MINNEAPOLIS, MINN., Jan. 30, 1900

To E. R. Buckley.

I have the pleasure of presenting, in the name of the board of regents of the University of Minnesota, this copy of the volume III. pt. I. 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.

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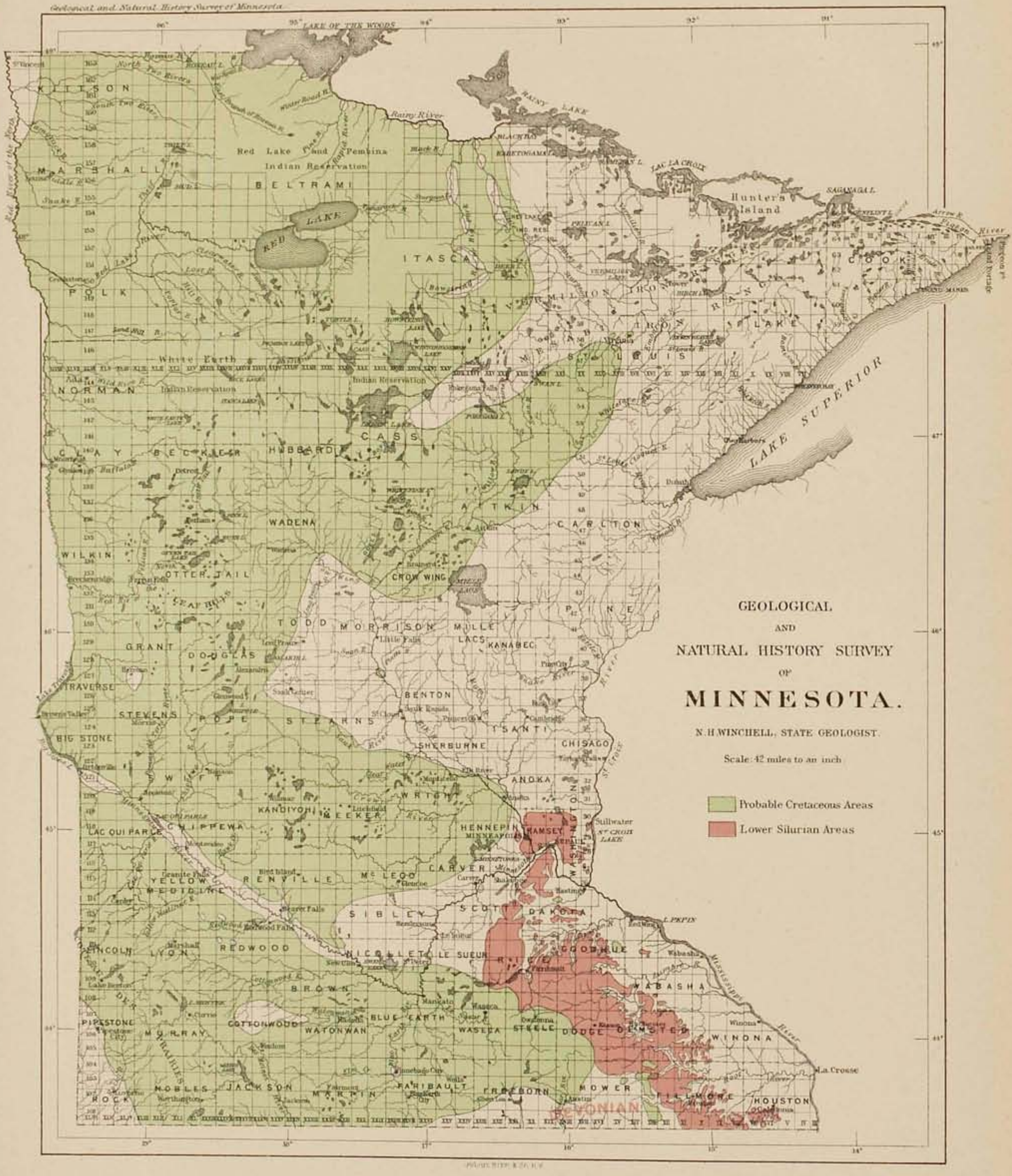
GEOLOGICAL
AND
NATURAL HISTORY SURVEY
OF
MINNESOTA.
N. H. WINCHELL, STATE GEOLOGIST.
Scale: 42 miles to an inch.
Probable Cretaceous Areas
Lower Silurian Areas
LAKE OF THE WOODS
RAINY LAKE
Rainy River
LAKE SUPERIOR
RED LAKE
Hunter's Island
Red Lake and Pembina Indian Reservation
White Earth Indian Reservation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

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.

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[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.

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*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 *Castln*, 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, Sehoharie, 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.
Pleurotomaria angulata Sow.
Turritella —
Orthis testudinaria?
Delthyris—
Strophomena sericea
Cyathophyllum profundum Con.

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

Crytoceras marginalis Con.
Orthoceras annellus Con.
Phragmolites compressus Con.
Turritella —
Pleurotomaria angulata Sow.
Bellerophon bilobatus Sow.
Euomphalus triliratus Con.
Inachus pervetus Con.
Subulites elongata.
Strophomena sericea Sow.
Strophomena deflecta Con.
Strophomena recta Con.
Orthis testudinaria?
Orthis disparilis Con.
Orthis perveta Con.
Orthis tricenaria Con.
Orthis bellarugosa Con.
Orthis subequata Con.
Atrypa schlottheimi Von Buch.
Nuculites —
Nuculites —
Delthyris —
Ceraurus pleurexanthemus Green.
Isotelus gigas DeKay.
Thaleops ovata Con.
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)	Trenton limestone of New York, corresponding with the lower part of the Caradoc,——perhaps still lower.
Asaphus, (new.)	
Ceraurus pleurexanthemus, (Green.)	
Portion of an Isotelus gigas.	
Calymene spinifera, (Conrad.)	

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, Birds-eye 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, II*a* and II*b*.

In the general table of stratigraphical and geographical distribution of fossils, Dr. Owen represents the lead-bearing beds (For. 3*b*) 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. 3*a*) 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 equivaleut 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 oj 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 convienence 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 Magneian 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 State 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."

Receptaculites iowene Owen. Galena limestone.

Receptaculites 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 aùta, 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. *Chætetes 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 (Tremanolus ?) 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 the 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 planidorsatum, 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 I. 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

TRENTON. Stone's River. Limestone.		TRENTON. Black River. Shales.				TRENTON. Trenton. Shales.		TRENTON. Trenton. Limestone.			Hudson River or Cincinnati. Utica. Shales.	Hudson River or Cincinnati. Richmond. Limestone.	
Building Layers.	Shaly Limestone.	Lower Third.	Middle Third.	Upper Third.		Basal beds.	Upper Galena Shales.	Galena limestone.			Lower part.	Upper part.	Formations. (As now known.)
	Vanuxemia bed.	Stictop'rella	Rhinidictya beds. Ctenodonta bed. Bryozoa layers.	Fucoid bed. Phylloporina horizon. Orthis pectinella beds. Bryozoa layers.		Prasopora insularis. Clitambonites	Nematopora bed.	Fusispira bed. Anastrophia and Upper Clitambonites beds.		Maclurea beds.	Nucula beds.		Special Designations Employed in this Volume.
Trenton. (Chazy?)		Green Shales.	Trenton Shales.	Upper Trenton.		Galena Shales.		Galena.			Maquoketa=Hudson River Group.		Names used in the Minnesota Reports, 1872–1892.
Buff.	Blue.	Stictoporella, 10 feet.	Stictopora, 30 feet.	Fucoid, 20 feet.	Zygospira, 8 feet.	Orthisina, 20 ft.		Camarella, 30 ft.	Lingulasma, 20 ft.	Maclurea, 50 ft.	Maquoketa.	? Wykoff.	F. W. Sardeson, 1892.
								Galena.		Unconformity	Cincinnati.		Joseph F. James, 1890.
Lower Buff.		Lower Blue.	Upper Buff.	Upper Blue.		Galena.					Hudson River.		R. P. Whitfield, 1882.
Lower Buff.		Lower Blue.	Upper Buff.	Upper Blue.				Galena.					G. D. Swezey, 1882.
Trenton.								Utica Slate.			Hudson River.		C. D. Walcott, 1879.
Trenton.		Glass rock—Lower $\frac{1}{3}$ of the Blue. Blue limestone.		Blue. Carbon-		aceous Shale?		Galena.			Cincinnati.		Moses Strong, 1878.
Lower Buff.		Lower Blue.											R. D. Irving, 1878.
Lower Buff.		Lower Blue.	Upper Buff.	Upper B'ue.		Galena.					Cincinnati.		T. C. Chamberlin, 1878.
		Blue Limestone=Trenton.						Galena.			Hudson River.		James Shaw, 1872.
Trenton.		Green shales.	Hudson River oil shales.			Clinton.		Devonian.					W. D. Hurlbut, 1871.
Trenton.													J. H. Kloos, 1871.
Trenton.								Galena.			Maquoketa.		C. A. White, 1870.

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 H," 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	†			†	†	†
				Dialapetaleæ.		
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, 2¼ 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, 1½ 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 5½ 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. I, 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 meeki 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(5a).
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.

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Fig. 3.	Populites litigiosus Heer.	12
Fig. 4.	Populites lancastriensis Lx.	12
Fig. 5.	Ficus austiniana, sp. nov.	14
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Plate A.

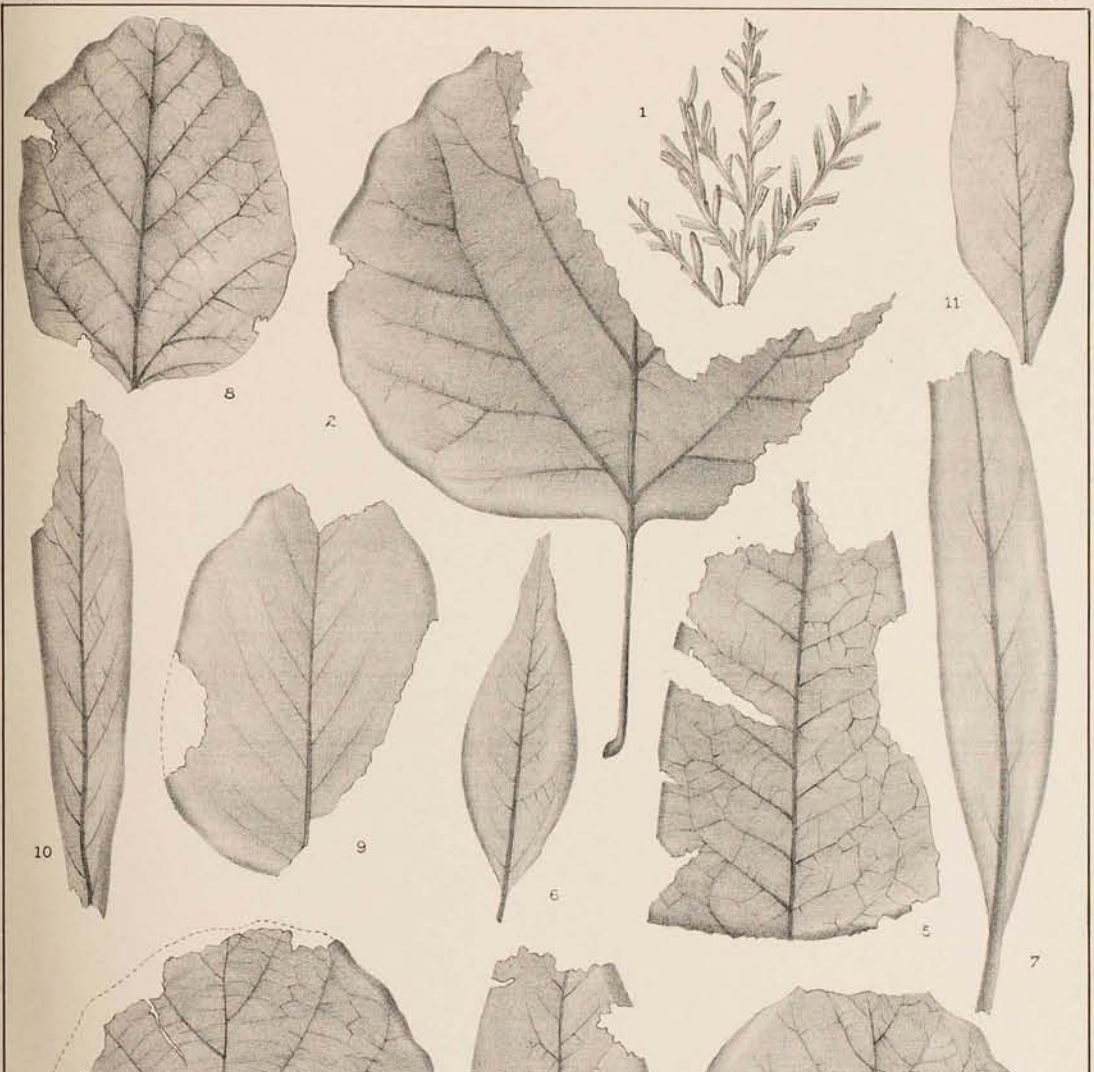
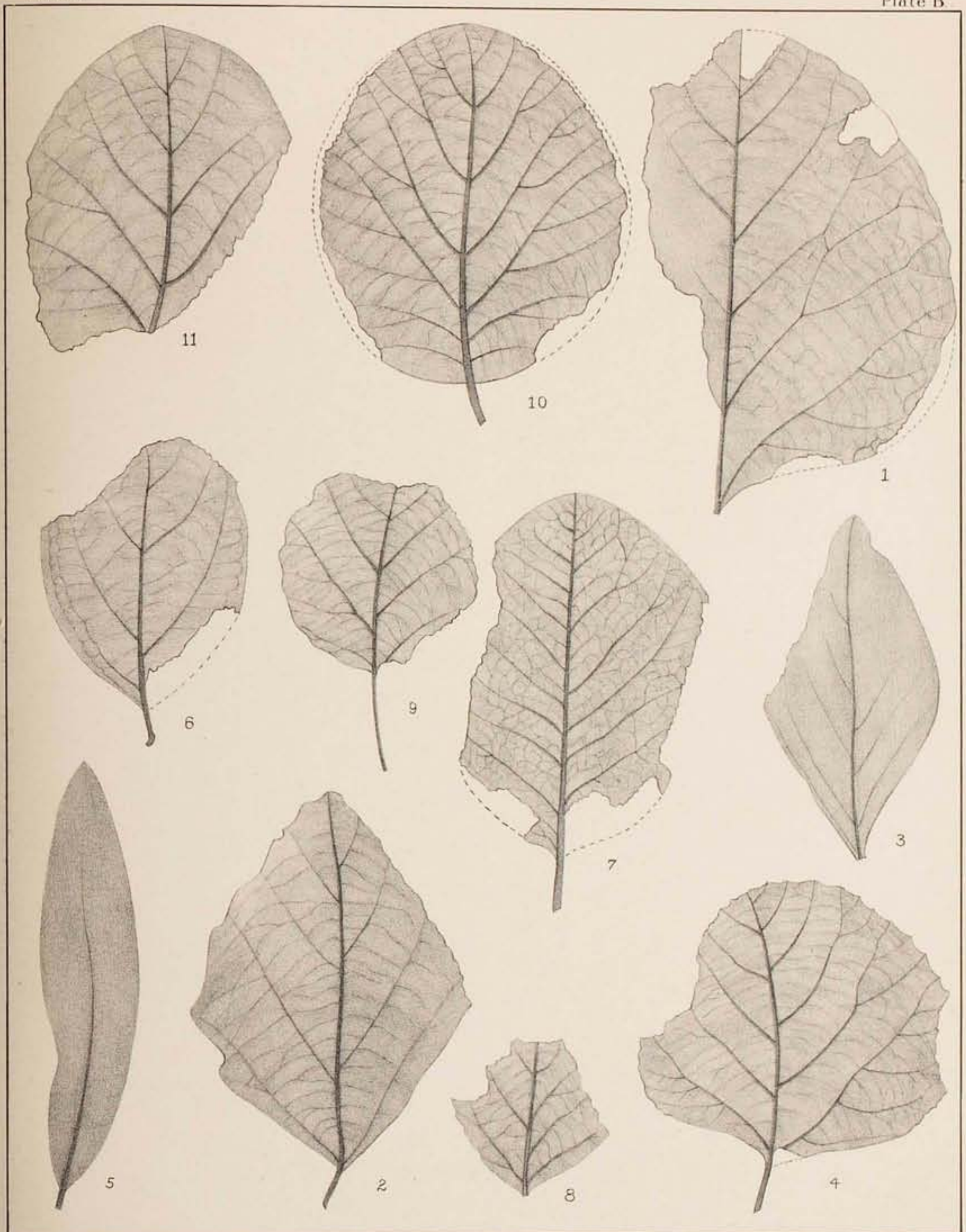


PLATE B.

Plate B.



E.O.U. del. et lith.

Macbrair Lith. Co. Chi.

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 ¼ or ½ 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 ¾ full of water, and after it has rested ten minutes, pour ¾ 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.

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*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; anfractibus 3; loculis globosis. Longitudo ⅕ 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 ⅕ 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. 1, 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 ½ 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, ½ 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. 1, 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; aperturâ 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. Dkschr., 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 ième 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 boncana 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 sub-complanate; 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. H, 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 eocæna, 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 protacmæa, 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 sphærule 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, 2ième 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.

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*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 externè rotundatis; loculis convexo. Diam. ⅓ miil." 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. ⅓ mill.

Locality. Lit le Fork river near Rainy lake, Northeastern Minnesota.

Operculina complanata RÜTIMEYER, 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 boueana 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 *Polycystinæ* (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 subspatulatus* 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.

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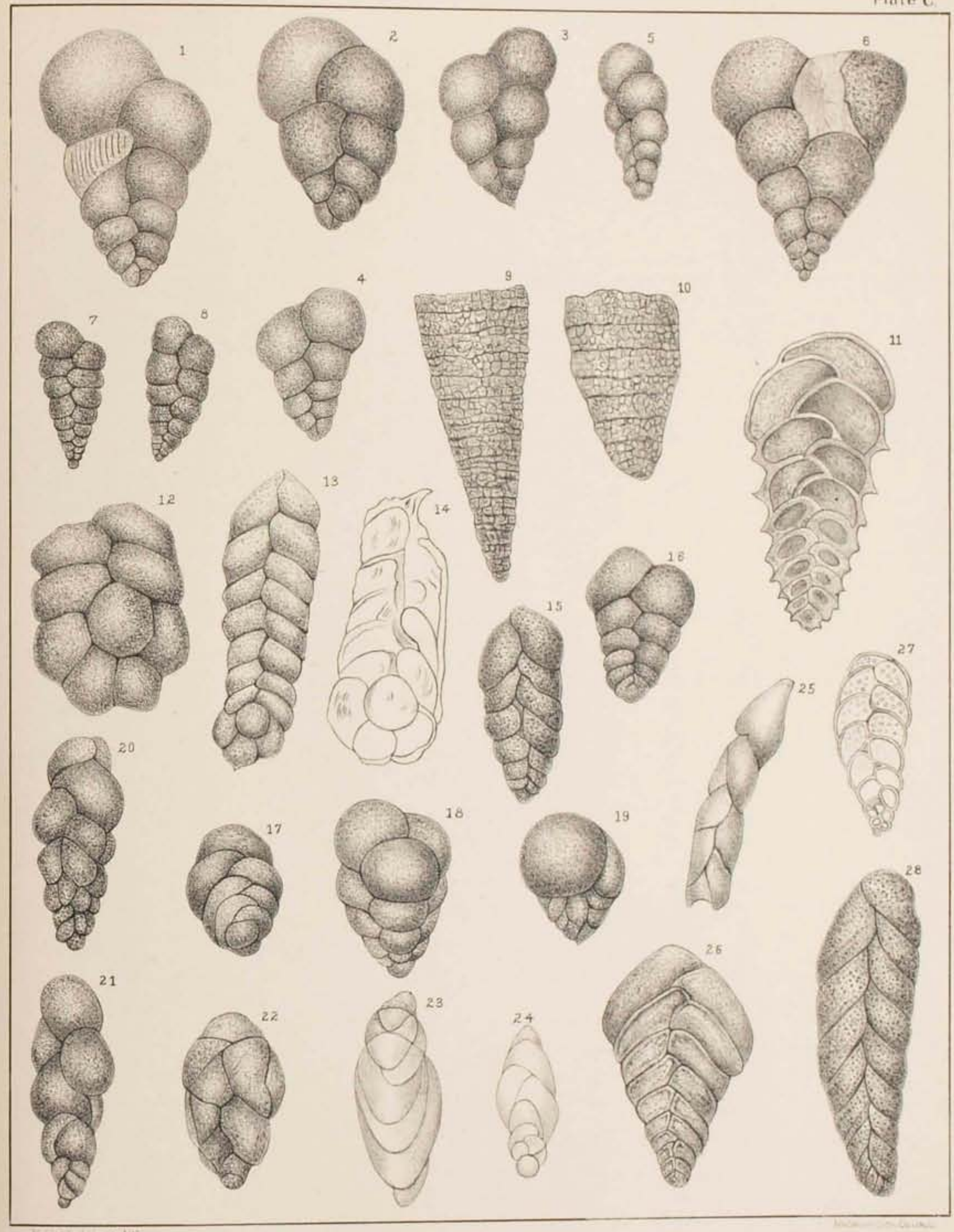
*Sixteenth Annual Report, pp. 403, 431, 434.
†Op. cit. pp. 110-11, 1872.
‡Op. cit. vol. x, [3], 307.
§Preliminary report on the Building stones, etc., of Minnesota, 1880, in the Eighth Annual Report.
‖The Iron Ores of Minnesota. Bulletin No. vi, 1891, p. 151.

PLATE C.

Plate C.



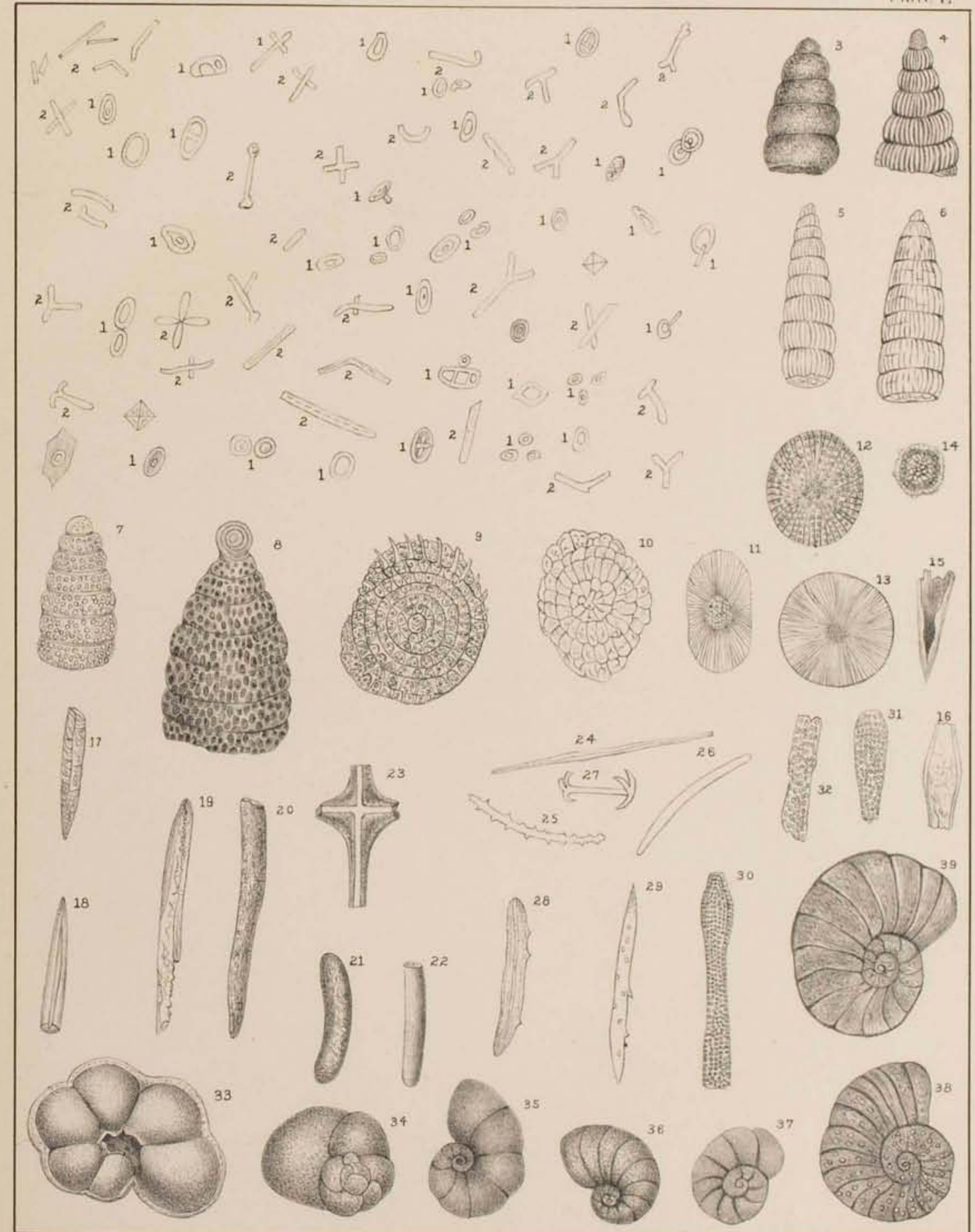
E.O.U. del. et lith.

PLATE D.

PLATE E.

VOL. III

Plate E.



E.O.U. del. et 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.)

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

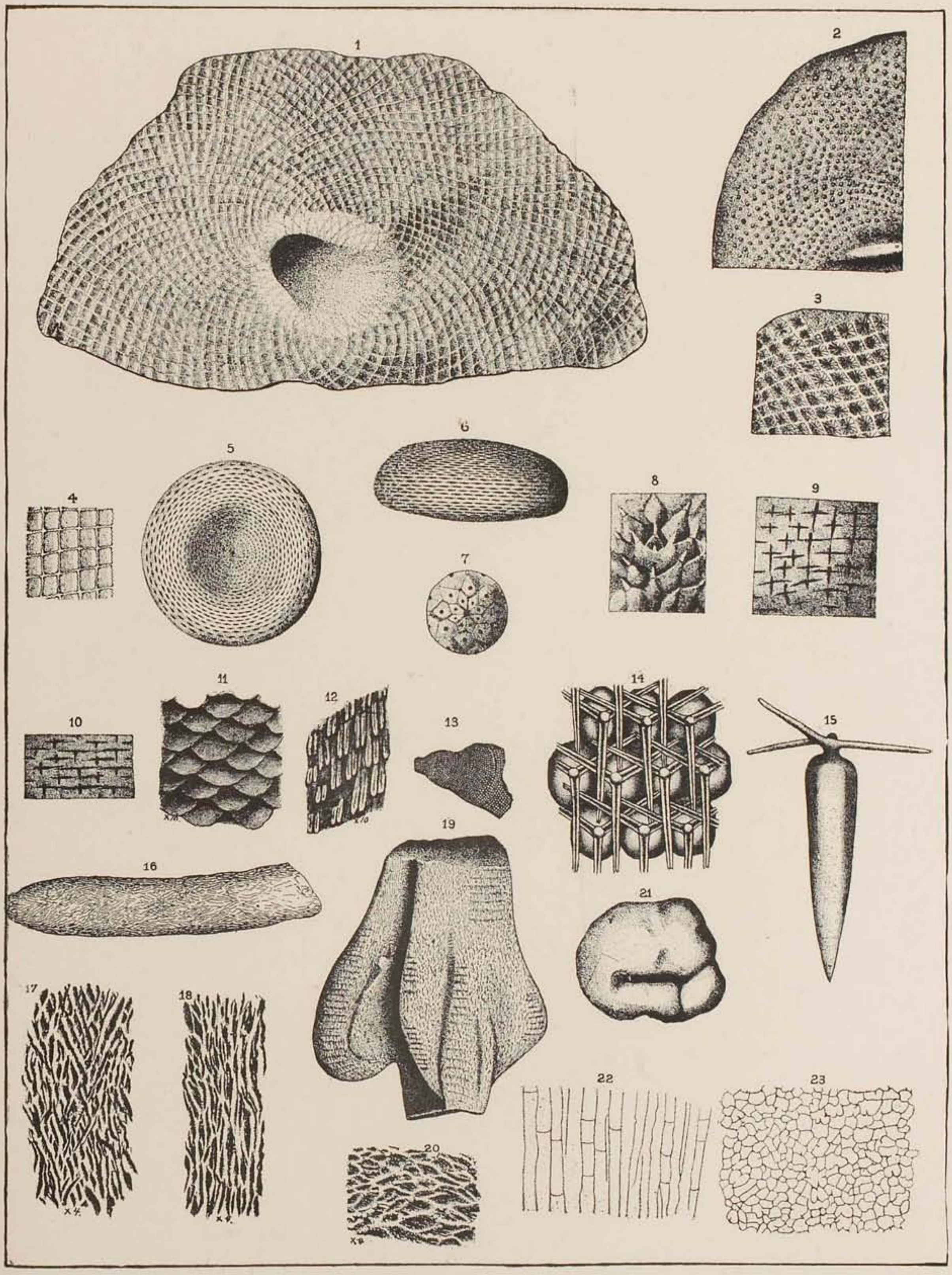
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PLATE G.

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 Trenton 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.

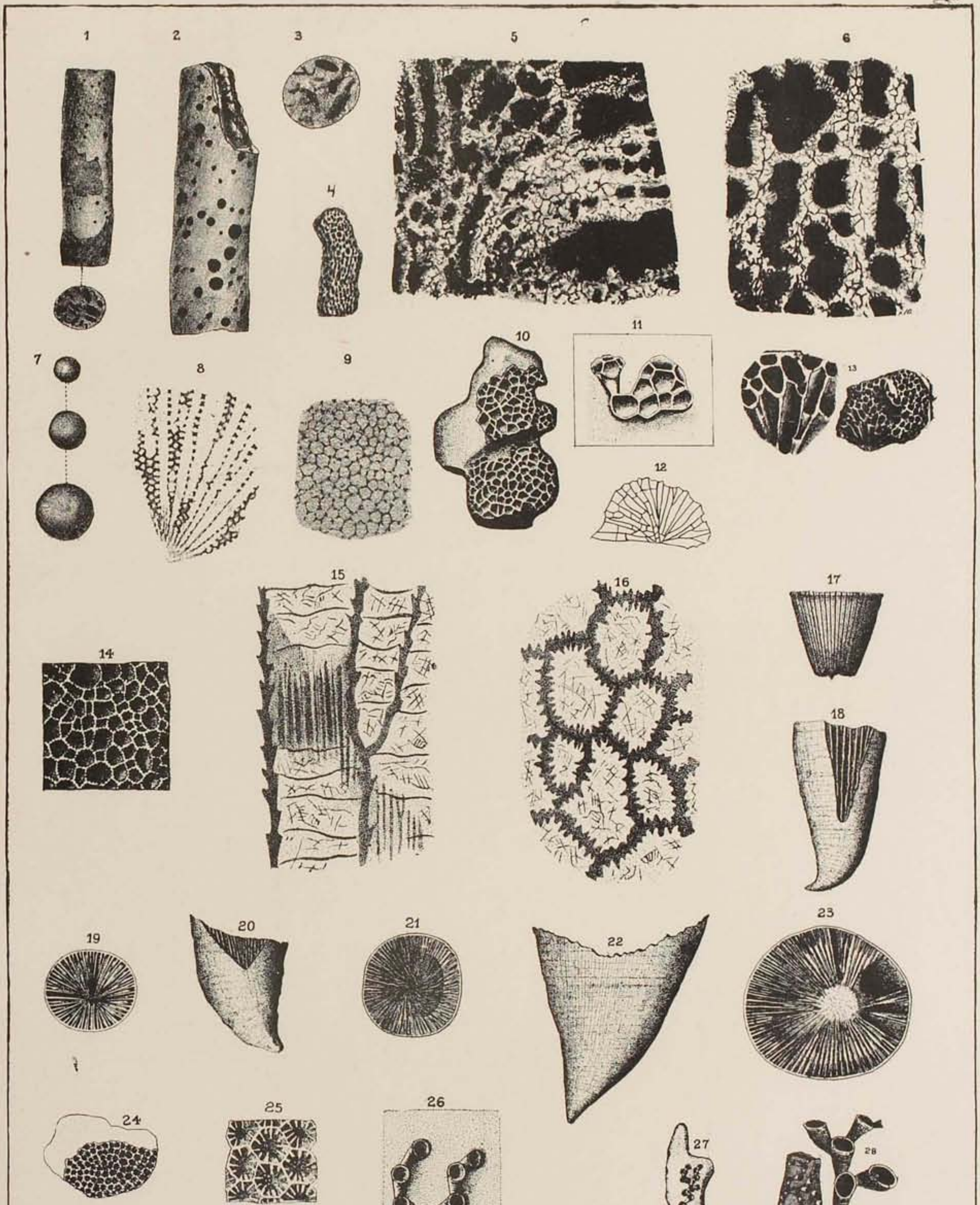
Figs. 26 to 28. AULOPORA (?) TRENTONENSIS, n. sp. 95

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.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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 cōnical 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–2o; 1868.

R. BURSIFORMIS *Hall.*

1863. *Receptaculites eatoni* 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.

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*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 aickhauti* 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).

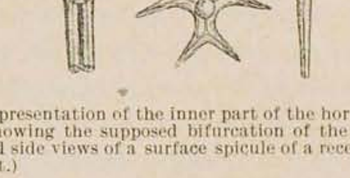

Fig. 1, *a*, diagrammatic representation of the inner part of the horizontal rays of a spicule of *Anomalospongia reticulata*, showing the supposed bifurcation of the rays and axial canals. *b* and *c*, highly magnified top and side views of a surface spicule of a recent lithistid sponge. (*Corallistes 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 stiongly 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."

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*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*.

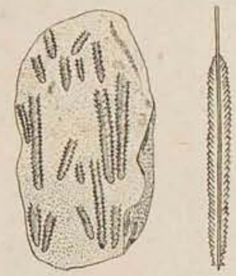

FIG. 2.

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 (Diplograptus) 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.*

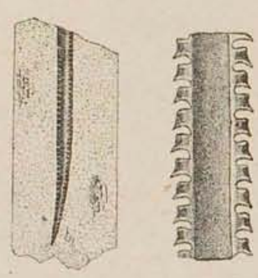

FIG. 4.

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

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*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.*)

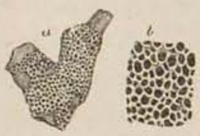

FIG. 5.

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, New York; 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*).

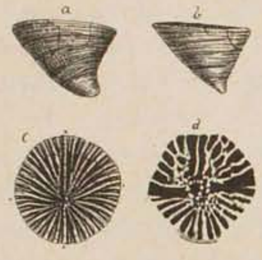

FIG. 7.

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 pseudo-columella. 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, *Diplopora* 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, *Caltrypa* 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., ? *Hedrella* HALL, ? *Hernodia* HALL, ? *Reptaria* ROLLE.

Family FRONDIPORIDÆ, *Reuss*.

Genus: *Scenellopora* 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 ETHERIDGE, *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.

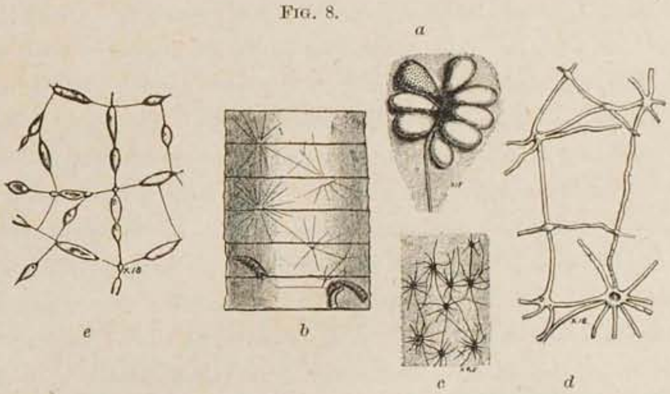

Figure *b* of the same cut represents a natural size view of the only specimen seen of the Cincinnati form, that I propose naming VINELLA RADIALIS. It consists of four principal colonies or nuclei, growing upon an *Orthoceras*. Only the form is preserved, and even that not well. However, sufficient remains 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.
Diastoporella, 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 out. 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* (*?Mito clema*) 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.

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*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[1] ? *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 noncommittal 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 semi-cordate 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