of the Lower Helderberg also has these lines sharply developed and more closely arranged than

*Geol. Wisconsin, vol. iv, p. 344, pl. xxvii, figs. 6, 7; 1882. †Pal. N. Y., vol. viii, pt. i, p. 18; 1892. ‡Ibid., p. 18.

the others. In several species of recent *Discinisca* such as *D. strigata* Broderip and *D. lævis* Sowerby the same kind of transverse lines are usually present on the ventral valve, orginating on each side of the pedicle slit, curving outwardly and terminate on the anterior third of the shell. In the above species of *Lingula* and *Lingulella* it is a constant feature in both valves, while in *Discinisca* it may or may not be developed in the same species and when present is restricted to the ventral valve.

Prof. Whitfield remarks that "the peculiar surface ornamentation of *Lingulella stoneana* seems to be one that characterizes many forms of this genus in the primordial formations." Since *Lingula* is a development from *Lingulella* the presence of the transverse lines in species of the former genus seems to indicate that they have acquired it through heredity rather than its being a sporadic development. If this inference is the correct one it seems to call for some recognition in a future classification of species of *Lingula*.

Prof. Whitfield also calls attention to a homologous growth in *Lucina divaricata* and other pelecypods and thinks this feature to depend "on a series of changes in the mantle of the animal during the formation of the shell." While we do not doubt this growth being due to a deposition from the mantle, yet how shell can be secreted externally, posterior to the anterior edge by a "series of changes in the mantle" is not clear.

Formation and locality.—A number of specimens were found by Mr. Ulrich in the middle third of the Trenton shales at St. Paul associated with *Rhinidictya mutabilis*.

LINGULA COBOURGENSIS *Billings?*

PLATE XXIX, FIG. 12.

1862. *Lingula cobourgensis* BILLINGS. Palæozoic Fossils, vol. i, p. 50, fig. 54.
1863. *Lingula cobourgensis* BILLINGS. Geology of Canada, p. 161, fig. 132.

Original description: "Almost regularly oval; greatest width about the middle; length one-fourth greater than the width; anterior extremity uniformly rounded; apex obtusely angular; both extremities sub-equal; sides gently convex. Both valves are moderately convex, and one of them has sometimes an irregular furrow extending from near the beak along the median line for one-half or three-fourths the length. Color dark brown, with some shades of light brown or yellow; general aspect smooth and shining, with fine concentric undulations of growth, which become fine, elevated, sharp, closely crowded striæ, on each side; longitudinal striæ are visible on some specimens.

"Length, about one inch; width, about three-fourths of an inch; depth of both valves, three or four lines. Smaller specimens occur associated with the larger."

We have two imperfect and exfoliated specimens which appear to be of this species. *Lingula covingtonensis* Hall and Whitfield is sometimes regarded as identical with *L. cobourgensis.* An examination, however, will show that it is more broadly oval and has sharply elevated, rather distant, concentric lines. The striæ in *L. cobourgensis* are fine, elevated, sharp and closely crowded on the lateral slopes, while medially there are fine concentric undulations with occasionally some radiating lines.

Formation and locality.—Rare in the Trenton limestone at Minneapolis and Chatfield, Minnesota; Cobourg and Collingwood, Canada.

Collectors.—H. V. and N. H. Winchell.

Mus. Reg. Nos. 309, 3504.

Sub-genus GLOSSINA, Phillips.

1848. *Glossina*, PHILLIPS. Memoirs of the Geological Survey of Great Britain, vol. ii. pt. ii, p. 370.
1892. *Glossina*, HALL. Palæontology of New York, vol. viii, pt. i, pp. 5, 6, 15.

Species of this sub-genus differ from *Lingula* in having "an acuminate or sub-triangular form, in which the rostral area is very narrow, with long, sloping post-lateral margins, and a rounded or transverse anterior margin." (Hall, *op. cit.* p. 5.)

This sub-genus is restricted to Palæozoic rocks.

LINGULA (GLOSSINA) HURLBUTI *N. H. Winchell*

PLATE XXIX. FIGS. 13 and 14.

1880. *Lingula hurlbuti* N. H. WINCHELL. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 62.

Original description: ' Shell ovate, broadest in the anterior half, and pointed posteriorly; the sides approaching the apex with a gentle convexity; lines tangent to sides at one-third the length from the apex, form an angle of 72°; anterior angles obsolete. The exterior surface of the shell is marked by sharply elevated concentric plications, which stand perpendicular to the shell, and on the anterior third portion five occupy the space of one line, but towards the beak they are reduced in size and increase in frequency so as to become mere striæ. Where these are largest and perfectly developed, the intervening grooves are destitute of fine striations. These plications leave corresponding lines on the interior cast when the shell is exfoliated. There are no longitudinal radiations visible on the exterior, but on the cast near the front are exceedingly dim, interrupted lines visible under the lens, that possibly have the same origin, but these do not extend more than a line and a half from the front margin, and they cannot be seen even with the lens except under a favorable angle of reflected light.

"The most elevated portion is at one-third the length from the beak, but the convexity of the valve is moderate and regular.

"Dedicated to Mr. W. D. Hurlbut of Rochester, Minnesota, one of the earliest patrons of the Geological and Natural History Survey."

Recently Mr. W. H. Scofield found two other specimens of this species at the same locality in which the type was discovered. These specimens, however, add nothing to the interior characters, except that, near the anterior portion, the valves are strongly pitted, a feature, moreover, which is visible also on the type specimen.

L. hurlbuti differs from *L. crassa* Hall,* the only species with which it need be compared, in being twice the size, and in having strongly elevated and comparatively widely separated concentric lines of growth. In *L. crassa* Hall, which also is referable to Phillips's subgenus *Glossina*, the surface is described as being "apparently smooth, but, under a magnifier, exhibiting fine concentric and radiating striæ."

Formation and locality.—From the lower portion of the Galena limestone, in the quarries at Mantorville, and at Weisbach's dam near Spring Valley, Minnesota.

Collectors.—N. H. Winchell and W. H. Scofield.

Mus. Reg. Nos. 393, 7674.

Lingula (glossina) deflecta *W. and S.*

PLATE XXIX, FIGS. 15-18.

1892, April 1. *Lingula (Glossina) deflecta* W. and S. American Geologist, vol. ix, p. 284.

Shell of medium size, subtriangular; lateral margins diverging more or less rapidly from an acute apex, to the broadly rounded and deflected anterior third. Shell substance thick, and marked by strong, irregular, concentric lines of growth, between which are numerous finer ones. In profile the line of junction of the valves is more or less convex, dorsally. Ventral valve flat or slightly concave medially, and strongly convex transversely. On the interior of the ventral valve there is a distinct but slightly elevated median septum, which originates near the apex, and terminates somewhat beyond the center of the valve, in front of which are the small, middle lateral muscular scars. Upon each side of the median septum are the scars of the progressive central muscles, which gradually expand anteriorly, and terminate just above the middle lateral impressions. The vascular trunks bound the limits of the central scars, and meet just in front of the middle lateral impressions, where they are no longer defined. In front of these scars there is a low median elevation, with a broad shallow depression on each side, the latter being anterior to the vascular trunks and slightly pitted. Numerous irregularly radiating obscure lines back of the anterior margin.

* Pal. New York, vol. i, p. 98, pl. xxx, fig. 8; 1847.

Dorsal valve strongly convex, both transversely and longitudinally. In the interior of this valve, the cardinal margin is broadly flattened, striated, and divided centrally by a well defined, narrow depression, which terminates at a point one-fourth the length of the shell from the posterior edge. Near the posterior end of this depression are faint traces of the umbonal scar. The vascular trunks are discernible on each side and anterior to the rostral depression, and having the same curve as the outer margin of the valve, thence proceed to a point somewhat beyond the posterior half of the shell, where they gradually converge and meet near the anterior margin. Vascular branches originate only from the outer side of the vascular trunks. The enclosed space seems to represent the tracks of the anterior and central muscular scars.

The outline of this species and the convexity of the dorsal valve are variable. The broadly subtriangular specimens have more strongly convex dorsal valves than the narrow and less triangular form. There is no other species of *Lingula* from Lower Silurian strata having the peculiarly deflected anterior portion of the shell so characteristic of this species. *Lingula linguata* Hall* from the Clinton group is the only other American species with this peculiarity, and differs from *L. deflecta* in having parallel lateral margins.

Formation and locality.—From the shales near the base of the Galena group on the farm of Ole Hansen, near Fountain, and in the Hudson River group near Spring Valley, Minnesota.

Collectors.—E. O. Ulrich and C. Schuchert.

Mus. Reg. Nos. 7675, 7676.

LINGULA IOWENSIS *Owen.*

PLATE XXIX, FIGS. 19-22.

1844. *Lingula iowensis* OWEN. Geol. Rep. Iowa, Wisconsin and Illinois, p. 70, pl. XV, fig. 1.
1851. *Lingula quadrata?* OWEN (not Eich.). Geological Report of Wisconsin, Iowa and Minnesota, pl. IIB, fig. 8.
1862. *Lingula quadrata* HALL. Geology of Wisconsin, vol. i, p. 46, fig. 1, and p. 435.
1868. *Lingula quadrata* MEEK and WORTHEN. Geological Survey of Illinois, vol. iii, p. 305, pl. II, fig. 4.
1882. *Lingulella iowensis* WHITFIELD. Geology of Wisconsin, vol. iv, p. 242, pl. IX, fig. 1.
1892. *Lingula iowensis* HALL. Palæontology of New York, vol. viii, part i, p. 8, pl. I, fig. 14.

Original description: "Resembles *L. lamellata* H., of the Niagara group, but is larger and straighter on the lateral edges. It differs from *L. rectilateris* [probably meant *L. rectilateralis* Emmons], in being flatter and not so pointed at the apex."

From the figure given by Owen, we cannot be positive in the identification of this species, but since comparison is made with *L. rectilateralis* Emmons, in the

* Pal. New York, vol. viii, p. 173, pl. IVK, fig. 5; 1892.

description, there can be no doubt that the name *L. iowensis* was applied by him to the widely distributed and characteristic *Lingula* of the Galena horizon. Professor Whitfield was the first to make use of Owen's name; the following is a copy of his description, with our additions: "Shell large, broadly ovate, elliptical or subquadrate in outline, generally a little narrower above the middle of the length than below; upper end very obtusely angular, the cardinal slopes forming an angle with each other of about one hundred and twenty degrees; sides of the shell gently rounded, and the basal line more sharply rounded, but never truncate. Valves convex, the ventral most strongly so, and generally subangular along the middle. Ventral beak projecting a short distance beyond the dorsal, and more pointed. The cardinal margins of the ventral [as well as the dorsal] valve are infolded along their border, forming an imperfect cardinal area of a very perceptible width on well-preserved specimens." These areas are striated, and immediately below the apex of each valve, the arched striæ meet, forming in the ventral valve a very slight linear elevation.

Gutta-percha impressions made from natural casts of the interior of the dorsal valve show a pronounced median septum, which is but slightly developed near the posterior end of the valve, and extends somewhat beyond the center of the shell, where it is strongly elevated, and terminates abruptly. On each side of the septum, for two-thirds of its length, are well-defined, progressive, concrete lateral, and central muscular scars. In the ventral valve, the median septum is faintly indicated, and does not extend beyond the progressive, lateral muscular scars, which are one-third the entire length of the valve. In front of these impressions, at the anterior end of the septum, are the small, middle lateral scars, which extend somewhat beyond the central muscular imprints on each side.

"Surface of the shell marked by strong, irregular lines of growth at irregular distances, the outer margins of which are slightly raised and free, presenting a strongly lamellose appearance under a magnifier; the spaces between being smooth and often polished. On exfoliated specimens, and more distinctly on internal casts, the surface is very strongly radiated by fine flattened, but irregular striæ for from one-third to one-half the length of the shell, and on nearly the entire width along the basal line; but a little higher on the sides they lose their regularity and become broken and wrinkled as well as more strongly divergent." The striæ are confined to the internal surface of the valves.

Lingula cincinnatiensis Hall and Whitfield is a closely related species, and may be a direct descendant from *L. iowensis* Owen. It differs from the latter in being usually more robust, the valves deeper or more convex, and in having the posterior portion of the shell more pointed.

Lingula quadrata, as identified by Hall,* and Billings,† we regard as identical with *L. rectilateralis* Emmons.‡ This species occurs in the Trenton, Utica slate and Loraine groups of New York and eastern Canada, and differs but slightly, if any, from *L. iowensis* Owen. The characteristic striated hinge areas of *L. iowensis* Owen and *L. cincinnatiensis* Hall and Whitfield have not been observed in *L. rectilateralis* Emmons. Should these parts eventually be discovered in the latter species, *L. iowensis* Owen will then give place to *L. rectilateralis*, as the latter has two years' priority over the former. Professor Hall in 1847** regarded Emmons' species as a synonym of *L. quadrata* Eichwald, while Whitfield†† regarded this form as identiccal with *L. iowensis* Owen.

We have seen four specimens of typical *Lingula quadrata* Eichwald from Esthonia in the collection of Mr. Ulrich, and these prove beyond a doubt that none of the American forms identified with this species are correctly named. The Russian species is larger, with very strongly convex valves and a more narrowly rounded anterior margin than in *L. iowensis*, *L. rectilateralis*, or *L. cincinnatiensis* Hall and Whitfield.

Formation and locality.—Throughout the Galena horizon of Wisconsin, Iowa and Minnesota. Some of the more prominent localities of Minnesota are Fountain, Mantorville, Kenyon, Aspelund and Hader.

From the Hudson River group near Wykoff and Spring Valley, Minnesota, Mr. Ulrich has collected four specimens which apparently cannot be separated from this species. They may, however, prove to be dwarfed or young individuals of *Lingula beltrami*, since this species also occurs in the above mentioned region.

Collectors.—W. H. Scofield, A. D. Meeds and the authors.

Mus. Reg. Nos. 2372, 3389, 7677–7680.

LINGULA BELTRAMI, *n. sp.*

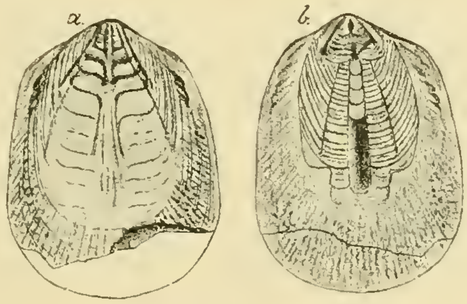


FIG. 25. *Lingula beltrami.*

In form and convexity of valves this species closely resembles *L. iowensis*, but attains a larger size with greater convexity of valves and a more subquadrate anterior margin. From *L. cincinnatiensis* Hall and Whitfield§ it can readily be distinguished in being wider, with valves not quite so convex and the cardinal slopes

*1847. Pal. New York, vol. i, p. 96, pl. XXX, fig. 4; p. 285, pl. LXXIX, fig. 1.
†1856. Canadian Naturalist and Geologist, vol. i, p. 319, fig. 8.
‡1842. Geology of New York; Report of the Second District, p. 399, fig. 6.
** Loc. cit., p. 285. †† Loc. cit., p. 242
§ *Lingulella (Dignomia) cincinnatiensis* Hall and Whitfield, Pal. of Ohio, vol. ii, p. 67, pl. I, figs. 2, 3; 1875.

more obtuse. The ventral valve in *L. iowensis* and *L. beltrami* is also less convex than the dorsal, while in *L. cincinnatiensis* and *L. quadrata* Eichwald (non Hall) they are equally deep, but the latter is more so than the former. In all of these species there is on the lateral slopes in the anterior half of the interior a more or less conspicuous wrinkling of the shell which may represent the vascular markings of other species of *Lingula*.

Formation and locality.—Four specimens have been found by Mr. Ulrich in the Hudson River group between Wykoff and Spring Valley, Minnesota.

LINGULA CANADENSIS *Billings?*

1862. *Lingula canadensis* BILLINGS. Palæozoic Fossils, vol. i, p. 114, fig. 95.
1863. *Lingula canadensis* BILLINGS. Geology Canada, p. 210, fig. 209.
1889. *Lingula? (Lingulasma?) canadensis* ULRICH. American Geologist, vol. iii, p. 384.

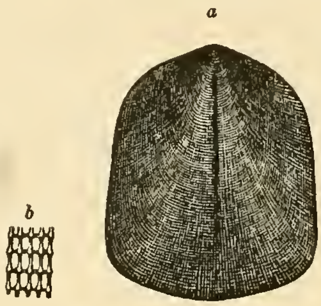


FIG. 26. Copy of Billings' original figure of his *Lingula canadensis.*

Original description: "Shell large, oblong, subpentagonal; front margin gently convex or nearly straight; anterior angles narrowly rounded; sides straight and nearly parallel for about two-thirds the whole length, then converging to the beaks; apical angle about 130°; cardinal edges on each side of the beak nearly straight. The valves are moderately convex, most tumid in the upper half, descending to the sides and front margin with three flat slopes. Surface with fine, thread-like, elevated, longitudinal ridges, five or six in the width of one line at the front margin; these are crossed by much finer concentric ridges, ten or twelve in one line, which are continued over the longitudinal ridges and give to the surface a minutely nodulose appearance."

The material upon which the above identification is based is rather fragmentary, consisting of two small broken individuals, and a piece of the lateral portion of a large specimen. These are not altogether identical in outline with the figure given by Billings, but since the surface ornamentation of *L. canadensis* is like that of the Minnesota specimens it has seemed best to refer them provisionally to this species rather than separate them under a new name. *L. tenuigranulata* McCoy* is another closely related species, but it and *L. canadensis* have three flattened slopes, another character not seen in the Minnesota material.

Formation and locality.—Lower portion of the Galena limestone, in the quarries at Mantorville and near Hader, Goodhue county, Minnesota. The type specimens are from the Hudson River group of Anticosti.

Collectors.—W. H. Scofield, E. O. Ulrich and C. Schuchert.

Mus. Reg. Nos. 7681, 7682.

Family LINGULASMATIDÆ, n. fam.

Genus LINGULASMA, Ulrich.

1889. *Lingulasma*, ULRICH. American Geologist, vol. iii, p. 383.
1889. *Lingulelasma*, MILLER. North American Geol. and Pal., p. 350.
1892. *Lingulasma*, HALL. Palæontology of New York, vol. viii, pt. i, pp. 24, 46.

Shell subquadrate, linguliform, inequivalve; the dorsal valve considerably the deeper. Beaks apical, that of the ventral somewhat extended beyond the dorsal; cardinal margins gently sloping to the sides. Surface with the concentric striæ raised at irregular intervals into points, these being arranged in radiating lines.

Interior of the ventral valve with a low concave or concavo-convex platform occupying from less to more than one-half the length of the shell; the anterior wall may or may not be profoundly excavated. The ventral area has been enclosed more or less within the shell, making a distinct sheath or shelf, beneath which is the umbonal scar. Platform occupied by the progressive anterior, external and middle lateral scars. Transverse scars present underneath the platform at its antero-lateral angles. Crescentic scars scarcely defined.

The dorsal valve deep, with a high platform occupying the posterior third or one-half of the valve, centrally produced into a short or very long septum. The anterior walls of the platform are more or less excavated, deepest close to the septum; marked by vascular sinuses laterally directed. The crescent is more or less strongly developed, with its center sharply pointed posteriorly. In front of it is the umbonal scar, and in the type species there is anterior to the latter impression a short, sharp, median septum. Platform occupied by the lateral, transmedian, central and anterior muscular scars. Transverse scars situated at the base of the platform at its antero-lateral angles.

Type: *Lingulasma schucherti* Ulrich.

Lingulasma and *Lingulops* are the only linguloid genera in which interior platforms are developed, and in this remind one strongly of the same parts in the

*See Davidson's British Silurian Brachiopoda, p. 37, pl. ii, figs. 9-14.

Trimerellidæ. We do not regard these genera, however, as in the direct line of development towards *Trimerella*, but rather as a branch from *Lingula*, probably having its origin during Trenton times, and terminating with the Niagara formation. In the Black River group, at Pauquette Rapids of the Ottawa river, in Canada, we find *Obolus canadensis*, and *O. magnificus* Billings. These species Billings subsequently referred to his genus *Obolellina*, now regarded as synonymous with *Dinobolus*, Hall. In the Galena formation of Wisconsin and Minnesota, there is another form related to the above species, *Dinobolus parvus* Whitfield. These species were in all probability derived from *Obolella*, while *Monomerella* and *Trimerella* had their origin in *Dinobolus*. If this opinion is the proper one, *Lingulops* and *Lingulasma* should be separated from the *Lingulidæ* and *Trimerellidæ*, and referred to a new family, the *Lingulasmatidæ*. This family will then follow the *Lingulidæ*.

Lingulasma galenensis.

PLATE XXX, FIGS. 1-4.

1892, April 1. *Lingulasma galenensis* W. and S. American Geologist, vol. ix, p. 285.

Shell large, oblong, subpentagonal. Anterior margin slightly convex, and somewhat produced in the center; anterior angles narrowly rounded; lateral margins straight, nearly parallel, rounding rapidly into the more or less convex postero-lateral margins. Ventral beak somewhat extended beyond that of the dorsal valve. Valves strongly convex, dorsal more than the ventral; point of greatest convexity, in the former at one-third the entire length of the valve from the posterior margin, in the latter nearly central. Surface of each valve with three slopes in the anterior half; the central one flat or very slightly convex, with two broad and shallow depressions, causing a small central extension of the anterior margin; lateral sides very rapidly descending and somewhat convex. Surface concentrically striated; at irregular intervals the striæ rise into small pointed pustules radially arranged. These radial series of granulations are most prominent on the flattened, central, anterior portion of the valves; thirteen to fifteen of them in 5 mm., while twenty-eight pustules occupy the same length, measuring along a series.

Interior of ventral valve with a diamond-shaped concavo-convex platform, strongly elevated, and excavated anteriorly. Posterior margin of the specimen slightly broken; an internal arched deltidium not present. Umbonal scar (*g*) close to the posterior broken edge, and upon each side of it is a diverging excavated ridge. In front of the umbonal scar, and occupying the lateral portions of the platform, are the progressive tracks of the lateral (*l*) scars. At the posterior end of the platform are two slightly diverging, linear depressions, which terminate near the mid-length of the platform; and here originate two linear and parallel median elevations, On each side of these are large shallow depressions, the middle lateral (*k*) scars. Transverse scars present at the base of the platform, at its antero-lateral angles. A broadly rounded, slightly elevated, median septum has its origin underneath the anterior end of the platform, and terminates at a point two-thirds the entire length of the valve from the posterior margin. The inner surface of both valves not occupied by the platform is marked by faint concentric undulations and radiating striations; the latter are conspicuous on the lateral portions.

Interior of dorsal valve with a concave platform occupying the posterior third, more or less defined laterally, profoundly elevated, and excavated anteriorly. Anterior edge of the platform produced in the center and supported by a short septum, which terminates at about the center of the valve. Underneath the platform, on each side of the septum, are well-defined vascular sinuses, laterally directed. Near the apex of the posterior margin is situated a small crescent (*ct*), and in front of it is a well-defined umbonal (*g*) scar, the anterior edge of which is strongly raised above the platform. Sides of the platform occupied by the lateral (*l*) scars. On the inner sides of the latter are situated the central (*h*) scars, leaving between them a median triangular space. The anterior produced portion of the platform occupied in part by the anterior (*j*) muscles. At the antero-lateral angles of the platform, and indenting it, are situated the strongly defined transverse (*t*) scars.

Length of the largest specimen, 35 mm.; width 28 mm.; thickness, 19 mm.; another specimen measures respectively 27x22x14 mm.

This species differs from *L. schucherti* Ulrich, the only other species of the genus, in that the dorsal valve is deeper, platform and median septum shorter, and the crescent smaller. In the ventral valve, the platform is also shorter and is of an entirely different shape. The muscular scars of this species are likewise more distinct than in *L. schucherti*, while the interior ventral area is absent in *L. galenensis*.

The posterior margin of the ventral valve in the two specimens of this species is somewhat broken, but it is certain that this valve extended beyond the dorsal, since the outline of the latter is distinctly visible. If an enclosed ventral area had been developed in this species, such as is present in *L. schucherti*, there should be evidence of it in these specimens. Since there is no proof of this nature, we are of the opinion that the ventral area was mainly external in *L. galenensis*, and that during the succeeding geological horizon, the Hudson River group, it receded more and more internally.

Formation and locality.—Near the top of the Galena limestone on Bear creek, just south of Hamilton, Fillmore county, and near the middle of this formation near Mantorville, Minnesota. Also in the Galena limestone at Decorah, Iowa, and at Neenah and Oshkosh, Wisconsin.

Collector.—Charles Schuchert.

Mus. Reg. Nos. 7683–7686.

Dinobolus (?) parvus *Whitfield.*

1882. *Dinobolus (?) parvus* Whitfield. Geology of Wisconsin, vol. iv, p. 347, pl. xxvii, figs. 8–10.

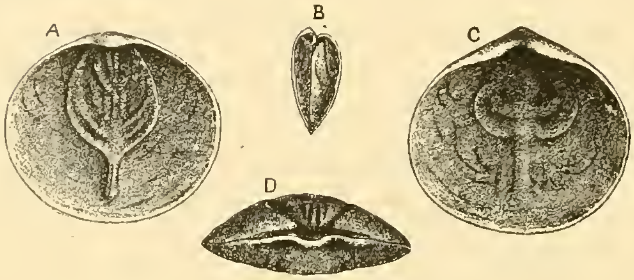


Fig. 27. *Dinoblus (?) parvus* Whitfield. A, interior of the dorsal valve as seen in a gutta-percha impression, × 2; B, profile view of a cast of the interior, with the thickness and form of the shell indicated by the outer line, natural size: C, gutta-percha impression showing the internal characters of the ventral valve, × 2; D, cardinal view of the cast of the interior, × 2.

Description: Shell small for the genus, subcircular in outline, lenticular in profile, with the dorsal side somewhat more convex than the other, and both more ventricose posteriorly than anteriorly. Posterior margin broadly triangular, curving rapidly in the lateral portion to the broadly rounded anterior edge. Each valve with a narrow false cardinal area, that of the ventral valve larger and slightly produced beyond the dorsal into a samll, acute and but little incurved beak, beneath which there appears to have been a narrow, concave triangular depression.

A gutta-percha impression of the dorsal side of a cast of the interior shows a large concave muscular area or platform, oval in outline and produced anteriorly into a narrow but slightly elevated mesial septum which terminates near the anterior margin. Upon this platform, and occupying the greater portion of it, are the progressive scars of the lateral muscles, except antero-medially where the anterior scar is present; the posterior portion is occupied by two well-defined, parallel, narrow, elongate elevations, separated by a narrow sinus, the front of which may be homologous with the cardinal scars, and the latter with the anal depression of *Obolella.* A crescent so characteristic of *Dinobolus* does not appear to have been developed in either valve. Platform of the ventral valve but slightly elevated, subquadrate in outline, widest anteriorly, occupied by broad progressive tracks of the lateral muscles, and separated medially by the faintly elevated median scars. Anterior edge of platform not excavated. Within the cardinal margin of the ventral valve are two short, narrow, rapidly diverging ridges, probably cardinal scars, separated by a broad but short pedicle muscle impression.

Shell substance originally not very thick, apparently smooth and now replaced by a coarsely crystallized calcite, a feature common to many species of the Trimerellidæ.

Of this species we have but a single specimen from Minnesota, found by Mr. E. O. Ulrich, which is in an excellent state of preservation. The interior characters are shown in greater detail than appears to have been the case in the material from Wisconsin upon which Prof. Whitfield based the species, otherwise the example agrees with his description and illustrations. In size and form it is nearer to *Dinobolus schmidti* Davidson and King,* from the Lyckholmer Schicht at Kirna, Esthonia, a horizon nearly equivalent to the Trenton limestone of New York, than to *Obolellina canadensis* and *O. magnificus* Billings** from the Black River group of Canada. The latter, of which only the exterior is known, are also much larger species than *D.? parvus.*

The interior of *D.? parvus*, as revealed in the Minnesota specimen, is highly instructive, since it appears to have characters both of the *Obolidæ* and *Trimerellidæ*. The structure of the cardinal region is similar to that of *Obolella*, while the platform and its muscular scars are as in *Dinobolus*. The crescent so characteristic of *Dinobolus* is, however, absent in *D. parvus*. The diverging elevations on each side of the pedicle muscle scar in *Obolella crassa*, (the cardinal scars), are also present in *D.? parvus* and occupy a position equivalent to the crescent of *Dinobolus*. It may be that here is indicated the line of development of the crescent from the cardinal scar of *Obolella*. The combination of these characters in *D.? parvus* seems to require its separation from *Dinobolus*, but until the interior is known of the species referred by Billings to *Obolellina* it is better to leave it provisionally in the former genus. Lower Silurian species of *Dinobolus* are also known from Esthonia (*D. schmidti*) and Brittany (*D. brimonti* Rouault†), but these have well-developed crescents.

Formation and locality.—Middle Galena, Wykoff.

Collector.—E. O. Ulrich. Type in the collection of C. Schuchert.

*Quart. Jour. Geol. Soc. London, vol. xxx, p. 164, pl. xix, figs. 5, 6, 1874.
**Canad. Nat. Geol. vol. iii, p. 441. 1858; vol. vi, n. ser., p. 329, 1872.
†See Davidson's paper in the Geol. Mag., vol. vii, decade ii, p. 340, 1880.

Order NEOTREMATA, Beecher.

Sub-order DAIKAULIA, Waagen.

Family SIPHONOTRETIDÆ, Kutorga.

Genus SIPHONOTRETA, De Verneuil.

1845. *Siphonotreta,* De Verneuil. Géol. de la Russia d' Europe et des mont. de l'Oural, p. 286.
1892. *Siphonotreta,* Hall. Palæontology of New York, vol. viii, pt. i, p. 110.

Description.—"Shell elongate-oval, inequivalve; valves inarticulated. Pedicle-valve the more convex, with a straight, elevated, conical, and perforated beak, the circular foramen opening at the apex and communicating with the interior of the shell by a tubular canal, which narrows slightly as it passes inward. No cardinal area or deltidium is present, the growth-lines passing between the beak and the posterior margin as elsewhere on the shell. Brachial valve depressed-convex; beak marginal; posterior margin regularly arched and thickened. Interior of pedicle-valve with muscular impressions confined to the umbonal region. Close alongside the opening of the sipho, just within the cardinal margin, lie two elongate scars which are accompanied on either side by broader somewhat expanded or flabellate, simple and less distinct impressions. Directly in front of the middle pair lies a small central scar, in the axis of the shell, and at either side of it a transversely elongate impression. These latter impressions are distinctly separated from the former by a transverse ridge.

"In the brachial valve the impressions are equally concentrated, the entire muscular area being bounded on the posterior margin by a prominent ridge which, at the sides, merges into a compound lateral scar. The central portion of the area is much depressed and is divided axially by a narrow ridge or septum.

"Shell ornamented with concentric lines and ridges, the epidermal layer bearing hollow spines, which are distended at the base. Shell-substance calcareo-corneous, the layers beneath the epidermis being punctured by radiating and branching tubules, these layers are concentric and not parallel to the internal surface.

"Type *Siphonotreta unguiculata* Eichwald sp." (Hall, *op. cit.*)

Siphonotreta? minnesotensis *Hall.*

PLATE XXIX, FIGS. 23 and 24.

1892. *Siphonotreta? minnesotensis* Hall. Palæontology of New York, vol. viii, pt. i, pp. 112, 177, pl. 4, figs. 37, 38.

Original description: "Shell subovate in outline. Pedicle-valve more convex than the brachial, slightly flattened along the median line, sloping with equal convexity toward the lateral and anterior margins. Foramen apical (?). Brachial valve depressed-convex, somewhat elevated about the umbo. Surface covered, in the umbonal region, with fine, anastomosing and gently undulating concentric lines, which, in the latter portions of the shell, are finely granulose or serrated; at about one-third the length coarser varieties of growth appear, between which the finer lines are retained. Surface covered with hollow spines of various sizes, which appear to have been mostly set over the umbonal region of the pedicle valve. Here, where the growth lines are absent, the spine-bases in the original specimen are large and all of about the same size, and are disposed without order. Over the other portions of the shell the spines are set along the edges of the varices, small and large being indifferently mixed. The bases of the spines make annular swellings on the interior of the valve. The length of the original specimen is 15 mm., width, 12 mm."

Since no additional material has been discovered other than that used by professor Hall, we give in addition his observations on the species, with its relations to a similar form which is tentatively referred by him to *Schizambon*. "The American palæozoic faunas have yet furnished no thoroughly satisfactory representative of *Siphonotreta*. Before us are two specimens of a form allied to, but probably distinct from the Canadian representatives of *Schizambon* (?), referred to on a following page [*Siphonotreta scotica* Whiteaves=*Schizambon fissus* var. *canadensis* Ami (Hall)], which have been collected by Mr. Charles Schuchert and Mr. E. O. Ulrich, from the Trenton limestone at Minneapolis, Minnesota. One of these is an exterior mould, the other retains both valves, though the umbonal part of the pedicle valve has been broken, leaving no indication of the character of its foraminal aperture. The shell differs somewhat from the Canadian specimens in outline, being broader over the pallial region: the brachial valve shows a low longitudinal depression, the shell substance is very thin, while in the other species referred to, it is remarkably thick, and its lamellose structure conspicuously developed; the ornamentation of the surface consists, not of sharp, concentric lines, broadening to ridges toward the margin, but of fine, concentric, anastomosing wrinkles, which are interrupted over the body of the shell by the edges of the spiniferous lamellæ; the spines are comparatively short and sparse. Though recognizing the difficulties in the discrimination of species of *Siphonotreta*, we are nevertheless disposed to regard the above mentioned features as of specific value; and in the absence of evidence determining the character and position of the pedicle passage, it seems judicious to leave the species for the present under the genus *Siphonotreta*, with the designation *Siphonotreta minnesotensis*."

Formation and locality.—From the Trenton limestone near the University of Minnesota, Minneapolis, Minnesota.

Collectors.—E. O. Ulrich and Charles Schuchert.

Family LINGULELLIDÆ, Schuchert.

LEPTOBOLUS OCCIDENTALIS *Hall.*

1871. *Leptobolus occidentalis* HALL. Description n. sp. Foss. from the Hudson River group, p. 3, pl. III, fig. 18.
1872. *Leptobolus occidentalis* HALL. Twenty-fourth Report N. Y. State Cab. Nat. Hist., p. 227, pl. VII, fig. 18.
1892. *Leptobolus occidentalis* HALL. Pal. N. Y., vol. viii, pt. i, pl. III, fig. 7.

This species will probably be found in the lower portion of the Hudson River group of Minnesota, since it occurs in abundance in Iowa and Wisconsin. Mr. E. O. Ulrich has collected one specimen which may prove to belong to this species, but its position is such as to leave its identity in doubt.

Formation and locality.—In the lower portion of the Hudson River group at Hawley's mills or Graf, Iowa; Plattville and Clifton, Wisconsin; Ottawa, Canada (Ami). The specimen from Minnesota was found three miles north of Spring Valley.

Genus SCHIZAMBON, Walcott.

1884. *Schizambon*, WALCOTT. Monograph U. S. Geological Survey, vol. viii, p. 69.
1887. *Schizambonia*, ŒHLERT. Manuel de Conchyliologie, Fischer's, p. 1266.
1892. *Schizambon*, HALL. Palæontology of New York, vol. viii, pt. i, p. 113.

Original description: "Shell ovate or oblong-oval, inequivalve; valves inarticulate; larger or ventral valve most convex, with a short obtuse beak at the cardinal margin. Foramen oblong and opening on the summit of the valve; no area nor deltidium; cardinal edge thin; smaller or dorsal valve nearly as convex as the larger, slightly flattened along the median line.

"Structure calcareo-corneous, consisting of a nacreous outer layer with a closely attached inner calcareous layer. Both layers are thought to be punctured by scattering spines apparently on the outer edges of the laminæ or lines of growth.

"The interior of the larger valve shows the oblong foramen in a slight elongate depression and a pair of muscular scars just in front of it on each side of a slight longitudinal depression; from near the beak on each side of the foramen, a shallow sharply defined depression extends obliquely outward. No other markings were observed. In the interior of the dorsal valve a pair of anterior central muscular scars terminate their path of advance from the beak, a slight rounded ridge rising on the central line; posterior to these a large pair occur, and still beyond and more posterior a third pair, a narrow rounded edge extending obliquely down from the beak on each side between the central and lateral scars."

Type *Schizambon typicalis* Walcott.

Since the interior characters are unknown in *Schizambon? dodgii*, n. sp., and *S.? lockii*. n. sp., these forms are placed in this genus provisionally. *S. typicalis* is said to have a short, obtuse beak at the cardinal margin, and judging from the illustration, it seems that little growth took place posterior to the protegulum, or initial shell. While no mention is made in *S. typicalis* and *S.? fissus* var. *canadensis* Ami, of shell growth posterior to the protegulum, yet undoubtedly this feature will be found when looked for in specimens preserving these parts.

The line of development was probably as follows: From *Paterina* to a form having an open pedicle notch at the posterior end as in *Schizocrania* and *Trematis*, next to one where this notch is closed, leaving a more or less circular excentric pedicle opening, as in *Acrothele* or *Acrotreta;* thence to *Schizambon.*

Schizambon (?) dodgii, *n. sp.*

PLATE XXX, FIGS. 5-7.

Shell broadly oval, or nearly circular in outline. Dorsal valve evenly convex laterally and anteriorly; deeper than the ventral valve; point of greatest elevation about mid-length; centrally it has a shallow, concave, narrow sinus, which has its origin at the beak, thence slowly expanding in width, and traversing the entire length of the valve. Surface with numerous, concentric, variously terminating growth lines. Near the beak these lines indicate a *Paterina*-shaped nepionic stage. They are very delicate, the shell appearing smooth and shining, and gradually assume the contour of the mature outline of the valve, becoming stronger and stronger as full development is attained. Every second, third, or fourth line prominent, strongly imbricating, wavy along the edges, and terminating in long, slender, hollow(?), radiating spines. The intermediate concentric lines between the spiniferous ones are sharply elevated and finely crenulated. The spines begin to develop at a very early age, are remote, but become more and more crowded toward the anterior margin, where there are about sixteen in 3 mm., with an average length of 2 mm.

Ventral valve somewhat larger than the dorsal; curvature along the center not very marked, with the lateral slopes broadly convex. Beak marginal, slightly produced, elevated, with a small, false cardinal area beneath it. Pedicle furrow originating at the beak, narrowly triangular, 4 mm. in length, becoming deeply concave, with an opening into the interior of the shell, probably at its inner end. The nature of this opening and the interior characters of both valves are unknown. At the apex, the concentric lines are first Paterina-shaped; then growth obtains all around the initial shell, being more rapid anteriorly than posteriorly. It is during this second stage that the false cardinal area is formed, and the position of the pedicle opening changed. After the initial shell, the first few lines of growth along the posterior margin do not pass over nor around the pedicle, but stops on each side; therefore during this period, there is an open pedicle slit, which is afterwards closed posteriorly by the addition of shell matter underneath the pedicle. As the pedicle opening advanced, the shell was resorbed anteriorly, and a deposit formed posteriorly, as indicated by the strong convex lines in the pedicle furrow.

Schizambon? dodgii differs from *S.? fissus*, var. *canadensis* Ami*, in being smaller, more broadly oval, in having a dorsal sinus, and the spines shorter, thicker, and therefore less numerous. If *Siphonotreta? minnesotensis* Hall should prove to belong to *Schizambon*, it will still be found to differ from *S.? dodgii* in the much thicker spines and the many large openings in the shell on the posterior portion of the dorsal valve.

Formation and locality.—Two specimens and fragments of others were collected by Mr. W. W. Dodge, of Cambridge, Massachusetts, for whom the species is named, in a dark, compact limestone near the top of the Trenton at Sandy Hill, New York. Associated fossils are *Trematis terminalis* Emmons, and *Trinucleus concentricus* Eaton. The types were kindly presented to one of the writers.

SCHIZAMBON (?) LOCKII, *n. sp.*

PLATE XXX, FIGS. 8-10.

Shell large, very thin and broadly oval in outline. Dorsal valve shallow, not as deep as the ventral, and evenly convex laterally and anteriorly. Surfaces shining, nearly smooth, marked by fine, concentric growth lines and delicate, radiating striæ. At the apex the former are Paterina-shaped, but after this stage growth takes place more strongly anteriorly than laterally, which soon gives to the shell its specific form. At about two-thirds the length of the shell from the beak to the anterior margin, the fine, radiating striæ have numerous, very small, elongate, but distinct pustules, which probably did not terminate in spines.

Ventral valve most elevated at the beak, with gradual slopes laterally and anteriorly, and abrupt ones posteriorly. Apex obtuse, situated at about one-sixth the length of the shell from the posterior margin, with the pedicle furrow originating at the highest point, and gradually widening and extending forward not quite to the center of the valve in the smaller specimens; while in the larger it terminates at one-third the length of the shell from the posterior margin. Surface marked by concentric, slightly elevated growth lines, a number of which continue around posterior to the apex, aud gradually become more distant and prominent as growth progresses. On each side of the pedicle furrow are a few radiating striæ, while in front of the former the concentric growth lines have numerous, very small but distinct tubercles, about ten in 3 mm., which are probably the bases of former spines.

*Ottawa Naturalist, Dec. 1887; see also Pal. N. Y., vol. viii, p. i, p. 115, pl. 4, figs. 32-36, 1892.

This species is readily separated from all other American species now referred to the genus by its thin valves, and particularly by the absence of all spines and imbricating growth lines on the posterior two-thirds of the dorsal valve. This species may prove to be the type of a new genus with relations nearer to the *Discinidæ* than with the *Siphonotretidæ*.

Formation and locality.—Two specimens have been procured, one of which, showing more of the detail, was recently collected by Mr. F. W. Sardeson on top of the hill just north of the Cincinnati University, in beds XII*b* of Mr. Ulrich's subdivision of the Cincinnati group. The specific name is given in remembrance of the pioneer geologist, John Locke, of Ohio.

Family DISCINIDÆ, Gray.

Genus ORBICULOIDEA, d'Orbigny.

1850. *Orbiculoidea*, d'ORBIGNY. Prodrome de Paleontologie, vol. i, p. 44.
1890. *Orbiculoidea*, HALL. Palæontology of New York, extract vol. viii, pt. i, p. 129.

Description: "Shells subcircular or subelliptical in outline, inequivalve. Apices eccentric. Pedicle-valve depressed convex, or flattened, with the apex slightly elevated and inclined posteriorly. On the exterior of the valve a narrow pedicle-furrow, abruptly intercepting the ornamentation, but not penetrating the substance of the shell, begins just below and behind the apex, extends over a greater or less portion of the radius of the valve, and, at its distal end, is produced into a short tubular sipho, which traverses the substance of the shell obliquely backward, emerging on the interior surface, where it produces a narrow groove, and usually terminates before reaching the margin of the valve. On the interior, the position of the external groove is marked by a thickened ridge extending from the apex, and this is continuous with the thickened margins of the internal groove, which, in advanced age, may become so developed as to envelop this groove, except at its outer end.

"The larger or brachial valve is depressed-conical, with the apex more strongly directed backward than in the opposite valve. The interior shows a fine longitudinal ridge or septum extending from the apex forward. Otherwise the internal markings are not satisfactorily known.

"Shell-substance composed of alternating lamellæ of corneous and mineral matter, the latter often removed in fossilization, making the shell appear essentially phosphatic. Surface ornamentation usually consisting of fine, crowded or distant, sometimes lamellose concentric lines, occasionally crossed by radiating lines or ridges.

"Type: *Orbicula morrisi* Davidson." (Hall, *op. cit.*)

The species now referred to this genus were formerly regarded as congeneric with the recent species *Discina striata* Schumacher, the type of *Discina*. So far as known that genus is restricted to a single species, all the other recent forms formerly referred to *Discina* now belonging to *Discinisca*, Dall. Other Palæozoic subgenera of the same type of structure as *Orbiculoidea* are *Schizotreta*, Kutorga, *Œhlertella*, *Lindstrœmella* and *Rœmerella*, Hall.

ORBICULOIDEA LAMELLOSA *Hall?*

PLATE, XXIX, FIG. 25.

1847. *Orbicula lamellosa* HALL. Palæontology of New York, vol. i, p. 99, pl. XXX, fig. 10 (not *Orbicula lamellosa* Broderip, 1833=*Discinisca lamellosa*).
1855. *Orbicula truncata* EMMONS. American Geology, part ii, p. 200, fig. 62.
1860. *Discina truncata* EMMONS. Manual of Geology, p. 99.
1862. *Discina circe* BILLINGS. Palæozoic Fossils, vol. i, p. 51, fig. 125.
1890. *Orbiculoidea lamellosa* HALL. Palæontology of New York, extract of vol. viii, pl. IVE, fig. 12.

Original description: "Orbicular, depressed; apex small, but little elevated, situated about one-third the breadth of the shell from the margin; surface marked by elevated lamelli-form concentric lines or ridges."

The following is Mr. Elkanah Billings' description of *Discina circe*, a species now regarded as a synonym of *O. lamellosa:*

"Circular; lower [ventral] valve with the apex central or nearly so; peduncular groove acutely oval, extending from the apex about two-thirds the distance to the margin. The foramen is probably situated at the outer extremity of the groove, but it cannot be seen in the specimen examined. The upper [dorsal] valve (supposed to be that of this species) has the apex situated about one-third the semidiameter from the margin. In both valves the apex is smooth.

"Surface with rather strong, sublamellose concentric striæ, which become more distant and coarser from the apex outwards. At the margin there are four or five ridges in one line, but next to the apex double that number in the same space. The ridges are somewhat irregular, being in some places slightly undulated, and occasionally branched, two or more running into one. The grooves are rather wider than the ridges, and the lamellose aspect of the latter appears to be due to their being more abruptly elevated on the inner side, or the side towards the apex, than on the outside.

"Width of the specimens of the lower valves examined, nine lines; length of peduncular sulcus, three and one-fourth lines; width of the same, one-half line. Another specimen (an upper valve) is seven lines wide.

"The lower [ventral] valve is depressed, conical and appears to have been about two lines in hight, but as it is somewhat distorted by pressure, the true elevation cannot be determined. The upper [dorsal] valve seems to be less convex than the lower."

The single specimen which is here referred, with some doubt, to this species is a dorsal valve about 4 mm. in hight. The apex is nearly central, with the anterior slope strongly convex, while the posterior slope is slightly concave.

Formation and locality.—From the Salmon River (Hudson River) group or Loraine shales near Spring Valley, Minnesota. Also in the Trenton formation at Middleville and Lowville, New York; Bellville and Ottawa, Canada.

Collector.—Charles Schuchert.

Genus SCHIZOTRETA, Kutorga.

1848. *Schizotreta*, KUTORGA. Verhandl. der russ.—Kais. Mineral. Gesellsch. zu St. Petersburg, pp. 272, 273.
1890. *Schizotreta*, HALL. Palæontology of New York, vol. viii, abstract, p. 135.

This subgenus is readily distinguished from *Orbiculoidea* "in having the perforated valve very convex and the imperforate one depressed-conical or flat.

"The pedicle-groove has essentially the character seen in *Orbiculodea*, d'Orbigny, but is usually much more distinctly retained on account of the greater thickness of the shell.

"Muscular impressions of the brachial or imperforate valve in *Schizotreta conica* Dwight, consist of two strong excavated anterior adductors approaching toward the center of the shell, and separated by a prominent septum which is continued from a somewhat thickened posterior muscular area." (Hall, *op. cit.*)

Interior of ventral valve with the posterior adductor scars situated on each side of the walls of the pedicle groove.

SCHIZOTRETA PELOPEA *Billings, sp.*

PLATE XXIX, FIGS. 26-28.

1862. *Discina pelopea* BILLINGS. Palæozoic Fossils, vol. i, p. 52, fig. 56.
1863. *Discina pelopea* BILLINGS. Geology of Canada, p. 159, fig. 124.
1892. *Discina concordensis* SARDESON. Bulletin of the Minnesota Academy of Natural Science, vol. iii, p. 328, pl. IV, figs. 13, 14.

Original description: "Upper valve circular, depressed-conical. Apex about half the semi-diameter from the posterior margin. Surface with fine concentric striæ when perfect, but when partially exfoliated, smooth and places shining. Color black; width, six lines. Lower valve unknown.

The following emended description is prepared from a series of specimens obtained from the quarries at Mantorville, Minnesota, in the Galena limestone horizon: Shell circular, biconvex, with the apex of the dorsal valve situated at about one-third the entire length of the shell from the posterior margin; apex of the ventral valve somewhat more excentric. Surface with numerous concentric, strongly elevated lines of growth, with the intermediate spaces wide and concave;

thirteen to fifteen in the space of 2 mm. Dorsal valve depressed-convex. Ventral valve strongly elevated at the apex, perforate; posterior slope rapid, convex; anterior slope flat, or slightly concave. Pedicle opening short, narrow, oval and surrounded by an elevated margin. In the interior, on each side of the pedicle area, are situated the very narrow posterior adductor scars. The margin of this valve is distinctly, but slightly reflexed, producing a broad, shallow groove along the outer margin of the natural casts.

This species differs from *Discina circe* Billings=*Orbiculoidea lamellosa* Hall, in having the ventral valve more elevated, while in the latter it is the shallower valve that has the pedicle opening. The apices of the valves also are much more excentric in *S. pelopea* than they are are in Hall's species, being very nearly central in the latter. From *Schizotreta conica* Dwight, and *S. ovalis* Hall, it differs in being in outline and not narrowly oval.

Formation and locality.—Not uncommon in the Galena limestone, just above the Galena shales, in the quarries at Mantorville and at Old Concord, Minnesota. Also from the same formation at Dubuque, Iowa, and Neenah, Wisconsin. From the Salmon River (Hudson River) formation at Spring Valley, Minnesota. Also in the Trenton limestone at Montreal, Canada.

Collectors.—A. D. Meeds and the authors.

Mus. Reg. Nos. 263, 296, 7688–7690.

SCHIZOTRETA MINUTULA, *n. sp.*

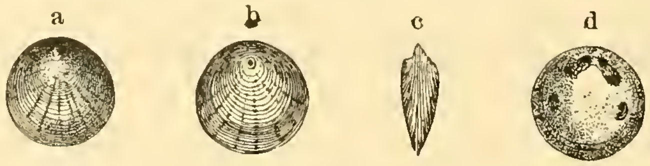


FIG. 28. *a*, dorsal valve; *b*, ventral valve; *c*, profile view; *d*, interior of dorsal valve; all × 18.

Description: Shell minute, nearly circular in outline, marked by numerous, delicate concentric lines of growth and sometimes a few radii, in the anterior region; valves about equally convex. Ventral valve with a minute circular pedicle opening in the apex of the shell. Area posterior to the dorsal beak more excavated than that of the other valve.

Interior of the dorsal (?) valve apparently with two pairs of muscle scars, the posterior pair the larger, diverging forward and situated one on each side of the beak cavity; the other pair is placed medially near the lateral margin.

Dimensions, $\frac{5}{10}$ of a millimeter in length.

This little species is the smallest adult brachiopod from paleozoic rocks known. Individuals occur in abundance associated with stems of *Diplograptus*, to which they were probably attached. This may account for their small size.

Formation and locality.—From the lower portion of the Hudson River group near Granger, Minnesota. *Mus. Reg.* No. 8392.

Genus TREMATIS, Sharpe.

1847. *Trematis*, SHARPE. Quarterly Journal Geological Society, vol. iv, p. 66.
1892. *Trematis*, HALL. Palæontology of New York, vol. viii, pt. i, p. 138.

Description: "Shell subcircular or transversely oval in outline. Pedicle valve unevenly convex, more or less depressed over the posterior region; apex at or behind the center; directly beneath it begins the pedicle-fissure, which transects the shell, vertically widening to the posterior margin with straight or outwardly-curving edges. Brachial valve evenly convex, with its apex marginal and slightly projecting. On the interior, the pedicle-valve shows a faint median furrow extending from the angle of the fissure to the apex of the shell; this groove widens at its apical termination and may represent a point of muscular attachment. The sides of the fissure are often thickened by callosites similar to those sometimes seen in species of *Orbiculoidea*. From the apex of the valve extend radiating and branching vascular sinuses.

"In the brachial valve the posterior margin is much thickened and broadly grooved to allow the extension of the pedicle. This thickening does not take the form of a cardinal area or shelf, but is rather a callosity closely appressed against the interior surface of the shell, the central portion being projected beyond the margin of the pedicle-valve. Directly below and in front of this area are two transversely elongate scars, adjustors or posterior adductors, which are usually partly concealed by the progressive overgrowth of the cardinal thickening. A faint median septum begins between these scars and passes forward, becoming more prominent over the tongue-shaped median elevation which separates the large central scars. These impressions are oblique and are not simple, each appearing to be composed of two, if not three distinct scars, making a posterior, a median and an anterior pair. What appears to be the posterior pair is small, and sometimes quite sharply defined, the central pair very much larger, and the anterior pair narrow, situated at either side of the angle of the median callosity and separated by the apex. The specialization of the first of these scars is not satisfactorily established; the entire impression is deeply excavated. In some well preserved specimens there is also evidence of external marginal scars lying just in front of the outer end of the posterior adductors.

"Surface of both valves more or less completely covered by a beautiful ornamentation consisting of punctures or small pittings of varying depth, arranged either in quincunx (*T. terminalis*) or in radiating rows; in the latter case they may be distant from one another without intervening ridges (*T. umbonata*), or lie in radiating furrows, when they are either circular (*T. punctostriata*) or subrectangular (*T. ottawensis*).

"Shell-substance composed of an outer calcareous layer with a series of inner corneous lamellæ. The outer layer varies in thickness in different species and is coarsely punctated by the pittings constituting the surface ornamentation. The corneous layers are impunctate." (Hall, *op. cit.*)

Type: *Trematis terminalis* Sharpe (not Emmons)=*T. millepunctata* Hall.

TREMATIS HURONENSIS *Billings?*

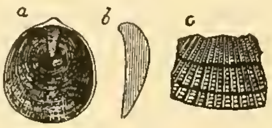


FIG. 29. Billings' original figure of *T. huronensis*. *a*, lower valve. *b*, longitudinal section, showing the curvature of both valves; *c*, a portion of the surface enlarged.

1862. *Trematis huronensis* BILLINGS. Palæozoic Fossils, vol. i, p. 53, figs. 59*a*, 59*b*, 59*c*.
1863. *Trematis huronenis* BILLINGS. Geology of Canada, p. 159, figs. 130*a*, 130*c*.
1892. *Productella minneapolis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 332, pl. IV, figs. 11, 12.

Of *Trematis* we have seen but four imperfect specimens. Since they preserve only the dorsal valve, no direct comparison can be made with the ventral valve of *T. huronensis* Billings, and therefore this identification is provisional. The surface pittings in these specimens are similar to those in *T. huronensis, i. e,* they are arranged in radiating lines, not in quincunx, and in this respect differ from *T. terminalis* Emmons, *T. millepunctata* Hall, and *T. quincuncialis* Miller and Dyer. Our specimens vary somewhat from Billings' species, in that the radial surface depressions become obsolete towards the anterior margin.

The "ventral valves" of *Productella minneapolis* Sardeson are identical with the upper or dorsal valve of the shells identified by the writers with *Trematis huronensis.* Moreover, *Productella* is not known below the Devonian.

Formation and locality.—From the Trenton limestone in the quarries along the river bluffs, and near the base of the Trenton shales at Minneapolis, Minnesota. The Canadian specimens are from the Black River limestone of Pallideau islands, lake Huron.

Collectors.—C. L. Herrick and C. Schuchert.

Mus. Reg. No. 7691.

Trematis ottawensis *Billings.*

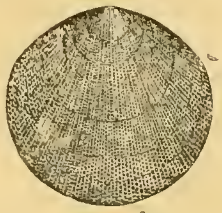


Fig. 30. Billings' original figure of *T. ottawensis.*

1861. *Trematis ottawensis* Billings. Paleozoic Fossils, vol. i, p. 53, fig. 58.
1892. *Trematis ottawensis* Hall. Palæontology of New York, vol. viii, pt. i, pl. ivG, figs. 15–17.

Original description: "Nearly circular; length a little greater than the width; upper valve moderately and uniformly convex, most elevated about the middle; apex small, obtusely pointed, slightly elevated, marginal. Surface with fine, radiating striæ, which increase by interstitial addition, sometimes closely crowded together, in which case there are ten or twelve in the width of one line; occasionally more distant, or from four to eight in one line. The intermediate grooves are divided into square compartments by cross-ridges, which connect the radiating ridges, but are not continuous, those in one groove not corresponding in position with those in the adjacent grooves, so as to form uninterrupted concentric lines. In specimens with the striæ closely crowded together only the radiating lines are distinctly visible, but the others can always be detected in good specimens, on close examination.

"Length from twelve to fifteen lines; width a little less than the length. Lower valve unknown."

Formation and locality.—Rare in the Galena beds at St. Anthony hill, St. Paul. Also in the Trenton limestone, Ottawa, Canada, and at Frankfort, Kentucky.

Collector.—E. O. Ulrich.

Genus SCHIZOCRANIA, Hall and Whitfield.

1875. *Schizocrania,* Hall and Whitfield. Palæontology of Ohio, vol. ii, p. 73.
1892. *Schizocrania,* Hall. Palæontology of New York, vol. viii, pt. i, p. 142.

Description: "Shells subcircular in outline, inequivalve, unarticulated. Pedicle valve flat or concave; apex subcentral. A deep triangular notch extends from just behind the beak to the margin, where its arc is equal to about one-sixth of the periphery. The apex of this broad pedicle-notch is occupied by a triangular transverse plate varying in size with the age of the shell, but extending for one-fourth to one-third the length of the opening. Surface marked by concentric-growth lines. On the interior no muscular impressions are visible. Brachial valve more or less convex, with the beak marginal. The interior bears a pair of strong posterior adductor scars, lying close together in the umbonal region; their outline is elongate-ovate, indicating a progressive increase in size, and they frequently appear to be divisible into anterior and posterior elements. In front of them, at about the center of the valve, are the small and faint anterior adductor impressions. A low median ridge extends from the apex to beyond the center of the valve. External surface marked by elevated striæ radiating from the beak.

"Substance of the shell composed of perlaceous calcareous laminæ which constitute the most of the shell. The inner layers appear to be corneous. All are impunctate?" (Hall, *op. cit.*).

Type: *Orbicula? filosa* Hall.

Species of this genus are found in the Trenton, Utica and Hudson River groups of America. *S. helderbergia* Hall, from the Lower Helderberg, and *S. superincreta* Barrett, of the lower Oriskany, are other American species.

SCHIZOCRANIA FILOSA *Hall*,

PLATE XXIX, FIGS. 29–31.

1847. *Orbicula? filosa* HALL. Palæontology of New York, vol. i, p. 99, pl. XXX, figs. 9*a*–9*d*.
1863. *Trematis filosa* BILLINGS. Geology of Canada, p. 159, fig. 126.
1873. *Trematis filosa* HALL. Twenty-third Rep. N. Y. State Cab. Nat. Hist., pl. XIII, figs. 21, 22.
1875. *Trematis (?) filosa* MILLER. Cincinnati Quart. Jour. Sci., vol. ii, p. 15.
1875. *Schizocrania filosa* HALL and WHITFIELD. Palæontology of Ohio, vol. ii, p. 73, pl. I, figs. 12–15.
1892. *Schizocrania filosa* HALL. Palæontology of New York, vol. viii, pt. i, p. 143, pl. IVG, figs. 22-30.

Original description: "Orbicular; one valve more or less convex; apex marginal; surface radiated with numerous fine elevated thread-like striæ which are more or less prominent, depending on exfoliation of the shell; intermediate striæ coming in between the others as they recede from the beak; but the striæ are not bifurcate."

This species was subsequently more fully described by Hall and Whitfield from material obtained at Cincinnati, Ohio. The description is as follows; "Shell orbicular, or very slightly ovate, the beak of the upper or free valve [dorsal] projecting a little beyond the limits of the circle, giving a somewhat greater diameter along the median line than in a transverse direction. Free valve moderately convex, the central region being the most prominent. Attached valve [ventral] discoid, very thin, deeply and broadly notched on the posterior side; the notch not extending quite to the center of the valve; occupying nearly one quarter of the circumference of the valve on the outer margin; border of the notch thickened, especially at the base, which is rounded and the center marked by a slightly projecting point. Interior of the free valve [dorsal] marked by two proportionally large, elongate, ovate, diverging muscular prominences [posterior adductor scars], leaving corresponding pits on the casts of the shell, or on exfoliated specimens; situated just below the beak, and extending nearly or quite one-fourth of the length of the valve from the apex. There are also two other muscular impressions [anterior adductor scars] smaller in size, circular in form, and situated near the middle of the valve below the extremities of the ovate imprints, and slightly more distant from each other. Beneath the beak there is a slight thickening of the cardinal border. The muscular markings of the lower valve have not been observed.

"Surface of the shell of the convex valve [dorsal] marked by fine, even, thread-like radiating striæ; increased both by division and implantation, and gradually increasing in strength toward the border of the shell; the interspaces where the shell is perfectly preserved are flattened, the striæ appearing as raised lines on the surface. The attached valve [ventral] is strongly marked by irregular concentric undulations circling the valve parallel to the margin, but interrupted at the border of the notch."

When the dorsal valve is broken away so as to show the ventral valve beneath, it is seen that the first overlaps and completely surrounds the latter, and it may, as believed by Hall, (*op. cit.* 1892, p. 143), have served as "an important accessory means of attachment" to foreign bodies. This species is usually found attached to brachiopods, particularly to *Rafinesquina alternata*, but is occasionally found on gastropods, as in the case of the Minnesota specimens before us.

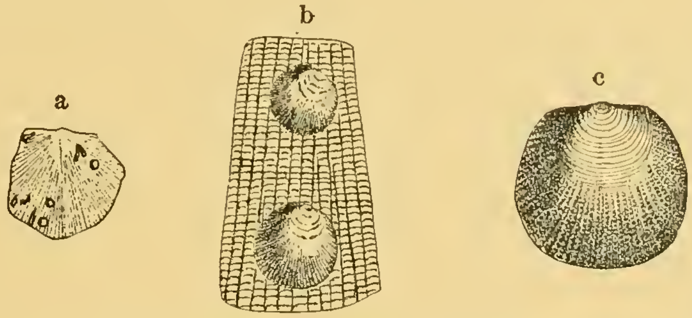


FIG. 31. *a*, three immature specimens attached to *Strophomena*, natural size; *b*, two of the same × 7; *c*, same × 18. Middle third of the Trenton shales, Minneapolis. Collection of C. Schuchert.

These figures are introduced to show various stages of the nepionic and early nealogic condition of *Schizocrania*. The "Paterina stage," with its straight hinge-line, continues throughout the nepionic growth and is succeeded in the early nealogic stage by the development of series of radially arranged pits strongly resembling those of *Trematis*. This is followed by the striated or specific stage. *Schizocrania*, therefore, seems to be phylogentically related to *Trematis*.

Formation and locality.—In the Trenton shales at Cannon Falls, Chatfield and Minneapolis, Minnesota. This species also occurs in the Trenton formation of New York and Kentucky; in the Utica formation at Utica, New York, and Ottawa, Canada; and in the Utica horizon at Cincinnati, Ohoi.

Collectors.—W. H. Scofield, E. O. Ulrich and C. Schuchert.

Suborder GASTEROPEGMATA, Waagen.

Family CRANIIDÆ, King.

Genus CRANIA, Retzius.

1781. *Crania*, Retzius. Schriften der Berliner Gesellsch. Naturf. Freunden, vol. ii, p. 72.
1892. *Crania*, Hall. Palæontology of New York, vol. viii, pt. i, p. 145.

Description: "Shell inequivalve, inarticulated, without perforation for a pedicle; subcircular in outline, generally somewhat transverse across the posterior margin; attached by the apex or the entire surface of the lower valve. Ventral or lower valve depressed-conical or conforming to the surface to which it is attached. Dorsal or upper valve more or less conical, with a subcentral, posteriorly-directed apex. External surface of the valves usually smooth, sometimes spinose or with concentric or radiating striæ. In the interior of both valves are two pairs of large adductor scars, the posterior of which are close upon the margin and widely separated, the anterior near the center of the shell and close together, more approximate in the lower than in the upper valve. These posterior scars are often strongly elevated on a central callosity which surrounds their anterior margins. The margin of the lower valve is usually broad and thickened. Impressions of the pallial genital canals coarsely digitate.

"Shell substance calcareous; strongly punctated by vertical canals which become subdivided toward the epidermal surface.

"Type: *Crania craniolaris* Linné." (Hall, *op. cit.*)

This genus had its origin in the Trenton formation and thence has existed through all geological time up to the present. One species is reported from the Chazy and another from the middle Primordial, neither of which have furnished undoubted evidence of their belonging to this genus.

Crania setigera *Hall.*

PLATE XXIX, FIGS. 32 and 33.

1866. *Crania setigera* Hall. Description of new species of Crinoidea and other Fossils, p. 12.
1872. *Crania setigera* Hall. Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., p. 220, pl. VII, fig. 15.
1892. *Crania setigera* Hall. Palæontology of New York, vol. viii, pt. i, pl. IVH, figs. 14-16.

Original description: "Shell small, suborbicular; length greater than width; cardinal margin nearly straight. Dorsal valve convex; beak elevated, pointed, situated nearly one-third the length of the valve from the cardinal border.

"Surface marked by comparatively coarse pustules or setæ, which are more distant [distinct] near the margin of the shell."

The individuals of this species from the thin-bedded Trenton limestone have the surface pustules strongly elevated, appearing more like short spines. Those from the Trenton shales often attain a greater size, and have the setæ usually less pronounced, while the beak is obtuse, the outline variable, and the cardinal margin only in rare instances straight. Free dorsal or upper valves are common, and but few specimens have been secured in which the valves conjoin, and are attached to an *Orthis* or *Rafinesquina*. These attached specimens are marked more or less with their host, causing the characteristic surface pustules to become obsolete, while the striæ of those growing upon smooth surfaces have developed the setæ. In specimens where these pustules have been removed by weathering or other causes, it is very difficult to decide whether they are individuals of *C. setigera* or *C. trentonensis*. Such specimens are usually referred to the latter species, but they commonly preserve a few pustules near the margin.

A specimen of *Monticulipora*, with an individual of this species* attached, also has a parasitic species of bryozoan growing on it, which grew towards the *Crania*. Its growth, however, was limited towards the anterior portion of the *Crania*, leaving between it and the encroaching bryozoan a space 3-4 mm. in width. This limiting of the growth of the bryozoan may have been caused by the frequent extension of the arms of the *Crania* during life.

Formation and locality.—In the Trenton limestone at Minneapolis; Trenton shales at Minneapolis, St. Paul, Cannon Falls, Fountain, Chatfield and Preston, Minnesota. Also from the Trenton at Decorah, Iowa; Mineral Point and Beloit, Wisconsin. In the Salmon River group or Loraine shales at Wilmington, Illinois.

Collectors.—C. L. Herrick, W. H. Scofield and the writers.

Mus. Reg. Nos. 718, 5500, 7692-7696, 7958,

CRANIA GRANULOSA *N. H. Winchell.*

PLATE XXIX, FIGS. 34 and 35.

1880. *Crania granulosa* N. H. WINCHELL. Eighth Annual Rep. Geol. and Nat. Hist. Survey of Minnesota, p. 63.

Original description: "Shell small, but prominently elevated at the beak; orbicular or somewhat widened between the antero-lateral margins; no concentric striæ or undulations visible on the exterior of the shell, nor radiations; the whole surface of the dorsal valve uniformly fine-granulated or pustulose; these granulations not disposed in any apparent order. The lower valve unknown."

Crania scabiosa Hall, when growing on a bryozoan, usually has the upper valve strongly pitted. Specimens of this nature have received the name *C. multipunctata* Miller and Dyer. The outer surface of *C. granulosa*, however, is not pitted, but is crowded with small pustules irregularly arranged.

Formation and locality.—Trenton limestone at Minneapolis, Minnesota.

Mus. Reg. No. 708.

* This specimen is figured in Pal. N. Y., vol. viii, pl. IVH, fig. 14, 1892.

Crania trentonensis *Hall.*

PLATE XXIX, FIGS. 36 and 37.

1866. *Crania trentonensis* Hall. Description of new species of Crinoidea and other Fossils, p. 12.
1872. *Crania trentonensis* Hall. Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., p. 219, pl. VII, figs. 11, 12.
1892. *Crania trentonensis* Hall. Palæontology of New York, vol. viii, pt. i, pl. IVH, figs. 21, 22.

Original description: "Shell medium size, strongly convex on the upper valve; width a little greater than the length, greatest width below the middle of the shell. Beak of dorsal valve small, pointed towards and situated near the cardinal border.

"Surface marked by strong concentric lines of growth. No striæ or radiating lines are visible. Transverse diameter eleven-twentieths of an inch; length half an inch."

This species differs from *C. setigera* Hall, in not having the upper or dorsal valve covered with elongate pustules. The shell of the dorsal valve of *C. trentonensis* is thick, and in this differs from *C. scabiosa* Hall, which is thin and usually partakes of the ornamentation of its host. Outline of the shell and position of the apex are variable features, and of little specific value among species of *Crania.*

Formation and locality.—In Minnesota this species has been found only in the Galena shales near Cannon Falls. One of the writers has found it in the "Lower Blue beds" of the Trenton at Janesville, Wisconsin, and Dixon, Illinois. The type specimens are from the Trenton at Middleville, New York.

Collectors.—W. H. Scofield and C. Schuchert.

Mus. Reg. No. 7697.

Genus CRANIELLA, Œhlert.

1888. *Craniella,* Œhlert. Bull. de la Soc d' Etudes Scientif. d' Angers, p. 37.
1892. *Craniella,* Hall. Palæontology of New York, vol. viii, pt. i, p. 153.

Description: "Shell somewhat irregular, outline subcircular or subquadrangular. Ventral valve thin, adhering by its entire surface; dorsal valve conoidal, more or less elevated; apex subcentral, posterior; interior of the dorsal valve without a well-defined border; impressions of the adductors large, very distinct, four in number, of which the posterior two are quite distant, the two subcentrals somewhat smaller, closely approximate or even confluent; from near each of the posterior impressions starts a vascular sinus, which is broad, strongly sinuous near its point of departure, narrowing gradually in following the contour of the valve, emitting from its marginal side dichotomizing secondary branches.

"Type: *Craniella meduanensis* Œhlert." (Hall's translation of the original diagnosis.)

The known species of this genus are *C. ulrichi* Hall of the Trenton, *C. hamiltoniæ* Hall of the Hamilton, and *C. meduanensis* Œhlert of the Devonian of France.

CRANIELLA? ULRICHI *Hall.*

PLATE XXIX, FIGS. 38 and 39.

1892, July. *Craniella ulrichi* HALL. Palæontology of New York, vol. viii, pt. i, pp. 153, 181, pl. IvH, figs. 1, 2.

Compare *Crania halli* SARDESON.* Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 328, pl. IV, figs. 8-10; April, 1892.

Description: "Shell moderately large. Outline normally circular. Apices subcentral, slightly posterior, inclined backwards. Upper valve with the posterior scars large and the adjustors well defined; anterior scars subdivided, the outer or posterior portion possibly representing the insertion of the brachial muscles. The vascular sinuses make a 3-shaped curve on the lateral portion of the valve, with the crest of the double arch towards the center; narrowing rapidly, becoming indistinct over the anterior region. Lower valve regularly curved, evidently unattached at maturity. Anterior adductors very large, situated on a thickened posterior area. Posterior adductor and adjustor scars very faint, lying just within the margin. The vascular sinuses are a series of low grooves extending forward in subparallel lines from the anterior and lateral margins of the central muscular area. External surface of the valves smooth or covered with concentric sublamellose growth-lines. Length of an upper valve, 16 mm." (Hall, *op. cit.*)

The specimens which can be referred to this species are free, separated, strongly convex valves, and are usually overgrown by bryozoans. Associated with them are numerous dorsal valves of *Crania setigera* Hall, also usually occurring as free valves. These can be separated from *Craniella? ulrichi*, when the interior is not shown, only by their outer spinose surface.

The material of *C. ulrichi* examined by Prof. Hall is identical with that which we have. All of the attached specimens on which he bases the statement, (p. 153) "is sometimes attached," have proved to be *Crania setigera.* Among the many specimens of *Crania* and *Craniella* observed in Minnesota, not a single attached ventral valve with the dorsal valve removed has been found. When the ventral valve is present it is attached to some other brachiopod and has the dorsal valve covering it. Such specimens have invariably proved to be *Crania setigera.* That we have both valves among the large and free specimens of *Craniella? ulrichi* is probable, since the muscular scars and vascular markings are quite different in the two type specimens described and illustrated by professor Hall. This species is, therefore, biconvex and probably attached by the apical portion of the ventral valve.

Formation and locality.—Rare in the Trenton shales at Minneapolis, St. Paul and near Fountain, in the Galena shales, six miles south of Cannon Falls, Minnesota.

Collectors.—E. O. Ulrich, W. H. Scofield and C. Schuchert.

Mus. Reg. Nos. 7698-7700.

*Mr. Sardeson's name may really apply to this species, but neither his description nor figures are sufficiently diagnostic to enable us to determine this point satisfactorily. On the other hand, it would seem that his specimens must be distinct, because he had on several occasions been informed by one of us that Prof. Hall had named and described the present species in the work above cited. As is well known, part I of that volume was printed nearly two years before it was published.

Genus PHOLIDOPS, Hall.

1859. *Pholidops*, HALL. Palæontology of New York, vol. iii, pp. 489, 490.
1892. *Pholidops*, HALL. Ibidem, vol. viii, pt. i, p. 155.

Description: "Shells small, patelliform, equivalve, equiconvex, inarticulate, unattached. Outline oval or subelliptical; apex subcentral, excentric or marginal, sometimes terminal and produced. Surface marked by strong, concentric, often lamellose lines of growth, which are crowded on the posterior and distant on the anterior portion of the valves; these are sometimes crossed by faint, interrupted radiating lines. In the interior the surfaces of contact make a broad, smooth, flat or slightly convex border, somewhat broader in front than behind. The muscular and visceral area occupies a sharply-defined and very limited space in the apical portion of each valve. In both it is of essentially the same size and subtriangular in outline, the apex of the triangle pointing forward and usually surrounded by a conspicuous callosity.

"The ventral(?) valve bears two well-defined central adductors occupying the same relative position as in *Crania;* these impressions are usually simple, but appear to be sometimes complicated by association with ill-defined scars of the anterior muscles. The posterior adductors or divaricators are situated at the basal angles of the muscular triangle and are distant from the posterior margin. The linear parietal scars are very strong, the posterior being more or less distinctly lobate, the anterior generally straight or rounding about the central adductors. In the opposite or dorsal(?) valve the scars have essentially the same arrangement; the anterior adductors, however, are separated by elongate median scars (anteriors) which traverse the elevated callosity surrounding the anterior margin of the area. The posterior scars are often more widely divergent than in the other valve. Shell substance calcareous and impunctate(?)." (Hall, 1892, *op. cit.*)

Type: *Orbicula ? squamiformis* Hall.

PHOLIDOPS TRENTONENSIS *Hall*, var. MINOR, *n. var.*

PLATE XXIX, FIG. 40.

The original description of *P. trentonensis* Hall* is as follows: "Shell small, broadly oval, very depressed-convex. Apex situated near the cardinal extremity. Surface marked by strong, concentric, lamellose lines of growth."

The Minnesota specimens in outline, convexity of valves, position of the apex and the strong lamellose lines of growth, agree with these parts as described and illustrated in *P. trentonensis* Hall. They are, however, one-half, but more often less

* Descript. of new species of Crinoidea and other Fossils, p. 14, 1866. Twenty-fourth Rep. N. Y. State Cab. Nat. Hist. p. 221, pl. VII. fig. 8, 1872.

than one-half the size attained by this species as found at Middleville, New York, and since they are constantly smaller, the varietal name *minor* is here applied to them. The growth lines are conspicuous in some specimens, while in others they are nearly obsolete. The muscular markings are undefined, owing to the tenuity of the valves.

Formation and locality.—Not uncommon near the base of the Galena shales at St. Paul; associated with *Clitambonites*, three miles south of Cannon Falls and at Kenyon, Minnesota. Also in the upper part of the Trenton shales at Chatfield.

Collectors.—A. D. Meeds and C. Schuchert.

Mus. Reg. No. 7279.

Subclass ARTHROPOMATA, Owen.

Order PROTREMATA, Beecher.

Family CLITAMBONITIDÆ, *n. fam.**

Genus CLITAMBONITES, Pander.

1830. *Klitambonites*, PANDER. Beitrage zur Geognosie des russischen Reiches, p. 70.
1892. *Clitambonites*, HALL. Palæontology of New York, vol. viii, pt. i, p. 233.
Orthisina, d'ORBIGNY (1847) and subsequent authors.

Description: "Shells with a subsemicircular marginal outline; convex or subpyramidal in the typical group. Hinge-line straight and forming the greatest diameter of the shell. Pedicle [ventral] valve elevated, cardinal area high, vertical, or sometimes incurved and crossed by a broad delthyrium, which is normally covered by a convex, perforate deltidium. On the interior of the valve the dental lamellæ are very strongly developed, converging and uniting in the median line before reaching the bottom of the valve, thus forming a spondylium, which with the deltidium encloses a conical subrostral vault. This plate is supported by a median septum extending for about one-half the length of the valve. [Adductor, diductor and adjustor scars occupy the upper surface of the spondylium.] In the brachial [dorsal] valve the cardinal area is considerably developed and the delthyrium filled by a conspicuous callosity, against the inner side of which the simple orthoid cardinal process abuts. The dental sockets are large, the crural plates low and continuous with the edges of the delthyrial callosity. A thickened transverse area is formed in the umbonal region by the union of the inner portions of the crural plates with the cardinal process, and thence a broad median ridge is continued forward through the muscular area, which is sharply defined and quadripartite. External surface covered with radiating striæ. Shell substance impunctate.

*This family will contain *Protorthis*, Hall, *Clitambonites*, Pander, *Hemipronites*, Pander, and *Scenidium*, Hall. Waagen (Pal. Indica, vol i, p. 576, 1884,) proposed the sub-family *Orthisinæ* for the genus *Orthisina*. D'Orbigny's family *Orthisidæ* contains *Strophomena*, *Orthis*, and *Orthisina*=*Clitambonites*, genera now referred to three distinct families.

"Type: *Pronites adscendens* Pander." (Hall, *op. cit.*)

In well-preserved specimens of *C. diversa* the upper surface of the spondylium is transversely striated, these striæ having three distinct curvatures in passing over it. Since their position and the area occupied agree with the muscular scars of this valve in *Orthis*, they are here regarded as homologous with the adductors, diductors and adjustors of that genus. In *Lingulelasma*, *Lingulops* and the trimerellids the muscular scars are not found in front nor underneath, but *on* the "platform" of those genera. The platform, therefore, is homologous with the spondylium of *Clitambonites* and *Pentamerus*. In *Pentamerus galeatus* Dalman, of the Lower Helderberg group of New York,* the adductors and diductors occupy nearly the entire spondylium, while the adjustors were probably situated on narrow flanges of the walls of the delthyrium. The portion of the valve immediately beneath the spondylium, and occasionally the sides of the septum, are strongly marked by the genital sinuses. Since there is no space posterior to these markings for the attachment of the muscles, this clearly indicates that they were situated on the upper surface of the spondylium.

CLITAMBONITES DIVERSA *Shaler, sp.*

PLATE XXX, FIGS. 11—17.

1865. *Orthisina diversa* SHALER. Bulletin of the Museum of Comparative Zoology, no. 4, p. 67.
1866. *Orthisina verneuiti* BILLINGS. Catalogue of the Silurian Fossils of Anticosti, pp. 43, 74.
1877. *Hemipronites americanus* WHITFIELD. Annual Report of the Geological Survey of Wisconsin, p. 72.
1882. *Hemipronites americanus* WHITFIELD. Geology of Wisconsin, vol. iv, p. 243, pl. x, figs. 15–17.
1889. *Streptorhynchus americanus* MILLER. North American Geology and Palæontology, p. 378.
1892. *Clitambonites americanus* HALL. Palæontology of New York, vol. viii, p. 239, pl. XVA, figs. 1-8.

Original description: "Toothed [ventral] valve, usually pentagonal; socket-valve quadrate; hinge-line usually equal to the greatest width of the shell. Toothed valve very strongly projecting; depth about one-half the width; deepest point about the hight of hinge-line; umbo somewhat laterally compressed, usually rising high above the plane of the hinge-line, but very variable in this respect; umbo always laterally inclined indifferently towards either extremity of the hinge-line. Surface near the extremities of the hinge-line a little depressed and slightly recurved; area very large, nearly half as wide as long. Fissure from one-fourth to one third the width of the hinge-line; deltidium large, massive, rarely central, with distinct circular or oval foramen. Socket-valve with a broad and shallow mesial fold."

Shell of medium size; subquadrangular in outline; hinge-line straight, rarely shorter, and usually as long as, or slightly longer, than the greatest width of the shell; cardinal angles often mucronate; lateral margins straight or nearly so, sloping

* Pal. New York, vol. iii, p. 257, pl. XLVI and XLVII, 1859.

more or less abruptly into the broadly-rounded and centrally somewhat sinuous, anterior edge. Surface marked with numerous, subangular, prominent, sometimes tubulose striæ, increasing in number by interpolation and bifurcation; from seventy to eighty-eight in adult examples along the margin and crossed by crowded, delicate, concentric growth lines some of which imbricate near the outer margin.

Ventral valve strongly and evenly convex, with the point of greatest elevation near the beak. Cardinal area very wide, broadly triangular, flat or elevated, and slightly convex, distinctly striated longitudinally and finely transversely; deltidium broadly triangular, strongly convex, with a large oval pedicle opening in the apical portion; anterior margin broadly excavated and, when perfect, completely occupied by the chilidium of the dorsal valve. On the interior the dental processes are not very large and are attached to the strong lamellæ, which converge and join centrally before reaching the bottom of the valve, forming the spondylium, which is supported by a well-developed septum terminating in the anterior third of the valve. The upper surface of the spondylium has a narrow median depression, which is sometimes faintly divided by a fine line; the lateral limits of this plate are also slightly depressed, and the whole is crossed by numerous transverse lines of growth. The lines have a constant curvature in the median depression, with another over the area on each side and are strongly reflexed along the edge of the delthyrium. These markings are believed to be due to the adductor, diductor and adjustor muscles, which were attached to the upper surface of the spondylium, as not the slightest trace of any scar can be seen on the under surface of this plate, nor on the valve immediately beneath it. Genital markings numerous, delicate, originating underneath the spondylium, radiating towards the antero-lateral margins and surrounded by the vascular sinuses. Outside of the latter there is a smooth space, while the anterior margin of both valves is slightly marked by radiating lines.

Dorsal valve slightly concavo-convex, or almost flat; point of greatest elevation at the apex, where a shallow, narrowly-expanding medial depression has its origin and extends to the anterior margin. Cardinal area conspicuous but not wide, centrally occupied by a broad, short and strongly elevated chilidium. Underneath the latter, and attached to it, is what may be termed a simple cardinal process. The muscles are not attached to the top of this process, as in species of *Orthis*, but to the striated thickening of the rostral cavity and slightly to the basal portion of the process, the whole being covered by the chilidium. Dental sockets prominent, situated at the point of union of the cardinal area with the chilidium. The crural plates form the inner edges of these sockets, are much elevated and continuous with the deltidium. The rostral thickening extends forward as a broad, low septum to near the center of the valve, and on each side are two strongly excavated, separate pairs of adductor scars. The antero-lateral edges of these are drawn out into short ridges, probably the bases of the vascular trunks. Outside the muscular scars are a number of small tubercles, indicating the genital spaces.

This widely-distributed species was first described by Shaler as *Orthisina diversa*. A year later Billings identified it as *O. verneuili* Eichwald, at the same time regard-Shaler's species as synonymous with it. On the other hand, Shaler has since referred *Orthisina verneuili* Billings to his species, in which he is correct. On comparison with the European species, as illustrated by de Verneuil,* it is seen that the American species is wider along the hinge-line, the ventral area much less incurved and elevated, with finer striæ and a narrow sinus in the dorsal valve. These differences are sufficient to distinguish the two species. Specimens of *Hemipronites americanus* Whitfield have been collected at Oshkosh, Wisconsin, and are found to agree with *O. diversa* Shaler of the Hudson River group of Anticosti. Castelnau,** as early as 1843, however, described as *Terebratala borealis* a shell derived from the "magnesian limestone of Green bay, Wisconsin," which may prove to be this species. The only illustration given is of a ventral valve, and this is not satisfactory for positive determination. These type specimens are probably in the collections of the Academy of Sciences at Paris, France.

C. diversa must have been quite often the prey of other animals, probably gastropods, as valves of this species are found with a single, large circular hole in them, such as are often seen in recent shells. Others have been partially crushed, generally near the anterior margin. That such injury was received during life, but was occasionally not sufficient to kill the animal, is shown by the fact that in some shells the damage was repaired. Such specimens are irregular in growth, the place of injury being indicated by more or less of a depression and great irregularity of the striæ.

Formation and locality.—Very common in the yellow shales here designated as *Clitambonites* beds of the Galena shales. With this species many forms are introduced which extend upward, while a number of species of the Trenton shales below do not pass into the *Clitambonites* horizon. A single specimen has been found in the uppermost layer of the shales on St. Anthony hill, St. Paul. Common at many localities south of Cannon Falls, Kenyon and Warsaw, Goodhue county; Eyota, and near Fountain, Minnesota. In the Galena at Oshkosh, Wisconsin. In the Trenton group, Ottawa, Canada. Also in division I of the Anticosti group, Anticosti. Some fragments of what appear to be a new species have been found by Mr. Ulrich one mile south of Burgin, Kentucky, in the middle Trenton beds.

Collectors.—Miss C. E. Seymour, W. H. Scofield, A. D. Meeds and the writers.

Mus. Reg. Nos. 5308, 5586, 5847, 5853, 6765, 7951–7957.

* Russia and the Ural Mts., vol. ii, pls. XI and XII.

** Essai sur le Système Silurien de l'Amérique Septentrionale, p. 40, pl. XIV, fig. 14.

Clitambonites diversa, var. altissima, *n. var.*

PLATE XXX, FIGS. 18 and 19.

1892. *Clitambonites americanus* var. HALL. Palæontology of New York, vol. viii, pl. XVA, figs. 7, 8.

This variety is readily distinguished by the exceeding elevation of the cardinal area of the ventral valve. This feature is so striking that its recognition seems to be demanded.

Formation and locality.—Several specimens of this variety have been found by Mr. W. H. Scofield associated with *C. diversa* in the Galena shales south of Cannon Falls, Minnesota.

Genus SCENIDIUM, Hall.

1860. *Skenidium*, HALL. Thirteenth Report N. Y. State Cabinet of Natural History, p. 70.
1892. *Scenidium*, HALL. Palæontology of New York, vol. viii, pt. i, p. 241.

Description: "Shell subpyramidal, somewhat semicircular, with or without median sinus and elevation. Area large, triangular, divided by a narrow fissure, which is sometimes closed at the summit by a concave deltidium [spondylium]. Valves articulating by teeth and sockets, which are often obscure or obsolete. Dorsal valve flat, or varying from depressed-convex to concave. Beak entire, or indented by the foramen; cardinal line straight and usually equalling the width of the shell; cardinal plates broad and well developed, marked by the imprints of the peduncular muscles, and produced in the middle in a pointed process; the cardinal process extends, as a median septum, through the length of the shell, and may be simple or divided at its anterior extremity. Ventral valve elevated, subpyramidal; beak straight or slightly arched; muscular impressions undetermined. Exterior surface covered with radiating striæ." (Hall, 1892, *op. cit.*)

Type: *Orthis insignis* Hall.

The ancestral stock from which *Scenidium* was developed is very uncertain, though it seems to have had its origin in the *Clitambonitidæ.* The genus appears in the Trenton, but it is not until the Lower Helderberg formation is reached that the greatest development of its generic character is attained. It is also known in the Middle Devonian of Europe.

Scenidium anthonensis *Sardeson.*

PLATE XXX, FIGS. 20–23.

1869. *Skenidium halli* SAFFORD. Geology of Tennessee, p. 287 (undefined).
1892. *Skenidium anthonensis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 333, pl. IV, fig. 7.
1892. *Scenidium halli* HALL. Palæontology of New York, vol. viii, pt. i, p. 242, pl. VIIA, figs. 33–39.

In its external characters this little species is much like the young of *Orthis tricenaria*, but the concentric growth lines show it to be an adult form. The hinge-line is longer, and the cardinal area of the ventral valve is wider, as compared with that species, while a more conspicuous mesial sinus and fold are present in *S. anthonensis.* Further in the apical portion of the delthyrium there is a small spondylium, and in the dorsal valve the space between the crural plates is thickened by shell deposit and is medially divided by a sharp, but low, cardinal process, the whole being drawn out into a long, angular, medial septum.

Formation and locality.—Rare in the Trenton limestone and shales at Minneapolis, St. Paul and near Cannon Falls, Minnesota. In the Trenton at Dixon, Illinois. Common in the "Glade limestone" at Lebanon, Tennessee.

Collectors.—E. O. Ulrich, W. H. Scofield and C. Schuchert.

Mus. Reg. No. 8252.

Family PENTAMERIDÆ, McCoy.

Genus ANASTROPHIA, Hall.

ANASTROPHIA ? HEMIPLICATA *Hall, sp.*

PLATE XXX, FIGS. 29–31.

1847. *Atrypa hemiplicata* HALL. Palæontology of New York, vol. i, p. 144, pl. XXXIII, fig. 10.
1856. *Atrypa hemiplicata* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 208, figs. 20-23.
1859. *Pentamerus hemiplicatus* BILLINGS. Canadian Journal, vol. iv, p. 316.
1859. *Pentamerus hemiplicatus* HALL. Twelfth Report N. Y. State Cabinet of Natural History, p. 66
1863. *Camarella hemiplicata* BILLINGS. Geology of Canada, p. 168, fig. 154.
1892. *Camarella bernensis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 328, pl. IV, figs. 4–6.

Original description: "Subglobose, pentagonal, wider than long, thickness often equal to the length; cardinal line distinct, short, with (in some specimens) the appearance of a small area on the dorsal [ventral] valve; dorsal [ventral] valve depressed-convex, with an abrupt, broad, not deep sinus, which commences nearly half way from the beak to the base, the beak very small and closely incurved [with a small triangular delthyrium underneath]; ventral [dorsal] valve very convex, becoming gibbous with a broad mesial elevation, commencing one-third of the distance from beak to base, more gibbous towards the beak; sinus marked by two or three strong plications, with three or four upon the mesial lobe, and two or three on each side, all of which reach from one third to one-half the distance from the base to the beak of the shell, leaving the upper half entirely free from these markings; entire surface ornamented by fine, concentric, filiform, subimbricating lines, which are more conspicuous towards the base of the shell and beautifully undulated in crossing the plications."

In Minnesota this species occurs not uncommonly near the base of the Galena and differs from New York examples in having the umbo of the dorsal valve more tumid and elevated beyond that of the ventral valve. The transverse diameter in the former is also shorter, while the individuals are commonly smaller than those from eastern localities.

The generic position of *Anastrophia? hemiplicata* and *A.? scofieldi* is left open for the present until more is known of the interior of those Lower Silurian shells with a camarelloid exterior.

Formation and locality.—Not uncommon in the upper part of the Galena shales eight to thirteen miles south of Cannon Falls; and more rarely at Weisebachs' dam near Spring Valley, Fountain and Preston, Minnesota; Decorah, Iowa; Neenah, Wisconsin. In the Trenton at Middleville, Watertown and Turin, New York; Center county, Pennsylvania; Ottawa, Canada.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 8232 to 8236.

ANASTROPHIA? HEMIPLICATA, var. ROTUNDA, *n. var.*

PLATE XXX, FIGS. 32–35.

This variety is distinguished in having the length and width nearly equal, the valves more convex and the plications somewhat more pronounced on the fold and sinus, and less numerous on the lateral portions of the shell. The figured specimen is strikingly distinct from typical *A.? hemiplicata* in its greater convexity. Younger specimens, however, are less pronounced in this respect, but are still distinguished by their shorter transverse diameter.

Formation and locality.—The specimen figured is from the middle portion of the Galena formation; other smaller individuals have been secured from near the base of the same formation associated with *A.? hemiplicta* near Cannon Falls, Minnesota, and at Decorah, Iowa.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. No. 8231.

ANASTROPHIA? SCOFIELDI, *n. sp.*

PLATE XXX, FIGS. 24–28.

This species seems to be a local development of *A.? hemiplicata*, and differs from it in having attained a larger growth, in being rounder in outline and in having the valves less gibbous, while the smooth or non-plicated portion of the shell is comparatively greater. The fold and sinus also are less marked features, while the number of plications, not only here but on the lateral parts of the shell as well, is greater, there being on the fold and on each side respectively five to seven and three to six in *A. (?) scofieldi* to three to seven and three to four in *A.? hemiplicata.*

In the interior of the ventral valve there is a long, triangular and very narrow spondylium, supported by a septum, and in the dorsal valve are the long crural plates not unlike those in *Anastrophia verneuili* Hall.* When the shell is distorted so that the posterior margins gape, it is seen that the dorsal valve has a very distinct cardinal area, which is more conspicuous than that of the other valve. This feature reminds one of species of *Stricklandinia.*

Formation and locality.—A cluster of thirty specimens was found by Mr. W. H. Scofield near the base of the Galena at a locality eight miles south of Cannon Falls, Minnesota.

Mus. Reg. No. 8230.

*Pal. N. Y., vol. iii, p. 260, pl. XLVIII, fig. 1.

Family STROPHOMENIDÆ, King.

Genus STROPHOMENA, Rafinesque (de Blainville).

1820. *Strophomena*, RAFINESQUE. Annales Gen. Sci. phys. Bruxelles, tom. v, p. 232.
1825. *Strophomena*, de BLAINVILLE. Manuel de Malacologie et Conchyliologie, vol. i, p. 513, pl. LIII, figs. 2–2a.
1892. *Strophomena*, HALL. Palæontology of New York, vol. viii, pt. i, p. 245.

Description: "Shells transversely subsemicircular or semielliptical; greatest width along the hinge-line. Surface concavo-convex and covered with fine radiating striæ, which are equal or alternate in size. The pedicle valve is slightly convex about the umbo, but becomes rapidly concave toward the middle, with the apex perforated, except in old age. The cardinal area is conspicuous and nearly vertical and the delthyrium closed by a convex plate or deltidium [which is internally much thickened medially]. The teeth are widely divergent and are supported by plates which are produced into elevated ridges nearly surrounding the muscular area. The latter is relatively short, subcircular in outline, deeply excavated and divided medially by a more or less distinctly defined longitudinal ridge which is often continued over the pallial region. [Upon each side of this ridge in the posterior half are situated the small, narrow adductor scars, and these are surrounded by the large diductors. It is probable that the adjustors are also present outside the latter, but so poorly defined as not to be recognizable.]

"The brachial valve is concave at the umbo, becoming strongly convex with growth; it has a much narrower cardinal area and the chilidium is rudimentary or incomplete. Dental sockets deep and continued as narrow grooves or indentations across the cardinal area. The crural plates are extended laterally with a slight curve, but are not supported by septa; at their inner margins they unite to form a callosity, upon which rests the short, bilobed cardinal process, which scarcely extends beyond the hinge-line. The muscular surface of this process is cordate in outline and is placed at a low angle to the plane of the area. A low median ridge extends forward from the hinge-plate separating two large adductor scars, in front of which are two narrow elongate impressions. Vascular and ovarian markings frequently well defined. Shell substance fibrous, strongly punctate.

"Type: *Strophomena rugosa* Rafinesque (de Blainville), 1825=*Leptæna planumbona* Hall, 1847." (Hall, *op. cit.*)

The well known species of *Strophomena* can be separated readily into two natural groups; (1) those in which the shell is concavo-convex, and (2) where the valves are biconvex. The interior features are very similar in the two sections and are not available for grouping. The external form of the valves, however, easily allows any of the species mentioned below being referred to either one of the groups. There are, besides these species, a few others, but they are not sufficiently understood by the writers for positive classification.

Group I.—Valves concavo-convex.

S. incurvata Shepard, Trenton.
S. thalia Billings, Trenton.
S. trentonensis, n. sp., Trenton.
S. septata W. and S., Trenton.
S. neglecta James, Hudson River.
S. naglecta, var. *acuta*, n. var., Hudson River.
S. vetusta James, Hudson River.
S. rugosa Rafinesque (de Blainville), Hudson River.
S. rugosa, var. *subtenta* Conrad, Hudson River.
S. planoconvexa Hall, Hudson River.
S. planodorsata W. and S., Hudson River.
S. wisconsinensis Whitfield, Hudson River.
S. trilobata Owen, Galena.
S. fluctuosa Billings, Hudson River.
S. nutans (James Ms.) Meek, Hudson River.
S. hecuba Billings, Hudson River.

Group II.—Valves biconvex.

? *S. minor* Walcott, Upper Pogonip.
S. scofieldi W. and S., Galena Shales.
S. billingsi, n. sp., Trenton and Galena.
S. emaciata W. and S., Galena.
S. halliana Miller, Lower Hudson River.
S. sinuata (James Ms.) Meek, Hudson River.
S. sulcata de Verneuil, Hudson River.
S. cardinalis Whitfield, Hudson River.

Strophomena incurvata *Shepard, sp.*

PLATE XXX, FIGS. 36–40.

1838. *Producta incurvata* Shepard. American Journal of Science, vol. xxxiv, p. 144, figs. 1, 2.
1843. *Orthis incurvata* Castelnau. Essai sur le Système Silurien de l'Amérique Septentrionale, p. 38.
1844. *Strophomena convexa* Owen. Geological Exploration of Iowa, Wisconsin and Illinois, p. 70, pl. xvii, fig. 2.
1847. *Leptæna filitexta* Hall. Palæontology of New York, vol. i, p. 111, pl. xxxiB, figs. 3a to 3f.
1856. *Strophomena filitexta* Billings. Canadian Naturalist and Geologist, vol. i, p. 203, figs. 1, 2.
1859. *Strophomena filitexta* Hall. Twelfth Report N. Y. State Cabinet of Natural History, p. 70.
1863. *Strophomena filitexta* Billings. Geology of Canada, p. 164, fig. 142.
1883. *Streptorhynchus filitexta* Hall. Second Annual Report New York State Geologist, pl. xxxix, figs 1-7; pl. xlii, figs. 11-14 (not figs. 10 and 15=*S. neglecta* James)
1892. *Strophomena filitexta* Hall. Palæontology of New York, vol. viii, pt. i, p. 251, pl. ix, figs. 1-17; pl. ixA, figs. 11-14.

Original description: "The extent of the magnesian limestone in Wisconsin, Upper Illinois and Missouri struck me with surprise. I observed it, in addition to the country already noticed between Chicago and Ottawa, as the prevailing formation about the northern extremity of Michigan, the islands about Michillimacinac, the mouth of Green bay, as well as near Navarino [now Green Bay city, Wisconsin], at the head of the bay. In the last mentioned region it abounded in a species of *Producta*, which I take to be undescribed and shall, therefore, denominate the *incurvata*. Specific character: Semi-circular; hinge nearly straight and the length of the shell; with fine longitudinal striæ; flattish; edge crenated; shallow valve, concave, basal margin incurved; muscular impressions and hinge-process very distinct. The space between the valves is very small in this species."

Shell moderately large, more or less strongly concavo-convex, semi-oval, wider than long, with the greatest breadth along the hinge-line; cardinal extremities acutely angular and deflected, lateral and anterior margins regularly rounded. Surface marked by numerous, fine, subequal, crowded and rounded, radiating striæ, increasing by intercalation, with every second, third or fourth one more prominent. This alternation in the size of the striæ is variable; it is nearly obsolete in some, while in others it is a prominent feature, the whole surface being crossed by numerous and crowded, very delicate, raised, concentric lines and a few stronger marks of growth. Sometimes there are some oblique wrinklings along the cardinal margin on each side of the beaks.

Ventral valve slightly convex in the umbonal region, but otherwise more or less deeply concave; point of greatest elevation at the beak, which is minutely perforated for the passage of the pedicle. Cardinal area variable in width and elevation, slightly retrorse in very gibbose specimens or strongly elevated in flattish specimens; deltidium conspicuous, broadly convex, as wide as, or wider, than long, broadly excavated anteriorly and entirely occupied by the chilidium. The teeth are divergent, not very prominent and attached to the much elevated outer margin of the large, strongly striated, suboval muscular area. In the center of the posterior half of this area there are two slender, short adductor scars, which are separated by a septum attaining its greatest development toward the anterior margin, upon each side of which are the large impressions of the diductors, and probably also of the adjustors. On either side of the muscular area there are numerous, elongated tubercles, arranged in more or less regular radiating series, the genitalia markings. Near the outer margin of the valve is a more or less strongly defined, concentric, irregular thickening, crossed in the anterior region by a number of short, irregular, vascular sinuses. The whole of the interior is minutely granulose.

Dorsal valve flattened or slightly concave in the umbonal region, and more or less strongly convex laterally and anteriorly; sometimes there is a shallow, narrow sinus present, becoming obsolete before reaching the anterior margin. Cardinal area narrow, vertical, centrally occupied by a very broad but short convex chilidium. Dental sockets conspicuous, rapidly narrowing and continued as grooves over the cardinal area along each side of the chilidium, with the thin, erect, crural plates forming their inner walls. The space between the crural plates is slightly thickened and occupied by a short, strong, bilobed cardinal process. Its upper surface is transversely striated and has a shallow median depression along each lobe. The rostral thickening is continued forward but a short distance and converges to a low median ridge which separates the two large, shallow scars of the adductor muscles. In front of the latter are sometimes seen two, linear, slightly diverging ridges, probably the markings of the main trunks of the vascular system. Genital markings on each side of the muscular scars, consisting of series of tubercles of various sizes radially arranged. Surface near the periphery more or less distinctly marked by numerous, short, irregular, radiating striæ, much the strongest in the medial region.

The variations of this species are mainly those of convexity, thickness of shell and alternation of striæ. In the "Lower Blue beds" of Wisconsin, where this species is abundant, the alternation of striæ is a very persistent character and the valves are usually flatter than specimens from other regions.

In the Trenton shales of Minnesota *S. incurvata* is also a common species, often preserving the delicate markings of the interior. The variation in convexity here attains its maximum, and while the striæ likewise alternate in size, this feature is never so conspicuous as in Wisconsin.

This species is usually known as *S. filitexta* Hall. It is thought that to this form Shepard applied the name *S. incurvata* nine years prior to that given by Prof. Hall. One of the writers, through Mr. John M. Clarke, has endeavored to find the types at Amherst College, but Prof. Emerson states that no specimens of it with Shepard's label attached exist at present in that collection. While the original description and illustrations are not very satisfactory, yet sufficient is shown, combined with the locality, to warrant the conclusion that the above specimens were of this widely distributed species. *Strophomena convexa* Owen, proposed three years earlier than Hall's name, is undoubtedly a specimen of the same species, which was derived from the "Blue and Grey limestone of Wisconsin and Iowa." Probably Owen subsequently regarded it as identical with some other form, for in a subsequent report (1852) no mention is made of it.

This species is commonly stated to occur in the Hudson River group, but a comparison of specimens from that horizon with those from the Trenton will show the interior of the dorsal valve of the former to be entirely different in its prominent vascular ridges, while the space beneath the cardinal area on each side of the teeth in the ventral valve is filled up by a deposit of shell matter. Since Mr. U. P. James has applied the name *Strophomena neglecta* to one variation of the species identified by Meek in 1873 as *S. filitexta*, it is advisable to refer to the specimens from the

Hudson River deposits under that name. The literature treating of *S. neglecta* is given below, for the convenience of those having occasion to study this species.

Formation and locality.—Somewhat rare in the Trenton limestone at Minneapolis and Fountain, Minnesota. Common in the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Fountain, Preston, near Caledonia and elsewhere in Minnesota; Decorah and McGregor, Iowa. One of the common species in the "Lower Blue beds" at Mineral Point, Beloit, Janesville and Green Bay city, Wisconsin. In the Trenton limestone at Dixon and Dunleith, Illinois; Auburn, Lincoln county, Missouri. In the Black River, and at the top of Birdseye limestone near High Bridge, Kentucky. Glade limestone at Lebanon and Lavergne, Tennessee. Trenton limestone at Middleville and elsewhere in New York; at Ottawa and county of Renfrew, Canada.

Collectors.—C. L. Herrick, W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 669, 2147, 3733, 3734, 6771, 6773, 6795, 8167-8178.

STROPHOMENA NEGLECTA *James, sp.*

1873. *Strophomena filitexta* MEEK (non Hall). Palæontology of Ohio, vol. i, p. 83, pl. VI, figs. 5a to 5d.
?1875. *Strophomena filitexta* WHITE. U. S. Geological and Geographical Survey west of the 100th Meridian, vol. iv, p. 69, pl. IV, fig. 8.
1875. *Hemipronites filitextus* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 43.
1881. *Streptorhynchus neglecta* JAMES. The Palæontologist, no 5, p. 41.
1883. *Streptorhynchus filitextus* (partim.) HALL. Second Annual Report New York State Geologist, pl. XLII, figs. 10 and 15 (not figs. 11-14); pl. XXXIX, figs. 1-7.
1892. *Strophomena filitexta* HALL. Palæontology of New York, vol. viii, pt. i, pl. IXA, figs. 10 and 15 (not figs. 11-14); pl. XIA, fig. 3.

This species is not known to occur in Minnesota, and is restricted to the Hudson River group. For further remarks see *S. incurvata* Shepard.

Formation and locality.—Oxford, Clarksville, Waynesville and elsewhere in southwestern Ohio. Richmond, Versailles and Weisburg, Indiana; Savannah, Illinois; ?Silver City, New Mexico.

STROPHOMENA NEGLECTA, var. ACUTA, *n. var.*

PLATE XXXI, FIGS. 6 and 7.

Shell of moderate size, resupinate, concavo-convex, the postero-lateral angles mucronate and deflected. Hinge-line wider than any part of the shell in front of it; cardinal area in the ventral valve three to four times as wide as that of the dorsal valve and somewhat elevated beyond it; cardinal margins more or less strongly wrinkled, the elevations being directed medially at various angles. Outer margin semi-ovate, narrowly rounding anteriorly, more broadly laterally, and terminating on the cardinal line in more or less prominent extensions. Dorsal valve plano-convex medially and regularly convex laterally; convexity varying with age, strongest in the larger specimens; point of greatest elevation about mid-length. Ventral valve convex from the beak to nearly mid-length, from here to the anterior margin, and laterally as well, strongly concave, with the postero-lateral portions somewhat deflected. Surface striæ distinctly alternating, from three to five smaller lines between the sharply elevated larger ones. The alternation of the striæ most distinct in the posterior half.

This variety in general appears to be closely related to *Strophomena wisconsinensis* Whitfield,* but is readily distinguished in being less convex and in the very distinct alternation of the striæ. That species is clearly related to *S. rugosa* Blainville, while *S. neglecta*, var. *acuta* belongs to the *S. incurvata* group of strophomenas. *Strophomena vetusta* James** is probably also closely related, but it is more evenly convex, never has a flat central disc in the dorsal valve, while the outline is subquadrate.

Formation and locality.—Not rare in the upper portion of the Hudson River group at Spring Valley, Minnesota.

Collectors.—E. O. Ulrich, W. H. Scofield and the writers.

Mus Reg. No. 5550.

Strophomena trentonensis, *n. sp.*

PLATE XXX, FIG. 41.

1847. *Leptæna subtenta* (partim.) Hall. Palæontology of New York, vol. i, p. 115
1883. *Streptorhynchus subtenta* Hall. Second Annual Report, New York State Geologist, pl. xxxix, fig. 18.
1892. *Strophomena subtenta* Hall. Palæontology of New York, vol. viii, pt. i, p. 251, pl. ix, fig. 18.

This species is closely related to *S. rugosa* var. *subtenta*. The valves are, however, thinner, the striæ more delicate and the oblique wrinkling along the cardinal margins a more constant feature than in that species. The interior characters of *S. trentonensis* are also less strongly developed than in *S. rugosa*. Whether from New York, Minnesota, Kentucky or Tennessee, they exhibit the same undefined internal markings when compared with the Hudson River group specimens of the latter species. It is deemed also advisable to indicate this line of development towards *S. rugosa* of the Hudson River group by separating the Trenton specimens on the above characters with the name *S. trentonensis*.

Prof. Hall (*op. cit.*, 1847) found among the drawings of Mr. Conrad the figure of a *Strophomena* with the name *S. subtenta* attached. The specimen from which this drawing was made Prof. Hall says "is from a western locality" of the upper portion of the Hudson River group of Ohio or Indiana. This form was again described and figured by Meek† as *S. plicata*. As the essential difference between this form and *S. rugosa* is only in the oblique wrinkling of the shell along the cardinal margins we do not consider it of greater importance than varietal.

Formation and locality.—Not common in the Trenton shales at several localities to the south of Cannon Falls, Minneapolis and Fountain, Minnesota. In the "Lower Blue beds" at Janesville and Beloit, Wisconsin. Near the top of the Trenton at Frankfort, Kentucky, and Nashville, Tennessee; Trenton Falls, New York. A few examples apparently of this species have also been found in the Galena shales in Goodhue county, Minnesota.

Collectors.—C. L. Herrick, W. H. Scofield and the writers.

Mus. Reg. Nos. 677, 8179, 8182, 8183.

*Geol. Wis., vol. iv, p. 263, pl. xii, figs. 11-13; 1882.
**Cincinnati Quart. Jour. Sci. vol. i, p. 241; 1874.
†Pal. Ohio, vol. i, p. 81, pl. vi, figs. 4a-4h.

Strophomena septata *W. and S.*

PLATE XXX, FIGS. 1–3.

1892, April 1. *Strophomena septata* W. and S. American Geologist, vol. ix, p. 285.

This species appears to be a local development of *S. trentonensis* W. and S., and as far as external characters are concerned, no distinguishing features can be pointed out. Compared with *S. rugosa*, a still closer resemblance, both externally and internally is seen. However, when the interior is shown it can be separated readily from both by the strong mesial septum of the ventral valve. This originates between the diductor scars and continues to increase in strength to near the anterior margin, where it often coalesces with one or two of the vascular ridges. In *S. trentonensis* the thickening of the interior near the anterior margin of the ventral valve is obsolete or entirely undeveloped, constituting another distinguishing feature between it and *S. septata*. The cardinal process of both species is also more elevated, while the rostral thickening upon which it rests is developed less strongly than in *S. rugosa*, these parts being much as in *S. incurvata*. *S. trentonensis* and *S. septata* never attain the thickness of shell nor the abundance of individuals of *S. rugosa*. The septum of the ventral valve in *S. septata* will also distinguish it from *S. incurvata*, in addition to its smaller size and comparatively greater width than length.

Formation and locality.—Common in the upper third of the Trenton shales at St. Paul, Minneapolis and near Rochester, Minnesota.

Collectors.—C. L. Herrick, E. O. Ulrich and the writers

Mus. Reg. Nos. 345, 676, 4936, 6795, 6798.

Strophomena rugosa (Rafinesque Ms.) *Blainville.*

PLATE XXXI, FIGS. 4 and 5.

1825. *Strophomena rugosa* (Rafinesque) Blainville. Malacologie et Conchyliologie, vol. i, p. 513, pl. liii, figs. 2, 2a.
1827. *Strophomenes rugosa* Defrance. Dictionnaire des Sciences Naturelles, vol. i, p. 151 and atlas.
1847. *Leptœna planumbona* Hall. Palæontology of New York, vol. i, p. 112, pl. xxxi, figs. 4a to 4e.
1850. *Strophomena rugosa* King. Permian Fossils, p. 103.
1862. *Strophomena planumbona* Hall. Geology of Wisconsin, vol. i, p. 54, fig. 7.
1873. *Strophomena (Hemipronites) planumbona* Meek. Palæontology of Ohio, vol. i, p. 79, pl. vi, figs. 3a–3h.
1874. *Streptorhynchus (Strophomena) elongata* James. Cincinnati Quarterly Journal of Science, vol. i, p. 240.
1875. *Hemipronites planumbona* Miller. Ibidem, vol. ii, p. 45.
1877. *Streptorhynchus planumbonus* Miller. American Palæozoic Fossils, p. 134.
1878. *Streptorhynchus elongata* Mickelborough and Wetherby. Journal Cincinnati Society of Natural History, vol. i, p. 76.
1880. *Strophomena planumbona* White. Second Annual Report, Indiana Bureau of Statistics and Geology, p. 483, pl. ii, figs. 13, 14.
1881. *Strophomena planumbona* White. Tenth Report, Indiana State Geologist, p. 115, pl. ii, figs. 13, 14.
1883. *Streptorhynchus planumbona* Hall. Second Annual Report New York, State Geologist, pl. xxxix, figs. 15–17; pl. xlii, figs. 8, 9.

1887. *Strophomena planumbona* (partim) SHALER. Memoirs, Kentucky Geological Survey, p. 13, pls. IV, V.
1892. *Strophomena rugosa* HALL. Palæontology of New York, vol. viii, pt. i, p. 247, figs. 13, 14.
1892. *Strophomena planumbona* or *rugosa* HALL. Ibidem, p. 251, pl. IX, figs. 15–17; pl. XIA, figs. 8, 9.

From the examination made by Prof. Hall (*op. cit.*, 1892,) it appears that this widely-distributed species was never described by Rafinesque. Undoubtedly the latter sent to Blainville or Defrance, or both, specimens of it, with the name *Strophomena rugosa* attached. The species is now well known as *S. planumbona* Hall. Blainville, 1825, was the first to give a diagnosis of *Strophomena* (*loc. cit.*), using as the type "*S. rugosa* Rafinesque," of which he gives two good figures. These have been reproduced by Prof. Hall (*op. cit.*, 1892). In 1827 a description was given of this species in the "Dictionnaire des Sciences Naturelles" by "D. F.," probably Defrance. King, 1850, (*op. cit.*) called attention to the fact that *Strophomena rugosa* (Rafinesque) Blainville and *Leptæna planumbona* Hall are one and the same species. A similar conclusion was also reached by Meek in 1873 (*op. cit.*, p. 73). The following is the description of *S. rugosa* of Defrance, which is copied from Palæontology of New York, vol. viii, pt. i, p. 247: "Strophomène rugueuse; *Strophomenes rugosa* Rafinesque. Coquille bombée en dessous, et dont la valve supérieure est un peu concave et chargée de petites stries rayonnantes. Largeur, un pouce. Fossile de l'Amérique septentrionale. On voit une figure d'une coquille de cette espèce dans l'atlas de ce dictionnaire, planche de fossiles. Des coquilles de ce genre, qu'on trouve à Dudley en Angleterre, ont de très-grands rapports avec cette espèce; elles en diffèrent pourtant en ce que le bord ce celles d'Amérique se retrousse un peu en dessous, tandis que c'est le contraire pour celles d'Angleterre, dont le bord s'abaisse en dessous. On trouve à l'embouchure de la rivière des Alleghanys près de Pittsborough (Amérique septentrionale), dans un grès rougeâtre, des empreintes de coquilles qui ont beaucoup de rapports avec cette espèce, mais qui sont plus aplaties."

"Shell of medium size, concavo-convex, semi-oval or more than semi-circular in outline; hinge line generally a little longer than the breadth of the valves at any point farther forward; lateral extremities, in most examples, somewhat less than rectangular, or sometimes rather acute, more or less compressed and deflected; lateral margins a little contracted posteriorly and rounding to the front, which forms a regular semi-circular curve.

"Dorsal valve flat [or somewhat depressed] in the umbonal region, and rather strongly and evenly convex in the central and anterior regions, from which it rounds off abruptly to the front and lateral margins; beak very small or not distinct from the edge of the narrow or sublinear area, which is inclined nearly directly backward, but not incurved. Interior showing the cardinal process to be small, depressed, divided to its base into two diverging tooth-like parts, a little flattened [or concave and striated] on their posterior faces and directed very obliquely forward and outward; socket ridges short and oblique [but much thickened, and upon them are placed the linear and but slightly elevated crural plates]; mesial ridge low [in some specimens, usually strongly elevated and rounded], extending but a little distance forward, while the space between it and the socket ridge, on each side, is occupied by a moderately distinct muscular scar. [Vascular trunks and genital markings faintly indicated and similar to those in *S. incurvata*.]

"Ventral valve broadly and rather deeply concave in the central and anterior regions, and slightly convex at the beak, which is very small, abruptly pointed, scarcely projecting beyond the edge of the area, and usually [always] minutely perforated; area moderately high, extending the whole length of the hinge, generally but little sloping laterally, flattened and inclined more or less backward, foramen [delthyrium] closed by a prominent, rounded deltidium, that is transversely striated and rather broadly sinuous on its inner edge, for the reception of the [chilidium, which partially covers the posterior portion of the] cardinal process of the other valve. Interior showing hinge-teeth to be well developed, trigonal and striated on their posterior sides, while from their inner bases the dental laminæ extend forward so as nearly to encircle the usual saucer-shaped depression for the [diductor and probably very small adjustor] muscular scars, which is sometimes [always more or less] divided by a small linear mesial ridge [upon each side of which are situated the narrow adductor scars]; cardinal margin prominent and sharp within, on each side of the hinge teeth; anterior and lateral regions more or less thickened within and roughened by the crossing of the vascular markings, which are scarcely visible on any part within this zone.

"Surface of both valves ornamented by numerous fine, closely-crowded, radiating striæ that are often alternately a little larger and smaller or, on some parts, with several of the smaller ones between each two of the larger: the smaller being always shorter than the larger, or ending at various distances between the free margins and the beaks without coalescing with those between which they are intercalated. Striæ and furrows minutely crenulated by extremely small, very regular, closely-arranged, concentric lines, invisible without the aid of a magnifier; a few subimbricating marks of growth are likewise seen near the free margins." (Meek, *op. cit.*)

The comparative length and width of the shell vary considerably in this species, the latter being in some cases equal to two-thirds, in other cases only about one-half of the former. The narrow specimens with the long hinge-line have received the name *S. elongata* James, but a large collection will show every gradation between this and *S. planumbona* or *rugosa*. Some specimens are nearly as long as wide and are often difficult to separate from *S. nutans* (James' Cat.) Meek. The latter, however, in its typical condition, is very distinct and approaches *S. fluctuosa* Billings.

S. incurvata Shepard, of the Trenton, became *S. neglecta* James, of the Hudson River group. *S. trentonensis* likewise was changed into *S. rugosa* Blainville, and *S. winchelli* developed into *S. nutans.* In the Trenton formation of Minnesota *S. septata,* a local variation of *S. trentonensis,* is found, and in the Hudson River group of the Northwest, *S. rugosa* and *S. wisconsinensis* are representatives of the latter.

Formation and locality.—Common in the Hudson River group in Ohio, Indiana and Kentucky: Anticosti; Iron Ridge, Wisconsin, and Spring Valley, Minnesota. At Graf, Iowa, and Iron Ridge, Wisconsin, a variety occurs in which the concentric growth lines are very conspicuous and farther apart than in *S. rugosa,* and this may prove, when more material is at hand, to be specifically distinct.

Collector.—C. Schuchert.

Mus. Reg. Nos. 8184, (? 8185, 8186).

Strophomena rugosa var. subtenta (*Conrad Ms.*) *Hall.*

1841. *Strophomena subtenta* Conrad. Fifth Annual Report, New York Survey, p. 37 (undefined).
1847. *Leptæna subtenta* Hall. Palæontology of New York, vol. i, p. 115, pl. xxxiB, figs. 9-9b.
1862. *Strophomena subtenta* Billings. Palæozoic Fossils, vol. i, p. 132, fig. 109 on p. 130.
1873. *Strophomena (Hemipronites) plicata* (James) Meek. Palæontology of Ohio, vol. i, p. 81, pl. vi, figs. 4a, 4b.

Conrad's specimens of *Strophomena subtenta* were found in the Hudson River group of the Ohio valley, and can be distinguished from *S. rugosa* Blainville only by the oblique wrinkling of the shell along the cardinal margins. This character we do not regard as of greater value than varietal. For further remarks see *Strophomena trentonensis.*

Formation and locatity.—Rare in the Hudson River group at Spring Valley, Minnesota. Other localities as for *Strophomena rugosa.*

Strophomena planodorsata *W. and S.*

PLATE XXXI, FIGS. 8–10.

1892, April 1. *Strophomena planodorsata* W. and S. American Geologist, vol. ix, p. 286.

Shell large, semicircular or subquadrate in outline, concavo-convex, wider than long, greatest width along the hinge-line, or immediately in front of it. Surface with fine, radiating striæ, every second or third one somewhat stronger than those intermediate, crossed by exceedingly delicate, closely crowded concentric lines, and towards the anterior margin by a few larger subimbricating lines of growth. Dorsal valve flat or very slightly concave for more than half the length and breadth of the shell from the cardinal margin, thence sloping rapidly towards the lateral and anterior edges. Cardinal area linear, slightly reflexed and centrally occupied by an inconspicuous deltidium. Interior unknown.

Ventral valve slightly concave, except near the lateral and anterior margins, where it is strongly bent. Cardinal area 5 mm. or more in width in adult examples, more or less elevated, but never very strongly so; deltidium depressed convex, about as wide as long and distinctly limited laterally by linear elevations, with a depression outside of the latter; internally much thickened; apical perforation or pedicle opening exceedingly minute. Teeth not large for a shell of the size of this species; unsupported. Muscular depression very large, subquadrate in outline, with a sharply elevated outer margin, which has its postero-lateral limits outside the hinge teeth; medially divided by a more or less prominent ridge, upon each side of which are the large, longitudinally striated, diductor scars, enclosing the small adductors situated centrally in the posterior half. Space underneath the cardinal area filled up with shell matter. Near the outer margin there is occasionally a slight elevation, which is crossed medially by a few, not very prominent, vascular ridges. Entire interior surface covered with more or less radially arranged, delicate, oblique granules, which become more pronounced immediately outside the muscular margin.

The size, large flattened area of the dorsal valve, and the subquadrate form of the muscular area of the ventral valve, distinguish this species from all others having the structure of *S. rugosa*.

Formation and locality.—Rare in the Hudson River group near Spring Valley and Wykoff, Minnesota; Iron Ridge, Wisconsin, and Wilmington, Illinois. The interior characters are described from specimens from the last named locality.

Collectors.—E. O. Ulrich, C. Schuchert.

Mus. Reg. No. 8191.

Strophomena winchelli *Hall.*

PLATE XXXI. FIG. 11.

1883. *Streptorhynchus* (*Strophonella?*) *deltoidea* Hall (not *Leptæna deltoidea*, 1847). Second Annual Report, N.Y. State Geologist, pl. xxxix, figs. 10, 12–14 (not fig. 11= *S. nutans.*)

1892. *Strophomena winchelli* Hall. Palæontology of New York, vol. viii, pt. i, p. 344, pl. ix, figs. 10, 12–14; pl. xx, fig. 26.

This species, though quite as large, differs from *S. trentonensis* in being more commonly longer than wide, and is probably the parent stock of the later appearing species *S. nutans* and *S. fluctuosa*. From these it is separated readily by its thinner, less convex shell, finer and more numerous striæ, the central disc also being without corrugations and less depressed than in *S. nutans*. A large collection would probably show intermediate variations between *S. trentonensis* and *S. winchelli*, as are found to occur between *S. rugosa* and *S. nutans* of the Hudson River group. These transitional specimens are, however, rare and should therefore not be used to unite the species. If this were done, to be consistent, all the above mentioned forms, together with *S. incurvata* and *S. neglecta* should be referred to one common, widely distributed and variable species.

Formation and locality.—Rare in the "Lower Blue beds" at Janesville and Clifton, Wisconsin. In the Galena at Oshkosh, Wisconsin. It has not been observed in Minnesota.

Collector.—C. Schuchert.

Mus. Reg. Nos. 8180, 8226.

Strophomena trilobata *Owen, sp.*

PLATE XXXI, FIGS. 12 and 13.

1852. *Leptæna trilobata* Owen. Geological Survey of Wisconsin, Iowa and Minnesota, p. 584, pl. II, figs. 17, 18.
1877. *Strophomena trilobata* Miller. American Palæozoic Fossils, p. 138.

Original description: "This species was at first referred to the species *deltoidea*, but the form is so decidedly different in several respects that it seems to constitute a distinct species. Dorsal valve broadly trilobate, very gibbous in front and depressed towards the hinge-line; margin undulating, semioval; ventral valve concave; hinge-line extended; fine and equally radiating striæ, partaking of the curvature of the surface of the shell.

"The outline of this shell is much more undulating, shell more gibbous and broader, and more distinctly trilobate than the *deltoidea*.

"It occurs in the shell-beds F. 3A, near the Agency, on the Turkey river, Iowa."

Owen's illustrations, and his statement that the shell is "very gibbous in front and depressed towards the hinge-line," leaves very little doubt that *S. trilobata* is identical with a species occurring in the middle beds of the Galena in Minnesota. It is true that associated with these specimens are also very gibbous examples of *Rafinesquina deltoidea*. These, however, are never as flat on the central disc nor have they the nasute anterior margin of *S. trilobata*. To *S. fluctuosa* this species is closely related, but can be distinguished by the following features: The flat central disc is comparatively smaller, the shell anteriorly is twice as long and incurved, while in *S. fluctuosa* it is always flat, and the ventral cardinal area is strongly retrose. The interior characters and the corrugation of the flat central disc are, as far as can be determined, essentially as in *S. fluctuosa*.

Formation and locality.—The species is abundant in the middle beds of the Galena horizon, but since it usually occurs as natural casts it is not often gathered by collectors. It occurs at Kenyon and elsewhere in Goodhue county, Mantorville, Old Concord and near Rochester, Minnesota. Turkey river Iowa. Probably also in the Galena of Wisconsin.

Collectors.—A. D. Meeds, W. H. Scofield, M. W. Harrington and N. H. Winchell.

Mus. Reg. Nos. 208, 293, 369, 371, 391, 7253, 8189, 8190.

Strophomena fluctuosa *Billings.*

PLATE XXXI. FIGS. 14–17.

1860. *Strophomena fluctuosa* Billings. Canadian Naturalist and Geologist, vol. v, p. 57, fig. 6
1862. *Strophomena fluctuosa* Billings. Palæozoic Fossils, vol. i, p. 123, fig. 102.
1863. *Strophomena fluctuosa* Billings. Geology of Canada, p. 209, fig. 207.
1892. *Strophomena fluctuosa* Hall. Palæontology of N. Y., vol. viii, pt. i, p. 251, pl. XIA, figs. 4, 5.

Original description: "Triangular or semioval, usually widest at the hinge-line and more or less narrowly rounded, pointed, trilobed or nasute in front.

"Dorsal valve convex, the visceral disc being in general equal to one-third the superfices of the whole valve, nearly flat, the remainder abruptly curved down all around so that the lower half of the length of the shell is sometimes at right angles with the upper half. The cardinal angles more or less compressed and often a little reflected, usually forming angular or narrowly rounded ears. Ventral valve concave, the curvature corresponding to that of the dorsal valve.

"Area of dorsal valve lying in the plane of the lateral margin, about one-third of a line high. Area of ventral valve forming a right angle with the marginal plane, in large specimens one line or a little more in hight at the beak, and gradually decreasing towards the extremities of the hinge-line.

"Foramen of ventral valve triangular; the width at the base somewhat exceeding the hight, completely closed by a convex deltidium, the basal margin of which is rendered a little concave by the convex margin of the similar deltidium [chilidium] which closes the foramen of the dorsal valve.

"Surface with a set of fine, rounded, elevated, radiating striæ, distant from each other usually about half a line, sometimes a little less, and occasionally one line. Between each two of these there are from two to ten much finer striæ; the whole crossed by fine, crowded, concentric lines. In most of the specimens the whole of the upper half of the shell is covered with short undulating wrinkles, which sometimes have a concentric arrangement and often form concentric rows converging from the hinge-line towards the center of the shell, crossing each other. The specimens from the Trenton limestone are usually without these undulations, [probably *S. winchelli*], but in those from the Hudson River group this character is prominently exhibited." Interior of both valves very much as in *S. nutans* (James) Meek, or *S. rugosa* Blainville.

This species has been confounded with *Rafinesquina deltoidea* Conrad, sp., as figured by Prof. Hall (Pal. New York, vol. i). The types now in the American Museum of Natural History, in New York city, have been carefully examined by Prof. Hall, Mr. Clarke and one of the writers. After considerable difficulty, owing to the thinness of the shells and the limestone matrix, it was proved that *R. deltoidea*, when compared with *S. fluctuosa*, has the convexity of its valves reversed and is, therefore, a species of *Rafinesquina*. *R. deltoidea* must therefore be restricted to the specimens figured by Hall in 1847. Trenton shells from Canada and Wisconsin, devoid of the corrugated surface, and usually referred to this species, are removed from *S. fluctuosa* and *R. deltoidea* and used as the type of a new species, *S. winchelli* Hall (*op. cit.*, pl. IX, figs. 10, 12-14). *S. fluctuosa* thus becomes a well marked species, restricted to the Hudson River group, and takes the place of *S. nutans* of the Ohio valley, in the deposits of this formation on Anticosti and in Minnesota.

Formation and locality.—Common in the Hudson River group at Spring Valley, Wykoff and near Granger., Minnesota: Anticosti.

Collectors.—E. O. Ulrich, W. H. Scofield and the writers. Also in the collection of Dr. C. H. Robbins, of Wykoff, Minnesota.

Mus. Reg. Nos. 232, 430, 4077, 8187, 8188.

STROPHOMENA BILLINGSI *n. sp.*

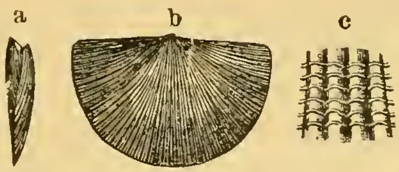


FIG. 32. Billings' original illustration of *Strophomena recta*. *a*, side view: *b*, ventral view: *c*, portion of face enlarged.

1862. *Strophomena recta* BILLINGS (non Conrad). Palæozoic Fossils, vol. i, p. 130, figs. 108*a*–108*c*.

Original description: "Semielliptical, both valves nearly flat, hinge-line equal to, a little greater or a little less than, the width; sides somewhat straight for about half the length, and either parallel or slightly converging forwards; all of the front half of the shell uniformly rounded, sometimes only gently convex or somewhat straight in the middle of the front margin. Ventral valve slightly convex in the umbonal regon, and elsewhere flat or gently concave; beak scarcely distinct from the cardinal area, slightly depressed below the umbo; area of medium size, flat, extending the whole length of the shell, forming an obtuse angle of from 110° to 135° with the plane of the lateral margin; foramen triangular, width at the base greater than the hight, closed by a convex deltidium which does not quite reach the hinge-line, but has its lower margin concave. Dorsal valve uniformly very depressed convex or nearly flat, slightly concave at the cardinal angles and with a barely perceptible mesial depression along the middle, which commences very near the beak and extends one-third or one-half the length of the shell; beak very small and minutely elevated above the cardinal edge; area varying in size from less than one-half to nearly equal that of the ventral valve.

"Surface with fine, rounded, slightly crenulated, radiating striæ of different sizes, the smaller coming in by implantation at various distances from the beak. In some specimens the striæ are more nearly of one uniform size than in others; at the front margin there are usually four of the larger and four or five of the smaller striæ in the width of one line. When the surface is perfectly preserved it is seen to be beautifully cancellated by fine, apparently squamose striæ, which are undulated slightly upward in passing over the ridges. There appear to be from ten to twelve concentric striæ in the width of one line.

"Width of largest specimen collected, one inch; length, nine lines; hight of ventral area, one line."

Strophmena recta Conrad we regard as founded on young specimens of the same author's *Strophomena deflecta,* which is no longer referred to *Strophomena,* but belongs to Prof. Hall's subgenus *Dinorthis* of *Orthis.* Even if the above conclusion is not accepted the specimens of Billings cannot be retained under Conrad's name, since they clearly belong to *Strophomena,* while *Strophomena recta* Conrad must be referred to *Dinorthis.* This leaves Billings' species without a name and we propose therefore to designate it as above.

S. billingsi belongs to our group II of *Strophomena* and is related to *S. scofieldi.* The former differs in having a far less defined sinus and fold, finer radiating striæ and the concentric growth lines more delicate and closely crowded.

Formation and locality.—In the Galena shales at St. Paul, near Cannon Falls and Fountain, Minnesota. In the upper beds of the Trenton limestone, Ottawa, Canada.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. No. 8192.

STROPHOMENA SCOFIELDI *W. and S.*

PLATE XXXI, FIGS. 18–21.

1892, April 1. *Strophomena scofieldi* W. and S. American Geologist, vol. ix, p. 286.
1892, April 9. *Streptorhynchus subsulcatum* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 335, pl. IV, fig. 39.

Shell small, semicircular in outline, biconvex, with a more or less prominent fold and sinus towards the anterior margin: hinge-line a little shorter than the greatest width; area of ventral valve forming an angle of about 140° with the plane of the lateral margin, centrally occupied by a convex, perforated deltidium, which fits closely against the chilidium of the other valve. Surface marked by numerous, crowded, rounded, radiating striæ, increasing in number by implantation, with from 110 to 120 along the outer margin in adult shells, crossed by delicate, crowded, concentric lines and a few larger growth marks.

Dorsal valve not deep, evenly convex, or with a fold near the anterior margin. Cardinal area very narrow and slightly reflexed. Crural plates prominent, very oblique, coalescing medially; upon this thickening at its base originate two low ridges, which continue upward and outward into the small, low cardinal process, about half of which is covered by the chilidium. Immediately underneath the crural plates are two pairs of small adductor scars, separated by a low, rounded and short septum, which bifurcates anteriorly. Near the anterior margin of the posterior pair of scars two other ridges arise, making four in all, probably the main trunks of the vascular system. Very small genital spaces indicated outside the muscular scars and in front of the crural plates.

Ventral valve somewhat deeper than the other, evenly convex, or with a broad, shallow sinus near the anterior margin. Hinge teeth prominent and joining the outer elevated margin of the short, suboval, muscular area. This is centrally divided by a low ridge, separating the two pairs of adductor and diductor scars.

This species is of the type of *S. sinuata* (James) Meek.* *S. scofieldi* can readily be distinguished from the latter by its smaller size and greater number of striæ, having about sixty. The profound fold and sinus, greater size, and less numerous striæ of *S. sulcata* de Verneuil,† will distinguish it from *S. scofieldi*. Another related species is *S. cardinalis* Whitfield.‡ The more elevated cardinal area, very convex dorsal valve and greater width of the shell, distinguish this form from *S. scofieldi*.

Formation and locality.—Rare near the base of the Galena shales at Minneapolis and St. Paul; common in association with *Clitambonites diversa* at several localities south of Cannon Falls, Minnesota. A single specimen of it has been collected near the top of the "Lower Blue beds" north of Beloit, Wisconsin.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. Nos. 8193-8195.

Strophomena emaciata *W. and S.*

PLATE XXXI, FIGS. 22—24.

1892, April 1. *Strophomena emaciata* W. and S. American Geologist, vol ix, p. 287.

Shell small, depressed, biconvex, semicircular in outline; hinge-line usually somewhat smaller than the greatest width of the valve. Surface marked by numerous angulated striæ, increasing in number by interpolation, having from sixty to seventy-five of the large and small ones along the anterior margin.

Ventral valve depressed-convex, subangulated medially, greatest point of elevation about mid-length. Cardinal area narrow, less than 1 mm. in width, strongly elevated, with a very convex, apically-perforated deltidium, which is somewhat wider than long and excavated for the reception of the chilidium.

Dorsal valve slightly convex, with or without a shallow sinus, having its origin near the beak and rapidly widening to the anterior margin, which is more or less sinuous, according to the depth of the medial depression. Cardinal area linear, with a short, broad chilidium partially covering the cardinal process. Interior unknown.

This little species was at first regarded as the young of some form of *Strophomena*. There are two species associated with it—*S. scofieldi* and *S. trentonensis*. If

*Pal. Ohio, vol. 1, p. 87, pl. v, figs. 5a—5f.

†Ibidem, p. 85, pl. v, figs. 4a-4e.

‡Geol. of Wisc., vol. iv, p. 261, pl. xii, figs. 9, 10.

immature examples of the latter of the same size as adult individvals of *S. emaciata* be examined, it will be seen that a greater number of less conspicuous striæ are present, that the shell near the anterior margin is decidedly more convex, and that the umbo is not depressed as in *S. emaciata,* the last feature being more or less strongly developed in all the concavo-convex *Strophomenas.* The subcarination of the ventral valve of *S. emaciata* is also present in *S. trentonensis,* but in the former the shell is evenly convex from the cardinal line to the anterior margin, while in the latter it is concavo-convex. With these constant differences there is no ground for assuming that *S. emaciata* is the young of *S. trentonensis.* In *S. scofieldi* it is seen that the hinge line is somewhat shorter, that the valves are more convex, and that the fold and sinus are just the reverse of those in *S. emaciata.*

Formation and locality.—Several specimens have been collected by Mr. W. H. Scofield near the base of the Galena in the *Clitambonites* beds south of Cannon Falls, Minnesota.

RAFINESQUINA, Hall, 1892.

Strophomena of most American authors.

1892. *Rafinesquina,* HALL. Palæontology of New York, vol. viii, pt. i, p. 280.

Description: "Shells normally concavo-convex. Surface ornamented by radiating striæ of alternating size, crossed and crenulated by finer concentric striæ. Cardinal margins without denticulations. Interior of the pedicle valve with the muscular area not strongly limited; consisting of two broad, flabellate, diductor scars enclosing an elongate, more distinctly defined adductor. The faintness of the limitation of this area is in marked contrast to the sharply defined muscular area in the corresponding valve of *Leptæna.* In the brachial valve the cardinal process is more closely sessile than in *Leptæna,* and there is frequently a linear callosity between the branches. The posterior adductor scars have the arborescent markings of *Leptæna rhomboidalis,* and these impressions are the only ones well defined, the anterior scars being narrow and rarely retained with distinctness. From the anterior margin of the muscular area radiates a series of irregular furrows and nodose ridges, which are, to some extent, of vascular origin.

"Type: *Leptæna alternata* Conrad. Trenton and Hudson River groups."

Rafinesquina had its origin in the Calciferous and died out in the Clinton group.

Rafinesquina minnesotensis *N. H. Winchell.*

PLATE XXXI. FIGS. 25–29.

1844. *Strophomena deltoidea* Owen (not Conrad). Geological Exploration of Iowa, Wisconsin and Illinois, pl. XVI, fig. 8; pl. XVII, fig. 6.
1852. *Leptæna deltoidea* Owen (not Conrad). Geological Report of Wisconsin, Iowa and Minnesota, p. 620, tab. 2B, fig. 10 (not the middle figure).
1862. *Strophomena incrassata* Hall (not 1847). Geology of Wisconsin, vol. i, p. 42, fig. 16.
1873. *Leptæna deltoidea* N. H. Winchell. First Annual Report of the Geological and Natural History Survey of Minnesota, p. 101; Ibidem, Fifth Report, p. 148; Ibidem, Eighth Report, p. 62.
1881. *Strophomena minnesotensis* N. H. Winchell. Ibidem, Ninth Report, p. 120.
1883. *Strophomena incrassata* Hall (not 1847). Second Annual Report New York State Geologist, pl. XXXVIII, figs. 1–5.
1892. *Rafinesquina incrassata* Hall. Palæontology of New York, vol. viii, p. 281, pl. VIII, figs 1–5.
Compare *Leptæna incrassata* Hall. Palæontology of New York, vol. i, p. 19, pl. IV bis, figs. 2a–2d, 1847.

Original description: "Shell semioblong or semioval, with the cardinal angle about 90°, or less than 90°; diameter from six to nine lines transversely, and from four and a half to eight lines perpendicularly [Wisconsin specimens attain a greater size]; the receiving [ventral] valve convex, sometimes more suddenly deflected after passing the visceral area; entering [dorsal] valve gently concave, but reflexed more rapidly about the margin; the exterior of the convex [ventral] valve marked by fine, radiating striæ, every third, fourth or fifth one being larger than the intervening ones; interior of the convex [ventral] valve, which is best known from its frequent casts, shows a large muscular impression much resembling that of *S. alternata* as figured by Meek in vol. i, Pal. Ohio, plate VII, fig. 3c, but somewhat bilobate in front and larger in proportion to the size of the valve; scars of adductor muscles closely approximate, small and in many casts of this valve undistinguishable; behind they are separated (on the casts) by a short mesial ridge, which between them becomes a narrow mesial furrow and then a deep furrow, terminating at the sinus between the outer larger scars; the outer larger scars [diductors] are radiately striated from the beak [at the base of the dental lamellæ small adjustors are occasionally indicated]; their margins are strongly marked (on the cast) along their posterior sides by distinct grooves formed by the dental plates, which diverge at once from the foramen at an angle of 100–120°, running nearly straight to the outer margins of the muscular scar, when they curve slightly towards the front; the anterior and lateral margins of the general muscular impression are slightly marked on the casts; outside of the muscular scar is a shallow marginal impressed line which is most evident at the cardinal angles as it converges toward the beak; interior edge of the cardinal line is carinate from the teeth to the cardinal angles; the details of the markings in the apex of the beak are seen on the valve itself to consist of two short, distinct, diverging ridges extending not much beyond the hinge teeth [enclosing the adductor

—26

scars], between the anterior ends of which rises a short mesial ridge of about the same size and length, with faint linear ridges parallel with it on each side, which extend a little further forward than the mesial ridge. The mesial ridge first gives place to a flat, unmarked interval, when it again rises more conspicuously, but narrower and sharper, extending nearly to the sinus separating the lobes of the outer muscular scar. The cardinal area of the convex valve slopes from the hinge-line obliquely backward, instead of being in plane with the lateral edges, thus differing from *S. alternata*. From three to five short undulations of the shell transverse to to the cardinal line, are seen often between the umbo and the cardinal angles, the heavier ones being near the cardinal angles. The cardinal process is bifid and prominent, the two parts being short, smooth, dentate protuberances that stand prominently exposed about parallel with the plane of the cardinal area.

"The interior of the entering [dorsal] valve is very different from that of the entering valve of *S. alternata*. The general visceral disc is nearly flat, surrounded by a suddenly flexed margin, inside of which is a shallow impressed broad line, most evident round the front; inside the cardinal angles are a few scattered, radiately-interrupted, short ridges or elevations [genital markings], but these do not prevail along the side nor in front, the surface there being smooth or finely granulated instead; in the center of the valve are five smooth, abrupt, digitately-spreading ridges, the middle one of which is a little larger and longer than the others; these rise more abruptly at their anterior extremities than behind, but none of them reach the beak, or even the umbonal region, though the exterior pair of lateral ones are placed further back than the others, converging at an angle of about 70° [and often pass through the large pair of adductor scars]. Socket [crural] ridges very short and widely divergent; behind them are small, doubly-grooved sockets." The beak of the ventral valve is often perforated by a minute, circular, pedicle opening.

R. incrassata Hall* seems to be a closely allied species, of which a few examples from the typical locality have been examined, but they are too poor for detailed comparison. These specimens and Prof. Hall's figures of the species are constant in size and always smaller than *R. minnesotensis*. Billings,† however, found *R. incrassata* "in the Chazy limestone at the Mingan islands, and in the Black River limestone at the Fourth Chute of the Bonnechère, Canada. Specimens from the latter locality agree precisely with those sent me from Tennessee by Prof. Safford." Of the Tennessee specimens referred to by Billings, the writers possess a complete series, and find them to be identical with *R. minnesotensis* Winchell. It is probable that *R. minnesotensis* is only a larger development of the eastern *R. incrassata*.

---

* *Leptæna incrassata* Hall. Pal. N. Y., vol. I, p. 19, pl. IV bis, figs. 2a-2d.
† Canadian Nat. and Geol., vol. IV, p. 443, 1859.

Formation and locality.—Very common in the upper portion of the Trenton limestone at Minneapolis, St. Paul, Cannon Falls and Fountain, Minnesota. Also abundant in the "Lower Blue beds" at Janesville and Beloit, Wisconsin; Rockton, Illinois. Very rare in the Trenton shales at St. Paul and Cannon Falls, Minnesota; Decorah and McGregor, Iowa. Also at Dixon, Illinois, in the Trenton; in the Birdseye limestone at High Bridge, Kentucky, and in the "Glade limestone" at Lebanon, Tennessee.

Collectors.—C. L. Herrick, H. V. Winchell, Wm. Howling, W. H. Scofield and the writers.

Mus. Reg. Nos. 671, 673-675, 681, 685, 704, 705, 2192, 3521-3523, 3731, 5059, 5097, 5673, 7919, 8143-8148.

Variety INQUASSA *Sardeson.*

PLATE XXXI, FIGS. 27, 28.

1892. *Strophomena inquassa* SARDESON. Bulletin of the Minnesota Academy of Natural Science, vol. iii, p. 334, pl. v, figs. 22-24.

This name is applied to large convex shells with a wide ventral hinge area which otherwise strongly resemble *R. alternata.* In Minnesota specimens are rare. They occur in the upper third of the Trenton shales and continue upward into the Galena, passing into a very gibbose form, *R. deltoidea* Conrad. In Wisconsin variety *inquassa* is quite abundant near the base of the "Upper Buff limestone" and has been identified by Hall as *Strophomena incrassata* (*op. cit.*, 1862). It is not always easy to distinguish between *R. minnesotensis*, var. *inquassa*, *R. deltoidea* and *R. alternata.* This is particularly the case between var. *inquassa* and the latter species when the exterior alone is visible. The thickening of the shell, however, near the anterior margin on the interior of the dorsal valve in *R. alternata* is much stronger, while the four ridges of *R. minnesotensis*, var. *inquassa,* two on each side of the median septum, are reduced to two in the former species. The tendency in the progressive line of development from *R. minnesotensis* seems to be towards larger growth (var. *inquassa*) and greater convexity (*R. deltoidea*), while another series tends to flatter shells and maximum of size (*R. alternata*).

Formation and locality.—Rare in the Trenton shales at Minneapolis, St. Paul and elsewhere in Minnesota. Common near the base of the "Upper Buff beds" at Mineral Point, Wisconsin.

Mus. Reg. Nos, 8141.

RAFINESQUINA DELTOIDEA *Conrad, sp.*

PLATE XXXI. FIGS. 30 and 31.

1839. *Strophomena deltoidea* CONRAD. Third Annual Report of the New York Geological Survey, p. 64; Fifth Report, p. 37, 1841.
1842. *Strophomena deltoidea* VANUXEM. Geology of New York; Report Third District, p. 46, fig. 2.
1842. *Strophomena deltoidea* EMMONS. Ibidem, Report Second District, p. 389, fig. 2.
1842. *Strophomena camerata* CONRAD. Journal of the Academy of Natural Sciences of Philadelphia, vol. viii, p. 254, pl. XIV, fig. 5.
1847. *Leptæna camerata* HALL. Palæontology of New York, vol. i, p. 106, pl. XXXIA, figs. 2a, 2b.
1847. *Leptæna deltoidea* HALL. Ibidem, p. 106, pl. XXXIA, figs. 3a-3e.
1863. *Strophomena deltoidea* BILLINGS. Geology of Canada, p. 163, fig. 141.
1883. *Streptorhynchus* (*Strophonella*) *deltoidea* HALL. Second Annual Report N. Y. State Geologist, pl. XLII, figs. 1, 2, 4 (not fig. 3).
1892. *Rafinesquina deltoidea* HALL. Palæontology of New York, vol. viii, pt. i, pl. IXA, figs. 1, 2, 4.

Original description: "Shell deltoid, with numerous radiating striæ and concentric rugose undulations, obsolete on the inferior half of the valves; inferior valve slightly convex above, gibbose, abruptly rounded and flattened at the base; striæ small and crowded; one or two lines in the middle of the valve larger and more prominent than the others; angles of the cardinal line slightly prominent. Length, one inch. *Locality*, Trenton Falls."

This species is closely related to *Rafinesquina alternata*, and differs from it both in its greater convexity and in the corrugations of the central disc. The latter feature is never very well developed in Minnesota specimens, while the convexity may be very great as in *camura*, with all variations to those nearly flat. These depressed convex specimens, especially when the concentric corrugations are obsolete, approach *R. alternata* so closely that it is difficult or impossible to separate them. Such forms are, however, rare. This same difficulty is also met with in New York specimens. Prof. Hall writes,* "it is certainly often very difficult to draw the line of distinction between this species [*R. deltoidea*] and *L. alternata*, and more particularly so between this and *L. camerata*."

R. deltoidea is associated with *Strophomena trilobata*, a species with about the same curvature and corrugations of the central disc. The latter can be readily distinguished by the reversed convexity of the valves, the upper, or strongly rounded valve being the dorsal, while in *R. deltoidea* this is the ventral valve. The nasute anterior portion of the shell and the small, flat, or even slightly concave, central disc will also assist in separating *S. trilobata* from *R. deltoidea*.

Formation and locality.—From the top of the Trenton shales at St. Paul and Cannon Falls, Minnesota, examples have been found which probably belong to this species. Near the middle of the Galena formation at Mantorville, it occurs commonly as casts and retains more or less of the shell at several localities in Goodhue county, and at Weisebach's dam near Spring Valley; close to the top of the formation near Hamilton, and in the lower portion of the Hudson River group at Granger, Minnesota. In the Galena at Oshkosh, Wisconsin, and near the top of the hills at Dubuque, Iowa. Prof. Whitfield gives it as occurring in the Trenton, Galena and ?Hudson River group of Wisconsin. In the Trenton of New York and Canada. Davidson† mentions it as occurring in the Caradoc or Bala period in England, Scotland and Ireland, also "at Paggart, in Esthonia, and at Reval; in Norway and elsewhere." It is believed by the writers, however, that a direct comparison of the British examples referred to *R. deltoidea* will prove them to be different from American specimens in their muscular markings and crural plates.

Collectors.—M. W. Harrington, W. H. Scofield and the writers.

Mus. Reg. Nos. 174, 182, 204, 261, 387, 389, 394, 3395, 8157–8164.

Rafinesquina alternata (*Conrad Ms.*) *Emmons.*

PLATE XXXI, FIGS. 32–34.

1838. *Leptæna alternata* Conrad. Second Annual Rep. N. Y. Geological Survey, p. 115 (undefined)
1838–41. *Strophomena alternata* Conrad. Ibidem, Third Report, p. 63; Fourth Report, p. 201; Fifth Report, p. 37 (undefined).
1842. *Strophomena alternata* Emmons. Geology of New York; Report Second District, p. 395, fig. 3.

* Pal. N. Y., vol. i, p. 107.
† Monograph of British Silurian Brachiopoda, p. 292.

1843. *Orthis huronensis* CASTELNAU. Essai sur le Système Silurien de l'Amérique Septentrionale, p. 37, pl XIV, fig. 6.
1843. *Orthis plana* CASTELNAU (not PANDER). Ibidem, p. 38, pl. XIV, fig. 1.
1844. *Strophomena angulata?* OWEN. Geological Explorations in Iowa, Wisconsin and Illinois, pl. XVIII, figs. 1, 3.
1847. *Leptæna alternata* HALL. Palæontology of New York, vol. i, pp. 102, 286, pl. XXXI, fig. 1; pl. XXXIA, fig. 1; pl. LXXIX, fig. 2.
1856. *Strophomena alternata* BILLINGS. Canadian Naturalist and Geologist, vol, i, p. 204, figs. 3, 4.
1858. *Leptæna alternata* ROGERS. Geology of Pennsylvania, vol. ii, pt. i, p. 818, fig. 600.
1860. *Strophomena alternata* BILLINGS. Canadian Naturalist and Geologist, vol. v, p. 51.
1862. *Strophomena alternata* BILLINGS. Palæozoic Fossils, vol. i, p. 117.
1863. *Strophomena alternata* BILLINGS. Geology of Canada, p. 163, fig. 140.
1865. *Strophomena antieostiensis* SHALER. Bulletin of the Museum of Comparative Zoology, vol. i, p. 62.
1873. *Strophomena alternata* MEEK. Palæontology of Ohio, vol. i, p. 88, pl. VII, fig. 1.
1875. *Strophomena alternata* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 51,
1880. *Strophomena alternata* WHITE. Second Annual Report of the Indiana Bureau of Statistics and Geology, p. 481, pl. I, figs. 6, 7.
1881. *Strophomena alternata* WHITE. Tenth Report State Geologist of Indiana, p. 113, pl. I, figs. 6, 7.
1883. *Strophomena alternata* HALL. Second Annual Report N. Y. State Geologist, pl. XXXVIII, figs. 6–11.
1887. *Strophomena alternata* SHALER. Fossil Brachiopoda of the Ohio Valley, p. 4, pls. II, III.
1892. *Rafinesquina alternata* HALL. Palæontology of New York, vol. viii, p. 281, pl. VIII, figs. 6–11.

Conrad did not define nor describe this species, but gave it the Ms. name *Leptæna* or *Strophomena alternata*, under which it became known to the geologists of the New York survey. Emmons published a figure of it in 1842, but Prof. Hall, in 1847, was the first to describe it as Conrad's species. In 1843, however, Castelnau described and illustrated the same species as *Orthis huronensis*, and were it not for the previously published figure of Emmons this name would have to be adopted. *S. angulata* Owen is probably a misprint for *S. alternata*, since the identification is queried, and his initial is not added to the name, as was Owen's custom with all new species.

The following detailed description is that of Meek, from which a few paragraphs relating to varieties have been omitted: "Shell attaining a large size, semioval, the breadth being nearly always greater than the length; hinge-line as long as the breadth of the valves at any point farther forward, or somewhat longer; lateral extremities rectangular, sometimes compressed and moderately deflected; lateral margins a little convex, or slightly sinuous posteriorly, and rounding forward to the front, which is semicircular in outline.

"Dorsal valve flattened in the umbonal and cardinal regions, and gently or more or less strongly concave in the central and anterior portions, and curved upward around the anterior and lateral margins; beak small, but projecting slightly beyond the edge of the area, which is very narrow or sublinear, and directed nearly backward. Interior with cardinal process strong, directed obliquely forward, with its two divisions distinctly diverging, and flattened and longitudinally striated on their posterior faces; sockets for the reception of the teeth of the other valve rather well defined; socket [crural] ridges very small and uniting behind the cardinal process to form a deltidium; [adductor] muscular scars comparatively small, but deeply impressed near the cardinal process on each side of a small, short, mesial ridge, and nearly surrounded by a low obtuse ridge formed by a thickening of the adjacent internal surface of the valve; anterior and lateral margins more or less thickened and geniculated within (especially in adult shells), the thickened zone being transversely furrowed [by the vascular sinuses], and sometimes granular, while outside of it the immediate edge of the valve is suddenly flattened and minutely striated and granulated.

"Ventral valve a little convex at the umbo, but generally much compressed over the whole visceral region in the adult (which includes the whole surface of the young and half-grown shell), but becoming more convex (sometimes strongly so) anteriorly, or antero-centrally and laterally, and thence more or less curved up to the anterior and lateral margins; area of moderate hight, flat and directed obliquely backward nearly at right angles to that of the other valve; beak very small, scarcely distinct from the margin of the area, and minutely perforated; foramen broadly triangular and arched over above by the deltidium, which is very deeply sinuous on its inner edge, the sinus being nearly or quite closed by the dental process and deltidium [chilidium] of the other valve.

"Interior with cardinal margin somewhat carinate within; hinge teeth moderately prominent, remote and widely divergent; dental ridges obscure and extending obliquely outward and forward, but not produced or curving to surround a saucer-shaped cavity for the muscular scars; scars of the adductor muscles narrow, long and closely approximated, or almost in contact; those of the cardinal [diductor] muscles on each side very large, fan-shaped, but shallow, separated sometimes by a small ridge in advance of the adductor scars, and marked by radiating furrows and ridges, while the anterior and lateral regions are usually marked by striæ and scattering granules.

"Surface of both valves ornamented by numerous radiating striæ, that increase in number, on the ventral valve, mainly by intercalation, and are usually arranged with one to six or eight smaller and shorter ones between each two larger and more prominent ones, the largest one of which often occupies the mesial line, while on the dorsal valve they more frequently increase by division and are generally of more uniform small size. On well preserved specimens all the radiating lines are crossed by numerous very minute, regular, closely arranged concentric striæ, that are invisible without the aid of a magnifier; a few moderately distinct subimbricating marks are also seen near the free margins of adult shells."

A comparison of the interior of Trenton specimens with those from the Hudson River group shows that the latter have all the parts more strongly developed, owing, in great measure, to the larger size attained and the greater thickness of the shell. Still, these differences are so conspicuous that it may prove desirable to distinguish the Hudson River forms by a varietal name. According to Hall,* the large thick-shelled variety occurring at Cincinnati is known to collectors there as *Leptæna ponderosa.* This name is very appropriate and if a separation is to be made it should be used, unless the objection is made that it was not defined; still, if the species is ascribed to Hall, there could be no doubt as to what form is meant. In England and Ireland this shell is commonly repreesented in the Caradoc and Lower Llandovery by *Orthis expansa* Sowerby, which is abundantly illustrated by Davidson in his monographs.†

In the Trenton shales *R. alternata,* when the exterior alone is shown, is not always easily distinguishable from large and not very convex individuals of *R. minnesotensis.* Usually, however, the stronger convexity and smaller size of the latter form and the five internal ridges of the dorsal valve will serve to separate them.

Formation and locality.—A few specimens have been found in the Trenton limestone at St. Charles and it also probatly occurs elsewhere in these beds in Minnesota. From the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Lanesboro and Preston, Minnesota; not rare at the base of the Galena in the shales at several localities south of Cannon Falls, and at Kenyon and Fountain. Near the top of the "Lower Blue beds" at Mineral Point, and probably elsewhere in Wisconsin. It also occurs in the Trenton at Dunleith, Illinois; Kentucky; Tennessee; New York, and Canada. Very common in the Hudson River group in Ohio, Indiana, Kentucky, Tennessee, New York and Anticosti.

Collectors.—C. L. Herrick, H. V. Winchell, W. H. Scofield and the writers.

Mus. Reg. Nos. 181, 287, 3396, 4037, 5859, 6761, 8151–8154.

Rafinesquina alternata, var. loxorhytis *Meek.*

PLATE XXXI. FIGS. 35–37.

1873. *Strophomena alternata,* var. *loxorhytis* Meek. Palæontology of Ohio, vol. i, p. 91.
1875. *Strophomena alternata,* var. *loxorhytis* Miller. Cincinnati Quarterly Journal of Science, vol. ii, p. 53.

Original description: "Attains a larger size [than *R. alternata*], moderately convex antero-centrally, or rather depressed; much extended on the hinge-line, with lateral extremities acutely angular, flattened and scarcely deflected; area very narrow; both valves marked near the cardinal margin, toward the lateral extremities, by six to eight distinct, very oblique wrinkles on each side."

The shells referred to this variety agree in all essential features, except that the convexity is somewhat greater than in the Ohio specimens. *R. kingi* Whitfield‡ is a closely related species, also occurring in the upper portion of the Cincinnati group, but it can be distingushed at once from *R. alternata,* var. *loxorhytis* by its fine and equal striæ.

*Pal. N. Y., vol. i, p. 104, pl. xxxi, figs. 1a, 1i, 1m, 1847.
†British Silurian Brachiopoda, p. 312, pl. xlv. figs. 1—10.
‡*Strophomena kingi,* Geol. Wisc., vol. iv, p. 261, pl. xii, figs. 15, 16.

Formation and locality.—Common in the Hudson River group at, and two miles east of, Spring Valley, Minnesota. Rather rare in the middle and upper portion of the same formation in Ohio and Indiana.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers. Also in the collection of Dr. C. H. Robbins, Wykoff, Minnesota.

Mus. Reg. Nos. 4098, 8155.

Genus TRIPLECIA, Hall.

1858. *Trip'esia*, HALL. Twelfth Report New York State Cabinet of Natural History, p. 44, figs. 1–3.
1892. *Triplecia*, HALL. Palæontology of New York, vol. viii, pt. i, p. 269.

Description: "Shell trilobate, transverse, unequally biconvex. Hinge-line straight and quite short. Pedicle valve shallow, convex about the beak, but depressed anteriorly by a broad and deep median sinus; cardinal area low, erect and well defined; delthyrium covered by a narrow convex [or flat] plate, with a circular foramen at the apex. In the interior the teeth are well developed and supported by short dental lamellæ longitudinally dividing the umbonal cavity near the apex. Muscular area small, comprising two lateral scars, separated by a longer central adductor impression. The brachial valve is very convex and bears a strong median fold. The cardinal area is very narrow and the beak closely incurved. In the interior is an erect cardinal process, which is deeply bifurcated, the distal extremity of each branch bearing a single deep groove. This process is supported on a subrostral callosity, which also bears two short spiniform crural points at its base. Shell substance fibrous, impunctate(?). Surface with obscure concentric growth lines, and fine radiating striæ on the inner laminæ; in rare instances there are radiating lines on the exterior.

"Type: *Atrypa extans* Emmons." (Hall, 1892, *op. cit.*)

Plicated species of this genus are unusual, *Triplecia* being characterized mainly by smooth forms. *T. radiata* Whitfield and the following new species are the only ones known in America. In Britain there is but one, *Triplecia sporiferoides* McCoy, sp., from the Upper Llandeilo and Caradoc, and another, *T. cava* Barrande, sp., from Etage D_2 of Bohemia. One is unwilling at first to regard these plicated species as congeneric with the smooth forms, but upon examination it is seen that the generic characters common to the one section are also present in the other. They were derived from smooth forms, since all of the nepionic and early neologic growth is without a trace of plications, they being first introduced during the later neologic stages.

Species of *Triplecia* are known from the Calciferous to the Upper Silurian.

TRIPLECIA ULRICHI, *n. sp.*

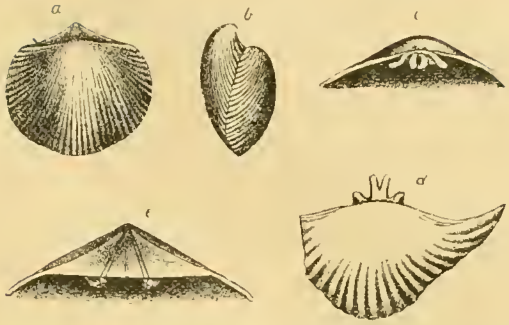


FIG. 34. *Triplecia ulrichi*, n. sp. *a* and *b*, slightly restored dorsal and profile views of an entire specimen; *c* and *d*, two views of the cardinal region of a dorsal valve, × 2; *e*, cardinal region of the ventral valve, × 2, showing the area, apical perforation, and other features. Lower part of the Hudson River shales, Fillmore county, Minnesota. Collection of E. O. Ulrich.

T. ulrichi is distinguished from all other American forms of the genus, except *T. radiata* Whitfield, in having rounded, rather distinct, radiating striæ, of which there are from thirteen to eighteen on each side of the fold and sinus, the median region having seven or eight, making in all from thirty-three to forty-four on each valve. The fold and sinus are well developed, but less than is usual with species of *Triplecia*, and the deltidium is flat, never convex. All of the specimens seen are more or less compressed, but the form in general seems to be near that of *T. nucleus** Hall. Interior characters as in *T. extans*† Emmons, sp., the type of *Triplecia*.

The other American striated species of *Triplecia* is *T. radiata*‡ Whitfield from the Calciferous horizon at Beekmantown, New York, differing from *T. ulrichi* in being much smaller and less tumid. *T. spiriferoides*** McCoy, sp., of the Caradoc sandstone of Wales, has a much longer cardinal line and a more sharply elevated fold of the dorsal valve.

The condition of the specimens of *T. ulrichi* may lead collectors to regard them as species of *Orthis* near *O. borealis* or coarsley striated specimens of *O. subæquata*, var. *gibbosa*, but the covered delthyrium of the ventral valve, or the tumid umbo of the dorsal valve, will distinguish them from all orthoids. The forked cardinal process is always broken in separated valves, appearing simple, but preparations from specimens with the valves in place show it to have two delicate branches.

Formation and locality.—Ten specimens were found by Mr. E. O. Ulrich in the Hudson River group at Wykoff and three miles north of Spring Valley, Minnesota.

Genus LEPTÆNA, Dalman.

1828. *Leptæna*, DALMAN. Kongl. Svenska Vet.-Acad. Handl., för ar 1827, pp. 94-96, 106, 107 pl. I, figs. 1, 2.
1892. *Leptæna*, HALL. Palæontology of New York, vol. viii, pt. i, p. 276.

In its relations this genus is nearest to *Rafinesquina* Hall, from which it differs in its greater transversity; more or less strongly corrugated and geniculated valves; internal strongly elevated ridges near the outer margin of the dorsal valve, in which

*Pal. New York vol i, p. 138, pl. XXXIII, figs. 2a-2c; 1847.
†See above report, p. 137, pl. XXXIII, figs. 1a, 1b; 1847.
‡Bull. American Mus. Nat. Hist., vol. ii, no. 2, p. 43, pl. VII, figs. 5-8; 1889.
**See Pal. New York, vol. viii, pt. i, p. 271, pl. XIC, figs. 10, 11; 1892.

the muscular area is also more elevated, and in the short, deeply impressed muscular area of the ventral valve. The surface corrugations are also developed among species of *Rafinesquina* and *Strophomena*. In the former, however, this character is never strongly marked, while the quadrangular outline and internal features will readily indicate their generic affinities. *Strophomena* can be distinguished at once from *Rafiesquina* or *Leptæna* by the reversal of the relative convexity of the valves.

For a detailed diagnosis of this genus, and for the reasons for restricting *Leptæna*, *Strophomena*, *Rafinesquina* and *Plectambonites* to the characters of their type species, see Pal. N. Y., vol. viii, pp. 245, 276, 281.

Type: *Leptæna rugosa* Dalman=*Producta rugosa* Hisinger=*Conchites rhomboidalis* Wilckens.

The following American species are of this genus:

L. charlottæ W. and S., Trenton Shales.
L. tenuistriata Sowerby, Trenton to Hudson River.
L. unicostata Meek and Worthen, Hudson River.
L. rhomboidalis Wilckens, sp., Niagara to Waverly.
L. rhomboidalis, var. *ventricosa* Hall, Oriskany.

Leptæna incrassata Hall, of the Chazy (Pal. N. Y., vol. i, p. 19), and *Strophomena nitens* Billings of the Hudson River group (Pal. Fos., vol. i, p. 118) may also belong here.

LEPTÆNA CHARLOTTÆ *W. and S.*

PLATE XXXII, FIGS. 1–5.

1892, April 1. *Leptæna charlottæ* W. and S. American Geologist, vol. ix, p. 288.
1892, April 9. *Strophomena halli* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 334, pl. IV, figs. 36-38.

Shell small, transversely semioval, plano-convex, geniculate, with the sides slightly convex and converging to the broadly rounded front, or drawn out tongue-shaped; hinge-line as long as, or somewhat shorter, than the greatest width of the shell. Surface marked by fine, closely crowded, alternating striæ, as in *Rafinesquina alternata*, crossed by exceedingly delicate concentric lines and over the central flat disc of each valve by more or less continuous zigzag undulations or wrinkles.

Ventral valve depressed-convex over the greater portion of the shell and more or less suddenly bent downward or geniculated along the margin, especially anteriorly. Cardinal area wide, broadly triangular, with a convex deltidium, wider than long, apically perforated by a rather large pedicle opening, posteriorly excavated and completely occupied by the chilidium of the other valve. Crenulated hinge teeth prominent and supported by short dental plates, which are attached to the elevated outer margin of the small, transversely oval muscular area. Within this area, in the center of the mesial thickening, are placed the short and narrow adductors, surrounded by the large diductors, and outside these, at the base of the dental plates, are the distinct scars of the small adjustors. Surface marked by delicate, crowded papillæ, strongest in front of the muscular area, and in the thin shells by the wrinkling of the outer surface.

Dorsal valve nearly flat, with the anterior margin more or less reflexed downward. Cardinal area narrow, about one-third that of the other valve, with a broad and strongly convex chilidium. Dental sockets deep; crural plates slender, very oblique and merging into the median thickening, upon which is situated the small, bilobed, cordate cardinal process; in front of this is a short, low septum separating the small adductor scars; in the central portion of the valve there are three other inconspicuous septa. Just inside the outer margin of the valve is situated a prominent, rounded ridge of the same nature as that in *L. rhomboidalis*.

L. charlottæ differs from any other American species of *Leptæna* in its zigzag, concentric, surface corrugations and in other minor features, which can be more readily seen in the illustration than by written comparisons.

Formation and locality.—This species, in a dwarfed condition, is first met with in the upper portion of the Trenton limestone, and is not uncommon in the upper part of the middle third of the Trenton shales in the Bryozoa layers at Minneapolis and St. Paul, Minnesota.

Collectors.—E. O. Ulrich and the writers.

Mus. Reg. No. 8142.

LEPTÆNA UNICOSTATA *Meek and Worthen, sp.*

PLATE XXXII, FIGS. 6–9.

1868. *Strophomena unicostata* MEEK and WORTHEN. Geological Survey of Illinois, vol. iii, p. 335 pl. IV, fig. 11.
1882. *Strophomena unicostata* WHITFIELD. Geology of Wisconsin, vol. iv, p. 262, pl. XII, fig. 14.

Original description: "Shell transversely subsemicircular, the greatest breadth being on the hinge margin, which terminates in rather acutely angular extremities; lateral margins generally nearly straight, or more or less concave in outline and converging from the extremities of the hinge to the front, which is rounded, a little straightened or slightly sinuous in the middle; geniculation of both valves from the ventral side, very abrupt all around the anterior and lateral margins to near the extremities of the hinge. Ventral valve almost perfectly flat [or slightly convex for a short distance anterior to the beak] and without any traces of concentric wrinkling on the disc between the hinge and geniculated front and lateral margins [in large Minnesota specimens there is more or less concentric wrinkling present in both valves, strongest along the cardinal line on each side of the beak and nearly obsolete medially]; beak very small or scarcely distinct from the cardinal margin and showing the usual minute [pedicle] perforation; area narrow, but a little wider than that of the other valve, and slightly arched and provided with a rather wider triangular fissure, closed by the convex deltidium [chilidium] and the cardinal process of the other valve. Interior with the hinge teeth not prominent; rostral cavity with a pair of small depressions, in front of which are two elongate and well marked scars of the adductor muscles; surrounding these, with their lateral margins strongly elevated, are the large bilobed and striated diductor scars, which continue forward for two-thirds the length of the valve; surface outside the muscular area covered with strongly elevated, oblique and minutely perforated pustules, more or less radially arranged; space underneath the cardinal area, on each side of the teeth, filled up with shell matter which, towards the extremities, is reflexed and becomes obsolete on the lateral portions of the valve.

"Dorsal valve with the disc or visceral region flattened and, like that of the other valve, without any traces of concentric undulations; deflected anterior and lateral margins conforming nearly to those of the other valve; beak nearly obsolete; area linear and provided with a marginal furrow for the reception of the edge of the other valve; cardinal process rather small, cordate or bilobed, with the [crenated] socket on each side for the reception of the teeth of the other valve well defined; interior with [a pair of medially divided adductor] muscular scars generally moderately distinct and separated by a small mesial ridge [which is nearly obsolete a little posterior to the mid-length, with a small, shallow scar on each side, the septum then again becomig prominent and continuing to the geniculated margin]; other parts of the visceral region occupied by rather crowded [oblique and rather large] granules. Surface of both valves ornamented by fine, crowded, radiating striæ, which increase by intercalation and division, while one of those on the middle of the ventral valve is generally five or six times as large as the others, and really forms a distinct rib."

Adult Minnesota specimens referred to this species have concentric corrugations on the central flat disc, the latter being more convex than in Illinois examples. Associated with the large shells are also numerous smaller ones, which are comparatively narrower, more mucronate and without wrinkles. Since these specimens are immature, and certainly of the same species as the larger ones, there is no hesitation in extending the specific description of *L. unicostata* so as to contain the corrugated examples. From *L. rhomboidalis*, var. *tenuistriata* Sowerby, this species can be distinguished only by the obsolete or inconspicuous wrinkling, the large mid-rib and, when the interior is shown, by the very large, bilobed, diductor scars of the ventral valve.

In the upper portion of the Hudson River group of the Ohio valley *L. rhomboidalis,* var. *tenuistriata* is a very common form, but is replaced by *L. unicostata* in the same formation in northern Illinois, Wisconsin, Iowa and Minnesota. The latter species, it seems, must be regarded as a branch of the line leading to *L.*

rhomboidalis, which so persistently recurs with more or less numerical strength throughout all formations from the Trenton of New York to the base of the Lower Carboniferous.

In Anticosti *Strophomena nitens* Billings* occurs, which, as far as external characters are concerned, appears to be identical with specimens from Wilmington, Illinois, examined by one of the writers. The interiors of these show them to be a species of *Leptæna* Dalman, and they are apparently closely related to *L. unicostata*.

Formation and locality.—Abundant in the upper portion of the Hudson River group at Spring Valley, and rare in the lower portion of the same formation at Granger, Minnesota. Common at Graf, Iowa; Iron Ridge and Delafield, Wisconsin; Savannah and Wilmington, Illinois.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers. Also in the collection of Dr. C. H. Robbins, Wykoff, Minnesota.

Mus. Reg. Nos. 275, 8138–8141.

Genus PLECTAMBONITES, Pander.

1830. *Plectambonites*, PANDER. Beiträge zur Geognosie des russischen Reiches, p. 90, pl. III, figs. 8, 16; pl. XXVIII, fig. 19.
Leptœna of authors, not DALMAN.
1892. *Plectambonites*, HALL. Palæontology of New York, vol. viii, pt. i, p. 295.

Description: "Shells usually small, normally concavo-convex. Surface covered with very fine striæ, often alternating in size. Hinge-line making the greatest width of the shell, the extremities often subauriculate. Cardinal area narrow in both valves, crenulated on the margins. On the pedicle valve there is a moderately broad delthyrium partly closed by a convex plate, but mostly occupied by the cardinal process of the opposite valve. Apical foramen sometimes retained. Teeth prominent and supported by thickened plates, which are continued in broad outward curves for more than half the length of the valve, returning and uniting in the umbonal cavity, thus limiting two linguiform [diductor] muscular scars, enclosing a more or less clearly defined adductor impression.

"In the brachial valve the dental sockets are deep and often appear to transect the cardinal area. The cardinal process is simple and erect, but by its coalescence with the short, prominent, crural plates the posterior face appears trilobate. The crural plates end abruptly as in *Orthothetes*, becoming thickened at about the middle of their length and giving origin to two low ridges or septa, which at first approach each other and thence continue forward with a slight divergence, thus forming the inner boundaries for two elongate [adductor] muscular scars, which are less sharply defined in their outer margins. The muscular area is rendered quadripartite by two short transverse or oblique posterior furrows. Vascular impressions radial, sometimes digitate. Shell substance fibrous, sparsely punctate.

* Pal. Foss., vol. i, p. 118, fig. 97, 1862; Canadian Nat. and Geol., vol. v, p. 53, fig. 1, 1860.

"Type: *Plectambonites planissima* Pander. Lower Silurian of Russia." (Hall, *op. cit.*,)

The following American species are referred to this genus:

P. (?) decipiens Billings, sp., Calciferous.
P. (?) sordida Billings, sp., Calciferous.
P. sericea Sowerby, sp., Trenton to Clinton.
P. gibbosa W. and S., Middle Galena.
P. plicatella Ulrich, sp., Hudson River.
P. glabra Shaler, sp., Anticosti.
P. transversalis Wahlenberg, sp., Clinton and Niagara.
P. transversalis, var. *alabamensis* Foerste, Clinton.
P. transversalis, var. *prolongata* Foerste, Clinton.

PLECTAMBONITES SERICEA *Sowerby, sp.*

PLATE XXXII, FIGS. 10–12.

1839. *Leptæna sericea* SOWERBY. Murchison's Silurian System, pl. XIX, figs. 1, 2.
1840. *Strophomena sericea* CONRAD. Third Annual Report, Geological Survey of New York, p. 201.
1842. *Strophomena sericea* EMMONS. Geology of New York; Report, Third District, p. 47.
1847. *Leptæna sericea* HALL. Palæontology of New York, vol. i, pp. 110, 287, pl. XXXIB, fig. 2: pl. LXXIX, fig. 3.
1852. *Leptæna sericea* HALL. Ibidem, vol. ii, p. 59, pl. XXI, fig. 1.
1856. *Leptæna sericea* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 41, fig. 2.
1858. *Leptæna sericea* ROGERS. Geology of Pennsylvania, vol. ii, pt. ii, p. 818, fig. 599.
1863. *Leptæna sericea* BILLINGS. Geology of Canada, p. 163, fig. 139.
1873. *Leptæna sericea* MEEK. Palæontology of Ohio, vol. i, p. 70, pl. V, fig. 3.
1874. *Leptæna aspera* JAMES. Cincinnati Quarterly Journal of Science, vol. i, p. 151.
1875. *Leptæna sericea* MILLER. Ibidem, vol. ii, p. 57.
1875. *Leptæna sericea?* WHITE. U. S. Geological and Geographical Survey west of the 100th Meridian, vol. iv, p. 70, pl. IV, fig. 7.
1883. *Leptæna sericea* HALL. Second Annual Report, N. Y. State Geologist, pl. XLVI, figs. 25, 29.
1890. *Leptæna sericea* FOERSTE. Proceedings of the Boston Society of Natural History, vol. xxiv, p. 293.
1892. *Plectambonites sericea* HALL. Palæontology of New York, vol. viii, pt. i, pl. XV, figs. 25-29.
1892. *Leptæna minnesotensis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 329, pl. IV, figs 24, 25.
1892. *Leptæna præcosis* SARDESON. Ibidem, p. 329, pl. IV, figs. 26–28.
1892. *Leptæna recedens* SARDESON. Ibidem, fig. 330, pl. IV, figs. 29–32.
1892. *Leptæna saxea* SARDESON. Ibidem, p. 330, pl. IV, figs. 33–35

Description: "Shell small, transverse, semioval, approaching semicircular, concavo-convex; hinge-line equaling or more frequently a little longer than the breadth of the valves at any point farther forward; lateral extremities varying from somewhat acutely angular to nearly or quite rectangular and not properly reflexed; anterior and lateral margins forming together nearly a regular semicircular curve.

"Dorsal valve concave, its deepest concavity being near the middle; beak not distinct from the cardinal margin; area narrow or nearly linear, and ranging at right angles to the plane of the valves. Interior showing cardinal margin to be minutely [in Minnesota, lower Hudson River specimens, strongly] crenate towards the lateral extremities; cardinal process moderately prominent [smooth] and trifid [simple, the lateral divisions are portions of the incomplete chilidium or crural plates], the middle division being most prominent, with a deep pit at its inner base;

brachial process short, appressed and widely divergent; muscular impressions [adductors] generally obscurely defined, occupying an obcordate area and separated from each other by two subparallel, narrow ridges that sometimes coalesce near the base of the cardinal process [and are strongly elevated and broadly thickened anteriorly] each impression usually nearly equally divided by a slender linear [sometimes thickened and much elevated], straight ridge; anterior and lateral regions more or less roughened by minute, granular, radiating striæ. [These are the markings left by the vascular and genital organs, anterior to which, in the thick shells, there is a well developed ridge just inside the front margin.]

"Ventral valve moderately convex, being nearly evenly, but gently, arched along the middle from the beak to the front, and thus following so nearly the curve of the other valve as to leave but a very thin visceral cavity within; beak very small, or scarcely, if at all, distinct from the cardinal margin; area twice to three times as high as that of the other valve, inclined backward or more or less nearly parallel to the plane of the valves; foramen arched over near the beak by a small deltidium, and [nearly] closed between this and the hinge margin by the prominent cardinal process [and chilidium] of the other valve. Interior showing hinge margin to be obscurely [sometimes prominently] marked by minute pits for the reception of the crenulations of that of the other valve; teeth small; [diductor] muscular impressions long, narrow, separated behind by a short, linear, mesial ridge [upon each side of which are slender, shallow depressions of the adductor muscles], and diverging and extending forward beyond the middle of the valve, with a moderately distinct dental ridge along the lateral margin of each; anterior and lateral regions granulo-striate." (Meek, *op. cit.*)

Surface of both valves marked by numerous, very minute, closely arranged, equal, radiating striæ, or with every fourth, fifth or sixth one a little larger or more prominent than those between.

Plectambonites sericea varies considerably in size, convexity, outline and in the strength of its muscular markings. The largest specimens observed were collected in the lower portion of the Hudson River group near Granger, Minnesota, and one of these is 28 mm. in width. Similar large examples occur at Cincinnati, Ohio, and have received the name *Leptæna aspera* James. The crenulations along the lateral margins of the hinge-line are a very marked character in specimens from the former locality, and the muscular scars of the ventral valve are often not as divergent as in others on the same slab. As a rule, shells from the Galena horizon are smaller than those from the Hudson River or Trenton formations, to which Mr. Sardeson has given the name *P. minnesotensis*. Specimens are usually abundant at most localities. *P. sericea* is one of the few species extending through the Lower Silurian, and is replaced in the Niagara by *P. transversalis* Wahlenberg. As stated in the discussion of *Orthis testudinaria*, there can be little advantage to the geologist or biologist in applying to the numerous local variations of *P. sericea* specific or varietal names.

Formation and locality.—Common in the Trenton formation of New York, Canada, Pennsylvania, central Kentucky, Tennessee, and Dixon, Illinois. From the "Upper Buff beds" of the Trenton at Rockton, Illinois; Mineral Point, Dodgeville and elsewhere in Wisconsin. In the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Fountain and Preston, Minnesota; Decroah and McGregor, Iowa. Very abundant in the Galena at many localities in Goodhue and Fillmore counties, Minnesota; Neenah and Oshkosh, Wisconsin. In the Hudson River group at Spring Valley, Minnesota; Graf, Iowa; Iron Ridge, Wisconsin; Savannah and Wilmington, Illinois; Indiana; Ohio; Kentucky; Anticosti; and Silver City, New Mexico. Clinton group of New York. In the Llandeilo, Caradoc and Llandovery formations of England. Also in the Lower Silurian of Scotland, Ireland, Russia, Esthonia, Bohemia, Norway and Spain.

Collectors.—C. L. Herrick, W. H. Scofield, E. O. Ulrich and the writers. Also in Dr. C. H. Robbins' collection.

Mus. Reg. Nos. 193, 228, 793, 3494, 3525, 4054, 4084, 4088, 4090, 5854, 5855, 6747, 6795a, 7929–7939, 7947–7950

PLECTAMBONITES GIBBOSA *W. and S.*

PLATE, XXXII, FIGS. 13–17.

1892, April 1. *Plectambonites gibbosa* W. and S. American Geologist, vol. ix, p. 288.

Shell small, semicircular in outline, strongly concavo-convex, wider than long, greatest width along the hinge-line. Surface very finely striate, with six or seven stronger lines on each valve, much as in *P. transversalis.*

Ventral valve very gibbous and subcarinate medially, lateral slopes rapid and slightly concave; greatest elevation about mid-length. Cardinal area strongly elevated, slightly concave, somewhat wider than that of the dorsal valve; delthyrium about as wide as long, with a small deltidium in the posterior portion, and more or less occupied by the cardinal process and chilidium of the other valve. Teeth small, supported by strong dental lamellæ, which join the outer, much elevated margin of the muscular area. Diductor muscle pits deep, short, strongly diverging and separated posteriorly by a small septum, on each side of which are slender depressions of the adductor scars. Interior otherwise smooth.

Dorsal valve concave and closely following the curvature of the other valve. Cardinal area wide, flat, retrose; delthyrium with a large, simple cardinal process more or less covered by a chilidium, which is usually imperfect medially. Crural processes short and widely divergent. Adductor scars broadly triangular in outline, lobate, with the outer margin strongly elevated. They are separated medially by a narrow, deep depression, which is interrupted near the anterior margin of the scars by a transverse thickening. Two sharply elevated ridges have their origin at the hinge-line on each side of the muscular area. These curve much laterally for a short distance and then converge, meeting medially quite close to the anterior margin, where they become obsolete. The depression between this ridge and the outer elevated margin of the muscular area is granulose, while the slope on the outer side of the former is quite abrupt.

This small species of *Plectambonites* is quite distinct from all other American forms. The convexity of the shell, surface ornametation and the interior characters of the dorsal valve will distinguish it at once from *P. sericea* Sowerby and *P. decipiens* Billings. Its relationship is rather with the latter species, on account of the sharp elevation just inside the margin of the dorsal valve. *P. gibbosa* seems to be closely allied to *P. quinquecostata* McCoy,* but until more is known of the interior characters of the latter further comparisons are impossible. That species is found in the Caradoc and Llandovery of England; also in Scotland, Ireland and Russia.

Formation and locality.—Not uncommon in the Galena at several localities in Goodhue county; also at Mantorville and Old Concord, Minnesota.

Collectors.—M. W. Harrington, A. D. Meeds, W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 147, 423, 8165, 8166.

Family ORTHIDÆ, Woodward.

Genus ORTHIS, Dalman, *emend* Hall.

1828. *Orthis*, DALMAN. Kongl. Vet. Acad.-Hand., pp. 93, 96.
1892. *Orthis*, HALL. Palæontology of New York, vol. viii, pt. i, p. 192.

Description: "The distinguishing features of these shells are the plano-convex contour; the strong, sharp and comparatively few costæ, rarely, if ever, bifurcating; the elevated and somewhat incurved cardinal area on the pedicle valve; the relatively slight development of the dental lamellæ, which do not extend the entire length of the umbonal cavity. The cardinal process on the brachial valve is an elongate, vertical plate, extending from the apex the whole length of the delthyrium, thus longitudinally dividing the deep deltidial cavity. It is usually simple, both on the outer edge and at its distal extremity.

"In this group of orthids [*Orthis* restricted], more frequently than elsewhere, we find a character rarely developed in any stage of growth, viz: the existence of a transverse apical plate in the delthyrium of the pedicle valve [the rudiments of a deltidium]. * * * The greatest development attained by this feature, in any of the numerous species of *Orthis* studied, is to be found in *O. tricenaria* of the Trenton and Hudson River faunas; it has also been observed in *O. calligramma*, var. *davidsoni*, although it does not appear in any of the figures of this species and its varieties given by Mr. Davidson, nor is any mention made of it in his descriptions. Its

*Sil. Foss, Ireland, p. 33, pl. III, fig. 8, 1846; and Davidson's Mono. British Sil. Brach., p. 322, pl. XLVIII, figs. 23-27.

appearance in this genus, and especially in the typical species of the genus, is interesting, but it cannot be embraced in the diagnostic characters, since its presence appears to be largely of a specific value, and the degree of its development dependent upon the stage of growth. [For further remarks on this plate see *Dinorthis*.]

"The muscular scar of the pedicle valve of *O. calligramma* is a subelliptical area scarcely longer than the cardinal face, faintly impressed, and its components rarely distinguishable.

"The structure of the shell is comparatively fibrous and impunctate. Specimens of *Orthis calligramma*, var. *davidsoni*, from Gotland, show openings of oblique tubules on the external surface, always situated upon the keels of the costæ. These are sparse and irregularly scattered, but of similar nature to those seen in the impunctate species *O. subquadrata* and the punctate species *O. subæquata*, *O. michelini*, *O. resupinata* and their allies." (Hall, *op. cit.*)

ORTHIS TRICENARIA *Conrad.*

PLATE XXXII, FIGS. 18–23.

1843. *Orthis tricenaria* CONRAD. Proceedings of the Academy of Natural Sciences of Philadelphia, vol. i, p 333.
1843. *Orthis disparilis* CONRAD. Ibidem, p. 333.
1844. *Orthis testudinaria?* OWEN. Geological Explorations in Iowa, Wisconsin and Illinois, pl. XV, fig. 11.
1847. *Orthis tricenaria* HALL. Palæontology of New York, vol. i, p. 121, pl. XXXII, fig. 8.
1847. *Orthis disparilis* HALL. Ibidem, p. 119, pl. XXXII, fig. 4.
1859. *Orthis disparilis* BILLINGS. Canadian Naturalist and Geologist, vol. iv, p. 440, fig. 20.
1859. *Orthis tricenaria* SALTER. Canadian Organic Remains, dec. i, p. 39, pl. IX, figs. 1–4.
1862. *Orthis tricenaria* HALL. Geology of Wisconsin, vol. i, p. 42, figs. 8–11.
1862. *Orthis disparilis* HALL. Ibidem, p. 435.
1863. *Orthis disparilis* BILLINGS. Geology of Canada, p. 130, fig 60.
1863. *Orthis tricenaria* BILLINGS. Ibidem, p. 167, fig. 151.
1875. *Orthis plicatella?* WHITE (not HALL). Report of the U. S. Geographical Survey west of the 100th Meridian, p. 72, pl. IV, fig. 10.
1883. *Orthis tricenaria* HALL. Second Annual Report, N. Y. State Geologist, pl. XXXV, figs. 1–5.
1884. *Orthis tricenaria* WALCOTT. Monograph of the U. S. Geol. Surv., vol. viii, p. 74, pl. XI, fig. 4.
1892. *Orthis tricenaria* HALL. Palæontology of New York, vol. viii, pt. i, pp. 191, 193, 221, 228, pl. V, figs. 9–12.
1892. *Orthis disparilis* HALL. Ibidem, pp. 191, 221, 228.

Original description: "Semioval, with about thirty prominent, very regular, rounded ribs; larger [ventral] valve ventricose; summit elevated; the dorsal margins subrectilinear, very oblique; lesser [dorsal] valve flat or slightly concave in the middle; cardinal area very wide; apex of the larger valve profoundly elevated above that of the opposite valve. Length, three-fourths of an inch."

Shell semicircular in outline; plano-convex; anterior margin somewhat deflected ventrally. Hinge-line equal to the greatest width of the shell, rarely shorter. Cardinal area well developed on each valve, widest in the ventral valve, striated longitudinally and transversely, and divided by a very narrow delthyrium, which is partially occupied by a deltidium. Surface with thirty to thirty-six radiating, equal, but sometimes unequal, simple, subangular costæ, with a linear elevation occupying the depressions, all crossed by exceedingly delicate concentric lines of growth.

Ventral valve strongly convex, subangular, with the greatest elevation on the umbo. Cardinal area very wide, more or less convex and elevated. Delthyrium in the apical third occupied by a flat, concave or convex deltidium, which extends as well defined linear ridges along the entire length of the walls of the pedicle opening. Hinge teeth strong, supported by well developed, excavated dental plates, which join the outer elevated margin of the rounded muscular area. Diductor muscles occupy the greater portion of the muscular area, the anterior margin of which is slightly thickened and unites with the two large, diverging vascular trunks. The adductor scars are two slender depressions situated between the diductors and separated by a central linear elevation, the whole being drawn out anteriorly into a very narrow and short septum. Genital markings close to each side of the muscular area. Exterior to these are numerous markings of the vascular system. Peripheral margins of valves marked by radiating, short and strongly elevated costæ, each with a central furrow.

Dorsal valve nearly flat, slightly elevated at the beak; from this the point of greatest elevation, the surface slopes gradually into the broad, scarcely perceptible, rarely well defined, median sinus. Cardinal area wide, flat, divided by a triangular delthyrium, as broad as long, and more or less covered by a convex chilidium, the anterior margin of which is concave. Deltidial cavity occupied by a thin, much elevated, smooth cardinal process. Crural plates broad, strongly projecting interiorly, their bases converging and joining a low, broadly rounded, median septum, which becomes obsolete at about the mid-length of the valve. On each side of this septum are two pairs of adductor scars, the posterior pair well defined. Vascular sinuses numerous, occupying the entire postero-lateral surface of the interior.

Orthis costalis Hall,* of the upper beds of the Chazy group of New York, is closely allied to *O. tricenaria*. Remains of the former, however, are always more or less exfoliated, and this condition makes it difficult to point out satisfactory differences between the two. Specimens figured by Mr. Walcott, and identified as *O. tricenaria*, occur in the upper beds of the Pogonip group (probably equivalent to the Chazy group of New York and Canada), but are smaller than this species usually is. Such specimens, however, are also found near the top of the Trenton limestone at Minneapolis, Minn. After a careful examination of these specimens, the writers are unable to point out characters by which they can be separated from *O. tricenaria*. This variety was doubtfully identified by Dr. White (*op. cit.*,) as *O. plicatella* Hall; but his illustrations show it to be the species cited above.

*Pal. Ohio, vol. ii, p. 78.

O. disparilis Conrad proves to be the young of *O. tricenaria*, as has been suggested by Hall and Whitfield.*

O. davidsoni de Verneuil,† of the Silurian of America, England and Scotland, is another closely related species, but can be distinguished from *O. tricenaria* by its more convex cardinal area and the strongly elevated subangular costæ. The costæ also have a few remote oblique perforations in the shell substance, a feature never seen in *O. tricenaria.*

Formation and locality.—This widely-distributed and characteristic Trenton fossil is often smaller in size in the Northwest than in either the eastern or southern exposures of the horizon. It occurs commonly as natural casts in the Trenton limestone at Minneapolis, St. Paul and Cannon Falls; but in the Trenton shales good shells are not rare at Minneapolis, St. Paul, Cannon Falls, Fountain, near Lanesboro, Eyota, Preston, and near Caledonia, Minnesota; also at Decorah and McGregor, Iowa. In Wisconsin it is very abundant, and is a characteristic fossil of the "Lower Blue beds" at Beloit, Janesville and Mineral Point; at the last locality it was also collected in a siliceous condition near the base of the "Upper Buff beds." It has also been collected by one of the writers in the Trenton formation at Dixon, Illinois; High Bridge and Curdsville, Kentucky; and Watertown, New York. Near Ottawa and Montreal, Canada; Mingan islands; Eureka and White Pine districts, Nevada. In Goodhue county, Minnesota, this species is known to extend upwards for at least fifty feet in the Galena formation at several exposures south of Cannon Falls.

Collectors.—Miss C. S. Seymour, C. L. Herrick, H. V. Winchell, J. C. Kassube, W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 372, 666, 668, 2191, 3509, 4034, 5057, 5091, 5130, 5150, 5582, 6802, 7795-7810, 7916.

Subgenus DINORTHIS, Hall.

1892. *Dinorthis*, HALL. Palæontology of New York, vol. viii, pt. i, p. 195.
1892. *Plæsiomys*, HALL. Ibidem, p. 196.

Original description: "This group of shells, in its most characteristic examples, presents a reversal of the relative convexity of the valves as seen in *Orthis calligramma.* The pedicle valve, elevated at the umbo, becomes gradually depressed as growth advances, and in the mature condition is flat or gently concave over the pallial region. The brachial valve, on the other hand, is eminently convex. The surface is marked by strong [and fine], simple, rarely bifurcating costæ, as in *O. calligramma.* The cardinal area of the pedicle valve is well developed, but not greatly elevated. In the interior the dental lamellæ are prominently developed and are extended around a subquadrate muscular area, the strength of which apparently depends upon the age and thickness of the shell. The three pairs of impressions may often be distinguished; the elongate adductors occupying a central position and separated by a faint median ridge, the diductors forming large antelateral expansions enclosing the adductors; the adjustors lie outside and behind these [pedicle muscles not always discernible]. Occasionally, in *Orthis pectinella*, there is again seen the gradual closing of the delthyrium of the pedicle valve by an

*Pal. New York, vol. i, p. 20, pl. IV bis, fig. 4, 1847.
†Bull. Soc. Geol. de France, sec. ser., vol. v, p. 341, pl. IV. fig. 9, 1848.

apical callosity, but it is never carried as far as in the forms mentioned in the group of *Orthis callactis*, and, so far as observed, its existence is confined to the species cited. In the brachial or more convex valve the area is narrower, the crural plates stronger than in the preceding groups [*Orthis callactis* and *O. plicatella*], and the cardinal process, instead of being a simple linear ridge lying in the bottom of the deltidial cavity, is an erect apophysis, broadened and frequently bilobed on its summit and posterior face.

"The shell structure, like that of *Orthis callactis* and *O. plicatella*, is compactly fibrous and, in all the species examined, impunctate. No evidence of tubulose plications has been seen."

Type: *Orthis pectinella* Emmons.

In establishing the subgenus *Dinorthis* Prof. Hall was justified in separating the species having a similar contour of the valves, as in *O. pectinella*, but differing in the far greater number of striæ. At that time no form was known to connect the subgenera *Dinorthis* and *Plæsiomys*, respectively typified by *O. pectinella* and *O. subquadrata*. In the Lower Silurian of Minnesota, beginning with the lowest fossiliferous member of the Trenton limestone, the first species is *O. deflecta*. This has characters common to the strophomenoids, but is clearly referable to *Dinorthis*. From this species to *O.* (*D.*) *pectinella*, the one occurring next higher in the series, in the Trenton shales, there is a wide departure in the surface striation. *O. deflecta* has very fine striæ, while in *O. pectinella* there are strong plications. From *O. pectinella* we pass to the variety *sweeneyi*, which is a local variation of it. Associated with the latter are specimens in which the strong plications begin to divide near the anterior margin. At the base of the Galena shales the strong, simple, plicated forms become rarer, while those with more numerous striæ prevail. Upon reaching the strata containing *Clitambonites diversa* Shaler, provisionally known to the survey as Galena shales, the numerously striated form, here described as *O. meedsi*, is the only one found. Ascending into the Galena formation for thirty or forty feet more we find *O. meedsi* still exhibiting a tendency to increase the number of its striæ, and finally assuming characters (variety *germana*) which attain their greatest development in *O. subquadrata* of the Hudson River formation. The change from *O. pectinella* to *O. subquadrata* is thus completed.

The cardinal process is linear and not much elevated in *O. deflecta*, and attains its greatest development in *O. subquadrata* and *O. proavita* of the Hudson River formation. The adjustor scars are conspicuous in *O. deflecta*, while in the other species here referred to *Dinorthis* they are much reduced in size.

In *Orthis* (*Dinorthis*) *deflecta* no pedicle muscle exists, but always a more or less large deltidium. *Orthis* (*Dalmanella*) *subæquata* has sometimes a short deltidium, the posterior end of which is drawn inwards, and is transversley striated. When this plate is absent, as is commonly the case, the apical portion of the delthyrium is filled with shell matter which served for the attachment of the pedicle muscle. In *Orthis tricenaria* the apical plate is always strongly developed and may be flat, concave or convex, the latter condition not being common. A small deltidium is also present in *Orthis* (*Dinorthis*) *pectinella*. In all the species of *Orthis* observed when a pedicle muscle is present a deltidium is absent; but where this plate is developed the muscle is rudimentary. This evidence leads the writers to the conclusion that the pedicle muscle is attached to the bottom of the valve in the apex of the delthyrium when the deltidium is wanting, but when it is developed the muscle is then more or less attached to the deltidium.

ORTHIS (DINORTHIS) DEFLECTA *Conrad, sp.*

PLATE XXXII, FIGS. 24–30.

1843. *Strophomena deflecta* CONRAD. Proceedings of the Academy of Natural Sciences of Philadelphia, vol. i, p. 332.
1843. *Strophomena recta* CONRAD. Ibidem, vol. i, p. 332.
1847. *Leptœna deflecta* HALL. Palæontology of New York, vol. i, p. 113, pl. XXXIB, fig. 5.
1847. *Leptœna recta* HALL. Ibidem, p. 113, pl. XXXIB, fig. 6.
1859. *Strophomena deflecta* HALL. Twelfth Report, N. Y. State Cabinet of Natural History, p. 70
1859. *Strophomena recta* HALL. Ibidem, p. 70.
1877. *Streptorhynchus rectus* MILLER. American Palæozoic Fossils, p. 134.
1889. *Streptorhynchus deflectum* MILLER. North American Geology and Palæontology, p. 378.
1892. *Plœsiomys deflecta* HALL. Palæontology of New York, vol. viii, pp. 197, 222, pl. VA, figs. 28-34.
1892. *Plœsiomys recta* HALL. Ibidem, pp. 197, 222.

Original description: "Semioval, superior [ventral] valve slightly concave deflected at the angles, the other valve reflected; radii very closely arranged, prominent, subequal, minutely crenulated; inferior [dorsal] valve slightly depressed in the middle; cardinal area wide; superior margin of the concave valve rather elevated. Breadth, half an inch."

Shell semioval or subquadrate in outline; concavo-convex or strophomenoid in form. Hinge-line two thirds, or as long as, the greatest transverse diameter of the shell; width of cardinal areas variable, in some specimens comparatively wide, widest in the ventral valve, and disposed at a right angle to each other; delthyrium of both valves broadly triangular and partly covered by a convex deltidium. Surface marked by fine, equal, sharply rounded striæ, which increase in number by interstitial addition and rarely by bifurcation. From 120 to 135 along the anterior margin of adult examples. Striæ and intermediate depressions crossed by numerous, elevated, thread-like, concentric lines and a few well marked minor imbrications, the latter indicating periods of rest in shell growth.

Ventral valve carinate medially in the posterior third, with the lateral and anterior portions concave; the latter part is the stronger and forms a broad and undefined mesial sinus; greatest elevation at the beak. Cardinal area flat, broadly triangular in outline, nearly horizontal, compared with that of the other valve, and marked by a number of parallel lines of growth; delthyrium widely triangular, covered from less than one-half to more than two-thirds its length by a depressed-convex deltidium, which is broadly excavated along the anterior margin. Interior with well developed dental plates, which join the outer elevated margin of the short, more or less quadrate-lobate muscular depression. In the center of this depression are the small, elongate, centrally divided adductors; on the outside of these and occupying the greater portion of the muscular area, are the diductors. At the base of the dental lamellæ are the variously defined adjustors. Immediately beneath the cardinal area, and originating on each side of the muscular depression, are numerous antero-laterally directed genital markings. Vascular sinuses indistinct. Interior surface of the valves along the anterior margin with radiating, centrally channeled striæ occupying the depressions between those of the outer surface.

Dorsal valve evenly convex medially, with a more or less reflexed or concave portion on each side and immediately in front of the cardinal line. A defined narrow depression has its origin at the apex, which is soon merged into the shallow, though sometimes deep, mesial depression. Cardinal area striated, comparatively wide for species of *Orthis*. Delthyrium broadly triangular and covered by a chilidium at the apex, which continues along the walls of the delthyrium as separated plates. Crural plates short, but prominent, originating at the inner ends of the walls of the delthyrium. The entire rostral cavity is occupied by a subhemispheric deposit of shell matter, upon the posterior surface of which is situated an elongate, linear, crenulate cardinal process, the anterior portion terminating in a short, broadly rounded median septum. On each side of the latter are situated the depressions of the adductor muscles, the posterior pair being most conspicuous.

This species has been regarded, until quite recently, as a true strophomenoid shell. The contour of the valves, elongate hinge-line and fine striæ, combined with more or less large deltidia, are doubtless strophomenoid features; yet the cardinal and articulating processes and the muscular arrangements are decidedly orthoid characters. Since these features are regarded as of greater importance than the former, this species should be referred to the subgenus *Dinorthis*. In the line of development between *O.* (*D.*) *deflecta* and *O.* (*D.*) *pectinella* some links are missing. In the second species there is still a small deltidium in the ventral valve, which has been reduced in the dorsal valve to linear ridges bounding the delthyrium. The cardinal process is larger, the striæ have become plications and have a tendency towards multiplication, while the general form and muscular scars are essentially those of *O.* (*D.*) *deflecta*. For further modifications of *O.* (*D.*) *pectinella*, see *O.* (*D.*) *meedsi* and its variety *germana*, and *O.* (*D.*) *subquadrata*.

Orthis platys Billings,* from the Chazy limestone at Montreal, Canada, appears to be a closely related species, but can be separated from *O.* (*D.*) *deflecta* by its convex and deeper ventral valve and more delicate striæ.

Billings identified *Strophomena recta* Conrad in the Trenton limestone at Ottawa, Canada. His illustrations clearly show that he had specimens of a true *Strophomena* before him, but not the *S. recta* Conrad, which is here regarded as the young of *O.* (*D.*) *deflecta*. For further remarks see *Strophomena billingsi, n. sp.*

Strophomena recta Conrad can be seen readily to be an immature condition of *O.* (*D.*) *deflecta*, by observing the growth lines on mature individuals of the latter species. The original material of both forms was obtained at Mineral Point, Wisconsin, and specimens of both have been collected by the writers at that locality and elsewhere in that state, all from the same geological horizon, and it is evident that the former is the young of the latter.

Formation and locality.—This common species is widely distributed in the Northwest, and is everywhere observed to hold an identical horizon. In Minnesota it is restricted to the Trenton limestone in beds known as the "upper building stone," occurring as casts at Minneapolis and St. Paul, and as free shells at Cannon Falls and in Allen Hunt's quarries near fountain. In Iowa near McGregor. In Wisconsin it is a characteristic fossil of the "Lower Blue beds" at Mineral Point, Beloit, Janesville, and Dixon, Illinois. In the "Glade limestone" of Central Tennessee a variety of this species is often met with at Lebanon, Murfreesboro and Lavergne. In Kentucky a specimen has been found near the top of the Birdseye limestone at High Bridge.

Collectors.—H. V. Winchell, C. L. Herrick, E. O. Ulrich and the writers.

Mus. Reg. Nos. 672, 682, 5060, 5092, 5095, 7790–7794, 7928.

ORTHIS (DINORTHIS) PECTINELLA (*Emmons*) *Hall.*

PLATE XXXII, FIGS. 31–34.

1842. *Orthis pectinella* EMMONS. Geology of New York; Report, Second District, p. 394, fig. 2 (not defined).
1847. *Orthis pectinella* HALL. Palæontology of New York, vol. i, p. 123, pl. XXXII, fig. 10.
1847. *Orthis pectinella*, var. *semiovalis* HALL. Ibidem, p. 124, pl. XXXII, fig. 11.
1856. *Orthis pectinella* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 205, fig. 5.
1858. *Orthis pectinella* ROGERS. Geology of Pennsylvania, vol. ii, p. 818, fig 602.
1863. *Orthis pectinella* BILLINGS. Geology of Canada, p. 165, fig. 147.
1880. *Orthis charlottæ* N. H. WINCHELL. Eighth Report, Geological and Natural History Survey of Minnesota, p. 67.
1883. *Orthis pectinella* HALL. Second Annual Report, N. Y. State Geologist, pl. XXXIV, figs. 39, 40.
1889. *Orthis pectinella*, var. *semiovalis* MILLER. North American Geology and Palæontology, p. 359.
1892. *Dinorthis pectinella* HALL. Palæontology of New York, vol. viii, pt. i, pp. 195, 222, 228, pl. V, figs. 27–33.

Original description: "Suborbicular or obtusely semioval, wider than long in the proportion of about nine to twelve; cardinal line extended, equal to, or less than, the greatest width of the shell, slightly deflected at the extremities; area moderately large and well defined; shell resupinate, or the area and foramen being principally on the latter valve, or partially common to both; dorsal [ventral] valve

*Can. Nat. and Geol., vol. iv, p. 438, fig. 15.

subconvex near the beak, with flat sides and a broad depression along the center, which is distinct in front; ventral [dorsal] valve regularly convex, most prominent in the center; beak extending only to the cardinal line; surface marked with from twenty-two to thirty prominent, rounded radii, which are equal to the spaces between; radii simple, or bifid and trifid towards the margin, crossed by small [closely crowded] elevated concentric [growth] lines."

In the interior of the ventral valve the dental lamellæ are well developed and unite with the outer elevated margin of the elongate-quadrate muscular area. Within this area, occupying the central portion, are the elongate adductors divided by a very faint median elevation. These scars are surrounded laterally and anteriorily by the diductors, while the adjustors lie outside of the latter at the base of the dental lamellæ. Genital spaces faintly indicated on the lateral area, each side of the muscular depression. The apical third of the delthyrium has a convex deltidium. Surface of both valves near the anterior margin more or less strongly marked by plications, each centrally sulcated and opposite the depressions of the outer surface.

Interior of dorsal valve with a well defined, bilobed and striated cardinal process occupying the apical portion of the delthyrium; immediately underneath it is a a low, rounded and short median septum separating the adductor scars, which are rarely divisible into four impressions. Crural plates first form the walls of the delthyrium and then extend into the interior as strong projections.

Orthis pectinella is very constant in its characters throughout its geographical distribution, and is restricted to the Trenton group. In Mercer county, Kentucky, the largest growth and number of individuals is obtained, while in Minnesota the tendency is towards dwarfing. The small size and neatness of the majority of individuals of this species led one of the writers to regard them as a distinct form, to which the name *O. sweeneyi* was applied. Recently, however, large specimens showing the interior have been discovered, and these prove to be *O. pectinella*. Since more than two-thirds of the individuals occurring in Minnesota are smaller than those obtained elsewhere, it is considered advisable to retain the name *O. sweeneyi* as a variety of the species. This new material has also shown that *O. charlottæ* Winchell is founded upon an unusually convex ventral valve of *O. pectinella*.

Formation and locality—Rare in the Trenton shales at St. Paul, Minneapolis and near Cannon Falls, Minnesota; Decorah, Iowa. Common in Mercer county, Kentucky; Middleville, Trenton Falls, Turin, Watertown and elsewhere in New York, Pennsylvania and eastern Canada.

Collectors.—W. H. Scofield, C. L. Herrick, E. O. Ulrich and the writers.

Mus. Reg. Nos. 667, 7767.

Orthis (Dinorthis) pectinella, var. sweeneyi *Winchell.*

PLATE XXXII. FIGS. 35–38.

1881. *Orthis sweeneyi* N. H. Winchell. Ninth Report, Geological and Natural History Survey of Minnesota, p. 117.
1892. *Dinorthis sweeneyi* Hall. Palæontology of New York, vol. viii, pt. i, pp. 196, 222, 228, pl. v, figs. 34–36.

Original description: "Shell suborbicular, with a straightening along the hinge-line, and having the general aspect of *Orthis pectinella*, but with a shorter hinge-line.

"The receiving [dorsal] valve is convex, with flattened lateral marginal areas and cardinal angles; costæ coarse and simple, numbering about twenty-two, all of which continue to the beak except two or three on each side, which in passing from the margin in front of the cardinal angles, rather terminate on the hinge-line. The costæ and the furrows, which have about the same width, are crossed by fine, crowded, concentric striæ; beak distinct, but not much elevated above the margin of the area; area slightly arched, but directed in the plane of the edges of the valves; area [foramen] triangular, equilateral, containing a simple tooth which rises to the apex, but is not developed so as to appear in the plane of the cardinal area, but is horizontally ribbed on either side.

"The entering [ventral] valve is flat, with a little elevation at the beak and umbo, and a broad, slight concavity between the umbonal region and the front margin; costæ the same as on the convex valve; beak small and more abrupt than that of the other valve; area low and flat, but of nearly the same hight as that of the other valve, with which it forms an angle of about 45°; foramen partially closed, but open below, broadly triangular.

"The transverse diameter is seven lines in the single specimen belonging to the survey, and the perpendicular is six."

The specimen described, and others now before us, are essentially but dwarfed individuals of *O. pectinella*. Their shells, however, are smaller and thinner than in the typical form of that species, while the costæ are usually simple, and the muscular scars undefined. Since these features are constant in the specimens observed, it is considered advisable to recognize them as a variety of *O. pectinella*.

Formation and locality.—Not rare in the upper portion of the Trenton shales at St. Paul, near Cannon Falls and Mineola, Minnesota; Decorah and McGregor, Iowa.

Collectors.—W. H. Scofield, F. W. Sardeson and the writers.

Mus. Reg. Nos. 3510, 3520, 5001, 6791, 7768, 7769, 7785.

Orthis (Dinorthis) meedsi *W. and S.*

PLATE XXXII, FIGS. 39–42.

1892, April 1. *Orthis meedsi* W. and S. American Geologist, vol. ix, p. 289.
1892, April 9. *Orthis minnesotensis* Sardeson. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 332, pl. v, figs. 14–17.

Shell of medium size, suborbicular in outline; biconvex; anterior margin broadly deflected dorsally; hinge-line about one-fourth shorter than the greatest width. Surface marked by strongly elevated, sharply rounded striæ, from forty-five to seventy on each valve along the anterior margin, crossed by numerous thread-like lines of growth; striæ arranged in bundles of two or three, those of the ventral valve bifurcating, while on the dorsal valve increase takes place by interpolation. Exfoliated specimens show two or three rows of small black spots, which may represent perforations in the shell substance.

Ventral valve slightly convex, with a broad, shallow sinus; greatest elevation near the apex; cardinal area of moderate width, slightly concave, somewhat elevated beyond or depressed below that of the dorsal valve, perforated by a small triangular delthyrium, which is bounded on each side by a thread-like elevation; beak slightly incurved. Internal characters of valves as in *O.* (*D.*) *pectinella*, but less sharply defined.

Dorsal valve strongly convex centrally, with the lateral-posterior areas somewhat concave; greatest elevation at a point one-third the length of the valve from the posterior margin; cardinal area very narrow, slightly concave, with a broad delthyrium, which is occupied in part by a striated cardinal process.

This common and widely distributed species throughout Minnesota is probably a lineal descendant of *O.* (*D.*) *pectinella*, var. *sweeneyi*. At first it appears rarely with that variety, and attains its distinguishing character in less than fifteen feet of shales above the horizon having var. *sweeneyi* in abundance, and which is here no longer met with. The feature distinguishing *O.* (*D.*) *meedsi* and *O. pectinella*, var. *sweeneyi* is, that bifurcation and interpolation of the striæ take place at a much younger stage of growth in the former than in the latter, and therefore the species at maturity appear quite different. In some of the localities of *O. pectinella* this tendency towards multiplication of the striæ is very noticeable, but it invariably takes place after the shell has attained more than one-half its growth. In Minnesota specimens it takes place close to the margin, and consequently after maturity has been attained. In *O.* (*D.*) *meedsi* the first increase in number of striæ occurs when the shell has attained but one-third its growth, and after this period bifurcation and interpolation are irregular. There is, moreover, a tendency towards a more convex ventral valve than in *O.* (*D.*) *pectinella*, but every now and then a specimen occurs with the characteristic flattened valve of that species.

The specific name is after A. D. Meeds of the University of Minnesota.

Associated with the above species, at its climax of development in number of individuals, a very characteristic and striking variety makes its appearance, which is named *germana.*

Formation and locality.—Rare near the base of the Galena shales at St. Paul, Minnesota, and McGregor, Iowa, a few feet above the horizon of *O. pectinella* and variety *sweeneyi.* It becomes a common and very characteristic fossil in the beds immediately above, and is there associated with *Clitambonites diversa* Shaler; it is known to extend for thirty feet above this horizon.

The following are the most prominent localities at which this species has been collected: Cannon Falls, Kenyon, Warsaw, Fountain and Preston, Minnesota; Decorah and McGregor, Iowa: Neenah and Oshkosh, Wisconsin.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 4055, 5860, 5861, 6746, 7771–7785.

Variety GERMANA *W. and S.*

PLATE XXXII, FIGS. 43–45.

1892, April 1. *Orthis meedsi* var. *germana* W. and S. American Geologist, vol. ix, p. 290.

This variety is distinguished from *O.* (*D.*) *meedsi* by the following characters: Smaller in size and squarer in outline; valves more strongly and more evenly convex; hinge areas nearly equal in width and narrower, with the beak of the ventral valve slightly elevated above that of the dorsal; ventral valve with a slight, somewhat angulated fold, while the dorsal has a shallow, but distinct sinus originating immediately below the apex of the valve. The fold and sinus produce a slight sinuosity in the anterior margin, the direction of which is just the reverse of that in *O.* (*D.*) *meedsi.*

The largest specimens of this variety observed have the general external expression of small individuals of *Orthis subquadrata*, and no external nor internal parts are known that preclude the form from being viewed as the ancestor of that species which attains its specific development in the upper portion of the Cincinnati group The beds from which var. *germana* is obtained are fully one hundred feet below those holding *O. subquadrata.* During this interval no specimens of *Dinorthis* have as yet been detected.

Formation and locality.—Not rare in the upper part of the Galena shales at several localities south of Cannon Falls, near Kenyon and Fountain, Minnesota. This horizon is also characterized by *Anastrophia hemiplicata* and a number of small Bryozoa.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. No. 7770.

ORTHIS (DINORTHIS) SUBQUADRATA *Hall.*

PLATE XXXII, FIGS. 46–50.

1847. *Orthis subquadrata* HALL. Palæontology of New York, vol. i, p. 126, pl. XXXIIA, fig. 1.
1862. *Orthis subquadrata* HALL. Geology of Wisconsin, vol. i, p. 54, figs. 1, 2.
?1863. *Orthis subquadrata* BILLINGS. Geology of Canada, p. 165, fig. 146.

1873. *Orthis subquadrata* MEEK. Palæontology of Ohio, vol. i, p. 94, pl. IX, fig. 2.
1875. *Orthis subquadrata* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 38.
1880. *Orthis subquadrata* WHITE. Second Annual Report, Indiana Bureau of Statistics and Geology, p. 484, pl. I, figs. 3-5.
1881. *Orthis subquadrata* WHITE. Tenth Report, State Geologist of Indiana, p 116, pl. I, figs. 3-5.
1887. *Orthis subquadrata* SHALER. Fossil Brachiopoda of the Ohio Valley, p. 22, pl. VII.
1892. *Orthis (Plœsiomys) subquadrata* HALL. Palæontology of New York, vol. viii, pt. i, pp. 194, 197, 222, pl. VA, figs. 17-19.

Original description: "Subquadrate, the cardinal line forming one side, the sides and base being nearly straight, with the angles rounded; cardinal line less than the width of the shell, extremities curved; area small, partially common to both valves; dorsal [ventral] valve nearly flat or slightly depressed near the margin, elevated towards the beak, which is small and well defined; ventral [dorsal] valve regularly convex with a shallow sinus along the center, producing a slight elevation of the dorsal valve in front; surface marked by uniform subangular radii, which bifurcate near the beak and again towards the margin, those near the cardinal line curving upwards; radii crossed by fine, elevated, concentric lines, which are very distinct in the depressions between the rays."

The following more detailed description is that of Meek, drawn up from specimens from typical localities:

"Shell attaining about a medium size, rather distinctly resupinate, somewhat wider than long, subquadrate in general outline; moderately convex; cardinal margin shorter than the breadth of the valves and rounding abruptly at the extremities into the lateral margins, which round and converge forward; front a little sinuous or straightened at the middle.

"Dorsal valve more convex than the other, its most prominent part being near the middle; mesial sinus small and rather shallow, sometimes continued nearly to the umbo, or in other instances scarcely more than reaching the middle; beak very short, or little distinct from the edge of the area, and more or less arched; area narrow, directed obliquely backward and downward. Interior with scars of the adductor muscles moderately distinct, the posterior pair being situaed close back under the brachial processes, one on each side of a well defined rounded ridge that becomes suddenly smaller between the anterior pair; cardinal process rhombic, subconical, moderately prominent and having its posterior side marked by deeply impressed, divaricating striæ; sockets well defined; brachial process rather strong and directed obliquely forward and laterally; internal surface, excepting the radiately striated front and lateral margins, nearly smooth.

"Ventral valve a little convex at the umbo and flat or slightly concave between the umbo and the front and lateral margins, but sometimes having a low, very obscure mesial elevation towards the front; beak small and very short or scarcely equalling that of the other valve, arched at the apex, but not strongly incurved; area about twice as high as that of the other valve, well defined, tapering rather rapidly towards the lateral extremities, arched with the beak, and directed backward and downward at decidedly less than a right angle to that of the other valve. Interior with muscular scars occupying a rather deep, bilobate impression extending nearly or quite to the middle of the valve and usually defined by a low ridge most distinct on each side; scars of adductor muscles small, separated by a mere trace of a raised line; those of the divaricator [diductor] muscles of moderate size, longitudinally striated and having their narrow posterior ends extending backward nearly to a small, triangular, transversely striated space [pedicle muscle scar] occupying the interior of the beak; those of the ventral adjustor muscles smaller and shorter than the divaricators [diductors] and situated nearly under the hinge teeth, which are moderately prominent, subtrigonal and oblique; vascular markings with their lateral divisions curving up backward and sending off several branches, while the other divisions extend forward and bifurcate so as to occupy the anterior region; anterior and lateral margins crenate within by very short striæ.

"Surface of both valves ornamented by moderately stout, radiating striæ, the posterior lateral of which curve so strongly outward that a few of them run out on the cardinal edge before reaching the lateral margins; striæ of ventral valve nearly always increasing by bifurcation [some of them dividing two or three times], while those on the dorsal valve generally increase by the intercalation of shorter ones between the larger. A few distant subimbricating marks of growth are sometimes seen towards the front and lateral margins; while, on perfectly preserved specimens, the radiating striæ may sometimes be seen to be roughened by minute, elevated concentric lines, that are more or less interrupted in crossing some of the striæ." (Pal. Ohio, vol. i, p. 94.)

This species is so well known that a comparison with other related forms is unnecessary.

It has been shown that *O. meedsi* is a development from *O. pectinella*, var. *sweeneyi*, in which a greater number of striæ have their origin at a much younger stage of growth. Moreover, as the tendency is to equalize the space between the ridges, new ones are continually added, so that these species at maturity are quite distinct. The multiplication of striæ is carried still further in *O. meedsi*. var. *germana*, and in addition to this, other features are introduced which link it closely to *O. subquadrata*. The latter has all the characters of the former more strongly developed, which is due to its greater size, and the line of development from *O. pectinella* to *O. subquadrata* is thus probably completed.

The following species, *O. proavita*, is closely related to *O. subquadrata* Hall. The striæ are simple, and it is rare to find interpolation and bifurcation taking place beyond the early nealogic stage. Here, then, is a reversion to ancestral characters, which is carried still further in *O. flabellulum* Hall* (non Sowerby)=*O. flabellites* (Hall) Foerste,** a species from the Niagara formation much resembling *O. pectinella* Emmons.

Formation and locality.—This is a very characteristic and common species in America, everywhere marking the upper portion of the Hudson River group. In Minnesota it has been found abundantly at Spring Valley, and is known to be equally common at Wilmington, Illinois; Richmond, Weiseburg and Madison, Indiana; Oxford, Clarksville and Waynesville, Ohio; Maysville, Kentucky; and Anticosti. It also occurs rarely at Graf, Iowa, and at Iron Ridge, Wisconsin.

Collectors.—E. O. Ulrich, John Kleckler and the writers. Also in the collection of Dr. C. H. Robbins, of Wykoff, Minnesota.

Mus. Reg. Nos. 274, 396, 4076, 4094, 7786-7788.

ORTHIS (DINORTHIS) PROAVITA *W. and S.*

PLATE XXXII, FIGS. 51–57.

1892, April 1. *Orthis proavita* W. and S. American Geologist, vol. ix, p. 290.
1892, April 9. *Orthis petræ* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 332, pl. v, figs. 18-21.

Shell of medium size; subqaudrate; hinge-line equal to, or less than, the greatest width of the shell; cardinal anlges rounded or rectangular; sides gently convex and converging to more or less straghtened or slightly concave anterior margin. Surface marked by simple subangular striæ having their origin at the apex of the valves or immediately below it, addition taking place by interpolation on the dorsal, and by bifucation on the ventral valve; one to three striæ terminating on the cardinal margin on each side of the umbo; thirty-seven to forty-two on mature examples, crossed by a variable number of imbricating growth lines near the anterior margin. In some specimens this margin is sharply reflexed, partly indicating old age.

Ventral valve slightly elevated at the umbo, flattened or somewhat concave toward the lateral and anterior margins, with an insignificant mesial elevation. Area comparatively narrow, with a broad, triangular delthyrium, two-thirds of which is occupied by the cardinal process of the other valve; beak slightly incurved. Interior characters as in *O. subquadrata*, with the muscular scars remarkably well defined for a specimen of medium size.

Dorsal valve more or less strongly convex, with the greatest elevation about mid-length. A shallow, or sometimes well pronounced, broad sinus is present, having its origin in the upper third of the valve. Area narrow, perpendicular or slightly inclined forward, with a broad delthyrium entirely occupied by the protruding, striated cardinal process.

O. (D.) proavita differs from *O. (D.) iphigenia* Billings,† in having the fold and sinus reversed; the latter also has a greater number of striæ and is restricted to the

*Geol. N. Y.; Rep. Fourth Dist., p. 105, fig 5, 1843; Pal. N. Y., vol. ii, pp. 254, 255, pl. XLII, figs. 6, 7, 1852.
**Proc. Boston Soc. Nat. Hist., vol. xxiv, p 308, pl. VI, figs. 4, 5, 1890.
†Pal. Foss., vol. i, p. 133, fig. 110, 1862.

Trenton group of Canada. *O.* (*D.*) *porcata* McCoy* has deeper valves, while the area of the ventral valve is more than twice as wide. *O.* (*D.*) *retrorsa* Salter is a somewhat larger species, but differs from *O.* (*D.*) *proavita* in its retrorse ventral area.

For the relation of *O.* (*D.*) *proavita* to other species of the subgenus *Dinorthis* see *O.* (*D.*) *subquadrata*.

Formation and locality.—Not rare in the upper portion of the Hudson River group at Spring Valley, Minnesota, and Wilmington, Illinois.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 273, 278, 7789.

Subgenus HEBERTELLA, Hall.

1892. *Hebertella*, HALL. Palæontology of New York, vol. viii, pt. i, p. 198.

Original description: "This division is distinguished both by its external and internal characters; the pedicle valve has a well developed, often much elevated, cardinal area and a long, straight hinge-line; its surface is depressed-convex, always less convex than the opposite valve, which is frequently gibbous or deflected. The surface is covered with a great number of fine, rounded, closely crowded plications which increase rapidly by intercalation, and are crossed by lamellose growth lines and fine concentric striæ. On the interior of the pedicle valve the teeth are large and supported by thick lamellæ, which are continued as a strong ridge around a short, obcordate muscular area. This area is medially divided by a prominent ridge, upon the summit of which lies the linear scar of the adductors. The flabellate lateral impressions are sometimes divisible into their two components, diductors and adjustors, and in old individuals the impression of the pedicle muscle is often distinct.

"In the brachial valve the dental sockets are narrow and are enclosed beneath and on the inner side by the strong crural plates. The cardinal process is elongate and simple, sometimes thickened, often crenulate, but not lobed, at its posterior extremity. This process unites with the inner bases of the crural plases and is produced forward as a median ridge dividing the four muscular scars, which are distinctly developed only in old shells.

"The shell structure is fibrous-impunctate, and the plications of the surface sometimes tubulose."

Type: *Orthis sinuata* Hall.

"Shells of this type of structure are abundant in the Trenton and Hudson faunas and extend upward into the Clinton group, but are not at present known in any later period."

* Sil. Foss. of Ireland, p. 32, pl. III, fig. 14, 1846; and Pal. Foss., vol. i, p. 135, fig. 111, 1862.

Orthis (Hebertella) borealis *Billings.*

FIG. 33. *Orthis (Hebertella) borealis* Billings. *a*, dorsal; *b*, ventral, and *c*, profile view of a variety of this species. Upper part of the Galena shales near Wykoff, Minnesota. Collection of E. O. Ulrich.

1859. *Orthis borealis* BILLINGS. Canadian Naturalist and Geologist, vol. iv, p. 436, fig. 14.
1863. *Orthis borealis* BILLINGS. Geology of Canada, p. 129, fig. 56; p. 167, fig. 148.
1873. *Orthis borealis* MEEK. Palæontology of Ohio, vol. i, p. 101, pl. VIII, fig. 4.
1875. *Orthis borealis* MILLER. Cincinnati Quarterly Journal of Science, vol. 2, p. 28.
1889. *Orthis borealis* NETTELROTH. Kentucky Fossil Shells, p. 36, pl. XXXIV, figs. 14–20.
1892. *Orthis (Hebertella) borealis* HALL. Palæontology of New York, vol. viii, pt. i, p. 222.

The Minnesota specimens of this species are closely related to *Orthis plicatella* of the Galena horizon, so that a detailed description is not necessary. They can be distinguished from each other by the fold and sinus, in *O. borealis*, being on the dorsal and ventral valves respectively, while in *O. plicatella* the conditions are the reverse. These differences are not so pronounced as in specimens from the Ohio valley, where *O. borealis* usually has, in addition, a much deeper dorsal than ventral valve. The latter character is one of the chief distinctions between Prof. Hall's subgenera *Hebertella* and *Plectorthis*, and is developed at its maximum in *O. sinuata* Hall. From the preceding it is readilly seen that these subgenera probably had their origin in the Chazy formation, and there and in the Trenton are not easily distinguishable, but in the Hudson River group of the Ohio valley *Hebertella* is one of the characteristic markers of that horizon, there reaching its maximum of growth, diversity and number of individuals. *Plectorthis* also attains its maximum in the Hudson River group, the tendency in the Cincinnati group being towards diminished size, but greater numerical strength and irregularity of plications, while in the northwest the radical form developed into other distinct, large, somewhat localized species. *Hebertella* persists into the Upper Silurian, while *Plectorthis*, which probably originated first, became extinct with the Hudson River group.

Formation and locality.—Rare in the upper Clitambonites horizon of the Galena shales near Wykoff, Cannon Falls and top of West St. Paul bluffs, in Minnesota. Prof. Whitfield mentions its occurrence in Wisconsin. Very common near the top of the Trenton limestone at Frankfort, Burgin, Lexington and elsewhere in central Kentucky. Near Nashville, Tennessee. In Canada Billings cites it from the Chazy to the Trenton at Caughnawaga, St. Genevieve, Isle Bizard and Cornwall.

Collectors.—E. O. Ulrich and C. Schuchert.

ORTHIS (HEBERTELLA?) BELLARUGOSA *Conrad.*

PLATE XXXIII, FIGS. 1–4.

1843. *Orthis bellarugosa* CONRAD. Proceedings of the Academy of Natural Sciences of Philadelphia, vol. i, p. 333.
1847. *Orthis bellarugosa* HALL. Palæontology of New York, vol. i, p. 118, pl. XXXII, fig. 3.
1892. *Hebertella bellarugosa* HALL. Ibidem, vol. viii, pt. i, p. 222.

Original description: "Semioval; valves nearly equally convex; lesser valve with a mesial subangular furrow; ribs prominent, linear, with unequal bifurcations; disk with numerous concentric, prominent, subsquamose wrinkles; apex of larger valve not much elevated above that of the opposite valve; cardinal area rather wide. Length, less than half an inch.

"Locality: Mineral Point, Wisconsin, (Trenton limestone)."

Shell subquadrate in outline; biconvex; anterior margin more or less sharply deflected ventrally. Hinge-line equal to, or a little shorter than, the greatest width of the shell. Cardinal area much the widest in the ventral valve, slightly concave and elevated above that of the dorsal. Delthyrium narrowly triangular in the ventral valve and three times as long as wide. Surface marked by unequal costæ, varying in number from thirty to fifty-two, increase taking place by bifurcation on the ventral valve, and by intercalation on the dorsal, crossed by numerous, strongly imbricating, concentric lines of growth.

Ventral valve strongly and evenly convex, sometimes with a very shallow median sinus, greatest elevation on the umbo, with the beak more or less elevated and slightly incurved. Hinge teeth large, supported by well developed dental plates, which join the lateral elevated outer margin of the more or less obcordate muscular area. This area, in the apical portion, is occupied by the transversely striated pedicle muscle; medially by the expanding adductors, while the diductors are situated on each side of the latter. The short, conspicuous and slightly diverging vascular trunks have their origin at the base of a more or less elevated muscular area and terminate rapidly. Large genital spaces are very faintly indicated on each side of the muscular area. Peripheral margin in the valves marked by prominent radiating striæ.

Dorsal valve convex, with a conspicuous, more or less broad, medial sinus. Cardinal area narrow, erect, slightly concave, divided by the delthyrium, which is as wide as long. Crural plates projecting and having their origin at the base of the walls of the delthyrium, which join the conspicuous, transverse apical thickening; and here the strong and simple cardinal process is centrally situated. Dental sockets deep, situated on the posterior-lateral areas of the crural plates. A stout, but short and narrowly rounded medial septum has its origin at the base of the apical thickening, and upon each side are placed two pairs of adductor muscles, the posterior ones much the smaller.

The larger specimens of this species occurring in the Trenton shales of Minnesota are difficult to separate from *Orthis insculpta* Hall of the Cincinnati group. Commonly, however, the former is much smaller, has a less convex dorsal valve. with more strongly defined muscular scars; the exterior, concentric, imbricating growth lines are also more prominent.

Formation and locality.—Rare in the Trenton limestone and Trenton shales at Minneapolis and St. Paul; not uncommon in the lower portion of the Galena in many localities in Goodhue county, and at Fountain, Minnesota: and Neenah, Wisconsin. Near the top of the Trenton at Decorah and McGregor. Iowa. In the "Lower Blue beds" of the Trenton at Janesville, Wisconsin, and in the "Upper Buff beds" at Rockton, Illinois. Also in the "Central limestone" of the Trenton near Murfreesboro, Tennessee.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. Nos. 6752, 7806-7812.

ORTHIS INSCULPTA *Hall.*

1847. *Orthis insculpta* HALL. Palæontology of New York, vol. i, p. 125, pl. XXXII, fig. 12,
?1863. *Orthis insculpta* BILLINGS. Geol. of Can., p. 167, fig. 150. (Compare with *O. bellarugosa* Conrad).
1873. *Orthis insculpta* MEEK. Palæontology of Ohio, vol. i, p. 99, pl. IX, fig. 1.
1875. *Orthis insculpta* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 40.
1883. *Orthis bellarugosa* HALL. Second Annual Report, N. Y. State Geologist, pl. XXXV, fig. 22.
1892. *Heberlella insculpta* HALL. Palæontology of New York, vol. viii, pt. i, p. 222.

It is peculiar that this prevalent species of the upper beds of the Hudson River formation does not occur in Minnesota, since it is found in Wisconsin and Iowa.

Formation and locality.—A characteristic fossil of the upper beds of the Cincinnati group in the Ohio valley; also at Wilmington, Illinois; Iron Ridge, Wisconsin, and Graf, Iowa.

Mus. Reg. Nos. 7813-7815.

Subgenus PLECTORTHIS, Hall.

1892. *Plectorthis,* HALL. Palæontology of New York, vol. viii, pt. i, p. 194.

Original description: "This is a persistent form, which in American faunas, so far as known, is limited to the Trenton and Hudson formations. While it retains the strong external ribs of the typical *Orthis*, these are not invariably simple (*O. fissicosta* Hall; *O. triplicatella* Meek; *O. æquivalvis* Hall, not Davidson; O. *jamesi* Hall); the cardinal area of the pedicle valve is comparatively low and the valves are subequally convex. In the interior the character of the muscular scars, dental lamellæ and cardinal process is essentially the same as in Group I [*Orthis callactis* Dalman]; and the minute structure of the shell appears to be in precise agreement with that of *O. calligramma*, though no evidence of tubulose costæ has been observed. In *Orthis jamesi,* which is placed in this association, there is occasionally a deviation toward the resupinate contour, exemplified in Groups IV and V [*Orthis subquadrata* Hall and *Orthis sinuata* Hall].

ORTHIS (PLECTORTHIS) PLICATELLA *Hall.*

PLATE XXXIII, FIGS. 5–7.

1847. *Orthis plicatella* HALL. Palæontology of New York, vol. i, p. 122, pl. XXXII, fig. 9.
?1863. *Orthis plicatella* BILLINGS. Geology of Canada, p. 165, fig 145.
1873. *Orthis plicatella* MEEK. Palæontology of Ohio, vol. i, p. 108, pl. VIII, fig. 7.
1875. *Orthis plicatella* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 30.
1892. *Plectorthis plicatella* HALL. Palæontology of New York, vol. viii, pt. i, p. 221, pl. V, figs. 18–20.

Original description: "Broadly semioval, nearly equivalve, length and breadth about as three to four; surface marked by strong, radiating plicæ, which are usually simple, about twenty to twenty-eight on each valve, crossed by simple, elevated concentric lines, which are more distinct in the depressions between the costæ, and often obscure or obsolete upon their exposed surfaces; valves nearly equally convex, without sensible depression or elevation on either one, meeting on the edges in a straight line; cardinal lines not extending beyond the width of the shell; area narrow; dorsal foramen not extending to the beak."

This well known species originates in the lower portion of the Trenton group of New York and is also found in the inferior strata of the Galena formation in Wisconsin and Minnesota, attaining its greatest development in numbers and variations in the Cincinnati group, at a horizon about 300 to 350 feet above low water in the Ohio river.

Orthis plicatella is rather a rare species in the Trenton of New York, and Galena of Wisconsin and Minnesota. It attains a larger growth and is fairly constant in its simple plications and has a more depressed and furrowed dorsal umbo than in specimens from the Cincinnati group. The size and number of plications in the specimens from Cincinnati are very variable, several forms having been described as distinct species. These are *O. fissicosta, O. dichotoma* Hall,* and *O. triplicatella* Meek.** In large collections of these forms, however, it is often difficult to know where to draw the line between them, and the above names can only be used to indicate the transition from the simple undivided *O. plicatella* to *O. dichotoma* with its numerous interpolated smaller striæ.

In the Cincinnati group of the Northwest, *O. plicatella* is not known to occur, but *O. whitfieldi* Winchell and *O. kankakensis* McChesney take its place. These species have attained a much larger size than *O. plicatella.*

Formation and locality.—Rare in the Trenton limestone of Middleville and Watertown, New York, and Burgin, Kentucky. One individual has been discovered in the Galena shales at St. Paul; it has also been obtained at Kenyon, Cannon Falls and elsewhere in Goodhue county, Minnesota. Prof. Whitfield reports it from about the same horizon in Wisconsin. Very common in the Cincinnati group around Cincinnati, Ohio.

Collectors.—W. H. Scofield, A. D. Meeds and the writers.

Mus. Reg. Nos. 7765, 7766.

* Pal. N. Y., vol. i, pp. 121, 125. pl. XXXII, figs. 7, 13, 1847.
** Pal. Ohio, vol. i, p. 109, pl. VIII, fig. 8, 1872.

Orthis (Plectorthis) whitfieldi *N. H. Winchell.*

PLATE XXXIII, FIGS. 8–13.

1881. *Orthis whitfieldi* Winchell. Ninth Annual Report of the Geological and Natural History Survey of Minnesota, p. 115.
1882. *Orthis pectinella* Whitfield (parti. not Emmons nor Hall). Geology of Wisconsin, vol. iv, p. 259, pl. xii, fig. 8.
1892. *Plectorthis whitfieldi* Hall. Palæontology of New York, vol. viii, pt. i, p. 221, pl. v, fig. 26.

Original description: "Shell semioval, the hinge-line being a little less than, or equal to, the greatest tranverse diameter, the cardinal angles being a little greater than 90°, the edge passing in a regular semioval curve through the antero-lateral angles, but sometimes with a very slight inclination in front toward the side of the receiving [ventral] valve. Size varying from nine and a half to fourteen lines in transverse diameter, and from eight to eleven and a half lines in perpendicular diameter, in the larger size the convexity being, between the umboes, six and a half lines.

"The receiving [ventral] valve has a distinct and full beak and umbo, from which the surface slopes evenly to the margin all round, but having a little flatness at the cardinal angles. The cardinal area is arched, and at its union with the cardinal area of the entering [dorsal] valve forms an angle with it of nearly 90°; its hight is about one-sixth its length; its foramen [delthyrium] is triangular and reaches the beak, the width across the base being somewhat less than the hight; plications of the surface are strong, direct and simple, but double their number on the umbo by implantations, and again in the same way before reaching the margin, where they number from thirty-six to forty-eight. Between the plicæ are fine cross ridges which sometimes rise to the tops of the plicæ, but do not cross them so as to be preserved in our specimens. A cast of the interior of this valve shows a distinct general muscular impression, reaching a little more than one-third the perpendicular diameter of the valve from the beak, and divided longitudinally into shallow furrows and ridges converging within the beak, four of the former and five of the latter, with a cross-striation visible on that portion between the teeth and near the foramen. The central ridge in the general muscular impression on the cast does not reach the front margin of the scar, but gradually dies out, giving place to the adjoining parallel furrows which widen and coalesce, and show a longitudinal finer furrowing or striation. The next ridges, on either side, are marked and prominent, extending to the anterior angles of the scar, giving it a nearly straight, elevated front and angular corners, somewhat as in *O. subquadrata*. The two outermost ridges are fainter, but extend to the lateral margins of the scar. Still, outside of all these ridges are traces of a similar furrowing within the beak, embracing that portion between the teeth which has the fine cross-striation. The outward plications of the valve are strongly marked on the cast for about two and a half lines from the margin, and some of them run faintly even to the edge of the muscular scar.

"The entering [dorsal] valve is much less convex, but cannot be said to be flat, though it has a faint flattening along the center, which widens to the front margin where it is changed, in the large specimen, to a slight concavity and produces a straightening and also a very slight flexure of the margin. In front of the cardinal angles also, on either side, is a flat, depressed area; cardinal angle parallel with the posterior margins of the valve, and a little more than one-half the hight of that of the receiving valve; beak indistinct; foramen triangular and about as wide as high, with a small, central, smooth tooth [cardinal process], which does not rise above the plain of the area and only becomes visible on being cleaned and excavated. A cast of the interior of this valve shows marked internal characters. While the impressions of the individual divaricator and adductor muscles of the same side are not separable with certainty, owing to the faintness of the lines between them, the pairs of each are divided, on the cast, by a deep, sharp furrow that extends from the beak where it divides the divaricately striated cardinal process into two equal lobes, toward the front between the depressions of the hinge teeth, to a point somewhat more than one-third the diameter from the beak, where it dies away or runs into a broad, abrupt, medial depression which produces the flatness in the valve extending to the front margin. The external costæ are deeply impressed on the cast about the margin, some of the lines running faintly within the vascular area. The exterior of this valve is also marked by concentric fine striations, especially between the costæ."

The vascular trunks are often conspicuous in the ventral valve, having their origin at the antero-lateral elevated margin of the muscular area; diverging slightly, they proceed but a short distance forward. Posterior to these and on each side of the muscular area are the faintly marked genital spaces.

This species is closely related to *O. kankakensis* McChesney,* but is always proportionately less elongated along the hinge-line, and therefore squarer in outline. The plications are also more numerous, there being from sixty to seventy along the margin of one valve in that species, while in *O. whitfieldi* there are usually not more than forty.

The specimen figured by Prof. Whitfield (*op. cit.*) as *O. pectinella* (Emmons) Hall, and found in the Cincinnati group at Delafield, Wisconsin, undoubtedly belongs to this species. It does not occur above the lower portion of the Galena, while *O. whitfieldi* is unknown below the Hudson River group, and always has a greater

*New Pal. Foss., p. 77, 1861; also Trans. Chicago Acad. Sci., vol. 1, p. 20, pl. IX. fig. 3, 1868.

number of plications, with a convex ventral valve. In *O. pectinella* this valve is flatter and its cardinal area is never so strongly elevated as in *O. whitfieldi.*

Formation and locality.—Common in the Hudson River group at Spring Valley and near Granger, Minnesota; Delafield, Wisconsin; Savannah, Illinois, and Graf, Iowa.

Collectors.—E. O. Ulrich, John Kleckler, W. H. Scofield and the writers.

Mus. Reg. Nos. 277, 429, 4094, 5549, 7762-7764.

Subgenus DALMANELLA Hall.

1892. *Dalmanella.* HALL. Palæontology of New York, vol. viii, pt. i, p. 205.

Original description: "Shells plano-convex or subequally biconvex. Pedicle valve usually the deeper, often gibbous, elevated at the umbo and arched over the cardinal area. Hinge-line generally shorter than the greatest width of the shell. In many of the species there is a more or less conspicuous, undefined median fold and sinus on the pedicle and brachial valves respectively. Surface covered with fine, rounded, bifurcating striæ.

"In the pedicle valve the teeth are quite prominent, thickened at their extremities and supported by lamellæ which are produced forward circumscribing a rather short suboval or subquadrate muscular area, which is more or less distinctly defined in different species and in different conditions of the shell. In *Orthis meeki* Miller, a somewhat ponderous, biconvex, multistriate variation of *Orthis testudinaria*, it is clearly resolvable into adjustor and diductor scars, the latter bounding, but not altogether enclosing the impression of the adductors; the pedicle scar is also discernable. In the brachial valve the cardinal process extends forward as a ridge to the bases of the crural plates, where it is broadened and continued thence as a median ridge separating the muscular impressions. The inner surface of this process is divided by a faint median furrow which produces two lobes at the posterior extremity, and each of these lobes is again divided, making the process quadrilobate. Sometimes the inner divisions of the two main lobes have coalesced, producing a strong median lobe and thus making the process appear trilobate. In some species at maturity, and in others from abnormal growth, this process becomes a broad plug, which fills the entire delthyrial opening. The dental sockets are small, the crural plates often greatly elevated, especially in the plano-convex forms, and they are not usually produced into a ridge about the muscular area, but end abruptly. Muscular impressions quadruplicate, sometimes with radiating ridges extending from the lateral and anterior margins.

"Shell substance finely fibrous and punctate."

Species of this subgenus probably make their appearance as early as the Calciferous (*O. electra* Billings), but certainly in the Chazy group, and are also known to occur in all the intervening formations up to the close of the Devonian.

Orthis (Dalmanella) hamburgensis? *Walcott.*

PLATE XXXIII, FIGS. 14–16

1884. *Orthis hamburgensis* Walcott. Monograph of the U. S. Geological Survey, vol. viii, p. 73, pl. II, fig. 5.

Original description: "Shell small, suborbicular in outline, plano-convex; hinge-line a little shorter than the greatest breadth of the valves. Dorsal [ventral] valve moderately convex, most elevated a little behind the center, along a slight ridge formed by two or three strong, slightly raised striæ; beak small, depressed about halfway down the cardinal margin. Ventral [dorsal] valve depressed, the slightly convex, mesial depression well defined from the beak to the front margin.

"Surface of both valves marked by from twelve to eighteen strong angular striæ, which increase by bifurcation or intercalation towards the margin."

The following description is based on Minnesota material: Shell very small, subquadrate in outline, hinge-line equal to, or slightly less than, the greatest width below; cardinal angles rectangular; sides in the posterior third straight or gently convex; anterior angles and front broadly rounded. Ventral valve convex, subcarinate along the middle, with a flat slope toward the sides; greatest elevation about one-third the length of the shell from the posterior margin. Cardinal area wide, broadly triangular, slightly concave, forming an angle of about 115° with the plane of the lateral margin; delthyrium narrowly triangular, more than twice as long as wide, with a linear elevation along each wall. Beak slightly incurved, raised above that of the dorsal valve. Dorsal valve less convex than the ventral, with a sinus beginning immediatly below the beak and rapidly expanding into a broad, shallow depression, which produces a more or less undulated anterior margin. Cardinal area conspicuous, slightly concave, less than half as wide and more erect than that of the other valve; delthyrium about as long as wide, bounded on each side by a linear elevation, and occupied centrally by a narrow and simple cardinal process.

Surface with moderately strong, radiating, bifurcating, angular striæ, of which from thirty-two to forty-six may be counted along the anterior margin. In some specimens the striæ are nearly equal in size, while in others those originating on the umbones increase rapidly in strength, and the ones coming in later by bifurcation remain smaller, giving to such shells the appearance of striæ in bundles. Interior features unknown, except that the dental plates are strong and attached to the bottom of the valve.

Since the cardinal areas, delthyrium and interior characters are unknown in the Nevada specimens, the writers are not satisfied that the Trenton forms are identical with *O. hamburgensis.* A specimen of the latter was sent to Mr. Walcott, who writes that "the cardinal line is a trifle shorter in the Nevada specimens than in those from

Minnesota, otherwise I do not see any difference between the two species. It is to be remembered, however, that the Nevada specimens do not show the cardinal area and that they are not quite as well preserved as the one you sent to me." *O. hamburgensis* is found in the central part of the Pogonip group of Nevada, a horizon probably equivalent to the lower portion of the Chazy group of New York. The great difference, geographically and geologically, between the localities of *O. hamburgensis* and the species here provisionally identified with it leads to the belief that the two may be specifically distinct.

In Minnesota this form is found associated with *O. testudinaria* and is easily confounded with it. Upon examination, however, characters are noticed reminding one of *O. tricenaria* and other species referred to *Orthis* in its strict generic sense. The wide cardinal area, narrow delthyrium, simple cardinal process, and the fact that none of the striæ terminate on the cardinal lines, are features of that genus. In *O. hamburgensis* the surface striæ exhibit a strong tendency towards bifurcation and upon them are series of minute black spots, probably infillings of the punctæ in the shell substance. Since *Orthis* is impunctate and always has simple plications, this species is better placed in *Dalmanella*. If this conclusion is correct, there is evidence to show that *Dalmanella* was derived from *Orthis*.

Formation and locality.—Rare in the Trenton shales at St. Paul, near Cannon Falls, Lanesboro and Fountain, Minnesota. Also from the top of the Birdseye limestone near High Bridge, Kentucky. The typical specimens are from the central part of the Pogonip group of the Eureka District, Nevada, where the species is common.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. No. 7897.

ORTHIS (DALMANELLA) TESTUDINARIA *Dalman.*

PLATE XXXIII, FIGS. 17–22.

1828. *Orthis testudinaria* DALMAN. Kongl. Svenska Vet.-Acad. Handl., för 1827, p. 115, pl. II, fig. 4.
1839. *Orthis testudinaria* CONRAD. Annual Report of the New York Geological Survey, p. 63.
1842. *Orthis striatula* EMMONS. Geology of New York: Report of the Second District, p. 394, fig. 3.
1842. *Orthis testudinaria?* EMMONS. Ibidem, p. 404, fig. 4.
1847. *Orthis testudinaria* HALL. Palæontology of New York, vol. i, p. 117, pl. XXXII, fig. 1; p. 288, pl. LXXIX, fig. 4.
1856. *Orthis testudinaria* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 40, fig. 1.
1858. *Orthis testudinaria* ROGERS. Geology of Pennsylvania, vol. ii, pt. ii, p. 818, fig. 601.
1863. *Orthis testudinaria* BILLINGS. Geology of Canada, p. 165, fig. 144.
1875. *Orthis testudinaria?* WHITE. Report of the U. S. Geographical Surveys west of the 100th Meridian, p. 72.
1875. *Orthis testudinaria* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 20.
1882. *Orthis testudinaria* WHITFIELD. Geology of Wisconsin, vol. iv, p. 258, pl. XII, figs. 5–7.
1883. *Orthis testudinaria* HALL. Second Annual Report, New York State Geologist, pl. XXXIV, figs. 1-4, 6-15.
1884. *Orthis testudinaria* WALCOTT. Monograph of the U. S. Geological Survey, vol. viii, p. 72, pl. XI, fig. 10.
1892. *Dalmanella testudinaria* HALL. Palæontology of New York, vol. viii, pt. i, pp. 190, 206, pl. VB, figs. 27, 39.
1892. *Orthis rogata* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 331, pl. V, figs. 1-4.

For other synonymy see Davidson's Monograph of British Silurian Brachiopoda, p. 226.

Original description: "O. testa confertissime striata, costis subalternis elevatioribus; valva minori subplana semiorbiculari; majori basi gibba, nate prominula nutante. Locus. Ostrogothia ad Borenshult, in calce cinera. Longit. 15 mm., latit. testæ 15, lat. valvæ minoris ad basin 12 mm., crass. 7 mm.

"Species quasi media inter *O. elegantulam* et *O. basalem*, ad utraque distincta ambitu magis orbiculari, minime ad cordatum tendente, præsertim vero costarum radiantium ratione, quæ enim duplicis sunt generis, videlicet; *elevatiores* (circiter 30), testæ basin fere attingentes; et *humiliores* plus minus abbreviatæ, quarum 2–3, inter par priorum.

"Valva minor subplana, 1, in medio longitudina liter subimpressa; suborbicularis, basi truncata, apice vero rotundato, minime prominulo. Linea cardinalis quam valvæ longitudo manifeste brevior. Valva major basi gibba, nate prominula, modice curva valvæ minoris convexitatem minime attingente. Subnate areola triangularis impresso-plana, foramine deltoideo brevi.

"Obs. Rostrum quam in *O. elegantula* minus sed quam in *O. basalis* magis curvtum; margo cardinalis quam in utraque specie brevior. Specimina plura consulti similia."

The following description of *O. emacerata* Meek (not Hall)=*O. testudinaria*, var. *meeki* Miller, is given, as it applies to this species in all of its details, except that the former is larger and more robust than in the majority of specimens usually referred to *O. testudinaria:* "Species small, plano-convex, rather depressed, transversely truncato-suboval, the length being about five-sixths its breadth [sometimes as wide as long]; hinge-line perhaps always a little shorter than the greatest breadth of the valves; lateral margins generally rounding to the hinge, most prominent at, or a little behind the middle, and rounding to the front, which is usually somewhat straightened, or very faintly sinuous, at the middle; or presents a regular semicircular outline.

"Dorsal valve nearly flat, or slightly convex on each side of a shallow mesial sinus, that commences very narrow at the beak and usually widens rather rapidly to the front; beak very small, scarcely projecting beyond the edge of the area, and not incurved; area low at the middle and narrowing off to nothing at the lateral extremities of the hinge, slightly arched, and directed obliquely backward; foramen [delthyrium] very small and filled by the [large trilobed, striated] cardinal process. Interior very shallow and provided with a slender mesial ridge that extends about halfway forward from the hinge, between the muscular impressions, which are not usually well defined; scars of posterior pair of adductor muscles smaller and usually deeper than the anterior and situated close back under the brachial processes; those of the anterior pair three or four times the size of the posterior [commonly not more than twice the size], suboval in form and extending to near the middle of the valve; cardinal process very small [comparatively large, striated] and trifid; brachial processes comparatively rather stout and prominent; internal surface having the radiating striæ of the exterior rather distinctly impressed through, as it were [each with a central furrow], in consequence of the thinness of the shell, and finely granular, the granules being apparently connected with the punctate structure of the shell.

"Ventral valve compressed-convex, the greatest convexity being near, or a little behind, the middle, along a more or less prominent, undefined ridge that sometimes, but not always, imparts a subcarinate appearance to the central and umbonal regions; beak small, projecting somewhat beyond that of the other valve, abruptly pointed and rather distinctly arched, but not strongly incurved; area about twice as high as that of the other valve and with its sharply defined edges sloping to the lateral extremities of the hinge, directed and arched obliquely backward with the beak; foramen [delthyrium] having nearly the form of an equilateral triangle, but rather narrowed upward to the apex of the beak [with a distinct linear ridge along each wall] and partly occupied by the cardinal process of the other valve. Interior showing the teeth to be moderately prominent; concavity for the muscular impressions very shallow, somewhat bifid anteriorly and not defined by a very distinct marginal ridge; at the base of the dental plates are situated the narrow adjustor scars, terminating at the transversely striated pedicle muscle, which occupies the posterior portion of the rostral cavity; on the inside of the former are the large diductors separated by the small, elongate adductors; striæ and fine granules of the interior as in the other valve.

"Surface of both valves ornamented by numerous, distinct radiating striæ that usually bifurcate about three times between the beak and free margins; posterior lateral striæ so strongly curved that a part of them run out on the hinge-line. Numerous very minute, regularly disposed, concentric lines may also be seen by the aid of a magnifier, most distinctly defined in the furrows between the radiating striæ, while a few distinct, subimbricating, stronger marks of growth are usually seen in adult shells." Shell structure distinctly punctate.

Size of shell, outline, convexity of valves and number of striæ are more or less variable features at all localities of this species. "The shells of this species usually characterize the Trenton and Hudson River beds at nearly all their outcrops, being one of the most persistent, as well as most characteristic fossils of these layers. Still, there are so many varieties of it that it is often difficult to refer it, without some hesitation, to its original place. Very many of these varieties have been described as distinct species, and others as varieties under varietal names, until collectors have almost lost sight of the original species. Some of these varieties seem to mark given horizons over limited areas, and others apparently characterize special localities; still, I do not believe they are sufficiently distinct or persistent enough to rank as species or to be worthy a varietal name beyond the purpose of the locality where found, or for local preservation." (Whitfield, *loc. cit.*) Specimens of *O. testudinaria* from the Trenton shales and from the lower portion of the Galena formation of Minnesota are slightly smaller and narrower than those from the Trenton of New York, while in central Kentucky they are generally twice the size of the eastern examples. Other specimens from the latter region are very thin-shelled and are referred by local collectors to *O. emacerata* Hall. In the Cincinnati group of the Ohio valley, *O. testudinaria* is abundant in certain horizons. It is, moreover, nearly always present in one form or another throughout the formation and is more or less variable, although constant in its characters in certain beds. Some varieties are known as *O. cyclus* James, *O. multisecta* (James) Meek, *O. emacerata* Hall, *O. jugosa* James and *O. meeki* Miller. The first two are synonymous and cannot be regarded as of greater significance than a local variation; the same is also true of the last two. *O. emacerata* can be distinguished from *O. testudinaria* by its thin, compressed valves and finer and more numerous striæ. If, however, a close examination is made between specimens of *O. testudinaria* from various localities it will be apparent to the observer that individuals from one region do not exactly agree with those from another. As long as one restricts himself in his studies of this species to a single horizon of one locality all goes well with the selected varieties, but as soon as the trial is made to apply them to specimens from other regions the chosen varieties drop out for want of constancy of characters.

In some Minnesota specimens there is a tendency to greater convexity of the dorsal valve. The mesial sinus may be obsolete or, as seen in one specimen, narrow and deep, sharply indenting the anterior margin. Probably if the development of the sinus were to become deeper and deeper in successive generations, it would eventually result in a species related to *Bilobites*. The general expression of *O. testudinaria* and species of *Bilobites*, excluding the strongly lobate condition of the latter genus, is essentially the same. While this may be the line of development, still *Bilobites* may have originated from an entirely different stock. Dr. Beecher, in his "Development of Bilobites," has suggested its relations to the group represented by *Platystrophia biforata* Schlotheim.*

Formation and locality.—Not common in the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Chatfield, Preston and elsewhere in Minnesota; Decorah and McGregor, Iowa. Very common in the Galena shales at various localities in Goodhue and Olmsted counties, Minnesota. Also from the base of the "Upper Buff beds" of the Trenton at Mineral Point, Wisconsin, and Rockton, Illinois. From the Galena at Decorah and Dubuque, Iowa; Neenah and Oshkosh, Wisconsin. In the Trenton limestone of

*American Jour. Sci., vol. xlii, p. 54. 1891.

central Kentucky, and near Nashville, Tennessee: New York and eastern Canada. In the Salmon River group, or Lorraine shales, at Graf, Iowa: Iron Ridge, Wisconsin; Cincinnati, Ohio; New York; Anticosti, and Silver City, New Mexico; Chazy group of New York and Canada. It is also found in Lower Silurian rocks in England, Scotland, Ireland, Sweden and on the island of Sardinia.

Mus. Reg. Nos. 790, 3511, 4035, 5856, 6766, 6806, 7892-7896, 7898-7909.

ORTHIS (DALMANELLA) TESTUDINARIA, var. EMACERATA *Hall.*

PLATE XXXIII. FIGS. 23 and 24.

1860. *Orthis emacerata* HALL. Thirteenth Report, N. Y. State Cabinet of Natural History, p. 121.
1862. *Orthis emacerata* HALL. Ibidem, Fifteenth Report, pl. II, figs. 1-3.
1862. *Orthis emacerata* BILLINGS. Canadian Naturalist and Geologist, vol. vii, p. 393.
1874. *Orthis cyclus* JAMES. Cincinnati Quarterly Journal of Science, vol. i, p. 19.
1875. *Orthis emacerata* MILLER. Ibidem, vol. ii, p. 24.
1883. *Orthis emacerata* HALL. Second Annual Report, New York State Geologist, pl. XXXIV, figs. 14, 15.
1892. *Dalmanella emacerata* HALL. Palæontology of New York, vol. viii, pp. 207, 224, pl. VC, figs. 1, 2.
1892. *Orthis macrior* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 330, pl. V, figs. 5-7.

Original description: "Shell semielliptical, length and width about as five to seven; hinge-line nearly equaling the width of the shell. Dorsal valve flat, with a slight depression down the center; area extremely narrow. Ventral valve depressed-convex, slightly elevated at the beak, which is inclined over the area, but scarcely incurved; an undefined elevation, extending from the umbo toward the front and sometimes quite to the margin of the shell; area narrow, almost linear.

"Surface finely striated; striæ bifurcating, curving upwards and running out on the hinge-line. Interior of the dorsal valve with two small teeth and a small cardinal process; valves thin.

"This species has the form and general characters of *Orthis testudinaria*, but the shell is much thinner than that species ordinarily is in the same formation, and the striæ are finer, there being at least twenty more on the margin in shells of equal size. The depression in the center of the dorsal valve and elevation in the center of the ventral valve are far less conspicuous or scarcely marked in some specimens, while the hinge-line is always proportionately longer than in *O. testudinaria*." For further remarks see *O. testudinaria*.

Formation and locality.—Rare in the Hudson River group at Spring Valley and Granger, Minnesota. It is common at Cincinnati at a horizon about 300 feet above the low water mark of the Ohio river; St. Croix, Quebec.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. Nos. 7917, 7934.

ORTHIS (DALMANELLA) TESTUDINARIA, var. MEEKI *Miller.*

PLATE XXXIII. FIGS. 25–29.

1873. *Orthis emacerata* MEEK (non Hall). Palæontology of Ohio, vol. i, p. 109, pl. VIII, figs. 1, 2.
1875. *Orthis meeki* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 20.

1879. *Orthis jugosa* JAMES. The Palæontologist, No 4, p. 31.
1892. *Dalmanella meeki* HALL. Palæontology of New York, vol. viii, pt. i. pp. 206, 224, pl. vc, fig. 3.
1892. *Orthis corpulenta* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 330, pl. v, figs. 8-10.

This variety is restricted to the upper portion of the Hudson River group and can be distinguished from *O. testudinaria* Dalman by the following characters: Attains a larger size; valves thicker and more convex; cardinal areas wider and shorter; striæ coarser in all stages of growth, with a larger number terminating on the cardinal lines; in the dorsal valve the muscular scars are more distinctly defined and often much thickened and elevated around the margin.

Formation and locality.—In the Hudson River group at Spring Valley, Minnesota, this variety occurs in great numbers; also in the upper portion of the same formation at Oxford, Clarksville and elsewhere in Ohio.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers. Also in the collection of Dr. C. H. Robbins, of Wykoff, Minnesota.

Mus. Reg. Nos. 231, 236, 272, 4078-7985.

ORTHIS (DALMANELLA) SUBÆQUATA *Conrad.*

PLATE XXXIII, FIGS. 30-36.

1843. *Orthis subæquata* CONRAD Proceedings of the Academy of Natural Sciences of Philadelphia, vol. i, p. 333.
1847. *Orthis subæquata* HALL. Palæontology of New York, vol. i, p. 118, pl. XXXII, fig. 2.
1862. *Orthis subæquata* HALL. Geology of Wisconsin, vol. i, p. 42, figs. 1-3, and p. 436.
1880. *Orthis minneapolis* N. H. WINCHELL. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 63.
1883. *Orthis perveta* HALL. Second Ann. Rept., N.Y. State Geologist, pl. XXXIV, figs. (?16,) 17, 18.
1883. *Orthis subæquata* HALL. Ibidem, pl. XXXIV, figs. 19-24.
1892. *Dalmanella subæquata* HALL. Palæontology of New York, vol. viii, pt. i, pp. 194, 207, 224, pl. VC, figs. 6-11.
1892. *Dalmanella perveta* HALL. Ibidem, p. 224, pl. VC, figs. 13, 14.

Original description: "Semioval; valves ventricose, subequal; lesser valve with a slight subangulated mesial furrow; larger valve prominent in the middle, with flattened sides; radiating striæ fine, closely arranged, unequal, rounded; cardinal area rather wide; apex of large valve prominent, not profoundly elevated above the opposite beak; the dorsal margin concave. Length, half an inch."

Adult shells vary considerably in size; biconvex, sometimes as wide as long, but generally attaining a greater breadth than length. In very young examples the hinge-line is as long as the greatest width; while in large and obese individuals it is only three-fifths of the breadth. Cardinal angles varying from acute to subacute and sometimes slightly rounded; lateral and anterior margins broadly and evenly rounding, the latter usually broadly, but slightly, deflected dorsally.

Surface with fine striæ, tubulose, bifurcating about twice. In the ventral valve they are less numerous down the middle, but increase in size and have, at varying intervals, very oblique, large openings. At the base of these perforations the striæ are reduced in size and commonly open again near the anterior margin. On each side of the median area the striæ are finer, more numerous and rarely tubulose. In some specimens, however, the perforations are more prolific near the cardinal margin. In the dorsal valve the arrangement of the larger and smaller striæ is the reverse of that in the other valve. The finer, less tubulose ones are developed medially, while those perforated and larger are situated laterally. Concentric lines excessively fine, with a few coarser lines of growth near the anterior margin. Shell structure finely punctate.

Ventral valve strongly and evenly convex, usually with a broad, shallow sinus; anterior margin slightly prolonged upward to correspond with the concavity in the dorsal valve; point of greatest elevation about mid-length, or somewhat posterior; apex greatly depressed. Cardinal area well developed, broadly triangular, elevated, slightly convex and striated; delthyrium triangular, with straight or slightly convex sides about twice as long as wide, the apex being occupied by a short plate or slightly filled with shell matter. Interior with strong dental processes, supported by well developed plates, which join the more or less strongly elevated postero-lateral margins of the muscular impression. Muscular area elongate, lobate, distinctly limited by a raised margin in thick shells, while in thin ones the anterior edge may be obsolete, the center being occupied by the elongate adductors. The latter are medially divided by a linear ridge, which in some specimens is well developed, separating the scars in front and continuing as a strong septum to near the anterior margin. Outside of the adductor scars are situated the diductors and adjustors, the latter being well defined only in thick shells; pedicle muscle located in the apex of the delthyrium, which may be either a thickening in that part of the shell or a short, transverse, flat plate, similar to a delthyrium, with its anterior portion inwardly directed and transversely striated. Genital spaces indicated on each side of the musular area in thick shells. In such specimens the anterior margin is slightly thickened and grooved, while in thin valves the entire interior is faintly striated, conforming with the striæ of the outer surface.

Dorsal valve evenly convex, but not as deep as the ventral. In some specimens there is a shallow and narrow medial depression, which has its origin immediately below the beak and becomes obsolete near the mid-length or shortly anterior to it. Cardinal area narrow and concave; delthyrium triangular, as wide as long, with a linear elevation along each wall and centrally occupied by a small, faintly bilobed, sometimes striated, cardinal process, which is anteriorly drawn out into a short, slender septum. Crural processes strong and curving upward; with deep dental sockets situated postero-laterally. The former are supported by strong plates, which also form the walls of the delthyrium and are attached to the bottom of the valve. The delthyrial cavity is more or less thickened, excavated anteriorly and produced centrally into a low, but distinct, median septum, which terminates at about the mid-length of the valve and separates the two paris of adductor scars, the posterior pair being slightly smaller. When the scars are more divergent than usual the septum is thickened laterally and fills the space left between the anterior pair. Surface in front of the scars marked with a few faint, short, radiating lines of the vascular system.

This widely distributed species is nearly always prolific in individuals at most localities and varies considerably in outline, number of striæ and in the mesial fold and sinus. The writers have several hundred examples, together with the varieties *conradi*, *perveta*, *gibbosa* and *circularis*, the greater number of which were collected in Minnesota, though specimens were also obtained from Canada, Kentucky, Tennessee, Illinois, Iowa and Wisconsin. In southern localities the circular form prevails, while in the northwest the species is commonly wider than long. In the Black River limestone of eastern Canada, a well developed fold and sinus, combined with a more or less short hinge-line, is the local change. These varieties also occur in the Trenton shales between the cities of Minneapolis and St. Paul, and are often not sufficiently constant to permit the positive separation of a large lot of individuals. This, however, is to be expected in any prolific and plastic species. The specimens with coarse striæ are separated as var. *perveta;* those with a more or less profound and angulated sinus are referred to var. *gibbosa*, while the circular forms, with fine and equal striæ, are placed in the variety *circularis.*

The types of Conrad's *O. perveta* and *O. subæquata*, now preserved in the American Museum of Natural History in New York city, have been compared with similar specimens from Mineral Point, Wisconsin, the original locality, and no specific differences between them have been made out. In Pal. New York, vol. i, *O. perveta* is figured as a small species, but in the Geol. of Wisconsin, Prof. Hall states that it attains a width of one inch. Numerous specimens, however, occur at Mineral Point which agree with the above illustrations of Conrad's type of *O. perveta.* These appear to be adult individuals and were probably so regarded by Conrad, as shown by the specific name. They differ from *O. subæquata* only in having coarser striæ, and the name *perveta* is retained for them as a variety. *O. minneapolis* Winchell proves to be identical with *O. subæquata*, while *O. conradi* Winchell, was applied to a small but mature form of the same species occurring in abundance in the Trenton limestone.

Formation and locality.—Rare in the Trenton limestone at Minneapolis and Rochester, Minnesota. Common in the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Lanesboro, St. Charles, Eyota, Fountain, Fremont, Chatfield, Preston and near Caledonia, Minnesota; Decorah and McGregor, Iowa. Near the base of the Upper Buff limestone at Mineral Point, Wisconsin; Auburn, Lincoln county, Missouri. "Of *O. subæquata* I have seen only a single specimen. It was found in an old quarry two miles north of Montreal." (Billings, Can. Nat. Geol., vol. iv, p. 434.)

Collectors.—Miss C. S. Seymour, H. V. Winchell, W. H. Scofield, W. H. Shelton, C. L. Herrick, E. O. Ulrich and the writers.

Mus. Reg. Nos. 321, 346, 374, 644, 618, 707, 720, 737, 739, 766, 789, 794, 3513, 3519, 4032, 4036, 4939, 4943, 4975, 4976, 5058, 5093, 5581, 5671, 6775, 6792, 6801, 6803, 7915, 7959-7968.

Variety CONRADI *N. H. Winchell.*

PLATE XXXIII, FIGS. 37–39.

1880. *Orthis conradi* N. H. WINCHELL. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 68.

Original description: "Shell having the shape and size of *Orthis disparilis* (Con.), but with a moderately convex entering valve, with from fifty to sixty fine radiating striæ on each valve, about half of which disappear before reaching the beak; foramen of the larger valve narrow, of the smaller valve triangular; surface with indistinct growth-bands, but without evident interradial crenulations; on the center of the smaller valve is a flattening that widens from the beak and disappears before reaching the margin."

In the upper portion of the Trenton limestone at Minneapolis, Minnesota, and Decorah, Iowa, also in the "Lower Blue beds" of Wisconsin at Janesville and Beloit, a small form of *Orthis*, belonging to the *O. perveta* group, is constantly met, and to this the name *O. conradi* has been applied by one of the writers. A similar species has been described by Mr. Billings as *O. electra*,* and was procured in the upper part of limestone No. 2 of the Quebec group at Point Lévis, Canada. Although these specimens are from a much lower horizon than the present material, yet the size and general external expression are strikingly similar. Of this species Billings writes: "The only differences that can be made out from a comparison with specimens [of *O. perveta*] from Tennessee and the figures given by Hall in the Palæontology of New York are, that in *O. perveta* the dorsal valve is more convex than it is in *O. electra*, and the beak of the ventral valve not so depressed, while at the same time it is more extended. At present I have no means of comparing the interior of the two species. When such a comparison can be made, should no greater differences be disclosed than are afforded by the external characters, I would be disposed to unite the two under one name." (Pal. Foss., vol. i, p. 80.) Some northwestern specimens have the beak as much depressed as in *O. electra*. However, it is usually, if not always, more extended than in the latter species, while the dorsal valve seems to be more convex. Dr. White** has doubtfully identified *O. electra* as occurring at Fish Spring, House range, Utah. The greater length of the hinge-line, 16 mm. in these specimens, compared with the figures of Canadian examples, the largest of which are only half that length, precludes the possibility of their being alike. The characters by which the northwestern shells can be separated from *O. electra* are internal. The latter is described as having the dental plates scarcely developed, while no

* Pal. Foss., vol. i, p. 79, fig. 72, and p. 217, 1862.

** Report of U. S. Geog. Surv. west 100th Meridian, vol. iv, p. 55, 1875.

divaricator process was seen in any silicified specimens observed. In *O. subæquata*, var. *conradi*, these parts are comparatively as strongly developed as in any of the larger forms of this species occurring in the shales above.

These small specimens are regarded as mature but dwarfed individuals of *O. subæquata*, and since they hold a constant horizon over a great area, the varietal name *conradi* will serve to distinguish them from the other varieties of this species.

Formation and locality.—Common near the top of the Trenton limestone at Minneapolis, Minnesota: and Decorah, Iowa. Also in the "Lower Blue beds" of the Trenton at Janesville and Beloit, Wisconsin. "In certain beds of the Chazy limestone there are multitudes of a small *Orthis* which have, as nearly as I can judge, precisely the form and dimensions of *O. perveta*, but, in consequence of their being imbedded in a rather compact subcrystalline rock, I have not been able to procure any specimens with the surface well preserved." (Billings, Can. Nat. and Geol., vol. iv, p. 434.) These localities are two miles north of Montreal, Canada, and two or three miles west of Chazy, New York. This same form is believed to be the one identified by Mr. Walcott as *O. perveta*, which also occurs abundantly in the upper beds of the Pogonip group in Nevada. (Mono. U. S. Geol. Survey, vol. viii, p. 72.)

Collectors.—C. L. Herrick, E. O. Ulrich and the writers.

Mus. Reg. Nos. 651 (type specimen lost), 753, 5072, 5094, 7978–7982.

Variety PERVETA *Conrad.*

PLATE XXXIII, FIGS. 40–42.

1843. *Orthis perveta* CONRAD. Proceedings of the Academy of Natural Sciences of Philadelphia, vol. i, p. 333.
1847. *Orthis perveta* HALL. Palæontology of New York, vol. i, p. 120, pl. XXXII, fig. 5
1859. *Orthis perveta* BILLINGS. Canadian Naturalist and Geologist, vol. iv, p. 434, fig. 10.
1862. *Orthis perveta* HALL. Geology of Wisconsin, vol. i, p. 42, fig. 7.
1863. *Orthis perveta* BILLINGS. Geology of Canada, p. 130, fig. 57.
1880. *Orthis media* N. H. WINCHELL. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 64.
1880. *Orthis kassubæ* N. H. WINCHELL, Ibidem, p. 65.
?1884. *Orthis perveta* WALCOTT. Monograph of the U. S. Geological Survey, vol. viii, p. 72, pl. XI, fig. 3.
1892. *Orthis (Dalmanella) perveta* HALL. Palæontology of New York, vol. viii, pt. i, pl. vC, fig. 12.

Original description: "Transversely oval, wider than the length of the hinge-line; valves slightly ventricose, subequal, with numerous prominent radiating striæ, bifurcated on the umbo; larger valve ventricose in the middle, with a slight central depression; sides somewhat depressed; the opposite valve flattened towards the base and depressed to correspond with the elevation of the other valve, forming a sinuous margin when viewed in profile; base truncated; superior lateral margin obliquely truncated, rounded inferiorly. Length, one-third of an inch; breadth, nearly half an inch.

"*Locality:* Mineral Point, Wisconsin, (Trenton limestone)."

This variety can readily be distinguished by its coarser striæ. The fold and sinus are also usually more pronounced than in *O. subæquata*, and occasionally are developed equally as strong as in var. *gibbosa*, when it is impossible to separate it from the latter. In Minnesota these shells are much distorted by pressure, a peculiarity at once striking. Well preserved specimens, however, show close relationship to *O. subæquata*. The specimens illustrated by Mr. Walcott (*loc. cit.*) and occurring abundantly in the upper beds of the Pogonip group=Chazy group of New York, seem to agree better with var. *conradi* Winchell.

Formation and locality.—In Minnesota this form is first met with at the top of the Trenton limestone, where it is fairly abundant, but usually much crushed; thence it extends upward in the Trenton shales. It has been collected at Minneapolis, St. Paul, Cannon Falls, Lanesboro and Fountain, Minnesota; Decorah, Iowa. In Wisconsin it has been found in the "Lower Blue beds" and near the base of the "Upper Buff beds" at Mineral Point, Janesville and Beloit; Dixon, Illinois. In the Glade limestone of middle Tennessee the variety seems to be rare. It is probably this form of *O. subæquata* that also occurs in northern New York and eastern Canada.

Collectors.—C. L. Herrick, W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 186, 322, 336, 643, 3514, 4032, 5147, 5148, 7973–7977.

Variety GIBBOSA *Billings.*

PLATE XXXIII, FIGS. 43—45.

1857. *Orthis gibbosa* BILLINGS. Geological Survey of Canada; Report of Progress for 1856, p. 296.
1859. *Orthis gibbosa* BILLINGS. Canadian Naturalist and Geologist, vol. iv, p. 434.
1892. *Dalmanella gibbosa* HALL. Palæontology of New York, vol. viii, pt. i, p. 224.

Original description: "About the size and shape of *Orthis testudinaria*, but with both valves convex; greatest width at the center or a little in front of the center of the length, above which the sides are somewhat straight and converging to the extremities of the hinge-line, the latter about one-sixth shorter than the greatest width; the front margin very broadly rounded; almost straight or even slightly sinuated in some specimens for one-third of the width in the center; front angles well rounded; the ventral valve is depressed, pyramidal, most elevated at about one line from the beak, which is small, pointed and but slightly incurved; a broad shallow [often pronounced] mesial depression occupies the front of this valve, but disappears usually at one-half the distance to the beak; cardinal area triangular at the base, nearly at right angles to the plane of the margin, but curved over above, owing to the backward projection of the beak. Dorsal valve exceedingly convex in most specimens; greatest elevation about the center, often a barely perceptible broad mesial elevation towards the front; cardinal area small, lying in the plane of the margin; beak very small and scarcely projecting from the upper edge of the area; the whole surface is covered with fine striæ, which are about twice sub-divided; the cast of the interior of the ventral valve shows that the muscular impressions were bordered by strong lamellæ extending downward, slightly converging at three lines from the beak; in a specimen eight lines wide they were separated by a median ridge with a broad base and sharp edge; width of large specimens, eight lines; length, six and a half."

Walter R. Billings has kindly presented to one of the writers specimens of *O. gibbosa* from the Black River limestone near Ottawa. These prove to be very closely related to *O. subæquata* and *O. perveta* Conrad. E. Billings states that* "it is distinguished from *O. subæquata* by having a broad, shallow, mesial sinus in the front half of the ventral valve. * * * It may be that, by comparison with extensive series of western specimens, these three species might be united. I shall, for the present, keep them separate provisionally." In Minnesota specimens occur which are identical with the *O. gibbosa* before us. The sinus toward the anterior margin is often profound in strongly convex specimens with angular sides, producing a fold in the dorsal valve which is distinctly limited laterally. For such shells we have retained the varietal name *gibbosa*. These and var. *perveta* at times merge into each other to such a degree that it is impossible to separate them.

Formation and locality.—Not uncommon in the Trenton shales at Minneapolis, Chatfield, Lanesboro and Cannon Falls, Minnesota; Decorah, Iowa. One specimen has been found in the "Lower Blue beds" at Mineral Point, Wisconsin. "*O gibbosa* occurs rarely in the Chazy limestone, island of Montreal; abundantly, but badly preserved, at the Pallideau islands, lake Huron, in rocks which are either Chazy or Black River. At La Petite Chaudière rapids near Ottawa, and at the fourth chute of the Bonne-chère, in the Black River limestone, and in the Trenton limestone at Bellville, Canada." (Billings, Can. Nat. Geol. vol. iv, p. 435.)

Collectors.—W. H. Scofield and the writers.

Mus. Reg. Nos. 4032, 5510, 7969-7772.

Variety CIRCULARIS *N. H. Winchell.*

PLATE XXXIII. FIGS. 46 and 47.

1880. *Orthis circularis* N. H. WINCHELL. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 66.

Original description: "Shell subcircular, the greatest diameter being from just in front of one cardinal angle to the antero-lateral margin on the opposite side; hinge-line about one-half the greatest diameter; along the front margin is a very slight inclination toward the smaller valve, but the valves are otherwise uniformly convex; umbo of the receiving [ventral] valve prominent and full, but the beak low and arched over the cardinal area; the other valve less elevated in the umbo and the beak less prolonged, but slightly incurved over the hinge-line; the open foramen [delthyrium] of the receiving valve long and narrow, with an obtuse apex, but two or three times as wide at the base as at the top; surface marked by numerous fine rays which, bifurcating once or twice between the umbo and the free margin, are subequal at the middle of the front margin and number six or seven in the space of one line, two or three curving backward from the beak and terminating on the hinge area. These rays are crossed by fine concentric lines, only visible in fresh specimens and under a magnifier, and by distant dim growth bands, which latter begin on the umbo; diameter, about half an inch. Interior unknown."

*Can. Nat. and Geol., vol. iv, p. 434. 1859.

Vairety *circularis* is distinguished by its subcircular outline, usually smaller size and very fine, equal and more numerous striæ, a greater number of which terminate on the cardinal line. The tubulose character of the striæ is also developed, but it is never a conspicuous feature. Occasionally specimens will be found with very fine striæ, which are, however, larger and wider than is usual in this variety.

O. subæquata, var. *circularis*, attains its maximum development in individuals in the "Glade limestone" in Tennessee, and is there somewhat coarser in its striæ.

Formation and locality.—Not rare in the upper part of the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Rochester and Fountain, Minnesota. Rare near the top of the Birdseye limestone two miles south of High Bridge, Kentucky. Common in the "Glade limestone" at Lebanon and elsewhere in middle Tennessee.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 279, 346, 3515, 4049, 4935, 5149, 6778, 6804.

Orthis (Dalmanella) amœna *N. H. Winchell.*

PLATE XXXIII, FIGS. 48 and 49.

1880. *Orthis amœna* N. H. Winchell. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 65.

Original description: "Shell transversely oval with a hinge-line that compares to the greatest diameter about as five to nine. Evenly rounded from the cardinal extremities, which hardly disturb the symmetry of the outline, through the front margin; valves nearly equal; umbonal region of the receiving [ventral] valve surrounded by a depressed or somewhat concave border, which in the front margin becomes flat or inclines toward the entering [dorsal] valve; the entering valve having a much less marginal concavity, but being moderately and evenly convex; cardinal areas small; foramen [delthyrium] also small; beak of the receiving valve somewhat incurved; that of the entering valve small, but abrupt and distinct, surface marked by rays which are doubled or tripled in number on the umbo by implantation, but maintain a larger size than the rest in passing to the margin, several of which are also curved so as to run out in the hinge-line; transverse diameter, nine to ten lines; perpendicular diameter from seven and a half to eight and a half lines. Interior unknown."

Two somewhat compressed type specimens are the only ones known of this species. They differ but slightly from *O. subæquata*, as the striæ which originate on the umbo increase in prominence to the anterior margin, between which are two or three smaller ones. A very similar striation is seen in *O. (D.) stonensis* Safford, a species also belonging to the *O. subæquata* section, but always smaller and narrower than *O. amœna* Winchell.

These specimens are supposed to have been derived from the Galena limestone, and no others of the type of *O. subæquata* occurring in this formation are known.

Formation and locality.—Rare in the Galena limestone(?) near Spring Valley, Minnesota.

Collector.—N. H. Winchell.

Mus. Reg. No. 642.

Subgenus PLATYSTROPHIA, King.

1850. *Platystrophia*, King. Monograph of the Permian Fossils of England, p. 486.
1892. *Platystrophia*, Hall. Palæontology of New York, vol. viii, pt. i, p. 200.

Description: "The name *Platystrophia*, proposed by Dr. King, has come into very general use for a group of orthids having a strikingly spiriferoid exterior. The hinge-line and area are long and straight and nearly equally developed on the two valves. Both are very convex, the brachial being the more so and bearing a very strong median fold corresponding to a deep sinus on the opposite valve. The valves are marked by strong, sharp plications which extend over the fold and sinus, and the external surface is finely granulose, the latter feature being rarely well retained. This peculiar exterior, so unlike anything met with elsewhere in the genus *Orthis*, readily deceived earlier writers into referring the species to *Delthyris* or *Spirifer*, and Mr. Davidson was the first to demonstrate* the true generic value of its internal and more essential characters. These are not materially different from those already described in the group of *Orthis occidentalis*. The delthyrium is open in both valves, being somewhat larger in the pedicle valve, and in old and gibbous shells of *Orthis lynx* has often encroached to a considerable extent upon the umbonal region of the valve. The teeth are thick and very prominent, the muscular area comparatively small, but usually deeply excavated in the substance of the shell and not readily divisible into the component scars. In the brachial valve the cardinal process is a simple linear ridge, always small and sometimes nearly obsolete. The dental sockets are comparatively small, the crural plates large and thick, uniting at their inner bases and produced into a prominent median ridge. The muscular area is quadruplicate and indistinct. The shell structure is very compact and finely fibrous, without punctation."

Type: *Terebratulites biforatus* Schlotheim.

"The genus appears in American faunas first in the Chazy and ranges upward into the Clinton and Niagara groups, attaining a great development in individuals and variety in external form in the Trenton-Hudson River fauna. It has also a considerable vertical range in the Silurian of Great Britian, Mr. Davidson citing it from the Caradoc, Upper and Lower Llandeilo and the Wenlock." (Hall, *op. cit.*)

* Bull. Soc. Géol. de France, sec. ser., vol. xxi, 1848.

PLATYSTROPHIA BIFORATA *Schlotheim, sp.*

PLATE XXXIII, FIGS. 49–52.

1820. *Terebratulites biforatus* SCHLOTHEIM. Petrefactenkunde, p. 265.
For other European synonomy see Davidson's Monograph of British Silurian Brachiopoda, pt. vii, p. 268, 1866–1871.
1843. *Spirifer sheppardi* CASTLENAU. Essai sur le Systeme Silurien Septentrionale, p. 42, pl. XIV, fig. 15.
1843. *Delthyris brachynota* HALL. Geology of New York: Report Fourth District, p. 70, fig. 6
1844. *Orthis* and *Delthyris* OWEN. Geological Exploration of Iowa, Wisconsin and Illinois, pl. XV, figs. 3, 7.
1847. *Delthyris lynx* HALL (partim) (non EICHWALD). Palæontology of New York, vol. i, p. 133, pl. XXXIID, fig. 1.
1852. *Spirifer biforatus*, var. *lynx* HALL. Ibidem, vol. ii, p. 65, pl. XXII, fig. 1.
1856. *Orthis biforata* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 206, figs. 6–10.
1863. *Orthis lynx* BILLINGS. Geology of Canada, p. 167, fig 149.
1865. *Platystrophia regularis* SHALER. Bulletin of the Museum of Comparative Zoology, p. 67.
1873. *Orthis (Platystrophia) biforata* MEEK. Palæontology of Ohio, vol. i, p. 112.
1874. *Orthis biforata* NICHOLSON and HINDE. Canadian Journal, vol. xiv, p. 158.
1875. *Orthis lynx* MILLER (partim). Cincinnati Quarterly Journal of Science, vol. ii, p. 25.
1875. *Orthis biforata* WHITE. Report of the U. S. Geographical Survey west of the 100th Meredian, vol. iv, p. 74, pl. IV, fig. 9.
1883. *Orthis (Platystrophia) biforata*, var. *lynx* HALL. Second Annual Report, New York State Geologist, pl. XXXV, figs. 11–14 (not figs. 9, 10, 15 of pl. XXXV, and fig. 30 of pl. XXXIV=*P. biforata*, var. *lynx*).
1885. *Orthis biforata*, var. *lynx*, forma *reversata* and *daytonensis* FOERSTE. Bulletin of the Denison University, vol. i, pp. 81, 82, pl. XIII, figs. 7, 8.
1889. *Orthis biforata* NETTELROTH. Kentucky Fossil Shells, p. 35, pl. XXIX, figs. 18–29.
1890. *Orthis biforata* FOERSTE. Proceedings of the Boston Society of Nat. Hist., vol. xxiv, p. 312.
1892. *Platystrophia lynx* HALL. Palæontology of New York, vol. viii, pp. 202, 223, pl. VB, fig. 10.

Description: Since the original description of this species is not accessible, that by Davidson (*op. cit.* p. 269) is here reproduced: "Transversely semielliptical or subquadrate, wider than long, more or less globose, the length, width and depth varying sometimes but little; hinge-line more often rather less than the width of the shell, sometimes slightly exceeding the general breadth, with short, acute mucronate wings, or rounded terminations; in front the ventral valve is abruptly deflected and indents the opposite one; beaks in both valves much incurved and approximating. Ventral valve convex, with a wide, deep medial sinus, commencing at the extremity of the beak and widening as it nears the front. Area triangular of moderate hight, fissure [delthyrium] open, beak angular, incurved. Dorsal valve deeper than the opposite one, at times gibbous, with a wide longitudinal fold, commencing at the extremity of the umbonal beak and extending to the front; area a little less wide than in the opposite valve, [erect], fissure [delthyrium] open. Surface of both valves ornamented with a greater or lesser number of radiating triangular ribs; of these from one to five (and in some varieties more) [in American forms usually three] furrow the medio-longitudinal sinus, while from two to six or seven [usually four in this country] compose the mesial fold. The valves are also crossed at intervals by numerous concentric, raised, subimbricating lines; the surface is also marked with small punctures [in well preserved specimens the surface is crowded with minute granules radially and concentrically arranged, which when worn away presents a punctate exterior]. In the interior of the ventral valve a prominent hinge tooth exists on each side of the fissure [delthyrium] and is supported by strong dental plates, which enclose an elongated, oval, raised [in America, depressed, with an elevated outer margin] muscular cavity of moderate dimensions. In the interior of the dorsal valve no prominent cardinal process is observable, but two short brachial processes deviate from the extremity of the umbonal beak and on the outer side of these are situated the hinge sockets. The quadruple muscle forms four very distinct cavities, strongly margined and divided longitudinally and transversely by prominent cross-like ridges." These adductor scars are not nearly as well defined in American examples.

The writers regret their inability to secure very young specimens of this species for the purpose of determining the ancestors or line of development. In several immature individuals it has been observed that in the early nealogic stage the beaks are strongly elevated, probably erect, and each has a very large open delthyrium, surface smooth at first, but gradually developing eight plications and a mesial sinus in each valve. The sinus in the dorsal valve is bounded by two elevations, which become plications, and between them is soon developed a single costa which immediately bifurcates. The four plications increase in strength and become strongly elevated as they proceed to the anterior margin, producing the conspicuous fold of this valve.

This widely distributed and protean species has its beginning, in North America, in the Chazy group, and is found in all the geological horizons upwards and into the Niagara formation. The earliest individuals are small in size and have but few and simple costæ. Such specimens are found in the Cincinnati group around Cincinnati, Ohio, and are probably to be regarded as the young of *P. biforata*, or of the various forms occurring there and designated by varietal names. In the Ohio valley it attains its maximum in number of individuals, variation and size. In succeeding horizons it becomes less numerous and assumes characters somewhat ancestral.

Adult individuals, occurring at a given horizon and locality, will be found to be fairly constant. However, in younger or older rocks, variations are continually taking place, and if specimens are gathered promiscuously from various horizons at a locality in which the shells are common, it will seem as if there were no constancy whatever in the species. While in a restricted region there is considerable permanence in shape and number of costæ, in the same geological formation other variable characters sufficiently fixed for specific use are wanting. The species is to be regarded as very persistent and capable of readily adapting itself to changes of environment. Among the Brachiopoda such forms appear to be long lived. Others equally protean are *Leptæna rhomboidalis*, which extends from the Trenton into the Waverly, i. e., from the Lower Silurian to the base of the Carboniferous; *Atrypa reticularis*, extending throughout the Silurian and Devonian; *Orthis testudinaria*, from the Chazy to the top of the Lower Silurian; *Plectambonites sericea*, from the Trenton to the Clinton, i. e., from the Lower Silurian to the Silurian.

The references treating strictly of the large and globose variety *lynx*,* as defined by Meek,** are not given in the above synonomy, since that variety is regarded as amply distinct for easy recognition. It is not known to occur in the northwest.

M. de Verneuil, in a foot note appended to the description of *Spirifer sheppardi* Castelnau, states that it is identical with *Spirifer lynx* Eichwald. The above description and figures have been studied by the writers, who find them to agree with examples here referred to *P. biforata*. If desirable to separate American specimens under another specific term, because they have, as a rule, a less number of costæ in the sinus and fold than European examples of *P. biforata*, the name given by Castelnau will have precedence.

Platystrophia biforata is sparingly found near the top of the Trenton shales and becomes one of the characteristic fossils of the Galena shales in Minnesota. Nearly all the specimens seen have three plications in the sinus, with four on the fold, while an individual is rarely found with one more or one less. In other regions, the number in the sinus is also usually three, while occasionally only one, five, or even six are developed. Commonly there are from twelve to sixteen costæ on each side of the fold and sinus. More rarely a specimen is found with ten, while several immature individuals have only from five to seven. Some of the plications are seen to terminate along the cardinal area, and since increase in number of costæ very rarely takes place on the lateral slopes by bifurcation or otherwise, new ones may be added along the postero-lateral margins as the length of the hinge is increased.

Formation and locality.—Chazy group near Montreal, Canada. Common in the Trenton of New York, Canada, Kentucky, Tennessee, and rare in this horizon in the northwest. In the lower portion of the Galena formation it is common at many localities in Goodhue, Olmsted and Fillmore counties, Minnesota: Decorah and Dubuque, Iowa; Neenah and Oshkosh, Wisconsin, and, according to Castelnau, at the mouth of Menominee river, Green Bay. In the Cincinnati group of the Ohio valley; Nashville, Tennessee; Iron Ridge, Wisconsin; Graf, Iowa, and Silver City, New Mexico. In the Clinton and Niagara formations of Ohio, New York, Canada and Anticosti. It is also a common fossil in the Lower Silurian and Silurian in England, Scotland, Ireland, Gotland, Scandinavia, Oeland and Russia.

Collectors.—Miss Cora E. Goode, Dr. Sandberg, W. H. Scofield, A. D. Meeds, E. O. Ulrich and the writers.

Mus. Reg. Nos. 2290, 4948, 5307, 5862, 7816–7828.

**Terebratula lynx* Eichwald. Skizze von Podolis, p. 202, 1830.
**Pal. Ohio, vol. 1, p. 114, figs. 1a–1e, 1872.

Platystrophia biforata, var. crassa *James.*

PLATE, XXXIII, FIGS. 53–54.

1873. Var. 3. *Orthis (Platystrophia) dentata* ?? Meek (non Pander). Palæontology of Ohio, vol. i, p. 117, pl. x, fig. 3.
1874. *Orthis (Platystrophia) crassa* James (non Lindström). Cincinnati Quarterly Journal of Science, vol. i, p. 20.
1875. *Orthis dentata* Miller. Ibidem, vol. ii, p. 27.
1889. *Orthis centrosa* Miller. North American Geology and Palæontology, p. 356.
1892. *Platystrophia crassa* Hall. Palæontology of New York, vol. viii, pt. i, pp. 223.

This variety can be distinguished readily by its short hinge-line, causing the shell to be as wide as long, and its very gibbous valves. This species occurs sparingly in the Hudson River group at Spring Valley, Minnesota, and differs from those found at Cincinnati, Ohio, in having about three more much less elevated costæ on each side of the fold and sinus. The muscular scars and other interior characters are more defined than in southern specimens.

Since this variety is now referred to the genus *Platystrophia*, the name *crassa* James will not conflict with *Orthis crassa* Lindström, 1860.* The latter is said to be related to *O. elegantula* Dalman, and is therefore referable to Prof. Hall's subgenus *Dalmanella.*

Mus. Reg. No. 5543.

Order TELOTREMATA, Beecher.

Family RHYNCHONELLIDÆ, Gray.

Genus RHYNCHOTREMA, Hall.

1860. *Rhynchotrema*, Hall. Thirteenth Report, New York State Cabinet of Natural History, p. 68, figs. 7–14.
1883. *Rhynchotrema*, Waagen. Palæontologica Indica, ser. xiii, vol. i, p. 410.

Rhynchonella is an extensive genus, if all the species are admitted that are currently referred to it. It then has its beginning at the base of the Lower Silurian, continues through all the subsequent ages, and is represented at present by five living species. Several names have been proposed by authors for the earlier forms, but none of them have come into general use.

Rhynchotrema will be employed for those early rhynchonelloid species having a prominent cardinal process between the crural plates of the dorsal valve. This process is very well developed in all Lower Silurian species of so-called *Rhynchonella* of which the interior has been examined.

* Gotland's Brachiopoden, p. 396, 1860. Also Davidson's Mono. British Sil. Brach., p. 213, pl. xxvii, figs. 17-19.

Rhynchotrema ainsliei *N. H. Winchell.*

PLATE XXXIV, FIGS. 1–8.

1886. *Rhynchonella ainsliei* N. H. Winchell. Fourteenth Annual Report of the Geological and Natural History Survey of Minnesota, p. 315, pl. ii, figs. 5, 6.

This species has the essential characters of *R. inæquivalvis*, therefore a detailed description will not be necessary. It differs from the latter in being usually larger, more transverse, and in having from twenty-eight to thirty-four plications, with six to eight on the fold, and five to seven on the sinus, while *R. inæquivalvis* has from sixteen to twenty-two plications, with four to five on the fold. Compared with *Rhynchonella altilis* Hall* of the Chazy group of New York, *Rhynchotrema ainsliei* is seen to be more transverse, has a more prominent fold and sinus, is less globose, and on the average has a few more plications.

Formation and locality.—Restricted to the lower portion of the Trenton shales, where it is common at Minneapolis, Cannon Falls, Lanesboro, Fountain, Chatfield and Preston, Minnesota; Decorah and McGregor, Iowa.

Collectors.—C. N. Ainslie, C. L. Herrick, W. H. Scofield, J. C. Kassube and the writers.

Mus. Reg. Nos. 324, 326, 734, 4031, 4938, 4974, 5480, 5489, 5492, 5498, 5505, 5512, 5517, 5521, 7917, 8204–8207.

Rhynchotrema inæquivalvis *Castelnau.*

PLATE XXXIV, FIGS. 9–25.

1843. *Spirifer inæquivalvis* Castelnau. Essai sur le Système Silurien de l'Amérique Septentrionale, p. 40, pl. xiv, fig. 8.
1847. *Atrypa increbescens* (partim) Hall. Palæontology of New York, vol. i, pp. 146, 289, pl. xxxiii, figs. 13a–13h; ? pl. lxxix. fig. 6.
1856. *Rhynchonella increbescens* (partim) Billings. Canadian Naturalist and Geologist, vol. i, p. 207, figs. 11–14.
1863. *Rhynchonella increbescens* Billings. Geology of Canada, p. 18, fig. 153.
1875. *Trematospira (?) quadriplicata* Miller. Cincinnati Quarterly Journal of Science, vol. ii, p. 60, figs. 6, 7.
1889. *Rhynchotreta quadriplicata* Miller. North American Geology and Palæontology, p. 370.
1889. *Rhynchonella increbescens* Nettelroth. Kentucky Fossil Shells, p. 83, pl. xxxiv, figs. 26–29.
1892. *Rhynchonella minnesotensis* Sardeson. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 333, pl. iv, figs. 21–23.
Compare *Atrypa subtrigonalis* Hall. Palæontology of New York, vol. i, p. 145, pl. xxxiii, figs. 12a–12c, 1847.

The original description of *R. increbescens* was drawn up from specimens now referred to that species and to *R. capax* Conrad. That by Castelnau is not accessible at the present time. The following description is based on material derived from Minnesota, Kentucky and New York: Shell small, varying from narrow to broadly subtriangular in outline, smooth in the nepionic stage, depressed-convex during the nealogic period, and becoming more globose in ephebolic and geratologic growth; posterior lateral margins straight or somewhat convex, rounding rapidly into the sinuous anterior edge. Surface with prominent subangular plications, from sixteen to twenty-two on each valve, with from three to five on the fold, and two to four in

*Pal. N. Y., vol. i, p. 23, pl. ivbis, figs. 9a–9d.

the sinus; commonly, however, the number is seventeen or eighteen, four and three, respectively; in Kentucky specimens the tendency is to have fewer plications, there being from thirteen to eighteen on each valve, all crossed by exceedingly delicate concentric zigzag lines, sometimes subimbricating and conspicuous over the anterior half of the shell.

Ventral valve strongly convex in the umbonal region and nearly flat on each side of the deep mesial sinus, sloping more or less abruptly laterally and often angular near the anterior margin; mesial sinus originating on the umbo, often profound anteriorly, with abrupt sides. Beak more or less incurved and always elevated beyond the umbo of the dorsal valve, with a narrow delthyrium partially closed by deltidial plates, which grow out from the walls of the former and, as far as observed, do not join medially. Hinge teeth prominent and supported by thin, short, dental plates. Muscular area much as in *R. capax*, except that in the present species it is very shallow, owing to the shells not being thickened as in *R. capax*.

Dorsal valve more convex than the other, with a mesial fold more or less strongly elevated anteriorly, beginning at the apex of the shell as a slight depression. Beak projecting into the delthyrium of the ventral valve. Crural plates large, separated medially by a depression which is partly occupied by a linear cardinal process strongly curved inward and upward, converging proximally and joining the angular median septum, which terminates at about the center of the valve on the crest of a plication; at the base of the crural plates and separated by the septum are two pairs of adductor scars, the anterior ones being the larger; dental sockets deep, situated lateral to the crural plates.

The variations in this species are numerous, yet are never such as to be of value to the geologist, with one exception, which is described below as variety *minnesotensis*. *R. inæquivalvis* has often been considered to merge into *R. capax;* this, however, is not known to occur anywhere in the Trenton formation, nor do the specimens of the Hudson River group, in their younger stages, look exactly like adult *R. inæquivalvis*. The figures given of the two species readily show the differences between them.

In the middle beds of the Trenton limestone a number of free and very well preserved specimens, collected by Mr. Ulrich, have from twelve to fourteen plications on each valve, and are globose and smaller than is usual for this species. Similar but larger shells also occur rarely in the shales above. These specimens approach *Rhynchonella orientalis* of Billings,* from the Chazy group, but differ from it in having three or four more plications, and none of them has the straight, lateral outline shown in the second series of his figures. This is probably the form to which Mr. Sardeson has given the name *R. minnesotensis*.

*Canadian Nat. and Geol., vol. iv, p. 443, 1859.

This species is known in America as *Rhynchonella increbescens* Hall, but unfortunately it must give way to *R. inæquivalvis*, a name defined and illustrated four years earlier by Castelnau. The latter obtained his specimens from the "Magnesian limestone, Drummond's island."† Of the Trenton brachiopods, this is the most persistent and serves as a good marker of this formation. Associated with *Orthis subæquata*, it at once establishes the outcrop as of Trenton age.

Formation and locality.—In the upper two-thirds of the Trenton limestone at Minneapolis, Minnesota. Very common in the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Chatfield, Lanesboro, Fountain, Eyota, Preston and near Caledonia, Minnesota; Decorah and McGregor, Iowa. Also common in the lower portion of the Galena in Goodhue and Fillmore counties, Minnesota. In the "Lower Blue beds" at Janesville, Beloit and Mineral Point, Wisconsin. In the Trenton at Dixon, Illinois; Auburn, Lincoln county, Missouri; Frankfort, Danville and Lexington, Kentucky; Nashville and elsewhere in Tennessee: Middleville, Trenton Falls, Watertown and other places in New York: Ottawa, Canada, and Drummond's island. In the Galena at Oshkosh and Neenah, Wisconsin. Two specimens have also been collected by one of the writers in the Hudson River group at Savannah, Illinois.

Collectors.—Miss C. L. Seymour, C. L. Herrick, J. C. Kassube, U. S. Grant, H. V. Winchell, W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 266, 323, 328, 331, 370, 382, 650, 3493, 3516, 3517, 4053, 4925, 4933, 4941, 4999, 5128, 5473-5476, 5478, 5479, 5482, 5484, 5488, 5490, 5491, 5493, 5496, 5497, 5506, 5508, 5509, 5513, 5515, 5516, 5518, 5519, 5522, 5852, 5858, 5583, 6486, 6764, 6777, 6790, 6793, 6799, 6800, 7918, 8209-8218.

Variety LATICOSTATA *W. and S.*

PLATE XXXIV, FIGS. 26—29.

1892, April 1. *Rhynchotrema inæquivalvis*, var. *laticostata* W. and S. American Geologist, vol. ix, p. 293.

1892, April 9. *Rhynchonella sancta* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 333, pl. IV, figs. 19-20.

In the lower portion of the Galena south of Cannon Falls *R. inæquivalvis* often attains a far greater width than is usual for the species. The four plications of the fold are closely arranged, while the five or six on the side are spread out and are therefore larger than usual. These shells, if found alone, would be regarded at once as a distinct species. Their development begins in the lowest portion of the Galena shales, where specimens are sometimes picked up at St. Paul. However, it is not until this species is found in association with *Clitambonites diversa* Shaler that the variety becomes common and attracts attention. In the Trenton of New York and Kentucky an occasional specimen is found which approaches var. *laticostata*, but none of them is so strongly transverse as Minnesota individuals.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. No. 8219.

†There is probably a slight mistake in referring this species to the "Magnesian limestone" of Drummond's island, which belongs to the Upper Silurian. That limestone constitutes most of the island, and is not likely to hold its fossils in as entire and perfect a condition as the specimen figured by Castelnau. However, there is a low exposure of the Lower Silurian along the north shore, rising about eighteen feet above the water, and these beds probably furnished the specimens described by Castelnau.

Rhynchotrema capax *Conrad, sp.*

PLATE XXXIV, FIGS. 30–34

1842. *Atrypa capax* Conrad. Journal of the Academy of Natural Sciences of Philadelphia, vol. viii, p. 264, pl. xiv, fig. 21.
1847. *Atrypa increbescens* (partim) Hall. Palæontology of New York, vol. i, p. 146, pl. xxxiii, figs. 13i, 13k–13y.
1856. *Atrypa increbescens* (partim) Billings. Candian Naturalist and Geologist, vol. i, p. 207, figs. 15, 16.
1860. *Atrypa increbescens* Hall (not 1847). Thirteenth Report, New York State Cabinet of Natural History, p. 66, figs. 6, 7, 9–11.
1862. *Rhynchonella increbescens* (partim) Hall. Geology of Wisconsin, vol. i, p. 55, figs. 5–7.
1863. *Rhynchonella capax* Billings. Geology of Canada, p. 211, fig. 213.
1873. *Rhynchonella capax* Meek. Palæontology of Ohio, vol. i, p. 123, pl. xi, fig. 2.
1875. *Rhynchonella capax* Miller. Cincinnati Quarterly Journal of Science, vol. ii, p. 17.
1880. *Rhynchonella capax* White. Second Annual Report, Indiana Bureau of Statistics and Geology, p. 489, pl. i, figs. 9–11.
1881. *Rhynchonella capax* White. Tenth Report of the State Geologist of Indiana, p. 121, pl. i, figs. 9–11.
1882. *Rhynchonella capax* Whitfield. Geology of Wisconsin, vol. iv, p. 263, pl. xii, figs. 26, 27.

Description: "Shell attaining about a medium size, varying with age from compressed subtrigonal to subglobose, old examples being often more convex than their diameter in any other direction; posterior lateral margins somewhat straightened and converging to the beaks at about a right angle in young shells, but becoming more rounded in the adult; lateral margins rounding to the front, which is more or less distinctly sinuous, or nearly straight in the middle.

"Dorsal valve generally a little more convex than the other, most prominent in the middle and rounding abruptly or sloping more gently from the central region in all directions; the more elevated part forming anteriorly a depressed mesial ridge that is nearly flat and occupied by four plications on top, and rarely continues two-thirds of the way to the strongly incurved beak, while on young or compressed individuals it is faintly marked even anteriorly; lateral slopes each occupied by four to seven or eight simple angular plications." Interior with the apex much thickened and converging anteriorly into a prominent subangular median septum, which extends about half way to the front margin; bases of the crural processes prominent and drawn out into slender inwardly and upwardly curving hooks, between which there is a thin, but often strongly elevated, cardinal process, while on the outside of the former are the large dental cavities; on each side of the septum in the posterior half are two pairs of deeply excavated adductor scars, the anterior pair being the larger.

"Ventral valve with its beak abruptly pointed and very strongly incurved upon that of the other valve in adult shells, but less distinctly curved and showing a small opening under its apex [for the protrusion of the pedicle; it is formed by the deltidial plates, which grew from the walls of the delthyrium and joined medially, leaving an oval or circular aperture apically] in young examples; mesial sinus deep and well defined in gibbous specimens and less so in the young and more compressed forms, never quite reaching the front of the beak and always having three simple [sometimes four], rather angular plications in the bottom that extend, like the others, to the apex of the beak in well preserved specimens; lateral slopes each occupied by from five to seven simple plications." Interior with prominent hinge teeth, supported, according to the age of the specimen, by more or less thickened dental plates which join the outer elevated margin of the deeply excavated pear-shaped muscular area. Posterior to the center of this area there is, in old examples, a deep, elongate depression containing the adductor scars, and surrounding these are the large pear-shaped diductors, the adjustors being placed postero-laterally to the latter. Posterior to, and above the muscular area, and between the hinge teeth in old or very obese examples, there is a rather deep rostral cavity, which seems to have been largely produced by the apex of the dorsal valve having been forced in that direction by anterior shell growth. In Wisconsin examples this cavity is often crossed by the coalesced, concave deltidial plates, leaving under it a narrow pasage for the peduncle to be extruded through the umbo of the valve.

"Entire surface of both valves marked by numerous very regular, strongly zigzag, prominent, sublaminar marks of growth, that become nearly or quite obsolete, sometimes on old examples." (Meek, *op. cit.*)

Obese specimens of this species are usually found with the apex of the ventral valve more or less worn away. This is nearly always ascribed to imperfect preservation, or due to weathering. Ohio specimens in which the delicate, sublaminar growth lines are well preserved also have the apex more or less broken. The writers, therefore, conclude that, as the pedicle opening was encroached upon by the dorsal umbo, owing to the shell becoming more convex with age, the peduncle was forced back through the beak of the ventral valve. Sometimes portions of the entire beak are worn away from the same cause. This condition is also seen in many species of both fossil and recent terebratuloids and may be due to convexity of the valves or to shortness of the peduncle.

R. capax is often confounded with *R. increbescens*=*R. inæquivalvis* Castelnau, but the larger size of the former, together with the greater convexity and thickness of the valves, will readily separate it from the latter. Even the young of *R. capax* can be distinguished from the adult of *R. inæquivalvis* by the obsolete fold and sinus, fewer and larger plications, greater transversity and more prominent subimbricating growth lines.

Formation and locality.—A very characteristic and common species of the upper portion of the Hudson River group; a few specimens have also been secured from the upper portion of the Galena, which as far as can be determined, are referable to this species. In the Hudson River group at Spring Valley and Granger, Minnesota; Graf, Iowa; Iron Ridge, Stockbridge and near Clifton, Wisconsin; Wilmington, Illinois; near Cape Girardeau, Missouri; Ohio; Indiana; Kentucky, and Anticosti. In the Galena near Cannon Falls and near Rochester, Minnesota.

Collectors.—John Kleckler, M. W. Harrington, W. H. Scofield and the writers. Also in the collection of Dr. C. H. Robbins, of Wykoff, Minnesota.

Mus. Reg. No. 177, 4092, 4095, 5547, 8196-8199.

RHYNCHONELLA (?) ANTICOSTIENSIS *Billings.*

FIG. 34. *Rhynchonella anticostiensis* Billings. *a*, *b*, *c*, different views of a specimen. From "Palæozoic fossils of Canada." p. 142.

1862. *Rhynchonella anticostiensis* BILLINGS. Palæozoic Fossils, vol. i, p. 142, fig. 119A-C.
1863. *Rhynchonella anticostiensis* BILLINGS. Geology of Canada, p. 211, fig. 212.
Compare with *Rhynchonella argenturbica* WHITE. Report of the U. S. Geological and Geographical Survey west of the 100th Meridian, vol. iv, p. 75, pl. IV, fig. 12.

Original description: "Subpentagonal; apical angle about 80°; side nearly straight or slightly convex for rather more than half the length from the beak, then curving to the edge of the mesial sinus; front nearly straight for the breadth of the sinus; side view oblong; front, dorsal and ventral sides nearly straight; umbo of dorsal valve abruptly curved in to the base of the beak of the ventral valve, which is conical, erect and scarcely incurved. Ventral valve with a deep mesial sinus, becoming obsolete at two-thirds the length from the base; dorsal valve with a strong mesial elevation which, on approaching the umbo, disappears and is succeeded by a scarcely perceptible sinus, which continues to the summit. Surface with eighteen or twenty radiating angular ridges, crossed by close zigzag imbricating striæ; three ribs in the ventral sinus and four on the dorsal mesial elevation."

The more or less erect beak of the ventral valve, and the conspicuous deltidial plates of *R. anticostiensis,* remind one much of species of *Rhynchotreta* Hall. This form is distinguished from *R. neenah* Whitfield by its greater triangular outline and in the four continuous plications of the less elevated median fold.

Formation and locality.—Common in the upper beds of the Hudson River group at Wilmington and Savannah, Illinois; Graf, Iowa; Wisconsin, and English Head, Anticosti.

Collector.—C. Schuchert.

Mus. Reg. Nos. 8201-8203.

RHYNCHONELLA (?) NEENAH *Whitfield*

PLATE XXXIV, FIGS. 35–37.

1882. *Rhynchonella neenah* WHITFIELD. Geology of Wisconsin, vol. iv, p. 265, pl. XII, figs. 19–22.

This species is distinguished from *R. anticostiensis* in being more tumid and less triangular, while two of the four plications on the strongly elevated median fold usually become obsolete before reaching the anterior margin.

Formation and locality.—Common in the upper portion of the Hudson River group at Iron Ridge and Clifton, Wisconsin; Savannah, Illinois, and probably also at Graf, Iowa.

Collector.—C. Schuchert.

Mus. Reg. No. 8146.

Suborder HELICOPEGMATA, Waagen.

Family ATRYPIDÆ, Dall.

Subfamily ZYGOSPIRINÆ, Waagen.

Genus ZYGOSPIRA, Hall.

1847. *Stenocisma*, HALL (not CONRAD, 1839). Palæontology of New York, vol. i, p. 142.
1862. *Zygospira*, HALL. Fifteenth Report, N. Y. State Cabinet of Natural History, p. 154.
1862. *Zygospira*, BILLINGS. Canadian Naturalist and Geologist, vol. vii, p. 393.
1864. *Stenocisma*, MEEK and HAYDEN. Palæontology of the Upper Missouri, p. 16.
1867. *Zygospira*, HALL. Twentieth Report, N. Y. State Cabinet of Natural History, p. 267.
1868. *Zygospira*, MEEK. Geological Survey of Illinois, vol. iii, p. 377.
1882. *Zygospira*, DAVIDSON. Supplement to British Silurian Brachiopoda, p. 122.
1882. *Anazyga*, DAVIDSON. Ibidem, p. 128.

Original description: "Shells bivalve, equilateral, inequivalve; surfaces plicate in the typical species; a sinus on the dorsal valve. Internal spires arranged somewhat as in *Atrypa*, with a broad loop passing from the outer limbs of the spiral band entirely across from side to side, near to or above the center and close to the inner side of the dorsal valve." (Hall, 1862, *op. cit.*)

It appears that *Zygospira* is the earliest known spire-bearing genus, and is therefore very instructive. The apices of its spires are medio-dorsally directed, never laterally as in the *Spiriferidæ;* this is the chief character by which the members of the family *Atrypidæ* can be distinguished from all other spire-bearing brachiopods. In the earliest species, *Z. recurvirostra*, the spiral cones are very loosely coiled, each with about three volutions, while the point of attachment of the connecting band is constantly near the base of the outer whorl. In *Z. modesta* there are four or five whorls to each spiral cone, but the point of attachment of the loop is variable. In *Z. headi* there are six whorls to a cone and the connecting band is in the posterior region. In *Atrypa reticularis* there is a very similar arrangement of the spirals, but with a still greater number of whorls to a cone, while the loop, which is no longer complete in mature individuals, is placed more posteriorly than in *Z. headi*. In the Devonian specimens of *Atrypa reticularis* the greatest number of revolutions to a spiral cone is attained. The evolution of the calcified brachial supports in the family *Atrypidæ* has gone on increasing in the number of whorls to a cone, the connecting band has progressed from the anterior to the posterior region, and all has kept pace with the gradual increase in size of the various species, from the Trenton to the Upper Devonian.

The species of *Zygospira* are divisible into two groups—(1) the depressed-convex species with coarse striæ in which the ventral valve is more or less carinated medially, and (2) those with the valves globose and finely striated.

Z. RECURVIROSTRA *Hall*—Trenton.

Group I.

Z. deflecta Hall, Trenton.
Z. modesta (Say) Hall, Hudson River.
Z. modesta, var. *cincinnatiensis* (James) Meek, Hudson River.
Z. kentuckiensis James, Hudson River.
Z. concentrica Ulrich, Hudson River.
Z. paupera Billings, Anticosti.
Z. mica Billings,* Anticosti.

Group II.

Z. uphami W. and S., Galena.
Z. erratica Hall, Hudson River.
Z. anticostiensis Billings, Hudson River.
Z. headi Billings, Hudson River.
Z. headi, var. *borealis* Billings, Hudson River

ZYGOSPIRA RECURVIROSTRA *Hall, sp.*

PLATE XXXIV, FIGS. 38–41.

1847. *Atrypa recurvirostra* HALL. Palæontology of New York, vol. i, p. 140, pl. XXXIII, figs. 5a–5d.
1859. *Rhynchonella ? recurvirostra* HALL. Twelfth Report, N. Y. State Cabinet of Nat. Hist., p. 66.
1863. *Rhynchonella recurvirostra* BILLINGS. Geology of Canada, p. 168, fig. 152.
1882. *Anazyga recurvirostra* DAVIDSON. Supplement to British Silurian Brachiopoda, p. 129.

Original description: "Elliptical, somewhat ovoid, very symmetrical; breadth about one-fourth of an inch, length a little greater; dorsal [ventral] valve with the middle elevated, regularly convex on the sides, the beak extended and gracefully incurved over the beak of the ventral [dorsal] valve, which is regularly convex, with a slight longitudinal depression; surface of each valve marked by about twenty-four regular, simple, longitudinal striæ, which continue entirely to the beak."

Minnesota examples of this species are usually a little shorter, and therefore rounder than eastern examples; otherwise they are identical. Compared with *Z. modesta* the latter is found to attain a larger size, is more transverse and never so gibbous as this species. The beak of the ventral valve is usually less incurved, while the striæ bounding the sinus are more prominent. Of interior characters nothing is known beyond the spires and the connecting band.

**Rhynchonella mica*, Cat. Sil. Foss. Anticosti, p. 44, 1866.

In the nepionic stage of this form, in specimens about 1 mm. in length, the shell is depressed-convex without striations and plications, the beak of the ventral valve being erect and perforated by a large triangular delthyrium. This stage agrees essentially with the same age in species of *Rhynchonella** and *Rhynchotrema inæquivalvis*. In some individuals of *Z. recurvirostra* the plications begin to develop along the anterior margin much earlier than in others. During the succeeding stages of growth the valves attain greater gibbosity, the delthyrium of the ventral valve becomes partially closed by the deltidial plates, the beak incurves over that of the dorsal valve and the striæ become larger until a certain size is reached, after which new ones are introduced maintaining their equality.

Z. uphami appears to be a descendant of *Z. recurvirostra*. It differs in having attained a larger growth and greater convexity. The striæ, however, do not increase in size, but numerous new ones are added, so that *Z. uphami* appears more finely striated.

Formation and locality.—This species occurs throughout the Trenton shales, but is very abundant near the base of the Galena shales in association with *Pholidops trentonensis*, var. *minor*, *Orthis pectinella*, var. *sweeneyi*, and *Rhynchotrema inæquivalvis* at Minneapolis, St. Paul, Cannon Falls and Fountain, Minnesota. Also common in the Galena south of Cannon Falls and Kenyon, Minnesota, and at Oshkosh, Wisconsin. Near the top of the Trenton in association with *Orthis borealis* Billings, at Lexington, Danville and Frankfort, Kentucky. Martinsburgh, Lowville and Middleville, New York; Ottawa, Canada.

Collectors.—C. L. Herrick, W. H. Scofield and the writers.

Mus. Reg. Nos. 437, 439, 735, 767, 4069, 5477, 5511, 8220–8223.

ZYGOSPIRA MODESTA (*Say*) *Hall*.

PLATE XXXIV, FIGS. 42–44.

1847. *Atrypa modesta* HALL. Palæontology of New York, vol. i, p. 141, pl. xv, fig. 15.
1859. Genus ? *modesta* HALL. Twelfth Annual Report, N. Y. State Cabinet of Natural History, p. 66. "Related to *Leptocœlia*."
1860. *Atrypa modesta* HALL. Ibidem, Thirteenth Report, p. 69.
1862. *Zygospira modesta* HALL. Ibidem, Fifteenth Report, p. 154.
1863. *Rhynchonella ? modesta* BILLINGS. Geology of Canada, p. 211, fig. 211.
1867. *Zygospira modesta* HALL. Twentieth Report, N. Y. State Cab. of Nat. Hist., p. 267, figs. 1, 2.
1873. *Zygospira modesta* MEEK. Palæontology of Ohio, vol. i, p. 125, pl. xi, fig. 4.
1875. *Zygospira modesta* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 58.

Original description: "Suborbicular or plano-convex, with the beak extended; width a little greater than the length; cardinal line distinctly marked and somewhat extended; dorsal [ventral] valve convex, with an elevated ridge along the center, occupied by four plaits which are stronger than the others; beak prominent, incurved and perforated, the perforation [pedicle opening] extending below the beak and occupying a portion of the area; ventral [dorsal] valve depressed-convex, broadly oval or nearly circular, with a broad but ill defined sinus along the middle, the central plication stronger than the others, with a smaller one on each side; each

*The Development of some Silurian Brachiopoda. By Beecher and Clarke. Mem. N. Y. State Mus., vol. i, no. i, 1889.

valve with about eighteen simple, rounded plications; surface obscurely punctate." Interior structure unknown. Brachial supports large, in the mature stage with about five loosely coiled volutions to each spire and more or less medially directed towards the dorsal valve. On the first or outermost volution on the dorsal side of each spire a band is given off which is more or less backwardly curved, joining medially, and thus forms the "loop" or connecting band. The point at which it is given off from the spires is variable. The band may cross in front of the apices of the spires or above the posterior turn of the second volution.

In the Hudson River group this species is quite distinct from *Z. recurvirostra*. Near the top of the Trenton in Kentucky, however, *Z. recurvirostra* and *Z. modesta* are found together, but these specimens, as a rule, are typically neither the one nor the other. The general expression, however, is more that of *Z. modesta*. In Minnesota the two species are always distinct and hold widely separated horizons. In New York, associated with *Z. recurvirostrr* near the middle of the Trenton, is found *Z. deflecta* Hall,* a species in many respects like *Z. modesta*, showing that the tendency of development of the former is toward the latter. For other remarks see *Z. uphami* and *Z. recurvirostra*.

Formation and locality.—Rare in the Huson River group at Spring Valley, Minnesota. Common in the same formation of the Ohio valley; Savannah, Illinois; New York and Canada. In the upper portion of the Trenton and Utica slate of New York. Whitfield (Geol. Wisconsin) gives it as occurring in the Trenton, Galena and Hudson River groups of Wisconsin.

Collectors.—E. O. Ulrich, W. H. Scofield and the writers.

Mus. Reg. No. 8228.

ZYGOSPIRA UPHAMI *W. and S.*

PLATE XXXIV, FIGS. 45—48.

1892, April 1. *Zygospira uphami* W. and S. American Geologist, vol. ix, p. 291.

This species occurs in the fine-grained portions of the Galena limestone about twenty feet beneath the Maclureabeds and fifty or more feet above the layers containing *Z. recurvirostra* in abundance. Its general expression shows it to be a probable descendant of *Z. recurvirostra*, having attained a larger size, greater convexity and somewhat finer striæ. The latter feature is more apparent than real, owing to the greater size of *Z. uphami*. Some specimens from which the shell has been partially exfoliated show the interior of the ventral valve to have a deep muscular cavity extending from the beak to about one-third the length of the shell. From the antero-lateral margins of this area originate two prominent, diverging ridges, probably the markings of the main trunks of the vascular system; which become obsolete near the front margin. The crural plates of the dorsal valve are very strong and at their bases coalesce with a stout, but rather short, median septum, upon each side of which, posteriorly, are situated two depressions of the. adductor scars, the second pair being undefined.

* Pal. N. Y., vol. i, p. 140, pl. xxxiii, figs. 4a, 4b.

Z. uphami is the transitional species between *Z. recurvirostra* and *Z. erratica* Hall,* and *Z. headi* Billings and its varieties *borealis* and *anticostiensis*.† Its nearest relations are with *Z. erratica*, from which it differs in being narrower, of smaller size, less quadrate in outline and without a sinus near the anterior margin of the ventral valve. *Z. headi* is a large, elongate species, more strongly biconvex, with the sinus of the dorsal valve far less conspicuous; var. *borealis* differs at once in its greater length and tumid umbo; var. *anticostiensis* has a more swollen umbo and its point of greatest convexity is near the mid-length, while in *Z. uphami* it is close to the posterior margin. The latter also has a shallow, rapidly expanding mesial sinus, which is obsolete or not present in var. *anticostiensis*. Named in honor of Mr. Warren Upham, of Somerville, Mass., for several years an assistant on the Minnesota survey.

Formation and locality.—This species seems to be abundant, but is restricted to beds only a few feet in thickness, near the middle of the Galena horizon at Weisebach's dam near Spring Valley, and near Wykoff and Fountain, Minnesota; also in equivalent position in Goodhue county.

Collectors.—W. H. Scofield, E. O. Ulrich and C. Schuchert. Also in the collection of Dr. C. H. Robbins, Wykoff, Minnesota.

Mus. Reg. Nos. 8227.

Family SPIRIFERIDÆ, King.

Subfamily SUESSIINÆ, Waagen.

Genus CYCLOSPIRA.‡

The important diagnostic character of *Cyclospira* is the nature of the calcified brachial supports. The primary lamellæ are straight at their point of origin from the crura, thence continuing anteriorly nearly parallel to each other, and recurving somewhat laterally. The Minnesota example in which the brachial supports have been developed does not show a complete revolution of the primary lamellæ, but in a specimen from New York, developed by Mr. John M. Clarke, there are about two and one-half turns to the spiral. This specimen also shows that the second and third turns are somewhat medially directed or introverted. There appears to be a complete loop joining the primary lamellæ near their point of origin with the crura in the Minnesota example, but in the New York example the loop appears to be represented by two prongs or remnants of a loop, as in *Spirifer*. These differences, if correctly ascertained, should be regarded as of generic value; but, since the shells from the two localities are alike exteriorly, we believe that when more material from Minnesota is investigated they will prove to be structurally in harmony with the eastern specimens.

**Orthis erratica* Hall. Pal. N. Y., vol. i, p. 288, pl. LXXIX, figs. 5a-5f, 1847.

† Pal. Foss., vol. i, p. 147, figs. 125-127, 1862.

‡The generic description of this genus will be published in Pal. N. Y., vol. viii, pt. ii. The type species is *Orthis bisulcata* Emmons.

In *Zygospira, Glassia, Dayia* and *Atrypa* of the *Atrypidæ* the primary lamellæ diverge widely and have between them the spirals; but in the *Spiriferidæ*, to which family *Cyclospira* belongs, the primary lamellæ remain close together and they are between the spirals, except in *Cyclospira*.

This type of calcareous brachial supports has heretofore not been known to occur in rocks older than the Upper Silurian, and it is therefore interesting to find a species possessing them so early as the Trenton of the Lower Silurian. In Upper Silurian genera of the family *Spiriferidæ* the number of revolutions in each spiral cone is always numerous, while in *Cyclospira* it never exceeds much more than two turns and is therefore more rudimentary. Since the primary lamellæ remain straight where they join the crural plates in both *Clyclospira* and in the members of the family *Spiriferidæ* the genus must be regarded as belonging to that family. It is also geologically and structurally nearer the ancestral stock which gave origin to the entire suborder *Helicopegmata*, or spire bearing families. *Zygospira*, however, is still nearer this ancestral stock, since it is known to occur in the Birdseye and Black River formations; but in this genus the apices of the spirals are dorso-medially directed. The direction of coiling serves well enough for family distinction, but we believe that both types of spirals, and also the *Terebratulidæ*, were derived from one stock, which probably is to be looked for in the *Rhynchonellidæ*. Waagen,† however, derived the family *Atrypidæ*, of which *Zygospira* is a member, from the *Rhynchonellidæ*, while all the other forms of spire-bearing genera he considered as developed from the *Terebratulidæ*.

CYCLOSPIRA BISULCATA *Emmons, sp.?*

PLATE XXXIV, FIGS. 49–54.

1842. *Orthis bisulcata* EMMONS. Geology of New York; Report, Second District, p. 396, fig. 4 (not described).
1847. *Atrypa bisulcata* HALL. Palæontology of New York, vol. i, p. 139, pl. XXXIII, fig. 3.
1859. *Genus ? bisulcata* HALL. Twelfth Report, N. Y. State Cabinet of Natural History, p. 65.
1877. *Camarella bisulcata* MILLER. American Palæozoic Fossils, p. 107.
1892. *Camarella owatonnensis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 328, pl. IV, figs. 1–3.

Original description: "Small, ovoid; dorsal [ventral] valve with a well defined, narrow, mesial sinus, which continues about halfway to the beak, and from there the center becomes much elevated; beak of the dorsal valve strongly incurved over that of the oposite valve; ventral [dorsal] valve depressed-convex, prominent on the umbo, beak very small and abruptly incurved; front with two short, well defined furrows, ending in two plications, which close on each side of the projecting plait formed by the extension of the mesial groove of the dorsal valve." (Hall, *op. cit.*)

†Pal. Indica., ser. xiii, vol. i, p. 550.

On each side the beak of the ventral valve two sharply elevated ridges have their origin, are semicircular in form, and terminate about mid-length on the lateral margins of the valve. These ridges occur in both New York and Minnesota examples. The beak of the ventral valve is strongly incurved and appressed on the umbo of the dorsal valve, with a small pedicle opening which has encroached on the umbo of the ventral valve. Surface, when well preserved, marked by delicate growth lines.

In the interior of the dorsal valve there is a subangular median septum, originating at the base of the crural plates and extending to near the anterior margin. The brachial supports are very simple in form, consisting of two long recurved primary lamellæ, joined near their origin by what appears to be a continuous, slightly bent, transverse band. In some New York specimens there are about two and one-half turns in each spiral, which are somewhat medially directed, and the transverse band appears to be disunited or incomplete. If these differences, more fully noted in the generic description of *Cyclospira*, prove to exist in nature and are not due to accidental causes, then Mr. Sardeson's specific name, *owatonnensis*, will come into use for the Minnesota form.

There is no known species in Lower Silurian rocks with which this form can be compared.

Formation and locality.—This shell is restricted to a limited horizon about fifty feet above the base of the Galena at several localities from three to five miles south of Cannon Falls, Minnesota. It is associated with *Plectambonites gibbosa*, *Orthis meedsi*, var. *germana* and numerous gastropods. In New York it is found at "Adams, Jefferson county, in shaly Trenton limestone associated with *Murchisonia* and *Pleurotomaria*, and in a situation where few Brachiopoda occur." It has also been found at Ottawa, Canada.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 6762, 8229.

Suborder KAMPYLOPEGMATA, Waagen.

Family TEREBRATULIDÆ, Gray.

Subfamily CRYPTONELLINÆ, Beecher, Ms.

Genus HALLINA, W. and S.

1892. *Hallina*, W. and S. American Geologist, vol. ix, p. 291.

Shells small, articulate, rostrate, biconvex and semiplicate. Pedicle opening usually bounded laterally by incomplete deltidial plates. Calcified brachial supports comparatively long, somewhat longer than half the length of the dorsal valve and in form much as in mature *Magellania*. The detailed structure of the articulating and cardinal processes unknown. In thin sections it is shown that the crural plates of the dorsal valve do not converge medially and join with the posterior end of the median septum, as in *Magellania*, but that they probably coalesce with each other; a median septum is not present. Muscular scars undetermined. Shell structure impunctate, distinctly fibrous.

Named for the veteran paleontologist of the New York survey, whose courtesy has enabled us to enhance greatly the scientific value of this volume.

Type: *Hallina saffordi* W. and S.

Waldheimia bicarinata Angelin, sp., and *W. mawii* Davidson* of Upper Silurian strata of Gotland and England, in all probability also belong to *Hallina*. *Terebratula melonica* Barrande† seems to be another species of this genus. The loops of these three species are like those in *Hallina nicolleti* and *H. saffordi*, but we are not positive that all have an impunctate shell structure except *W. bicarinata*, of which alone we have specimens for comparison, and are unable to detect any punctæ in them.

Hallina is the earliest loop-bearing genus known, and since it is chronotogenetically probably near the stock in which the loop and spire-bearing genera had their origin (the *Rhynchonellidæ*) it is safe to say that its calcareous brachial supports do not pass through any metamorphoses as in the *Terebratellidæ*. The fundamental difference between the familiies *Terebratulidæ* and *Terebratellidæ* is not that the former have short loops and the latter long ones, but that the first develops its various generic types of calcareous brachial supports direct, while in the *Terebratellidæ* the mature form is attained by a series of changes or metamophoses. The value of these differences as characters of first importance for family distinction was first announced by Deslongchamps.‡ The recent work of Fischer and Œhlert§ on antarctic living *Terebratellidæ* emphasizes this difference in the development of the loop-bearing forms still more.‖ While *Hallina* has a long loop, in most respects like mature *Magellania*, it cannot be associated with the latter for the above given reasons, but must be referred to the family *Terebratellidæ*. *Hallina* has its nearest relatives in *Cryptonella*, Hall and *Megalanteris* (*Meganteris*), Suess of the Devonian. The former can be distingushed from *Hallina* by its punctate shell structure and the anomalous band joining the crural plates on the dorsal side, while *Megalanteris* differs from both in the long anteriorly-directed prongs of the crura. It is upon these three genera that Beecher will establish the subfamily *Cryptonellinæ*.

If the loop-bearing families (*Terebratulidæ* and *Terebratellidæ*) had their origin in the *Rhynchonellidæ*, which seems probable since the greater portion of the genera of that family are rostrate in form and with more or less completely developed

*British Silurian Brach., vol. v, pt. i, p. 76, 1882.

†See Hall's illustrations of this species in Sixteenth Rep. State Cab. Nat. Hist., p. 49, 1863.

‡Etudes Critiques sur des Brachiopodes Nouveaux ou peu connus, fasc. 4, 5, 6, pp. 153 and 161, 1884.

§Mission Scientifique du Cap Horn, Brachiopodes. Ext. Bull. Soc. d' Hist. Nat. d' Autun, t. v, 1892.

‖We will not enter into further remarks on this point, since Dr. C. E. Beecher has in press a revision of these families.

deltidial plates, characters also common to the *Kampylopegmata*, it seems natural to expect that the earliest members of this suborder should have impunctate shells as their immediate ancestors, the *Rhynchonellidæ*. We find that the species of *Hallina* of the Lower and Upper Silurian are impunctate, but that punctate *Kampylopegmata* are already present in the Lower Helderberg, where the other type of shell structure of this suborder is no longer met with.

HALLINA SAFFORDI *W. and S.*

PLATE XXXIV, FIGS. 55–58.

1892; April 1. *Hallina saffordi* W. and S. American Geologist, vol. ix, p. 292.

Shell very small, rostrate, regularly elongate oval, striate and evenly biconvex. Ventral valve somewhat more convex than the dorsal. Point of greatest elevation about mid-length, slightly carinated, but otherwise evenly convex in all directions. Beak strongly incurved, but not in contact with the umbo of the dorsal valve, with a small pedicle opening in the apex, which is partially surrounded anteriorly by incomplete deltidial plates. Teeth well developed and supported by delicate, strongly oblique, dental plates; other interior characters undefined.

Dorsal valve evenly convex, with a very shallow sinus in the anterior half. Brachial supports straight from the crural plates for a short distance forward, then bend backwards and laterally, turn and proceed anteriorly to within a short distance beyond mid-length and nearly parallel to each other, where they again turn rather abruptly upward and inward, joining medially at a point which is about half the length of the brachia. Thin sections do not show strongly thickened crural plates, nor a median septum amalgamated with the former, as is so common in terebratuloids.

Surface marked with from fifteen to twenty subangular striæ, which terminate on the posterior third of the valves; no concentric lines of growth observable. Shell structure fibrous and impunctate.

This common little shell occurs in association with *Leperditia fabulites*, *Scenidium anthonensis* and *Rafinesquina minnesotensis*. The only species with which it is likely to be confounded, if the exterior alone is taken into account, is *Zygospira recurvirostra*. In the latter, however, the striæ are more prominent and numerous and extend to the beak on each valve, while in *Hallina saffordi* they are obsolete on the posterior third.

Named after Prof. James M. Safford, Nashville, Tenn.

Formation and locality—Common in the "Glade limestone" at Lebanon, Tennessee, where they were discovered by Mr. E. O. Ulrich several years ago. Also near the top of the Birdseye limestone at High Bridge, Kentucky.

Types in the collection of Charles Schuchert.

Mus. Reg. No. 8237.

Hallina nicolleti, *n. sp.*

PLATE XXXIV. FIGS. 59–62.

1892, April 1. *Hallina nicolleti* W. and S. American Geologist, vol. ix, p. 293.
1892, April 9. *Zygospira aquila* Sardeson. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 335, pl. IV, figs. 15–18.

Shell small, rostrate, biconvex, oval or subcircular in outline. Ventral valve convex, point of greatest elevation about mid-length, with a shallow, very narrow sulcus down the center, bordered on each side with a low, rounded ridge, which becomes more prominent toward the anterior margin. The antero-lateral limits of the shell may be smooth or with as many as five low, rounded plications or marginal undulations. Beak strongly incurved, with a small, oval pedicle opening bounded by rudimentary deltidial plates on each side. Dorsal valve evenly convex and trilobed toward the anterior edge; in some specimens the lateral lobes may have as many as six low, rounded plications along the front margin. Calcified brachial supports much as in *Hallina saffordi,* except that the outer bands are curved laterally, while the anterior recurved portion is shorter. Articulating processes and muscular scars unknown.

Hallina nicolleti is easily distingushed from associated species, on account of its small size and camarelloid exterior. It differs from *Hallina saffordi* in its fold and sinus, and the usually obsolete marginal plications. Its associated species are the same as occur with *H. saffordi.*

Named for Jean N. Nicollet, geologist and geographer of the Northwest.

Formation and locality.—Abundant in the upper third of the Trenton limestone at Minneapolis, St. Charles, Rochester and Fountain, Minnesota; Decorah, Iowa, and in the "Lower Blue beds" at Beloit, Wisconsin.

Collectors.—E. O. Ulrich, W. H. Scofield and the writers.

Mus. Reg. Nos. 339, 434, 436, 438, 440, 652, 660, 8238, 8239.

PLATE XXIX.

PAGE.

Figs. 1 to 4. LINGULA ELDERI Whitfield 339

1. Dorsal view of an exfoliated specimen to show the flattening along the lateral margins. Trenton limestone, Minneapolis, Minn. Minnesota Geological Survey collection.

2. Interior of the ventral valve, drawn from a natural cast, the usual mode of occurrence of this species. *g*, umbonal scar; *h*, central scars; *k*, middle laterals; *ji*, anterior lateral and transmedian scars; *v*, vascular sinuses; *vs*, vascular trunks. (After Whitfield.)

3. View of the interior of the dorsal valve taken from a natural cast. *j*, anterior lateral scars; *lik*, lateral, transmedian and middle lateral scars; other letters as above. (After Whitfield.)

4. Profile outline, to show the relative convexity of valves and the great elevation of the ventral beak. Trenton limestone, Fountain, Minn. Collection of C. Schuchert.

Figs. 5 and 6. LINGULA EVA Billings 341

5. A dorsal valve with strong radiating lines in the anterior half.

6. Profile outline of the same specimen. Trenton shales, Fremont, Winona county, Minn. Minnesota Geological Survey collection.

Figs. 7 and 8. LINGULA PHILOMELA Billings 342

A view of one side of the only specimen seen and a profile outline of the same. Base of Hudson River group, near Granger, Minnesota. Minnesota Geological Survey collection.

Fig. 9. LINGULA RICINIFORMIS Hall 343

Ventral valve, showing the rounded Obolella stage of growth in the posterior portion. Trenton shales, St. Paul, Minn. University of Minnesota collection.

Figs. 10 and 11. LINGULA RICINIFORMIS, var. GALENENSIS W. and S. 344

View of the ventral valve and profile outline of the same. Galena shales, near Kenyon, Minn. Collection of W. H. Scofield.

Fig. 12. LINGULA COBOURGENSIS Billings (?) 346

View of a specimen provisionally referred to this species. Trenton limestone, Chatfield, Minn. Minnesota Geological Survey collection.

Figs. 13 and 14. LINGULA (GLOSSINA) HURLBUTI N. H. Winchell 347

13. A view of the ventral (?) valve of the type specimen.

14. Enlarged view of the concentric surface striæ, $\times 2\frac{1}{2}$. Middle Galena, Mantorville, Minn. Minnesota Geological Survey collection.

Figs. 15 to 18. LINGULA (GLOSSINA) DEFLECTA W. and S. 348

15 and 16. A dorsal valve and profile outline of the same. Galena shales, near Fountain, Minn.

17. Natural cast of the interior of the dorsal valve, showing the striated internal cardinal area, the vascular trunks and sinuses which apparently surround the anterior and lateral muscular scars.

18. Natural cast of the ventral valve of the same specimen, preserving the markings of the muscles and vascular system. Hudson River group, Spring Valley, Minn. Collection of C. Schuchert.

Figs. 19 to 22. LINGULA IOWENSIS Owen 349

19. A dorsal valve with the shell broken along the median line, which is due in great part to the decomposition of the shell forming the internal septum. The projecting cardinal area of the ventral valve is also shown.

20. Profile outline of the same specimen. Galena limestone, near Hader, Minn. Collection of W. H. Scofield.

21. An internal view of the dorsal valve, taken from a gutta percha impression. *h*, central scars: *s*, septum; *x*, concentric laterals. (After Hall.)

22. Natural cast of the ventral valve of the specimen from which figure 21 was taken, showing the slightly elevated muscular scars and median septum. Galena limestone, near Fountain, Minn. Collection of C. Schuchert.

Figs. 23 and 24. SIPHONOTRETA (?) MINNESOTENSIS Hall 358

23. View from the dorsal side of a specimen retaining the valves in juxtaposition and preserving most of the epidermal layer of the shell.

24. The ventral valve of the same specimen, imperfect in the umbonal region. (After Hall.) Trenton limestone at Minneapolis, Minn. Collection of C. Schuchert.

Brachiopoda

VOL. III

Plate XXIX

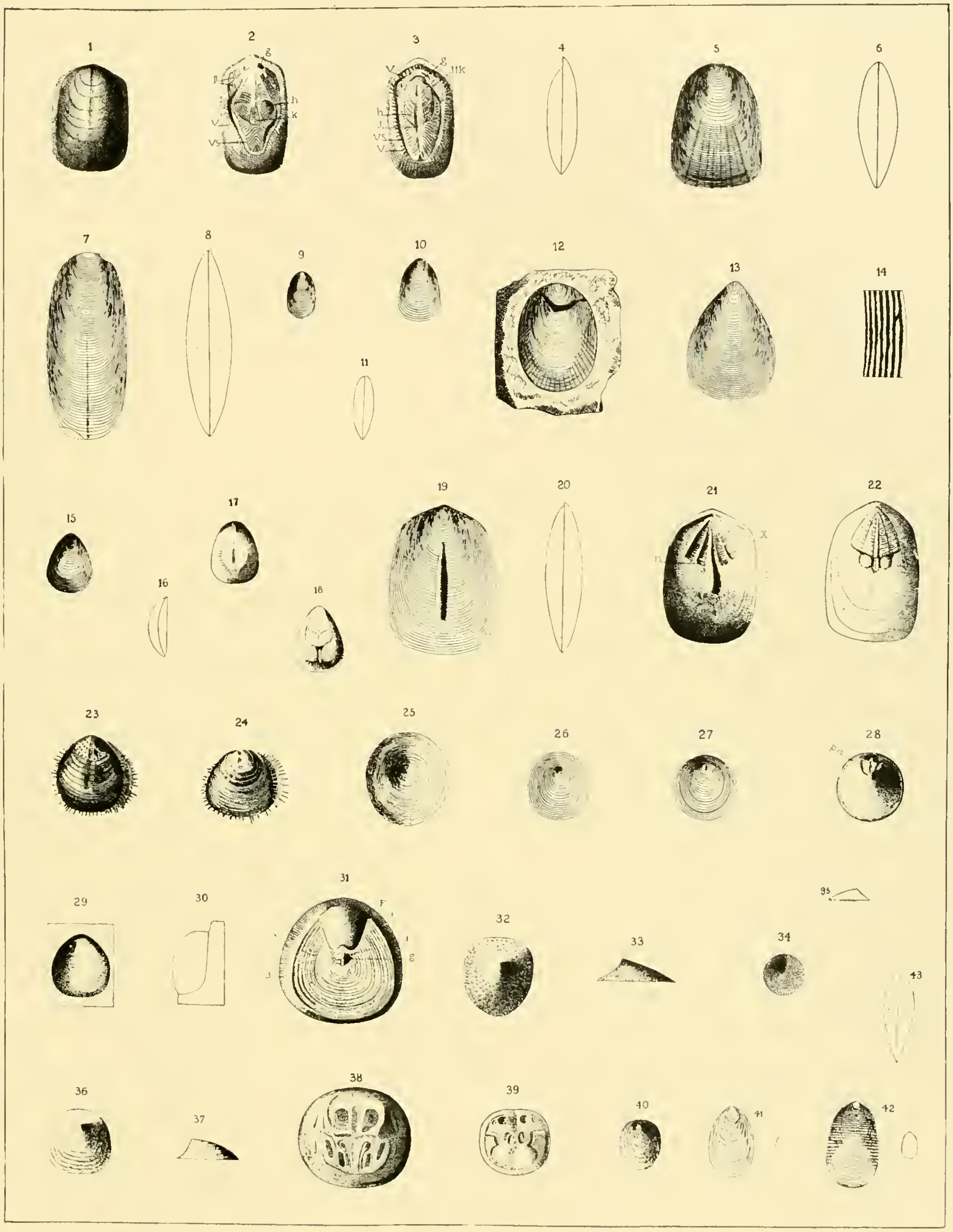


PLATE XXX.

PAGE.

Figs. 1 to 4. LINGULASMA GALENENSIS W. and S. 354

1. Interior of the ventral valve from a gutta percha impression. *g*, umbonal scar; *k*, middle; *l*, lateral scars; *s*, septum.
2. Interior of the dorsal valve from a gutta percha impression. *cr*, crescent; *h*, central scars; *j*, anterior scars; *t*, transverse scars; other letters as in fig. 1.
3. Profile of the type specimen from which the impressions of figs. 1 and 2 were made. The space between the dotted line and the natural cast shows the relative thickness of the shell.
4. A portion of the exterior surface, × 5, to show the arrangement of the linear series of papillæ on the concentric lines of growth. Near the top of the Galena limestone, near Hamilton, Minn. Minnesota Geological Survey collection.

Figs. 5 to 7. SCHIZAMBON (?) DODGII, n. sp. 361

5. View of the ventral valve, showing the strongly lamellose concentric lines, spine bases and pedicle opening, × 2.
6. A dorsal valve preserving some of the surface spines, × 2.
7. Profile outline to show the relative convexity of valves and the projecting beak of the ventral valve, × 2. Upper Trenton at Sandy Hill, New York. Collection of C. Schuchert.

Figs. 8 to 10. SCHIZAMBON (?) LOCKII, n. sp. 362

8. The ventral valve, showing the submarginal beak and the pedicle opening.
9. The dorsal valve of the same specimen in which the beak is marginal.
10. Profile outline of the same specimen. *p*, pedicle valve. Middle beds of the Hudson River group, Cincinnati, Ohio. Collection of C. Schuchert.

Figs. 11 to 17. CLITAMBONITES DIVERSA Shaler, sp. 378

11. A dorsal view, showing the elevated area of the ventral valve, in which the deltidium has been worn away, exposing the spondylium. (After Hall.)
12. Ventral view of the same specimen. The distorted beak is not accidental, but a feature often developed in the species. (After Hall.)
13. Interior of the ventral valve, showing the spondylium (*sp*) supported by a short septum (*s*). (After Hall.)
14. Interior of the dorsal valve. *cp*, cardinal process; *ad*, adductor scars; *o*, genital markings. Galena shales, near Cannon Falls, Minn. Collection of C. Schuchert.
15. Interior of another dorsal valve in which the deltidium is preserved. The impressions of the vascular system are also shown on each side of the septum, and posterior to these are the genital markings.
16. A portion of fig. 15 in which the deltidium is broken away to show the muscular scars of the spondylium, × 2.
17. An oblique view of the same specimen, to show the adjustor scars on the lateral limits of the spondylium, × 2. Galena shales, near Cannon Falls, Minn. Collection of W. H. Scofield.

Figs. 18 and 19. CLITAMBONITES DIVERSA, var. ALTISSIMA, n. var. 381

18. Profile view, to show the great elevation of the ventral valve.
19. Cardinal view of the same specimen. D, deltidium; F, foramen or pedicle opening. (After Hall.) Galena shales, south of Cannon Falls, Minn. Collection of C. Schuchert.

Figs. 20 to 23. SCENIDIUM ANTHONENSIS Sardeson 381

20 and 21. Ventral and cardinal views of a specimen, × 4. Trenton shales, near Cannon Falls, Minn. Collection of W. H. Scofield.

22 and 23. Views of the exterior and interior of a dorsal valve. (After Hall.) Glade limestone, Lebanon Tennessee.

Figs. 24 to 28. ANASTROPHIA (?) SCOFIELDI, n. sp. 383

24 and 25. Views of the dorsal and ventral valves respectively.

26. Profile view of the same specimen.
27. Cardinal view of a distorted specimen, showing an area on the dorsal valve, × 3.
28. Profile outline, through the center of the shell, to show the extent of the spondylium, and the septum in the ventral valve, and the septal plates of the dorsal valve. Galena shales, near Cannon Falls, Minn. Minnesota Geological Survey collection.

Figs. 29 to 31. ANASTROPHIA (?) HEMIPLICATA Hall 382

29 and 30. Dorsal and ventral valves respectively.

31. Profile view of the same specimen. Galena shales near Cannon Falls, Minn. Minnesota Geological Survey collection.

{Brachiopoda}

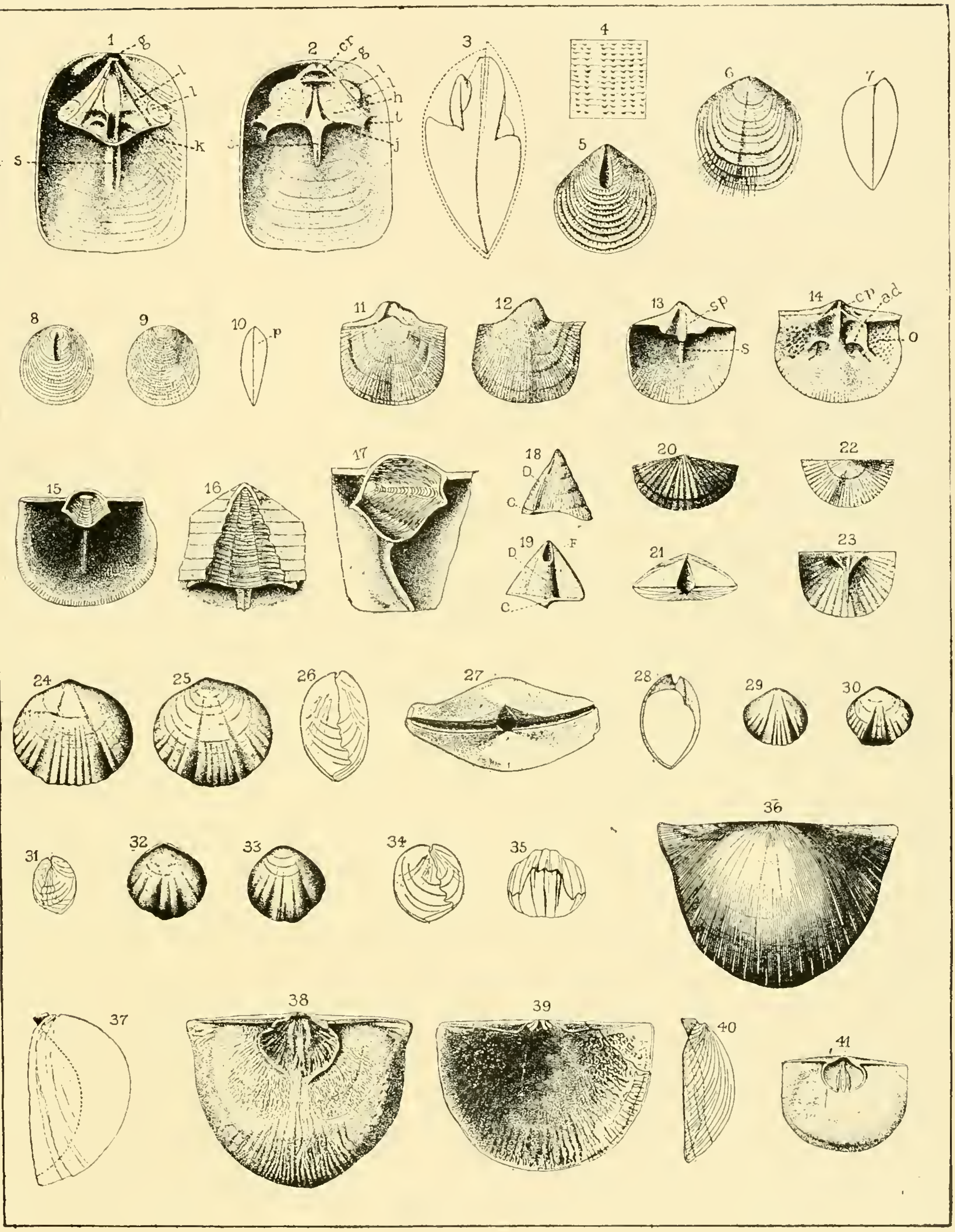


PLATE XXXI.

		Page.
Fig. 1 to 3.	STROPHOMENA SEPTATA W. and S.	390
1 and 2.	Dorsal and profile views respectively of the same specimen.	
3.	Interior of the ventral valve, to show the long median septum of this species. Trenton shales, St. Paul, Minn. Collection of C. Schuchert.	
Figs. 4 and 5.	STROPHOMENA RUGOSA (Rafinesque Ms.) Blainville.	390
4.	Interior of the ventral valve. The septum of the muscular area does not extend to near the anterior margin, as in *S. septata*.	
5.	Interior of the dorsal valve. Hudson River group, Oxford, Ohio. Collection of C. Schuchert.	
Figs. 6 and 7.	STROPHOMENA NEGLECTA, var. ACUTA, n. var.	388
6.	A view of the dorsal valve, to show the oblique wrinkling along the hinge line and distinct alternation of the striæ.	
7.	Profile outline of the same specimen. Hudson River group, Spring Valley, Minn. Collection of C. Schuchert.	
Figs. 8 to 10.	STROPHOMENA PLANODORSATA W. and S.	393
8.	A dorsal view of the largest specimen seen, somewhat restored. The outline of smaller individuals is more like that of fig. 10.	
9.	Profile outline of same specimen. Hudson River group, Spring Valley, Minn. University of Minnesota collection.	
10.	Interior of a ventral valve referred to this species. Hudson River group, Wilmington, Illinois. Collection of C. Schuchert.	
Fig. 11.	STROPHOMENA WINCHELLI Hall	394
	A view of the dorsal valve of this species. (After Hall.) Lower Blue beds of Wisconsin.	
Figs. 12 and 13.	STROPHOMENA TRILOBATA Owen.	395
	Dorsal and profile views of a specimen showing the small, flat corrugated visceral disc, and the long median extension. Middle Galena, Old Concord, Minn. Collection of C. Schuchert.	
Figs. 14 to 17.	STROPHOMENA FLUCTUOSA Billings	395
14 and 15.	Dorsal and profile views of a specimen intended to show the strongly wrinkled visceral disc.	
16 and 17.	The interior of a ventral and a dorsal valve respectively. Hudson River group, Spring Valley, Minn. Collection of C. Schuchert.	
Figs. 18 to 21.	STROPHOMENA SCOFIELDI W. and S.	398
18 and 19.	Dorsal and profile views of a specimen of the usual size of this species.	
20.	An interior of the dorsal valve. Minnesota Geological Survey collection.	
21.	Interior of the ventral valve. Galena shales, near Cannon Falls, Minn. Collection of W. H. Scofield.	
Figs. 22 to 24.	STROPHOMENA EMACIATA W. and S.	399
22 and 23.	View of the ventral valve, natural size, and a profile of the same specimen, × 2.	
24.	View from the dorsal valve, × 2. Galena shales, near Cannon Falls, Minn. Collection of W. H. Scofield.	
Figs. 25 to 29.	RAFINESQUINA MINNESOTENSIS N. H. Winchell.	401
25.	View of a natural cast, one of the type specimens, of the ventral valve as preserved in the Trenton limestone, Minneapolis, Minn. Minnesota Geological Survey collection.	
26.	Profile view of a specimen from the Trenton shales, St. Paul, Minn. Collection of C. Schuchert.	
27 and 28.	Variety INQUASSA Sardeson	403
	Dorsal and profile views respectively of a specimen of the ordinary size of this species as it occurs near the base of the Upper Buff beds at Mineral Point, Wis. Minnesota Geological Survey collection.	
29.	Interior of the dorsal valve, showing the five characteristic septa of this species. (After Hall.)	
Figs. 30 and 31.	RAFINESQUINA DELTOIDEA Conrad, sp.	403
	Views of a natural cast of the interior of the ventral valve and a profile of same. Middle Galena, Mantorville, Minn. Minnesota Geological Survey collection.	
Figs. 32 to 34.	RAFINESQUINA ALTERNATA (Conrad Ms.) Emmons, sp.	404
32 and 33.	A ventral and a profile view of this species as it occurs in the Galena shales in Goodhue county, Minn. Minnesota Geological Survey collection.	
34.	Interior view of a thick dorsal vavle in which the various parts are strongly developed. Trenton shales, St. Paul, Minn. Collection of W. H. Scofield.	
Figs. 35 to 37.	R. ALTERNATA, var. LOXORHYTIS Meek, var.	407
35 and 36.	View of the ventral valve and a profile outline of the same specimen, to show the great convexity and transversity of this variety. Collection of C. Schuchert.	
37.	Interior of the dorsal valve. Hudson River group, Spring Valley, Minn. Minnesota Geological Survey collection.	

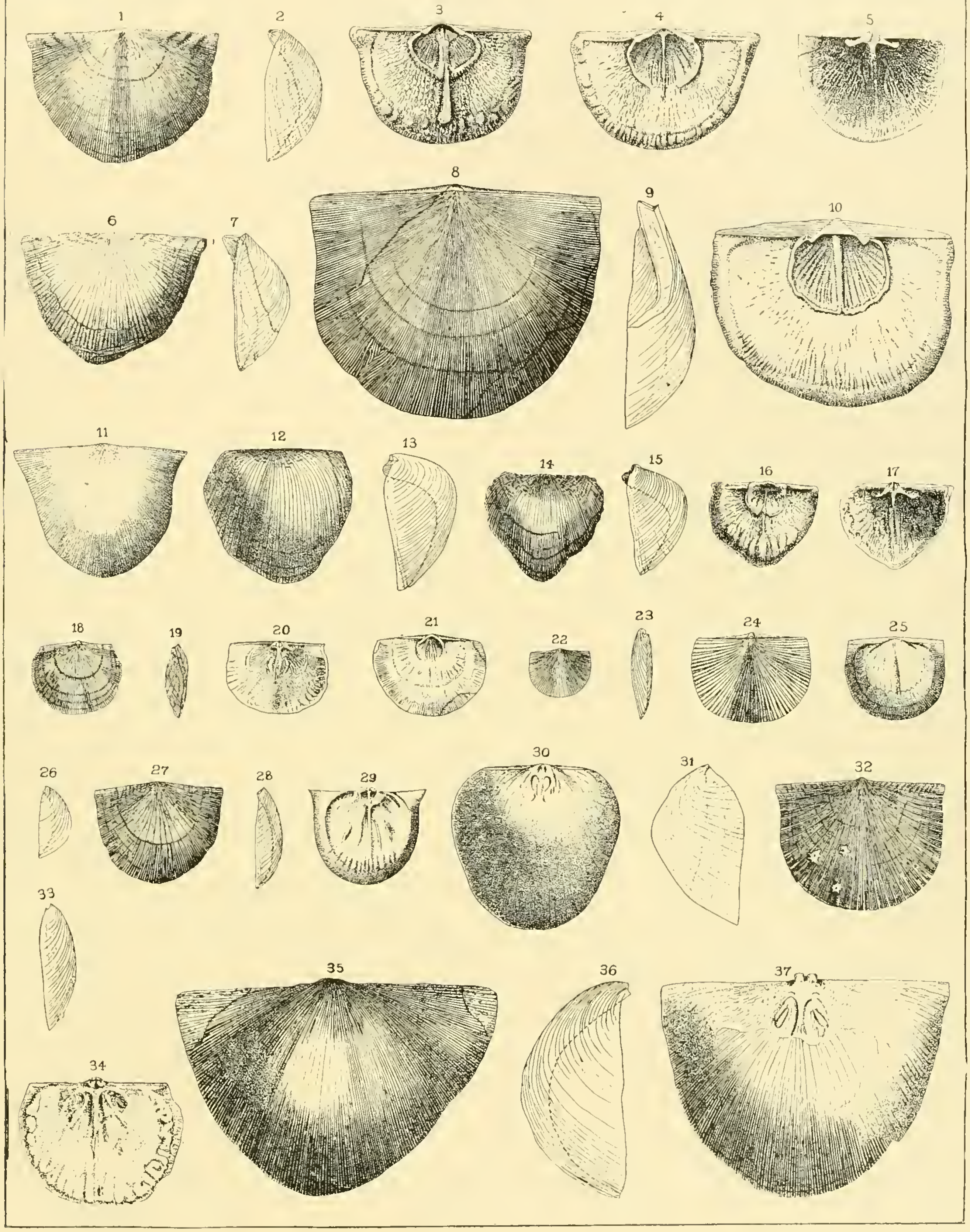

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37

PLATE XXXII.

		PAGE.
Figs. 1 to 5.	LEPTÆNA CHARLOTTÆ W. and S.	410
1 and 2.	Views of the ventral and dorsal valves respectively of an entire specimen, showing the zigzag surface ornamentation and the deflected anterior margin.	
3.	Profile outline of the same specimen.	
4.	Interior of the dorsal valve of a similar specimen. Collection of C. Schuchert.	
5.	Interior of a ventral valve. Trenton shales, St. Paul, Minn. Minnesota Geological Survey collection.	
Figs. 6 to 9.	LEPTÆNA UNICOSTATA Meek and Worthen, sp.	411
6 and 7.	An exterior view of the ventral valve and a profile outline of the same specimen. Minnesota Geological Survey collection.	
8.	Interior of the ventral valve, showing the adductor and the elongate diductor muscle scars and the strongly tuberculose surface.	
9.	Interior of the dorsal valve, which is much as in L. RHOMBOIDALIS, var. TENUISTRIATA. Hudson River group, Spring Valley, Minn. Collection of C. Schuchert.	
Figs. 10 to 12.	PLECTAMBONITES SERICEA Sowerby, sp.	414
10.	A view from the dorsal valve of a specimen from the Hudson River group of Ohio. D, deltidium. (After Hall.)	
11.	Interior of the dorsal valve of another specimen from the same locality. *a*, adductor muscle scars; *c*, crural plates; *j*, cardinal process; *v*, vascular impressions. (After Hall.)	
12.	Interior of a ventral valve to show the crenulated hinge margin and the muscular scars. Hudson River group, Granger, Minn. Minnesota Geological Survey collection.	
Figs. 13 to 17.	PLECTAMBONITES GIBBOSA W. and S.	416
13, 14 and 15.	Ventral, dorsal and profile views respectively of an entire specimen, × 2.	
16 and 17.	Dorsal and ventral valve interiors, drawn from gutta percha impressions made from natural casts. Middle Galena, near Cannon Falls, Mantorville and Old Concord, Minn. Minnesota Geological Survey collection.	
Figs. 18 to 23.	ORTHIS TRICENARIA Conrad	418
18, 19 and 20.	Dorsal, ventral and profile views of a specimen wider than is common for the species. Minnesota Geological Survey collection.	
21.	The interior of a well preserved dorsal valve. University of Minnesota collection.	
22.	An interior of the ventral valve.	
23.	A cardinal view to show the small deltidia on both valves, and the chilidium of the dorsal valve, × 2. Trenton shales, Minneapolis, Minn. Collection of C. Schuchert.	
Figs. 24 to 30.	ORTHIS (DINORTHIS) DEFLECTA Conrad, sp.	422
24 and 25.	Exterior and interior views of a ventral valve. (Fig. 24 after Hall.)	
26.	The interior of a dorsal valve. (After Hall.) Trenton limestone, near Fountain, Minn.	
27, 28 and 29.	Ventral, dorsal and cardinal views of a rather thick specimen. (After Hall.) Trenton limestone, Minneapolis, Minn. Collection of C. Schuchert.	
30.	Profile outline of another specimen. Lower Blue beds, Janesville, Wis. Minnesota Geological Survey collection.	
Figs. 31 to 34.	ORTHIS (DINORTHIS) PECTINELLA Emmons	424
31.	The interior of the ventral valve of the type specimen of *O. charlottæ* Winchell. The outer margin of the shell is slightly broken. Trenton shales, Minneapolis, Minn. Minnesota Geological Survey collection.	
32 and 33.	Dorsal valve and profile outline of another specimen.	
34.	Cardinal view of the dorsal valve of a smaller specimen, to show the small deltidium. Trenton shales, St. Paul, Minn. Collection of C. Schuchert.	
Figs. 35 to 38.	O. (D.) PECTINELLA, var. SWEENEYI N. H. Winchell	426
35 and 36.	View from the dorsal valve and profile of same specimen. (Fig. 35 after Hall.)	
37 and 38.	Interiors of the dorsal and ventral valves. (After Hall.) Trenton shales, St. Paul, Minn. Collection of C. Schuchert.	
Figs. 39 to 42.	ORTHIS (DINORTHIS) MEEDSI W. and S.	427
39 and 40.	Dorsal and cardinal views of a specimen in which the striæ are separated more than is usual.	
41 and 42.	Ventral and profile views of a larger specimen. Galena shales, Kenyon, Minn.	
42*a*.	Cardinal view. Collection of W. H. Scofield.	

		Page.
Figs. 43 to 45.	O. (D.) MEEDSI, var. GERMANA W. and S.	428
	Dorsal, ventral and profile views of a very characteristic specimen of this variety. Galena shales, near Cannon Falls, Minn. Collection of C. Schuchert.	
Figs. 46 to 50.	ORTHIS (DINORTHIS) SUBQUADRATA Hall	428
46, 47 and 48.	Dorsal, ventral and profile views respectively of an entire specimen. Minnesota Geological Survey collection.	
49.	An interior view of the ventral valve of a very old specimen in which the anterior margin is much thickened and reflexed. The vascular sinuses are abnormally developed, due to old age. Hudson River group, Spring Valley, Minn.	
50.	Interior of a dorsal valve. (After Meek, Ohio Pal., vol. i.)	
Figs. 51 to 58.	ORTHIS (DINORTHIS) PROAVITA W. and S.	431
51, 52 and 53.	Dorsal, ventral and profile views of an entire specimen. Collection of the Minnesota Geological Survey.	
54 and 55.	Dorsal and profile views of a large specimen. Hudson River group, Wilmington, Illinois.	
56 and 57.	Interior and profile views of a thick ventral valve. Hudson River group, Spring Valley, Minn.	
58.	Interior of a dorsal valve. Hudson River group, Spring Valley, Minn. Collection of C. Schuchert.	
Figs. 59 and 60.	RAFINESQUINA ALTERNATA, var. LOXORHYTIS Meek	407
59.	Perpendicular view of the hinge and muscular impressions of the specimen illustrated on plate XXXI, fig. 37.	
60.	Profile view of the same specimen.	

GEOL. AND NAT. HIST. SURVEY OF MINNESOTA,

(Brachiopoda)

VOL. III. Plate XXXII

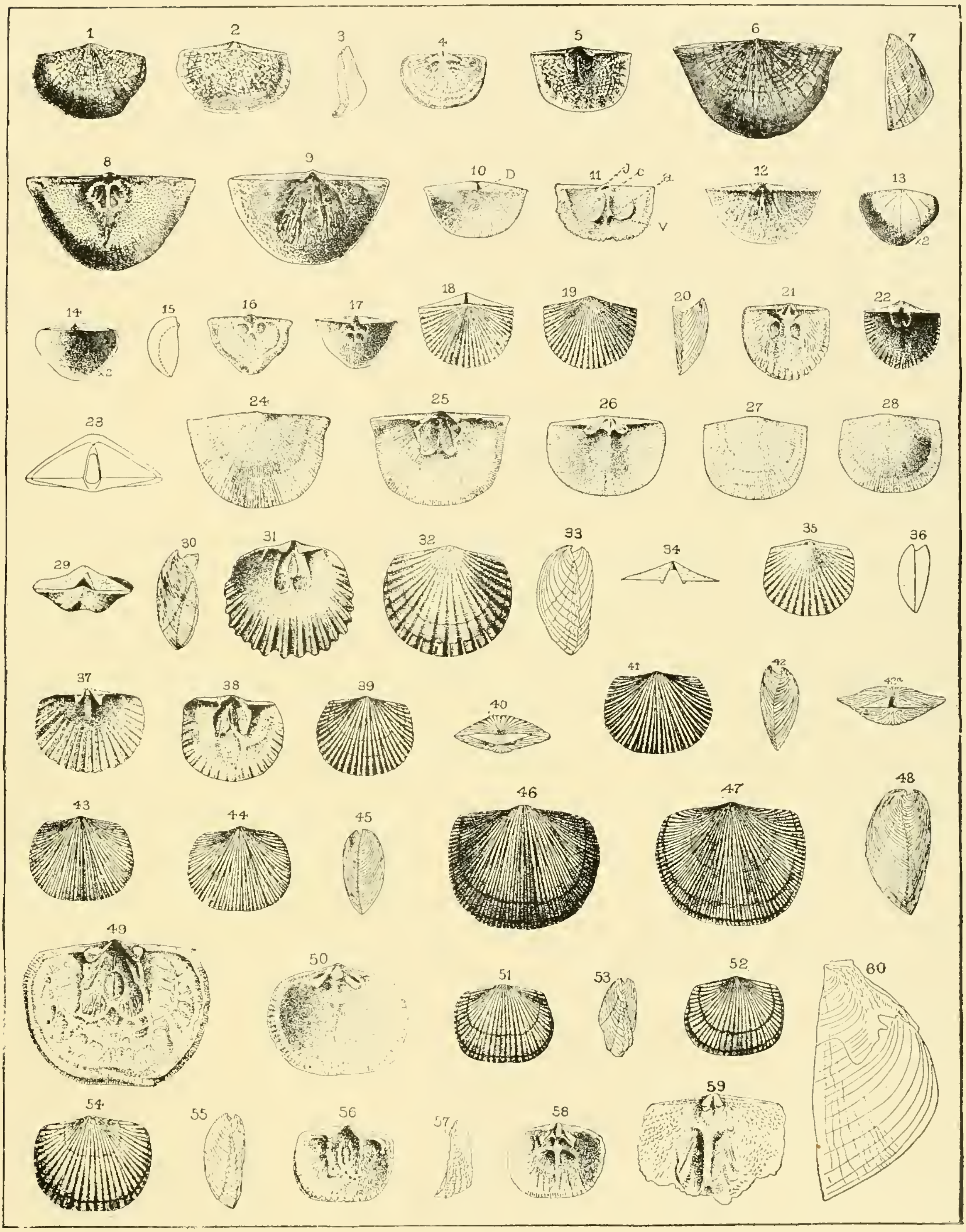


PLATE XXXIII

		Page.
Figs. 1 to 4.	Orthis (Hebertella?) bellarugosa Conrad	434
1 and 2.	Views of the exterior and interior of a large ventral valve. Galena shales, Minneola, Minn. Minnesota Geological Survey collection.	
3 and 4.	Exterior and interior views of a dorsal valve of the ordinary size. Galena limestone near Fountain, Minn. Collection of C. Schuchert.	
Figs. 5 to 7.	Orthis (Plectorthis) plicatella Hall	436
	Ventral, dorsal and profile views respectively of an entire specimen. Galena shales, Kenyon, Minn. Collection of C. Schuchert.	
Figs. 8 to 13.	Orthis (Plectorthis) whitfieldi N. H. Winchell	437
8 and 9.	Ventral and dorsal views of one of the type specimens, a natural cast of the interior.	
10 and 11.	A view of the ventral valve and profile outline of same of another type specimen. Hudson River group, Spring Valley, Minn. Minnesota Geological Survey collection.	
12.	The interior of a small ventral valve.	
13.	A large ventral valve, abnormal in its growth. Hudson River group, Spring Valley, Minn. Minnesota Geological Survey collection.	
Figs. 14 to 16.	Orthis (Dalmanella) hamburgensis? Walcott	440
14 and 16.	Ventral, profile and dorsal views respectively of an entire specimen referred with doubt to this species; 16*a*, fig. 16 × 2. Trenton shales near Fountain, Minn. Minnesota Geological Survey collection.	
Figs. 17 to 22.	Orthis (Dalmanella) testudinaria Dalman	441
17 and 18.	Ventral and dorsal views of a specimen of this species from the Trenton shales, Minneapolis, Minn.; fig. 18 × 2.	
19 and 20.	Dorsal and profile outlines of the same specimen, × 2, Minnesota Geological Survey collection.	
21 and 22.	Interior of the ventral and dorsal valves, × 2. St. Paul, Minn. Collection of C. Schuchert.	
Figs. 23 and 24.	O. (D.) testudinaria var. emacerata Hall	445
	Two views, a dorsal and profile, of a specimen referred to this variety. Hudson River group, Spring Valley, Minn. Minnesota Geological Survey collection.	
Figs. 25 to 29.	O. (D.) testudinaria var. meeki Miller	445
25 to 27.	Ventral, dorsal and profile views respectively of an entire specimen.	
28.	Profile view of another somewhat thinner specimen. Minnesota Geological Survey collection.	
29.	The interior of a dorsal valve in which the parts are strongly developed. Hudson River group near Spring Valley, Minn. Collection of C. Schuchert.	
Figs. 30 to 36.	Orthis (Dalmanella) subæquata Conrad	446
30 to 32.	Ventral, dorsal and profile views respectively of the type specimen of *Orthis minneapolis* Winchell. Trenton shales, Minneapolis, Minn. Minnesota Geological Survey collection.	
33, 34 and 34*a*.	Dorsal, ventral and profile views of a specimen in which the fold and sinus are obsolete and the tubular striæ conspicuous. Trenton shales, Minneapolis, Minn. Collection of C. Schuchert.	
35.	Interior of the ventral valve, × 2. (After Hall.)	
36.	Interior of the dorsal valve. (After Hall.) Base of the Upper Buff limestone, Mineral Point, Wisconsin.	
Figs. 37 to 39.	O. (D.) subæquata var. conradi N. H. Winchell	449
37.	View from the dorsal valve of a typical example of this variety, × 2.	
38 and 39.	Ventral and profile views of the same specimen of the natural size. Trenton limestone, Minneapolis, Minn. Minnesota Geological Survey collection.	
Figs. 40 to 42.	O. (D.) subæquata var. perveta Conrad	450
40 and 41.	Ventral and dorsal views of the type specimen of *Orthis media* Winchell. Base of Trenton shales, Minneapolis, Minn. Minnesota Geological Survey collection.	
42.	View from the dorsal valve of Conrad's type specimen of *Orthis perveta*. (After Hall.) Base of Upper Buff beds at Mineral Point, Wisconsin.	
Figs. 43 to 45.	O. (D.) subæquata var. gibbosa Billings	451
	Dorsal, ventral and anterior views of a characteristic specimen of this variety. Trenton shales, Minneapolis, Minn. Collection of C Schuchert.	

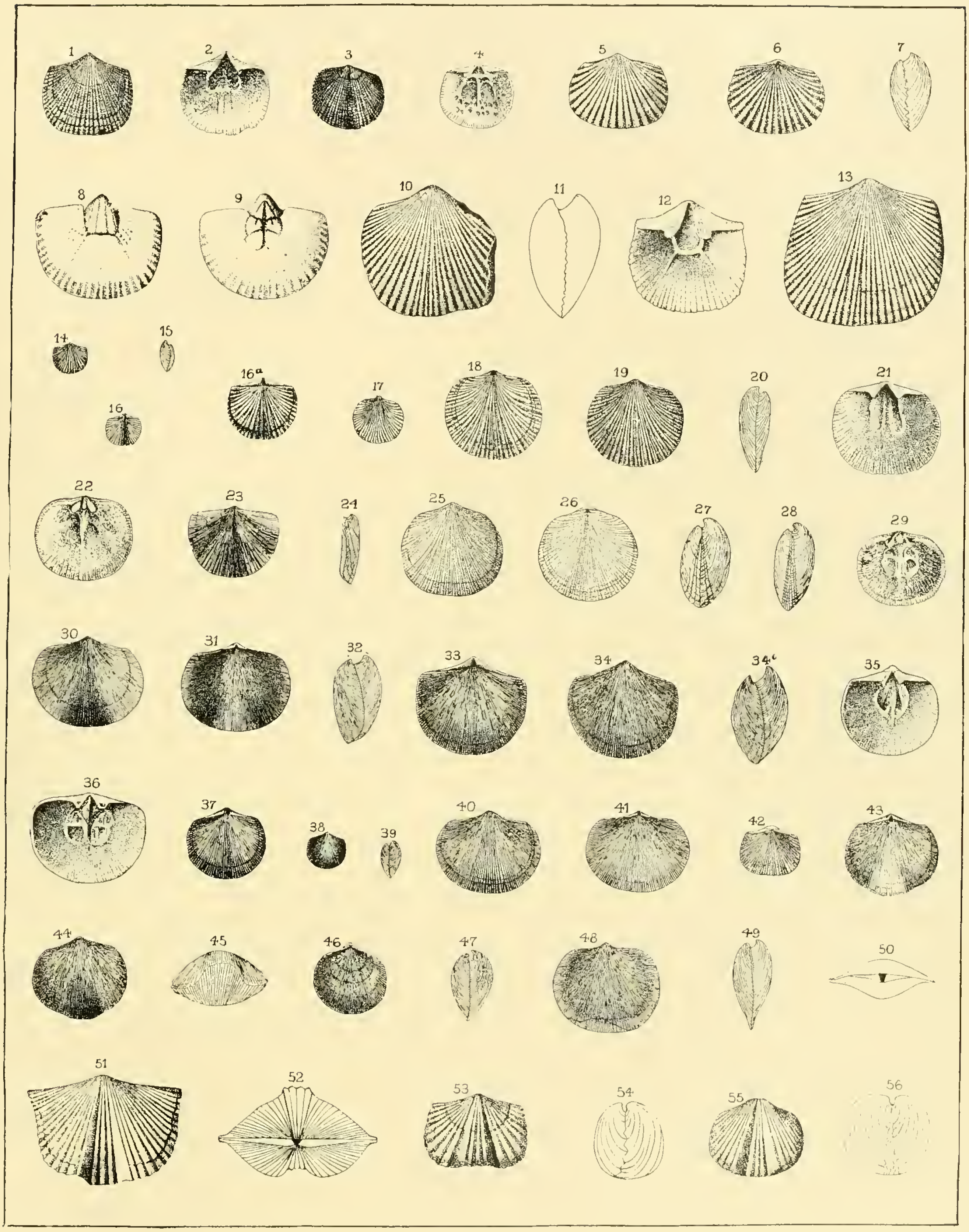
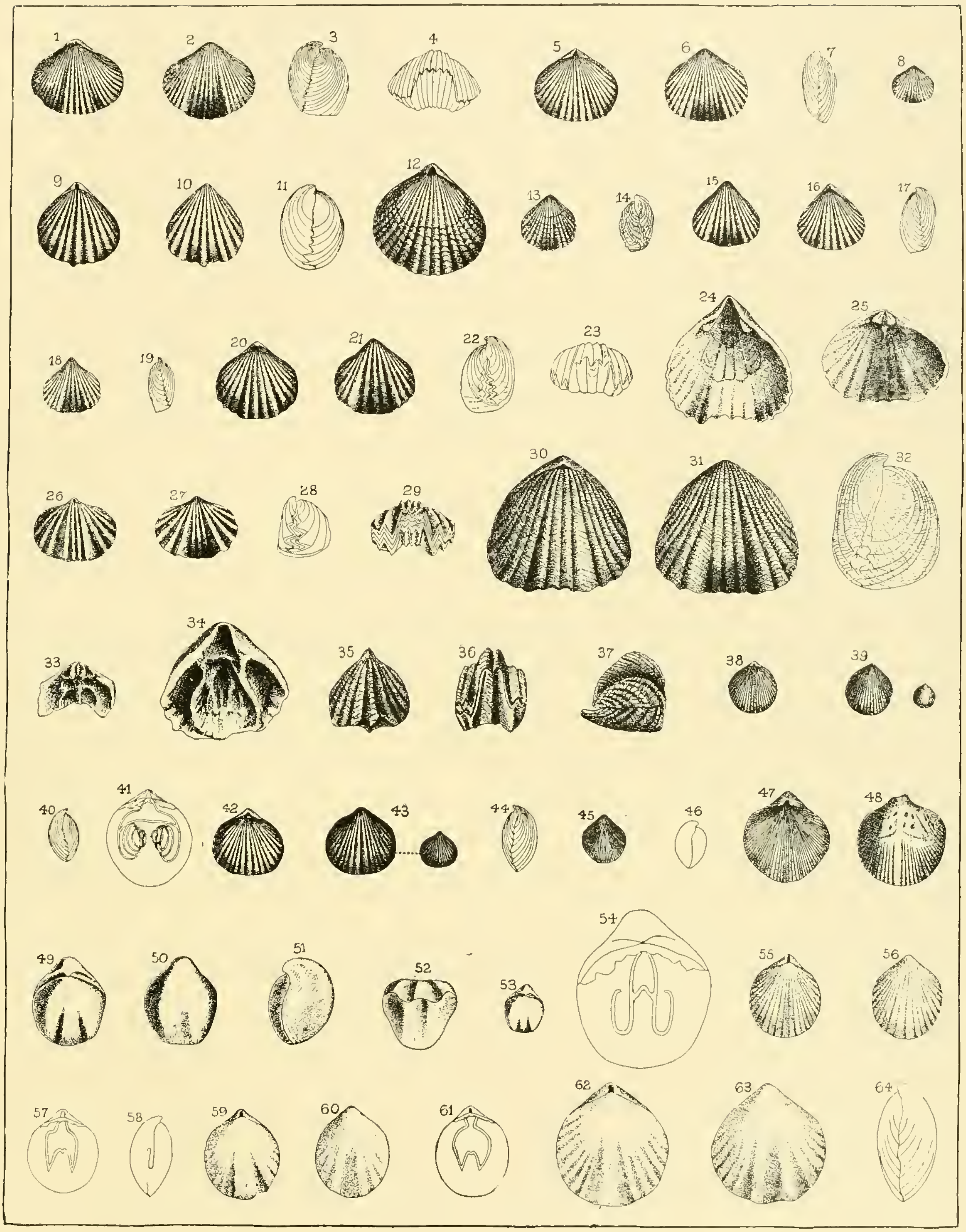

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
16a
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
34c
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56

PLATE XXXIV.

(Brachiopoda)



GEOGRAPHICAL AND PERSONAL INDEX.

PART 1. PAGES 1 TO 474.

SCIENTIFIC INDEX.

PART I. PAGES 1 TO 474.

The most important reference is given first; others follow in numerical order. Each scientific name is indexed for every page on which it occurs. Synonyms, and also the figures referring to the pages on which they are mentioned, are in italics. An asterisk after a page reference signifies that an illustration of the form in question is given on that page. A page reference in bold face type signifies that on this page the form is described.