

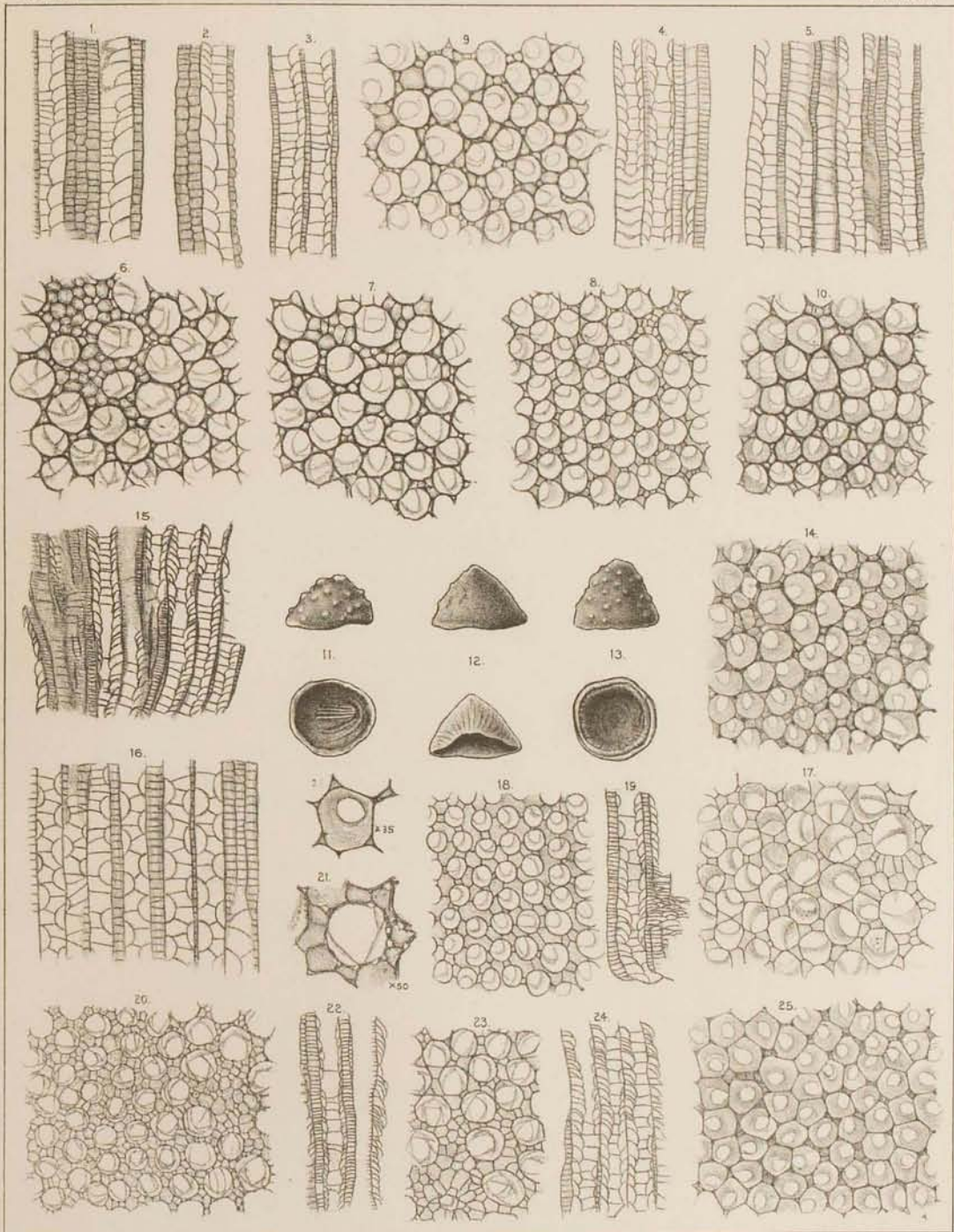
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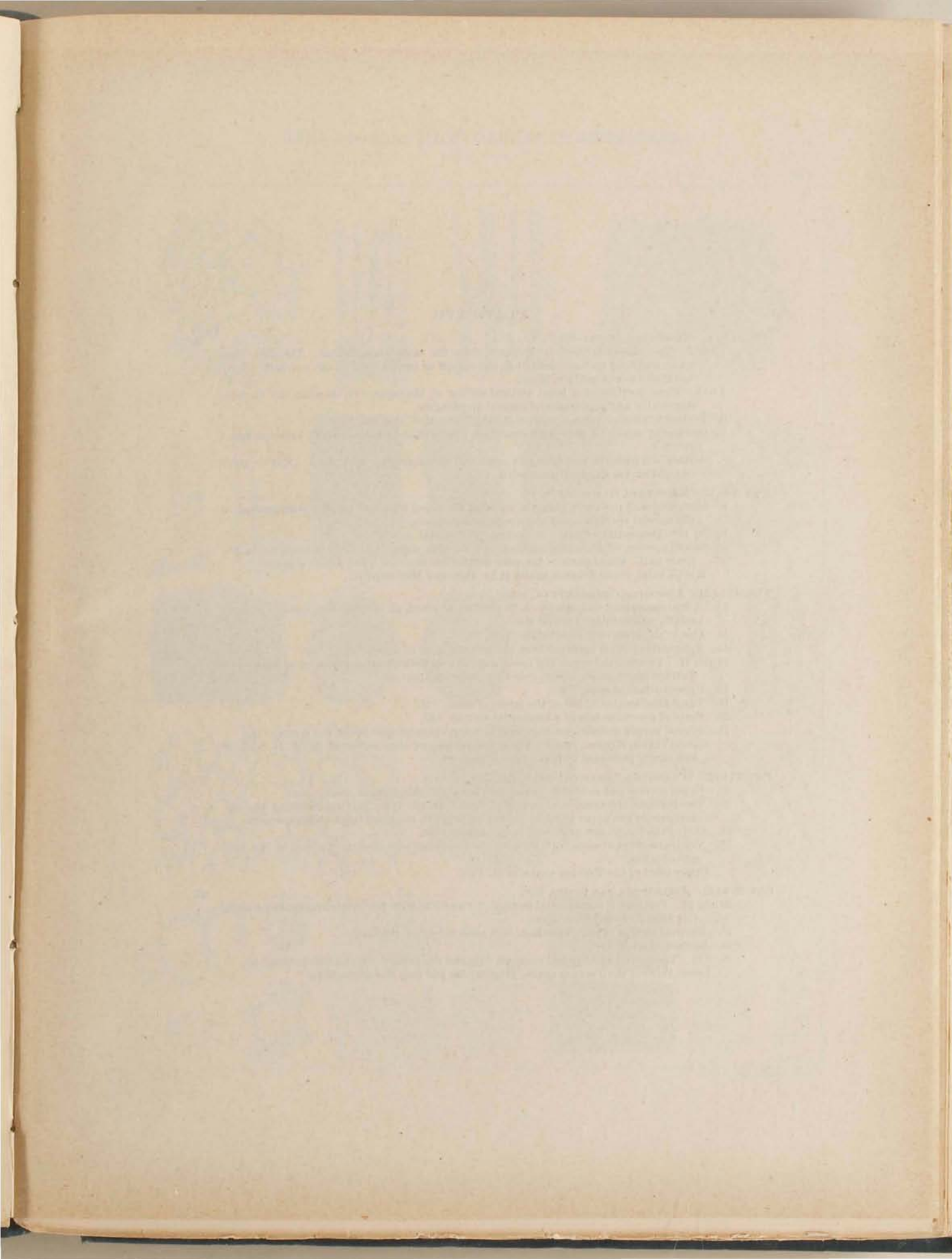
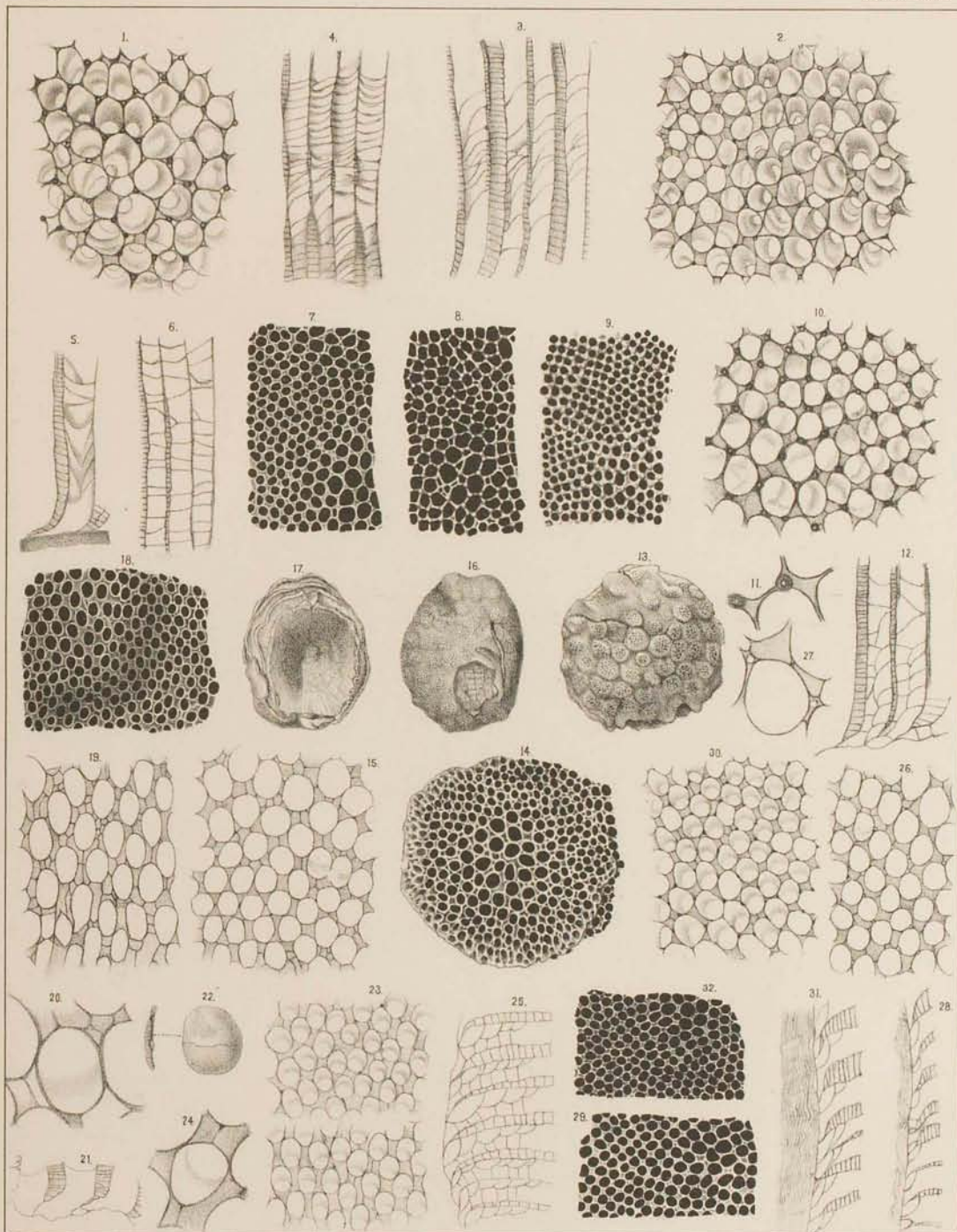


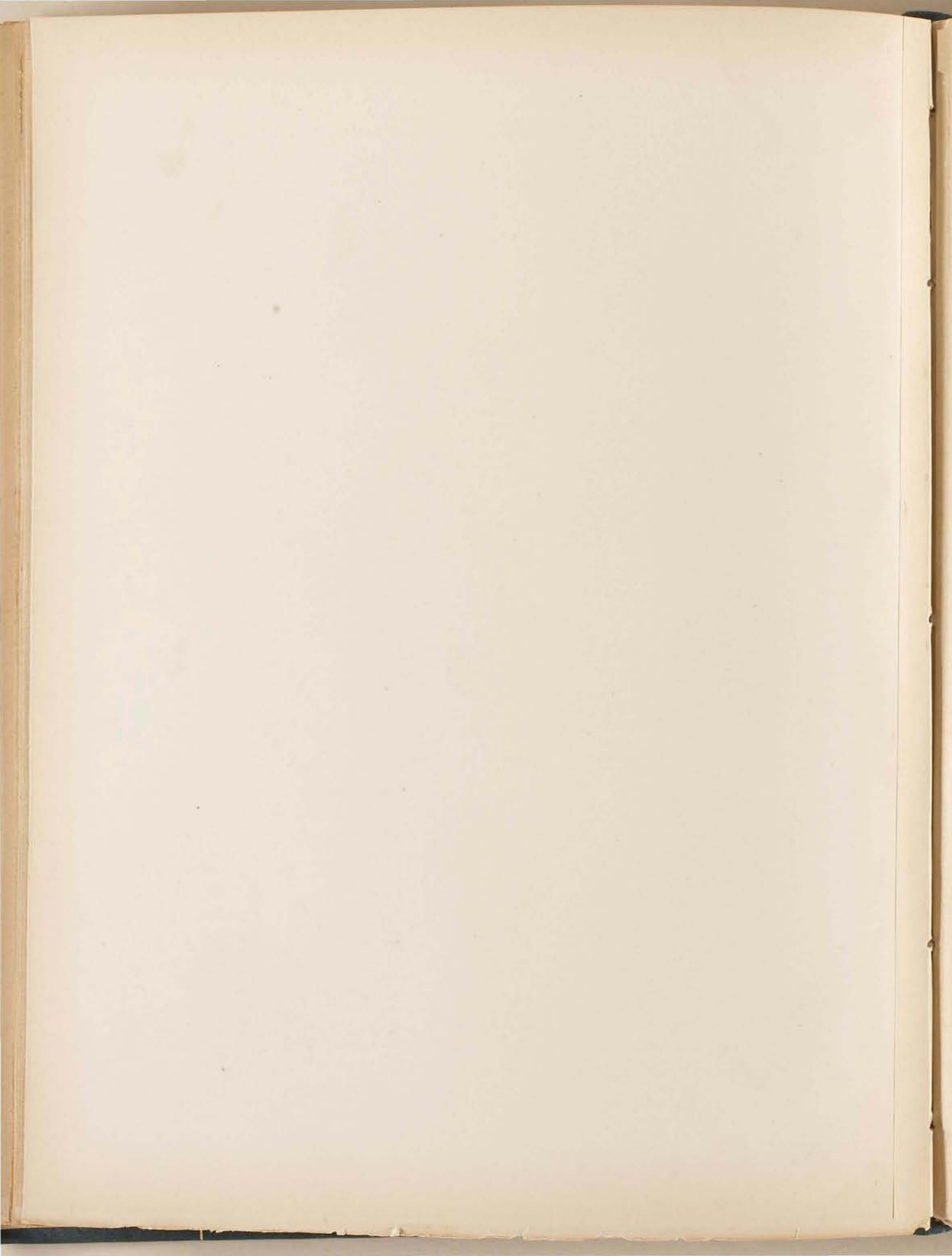
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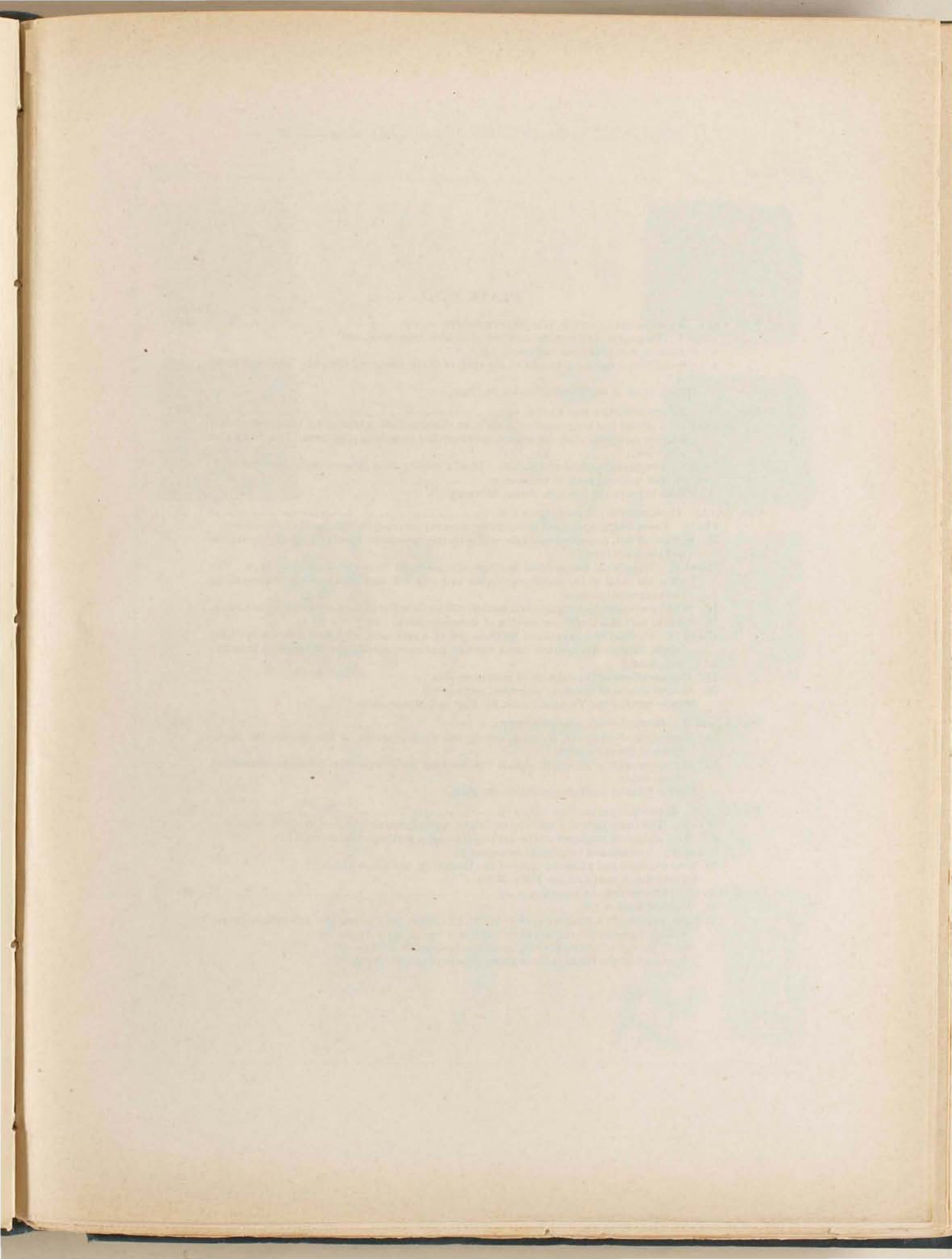
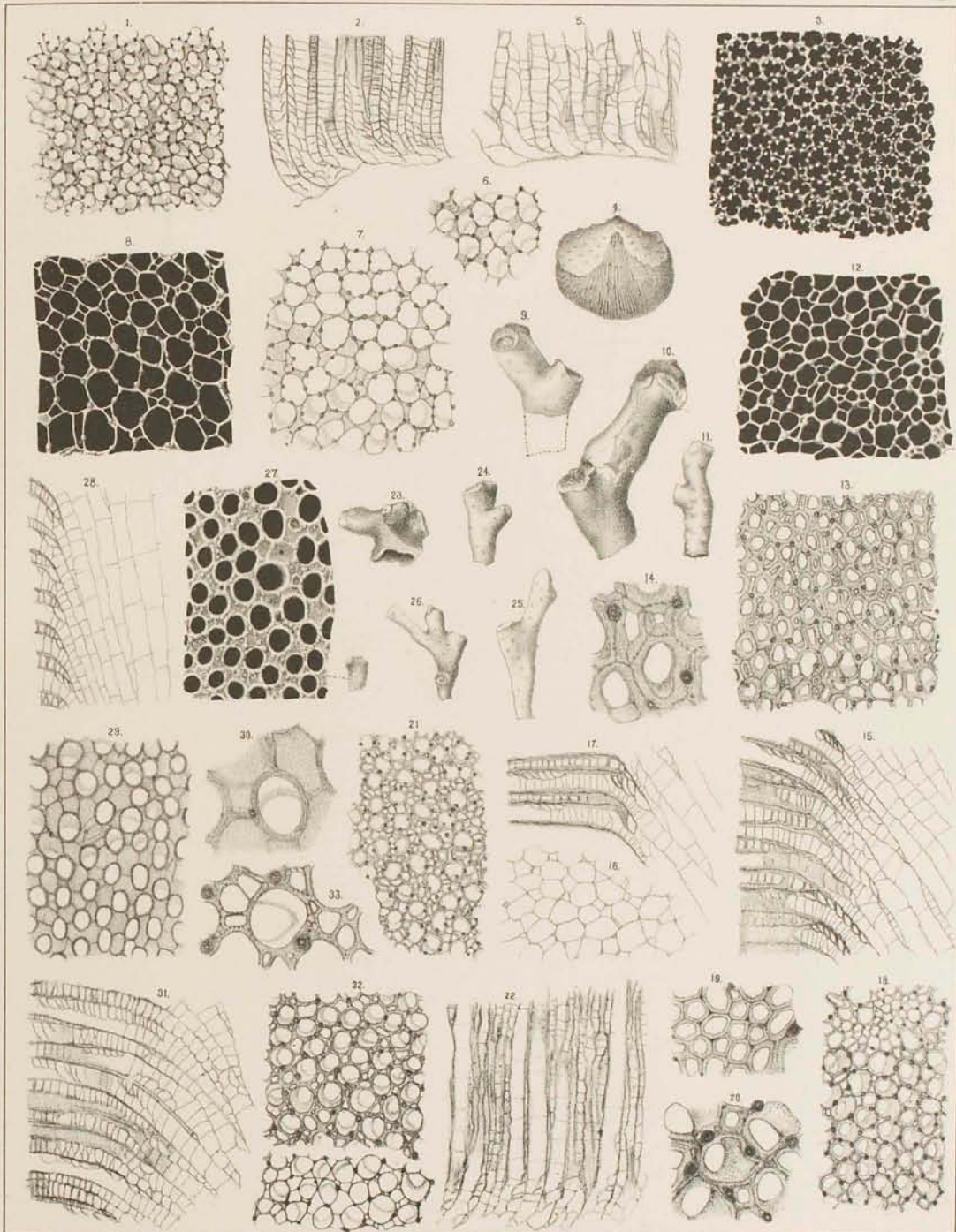


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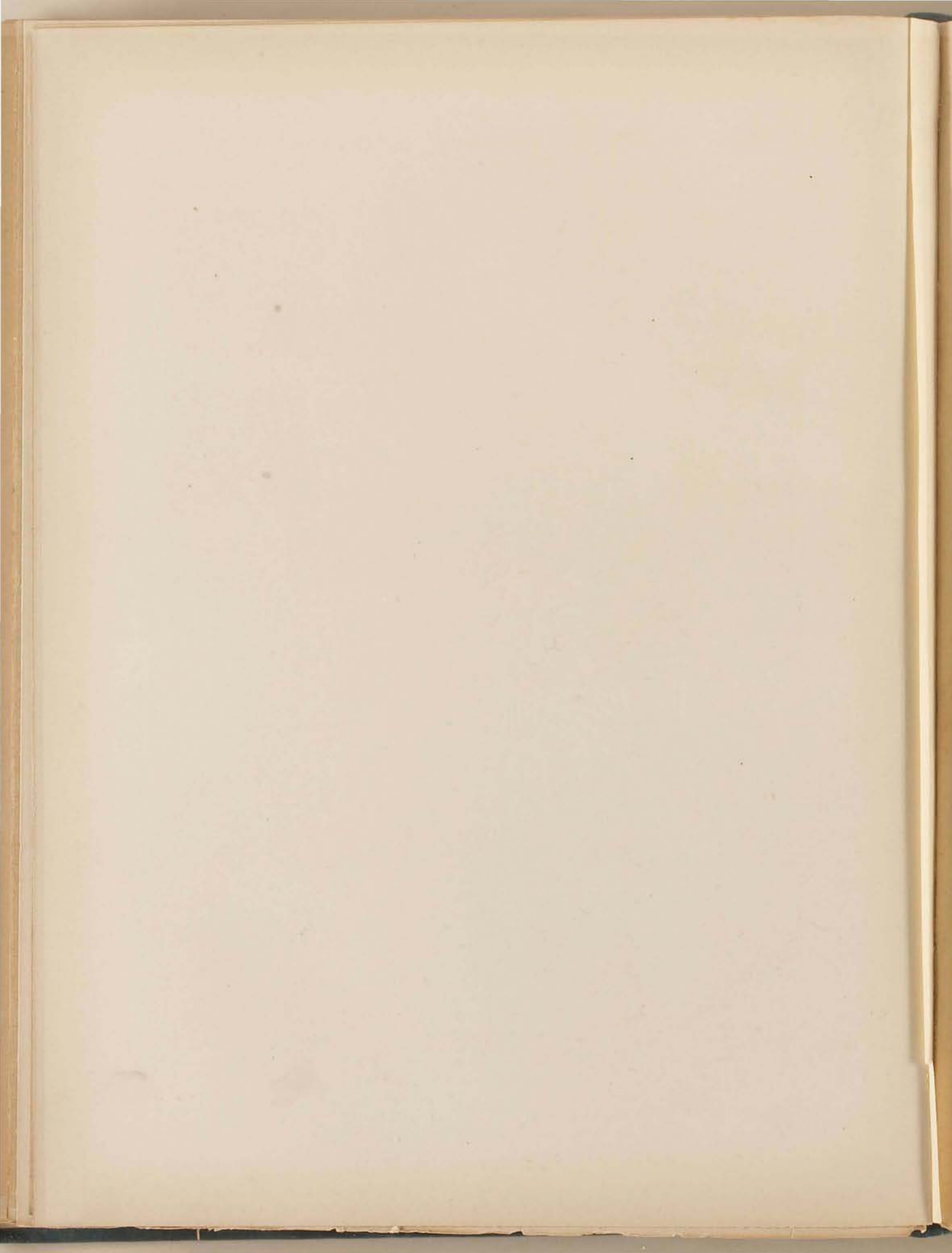


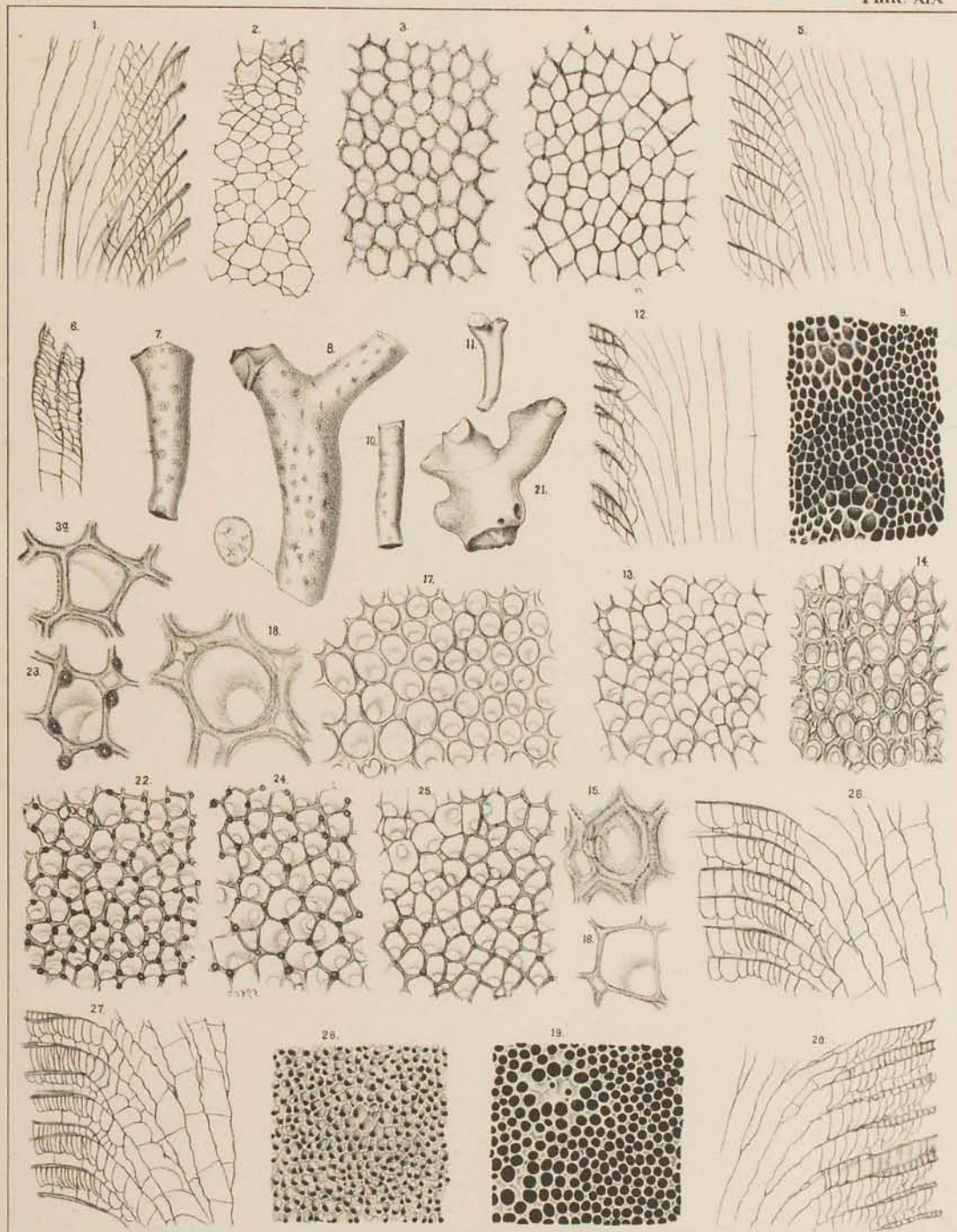
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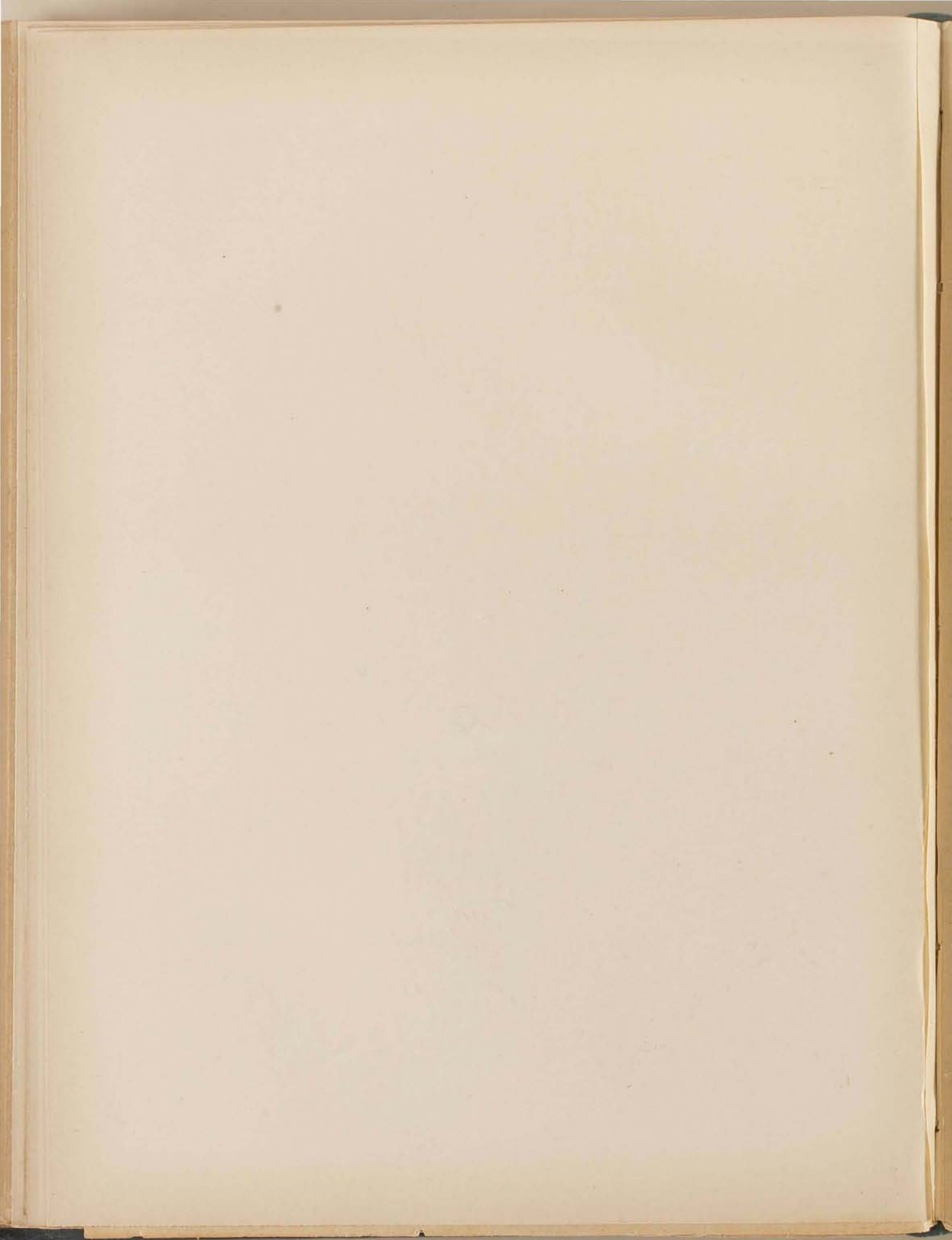
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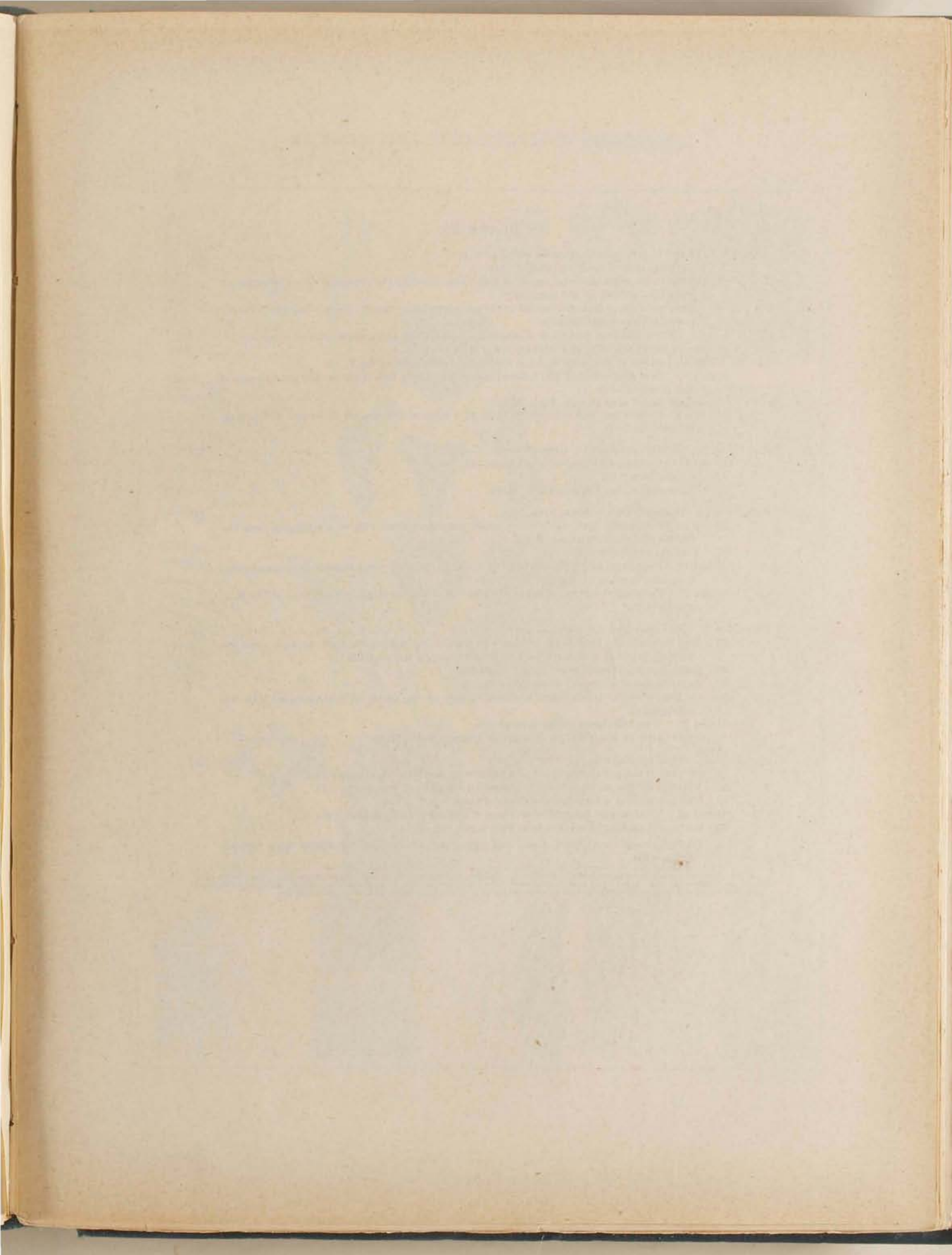
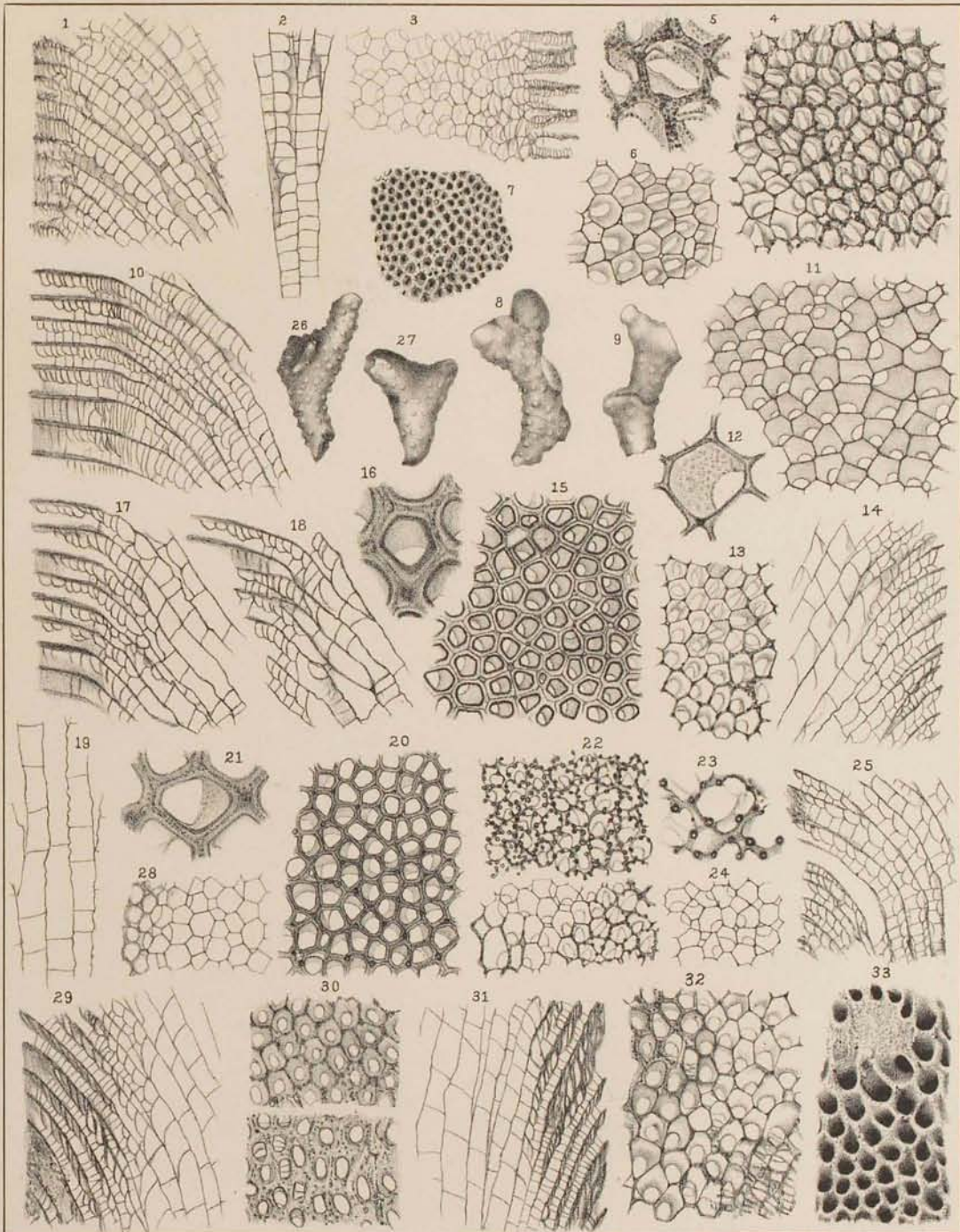


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*The systematic position of this species is doubtful. Though falling in a loose way under *Homotrypa* some of its characters are so peculiar that it can in no wise be regarded as a true representative of the genus. Thin sections are suggestively like those of *Homotrypa instabile* and in some features also simulate those of *Eridotrypa mutabilis*.



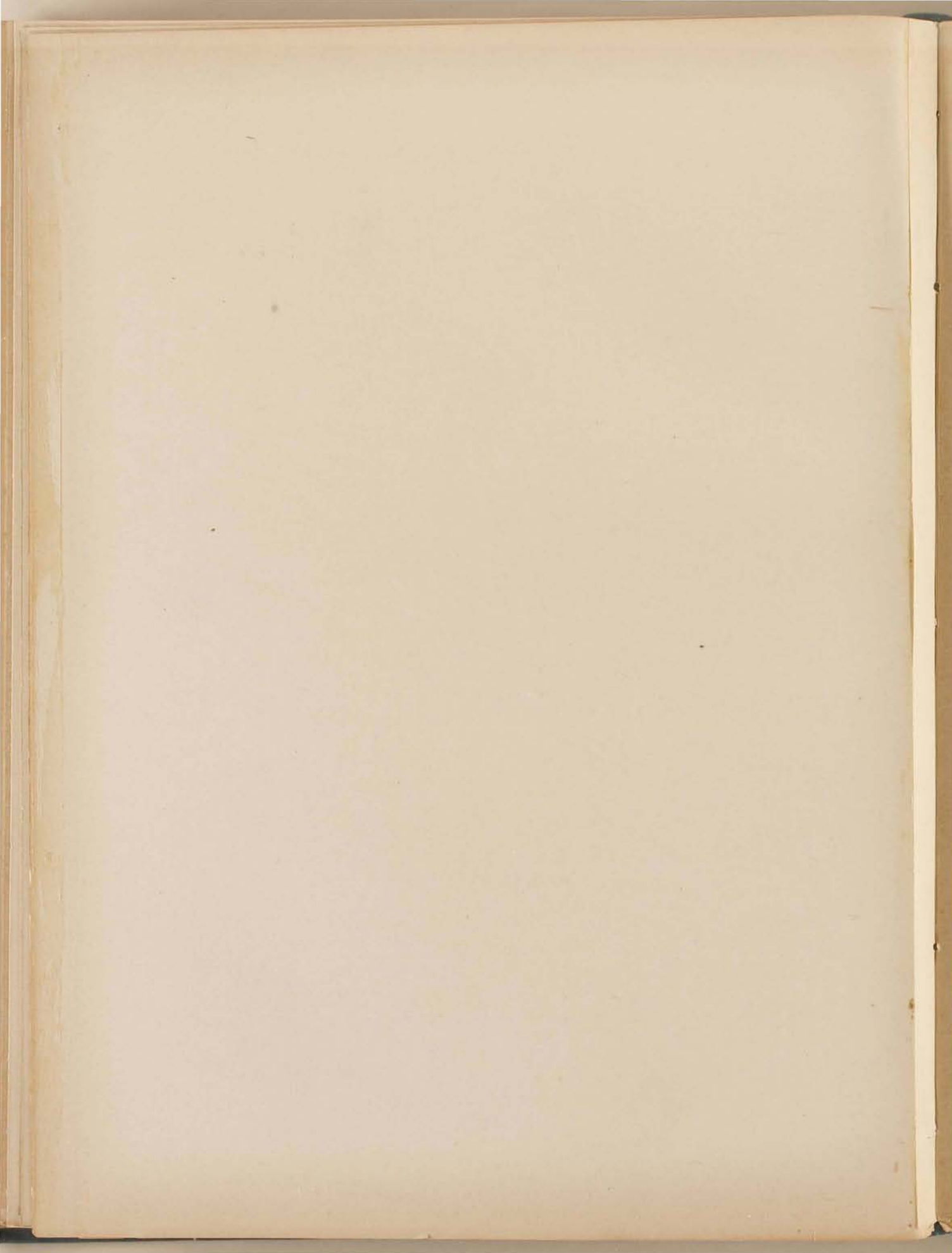


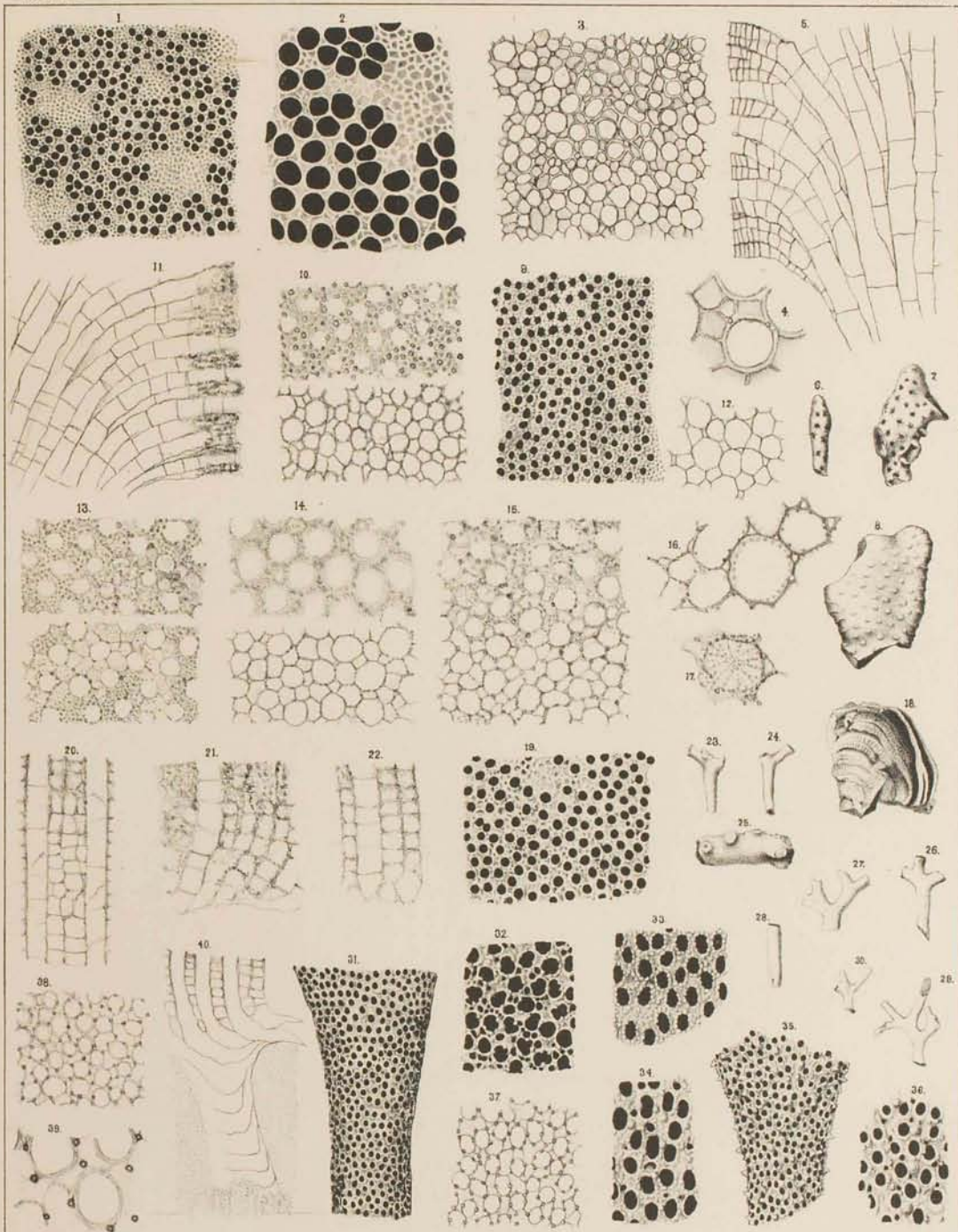
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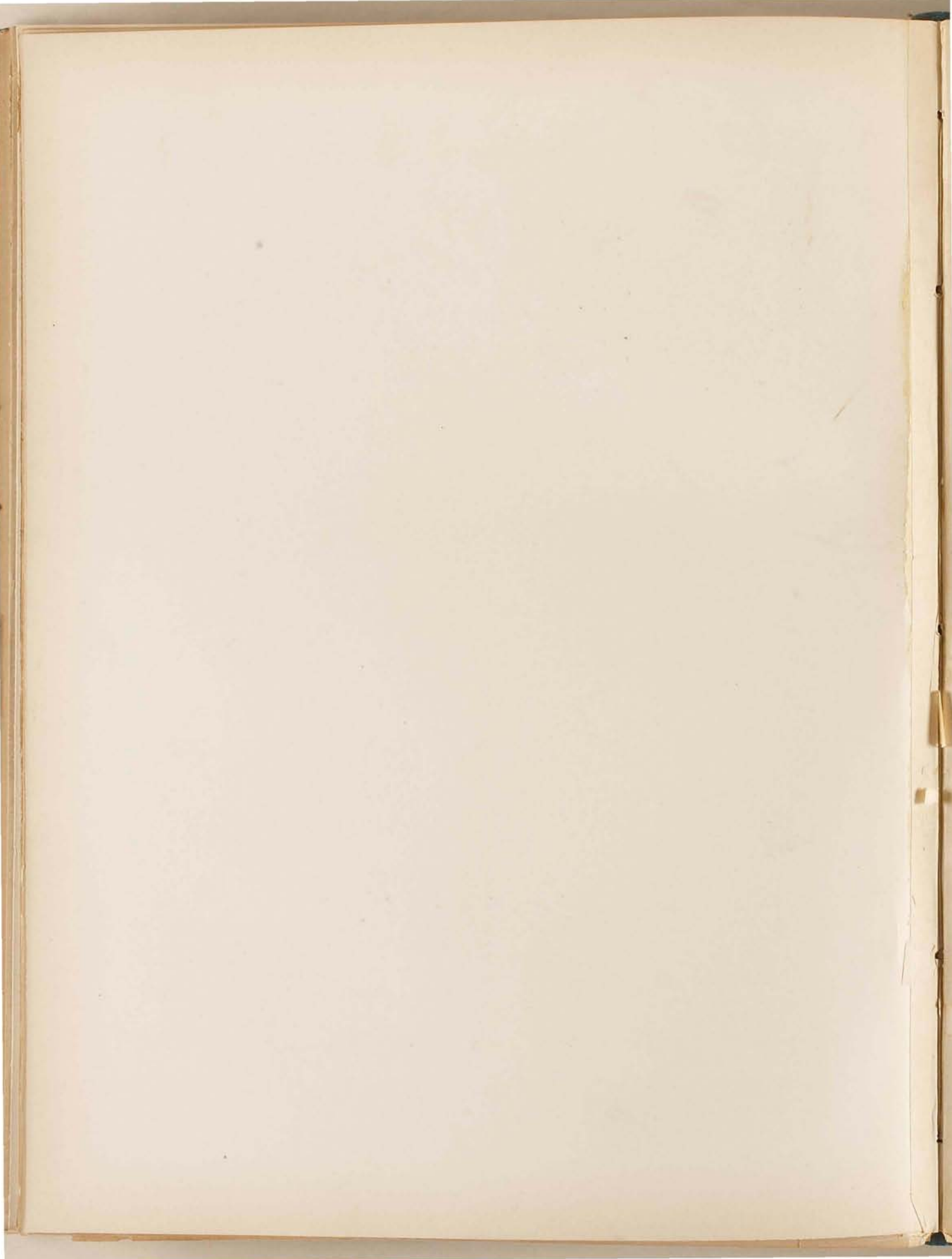
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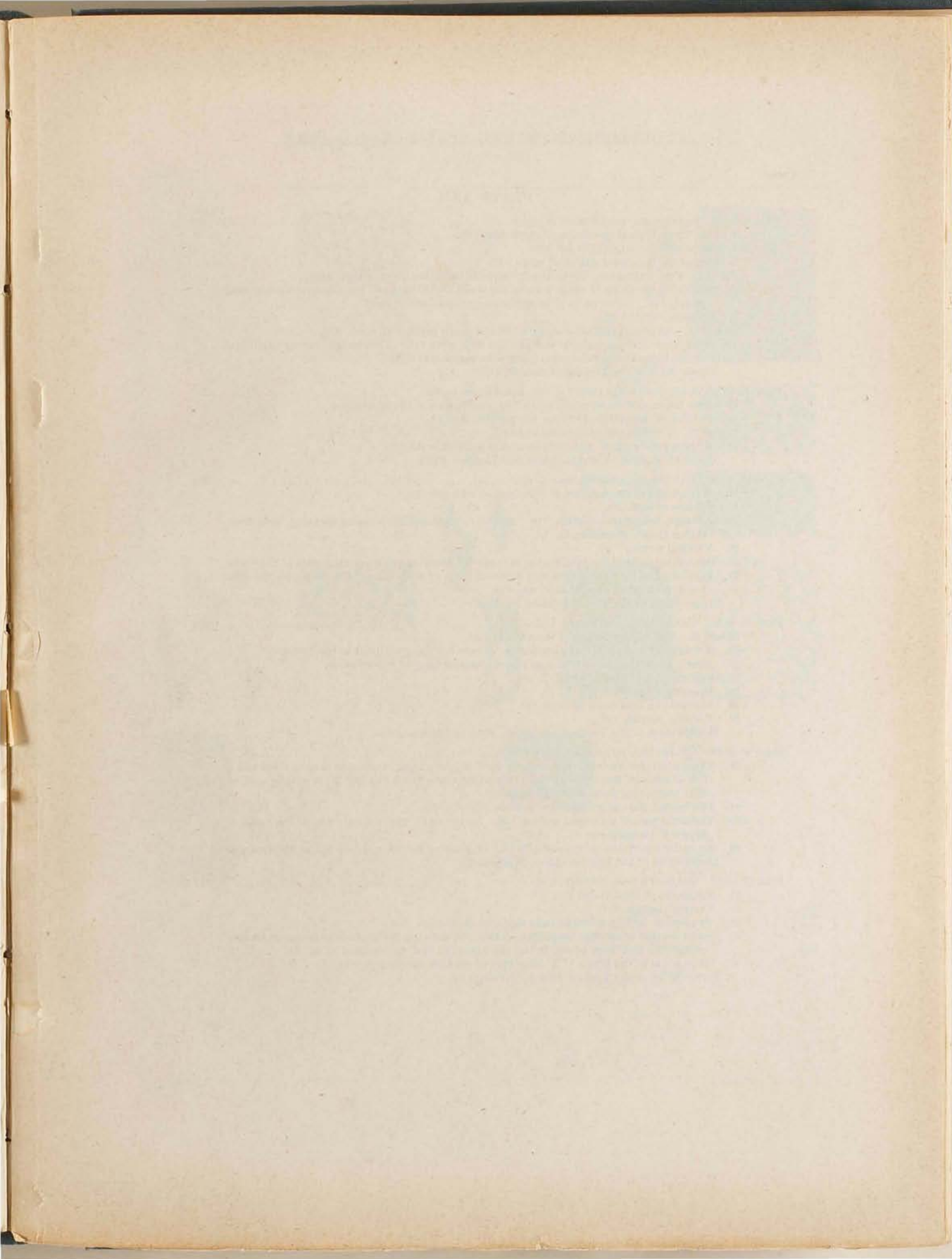
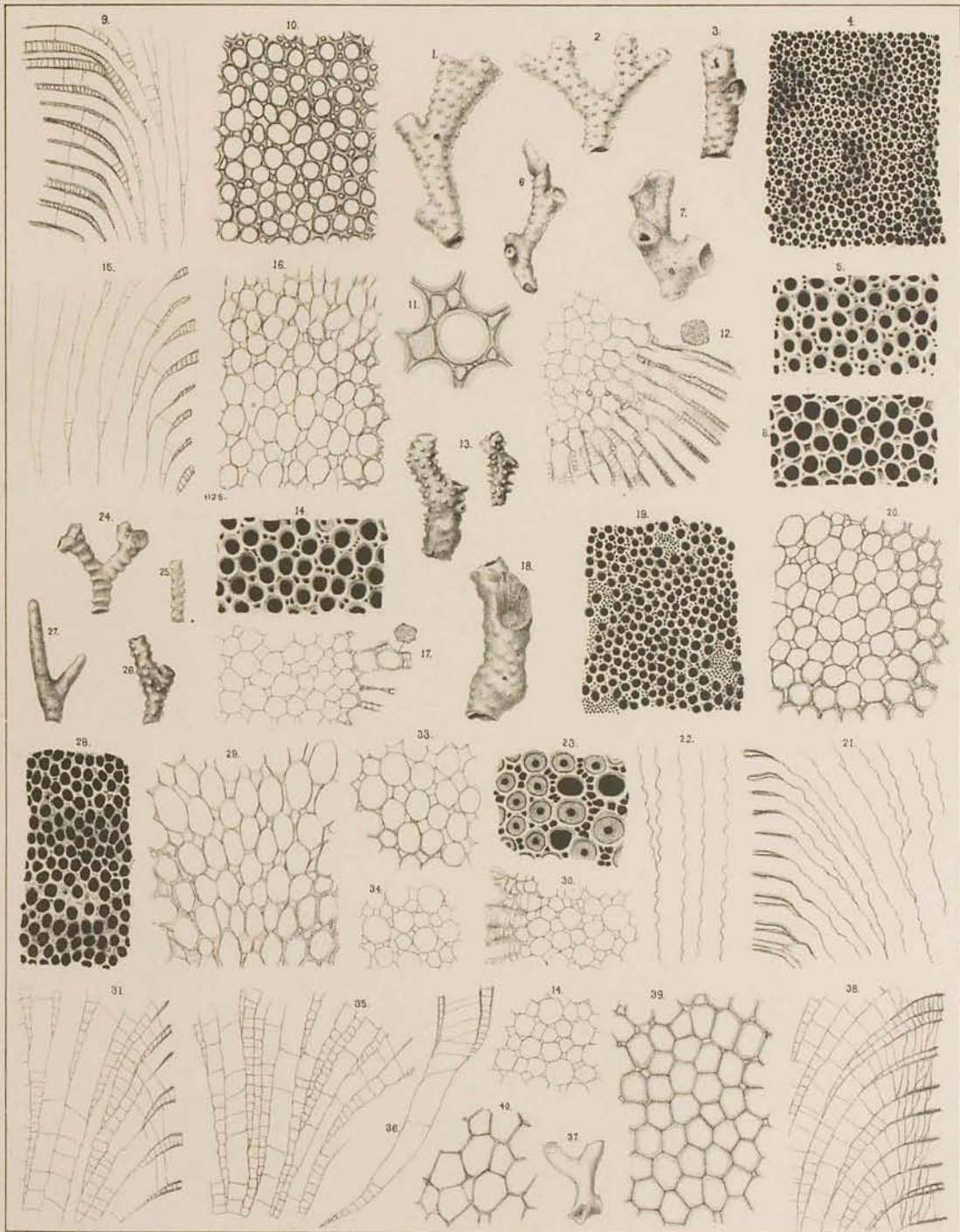
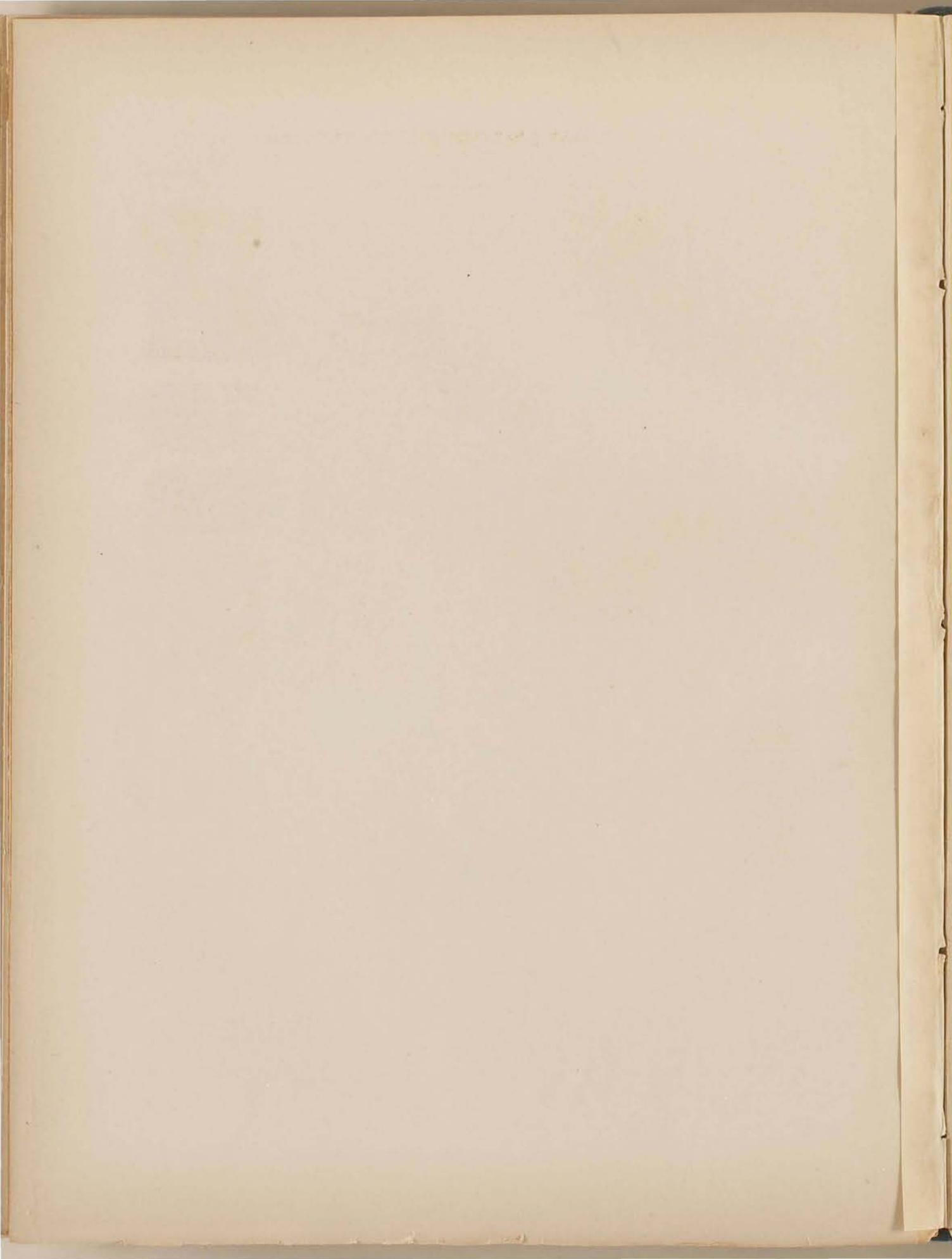


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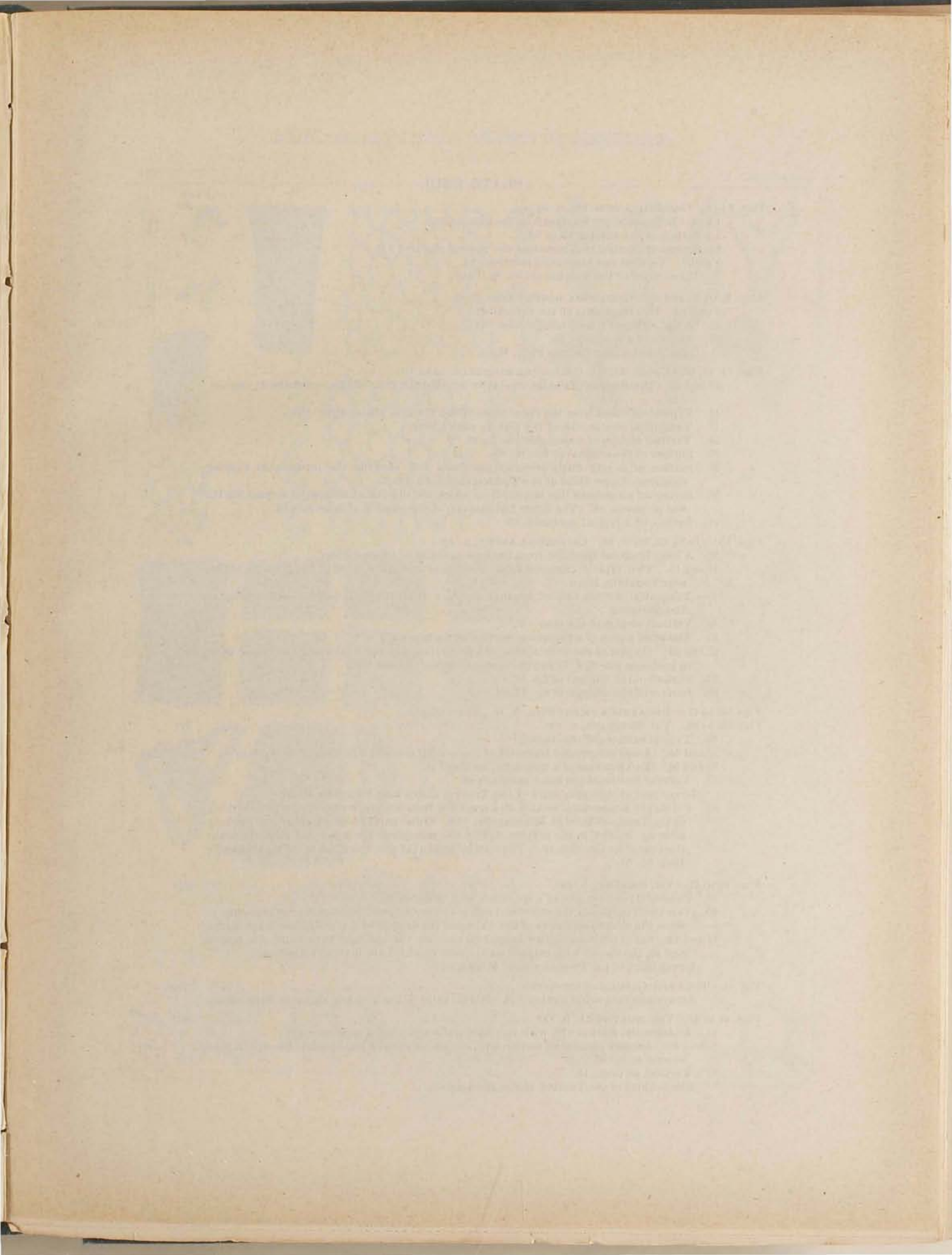


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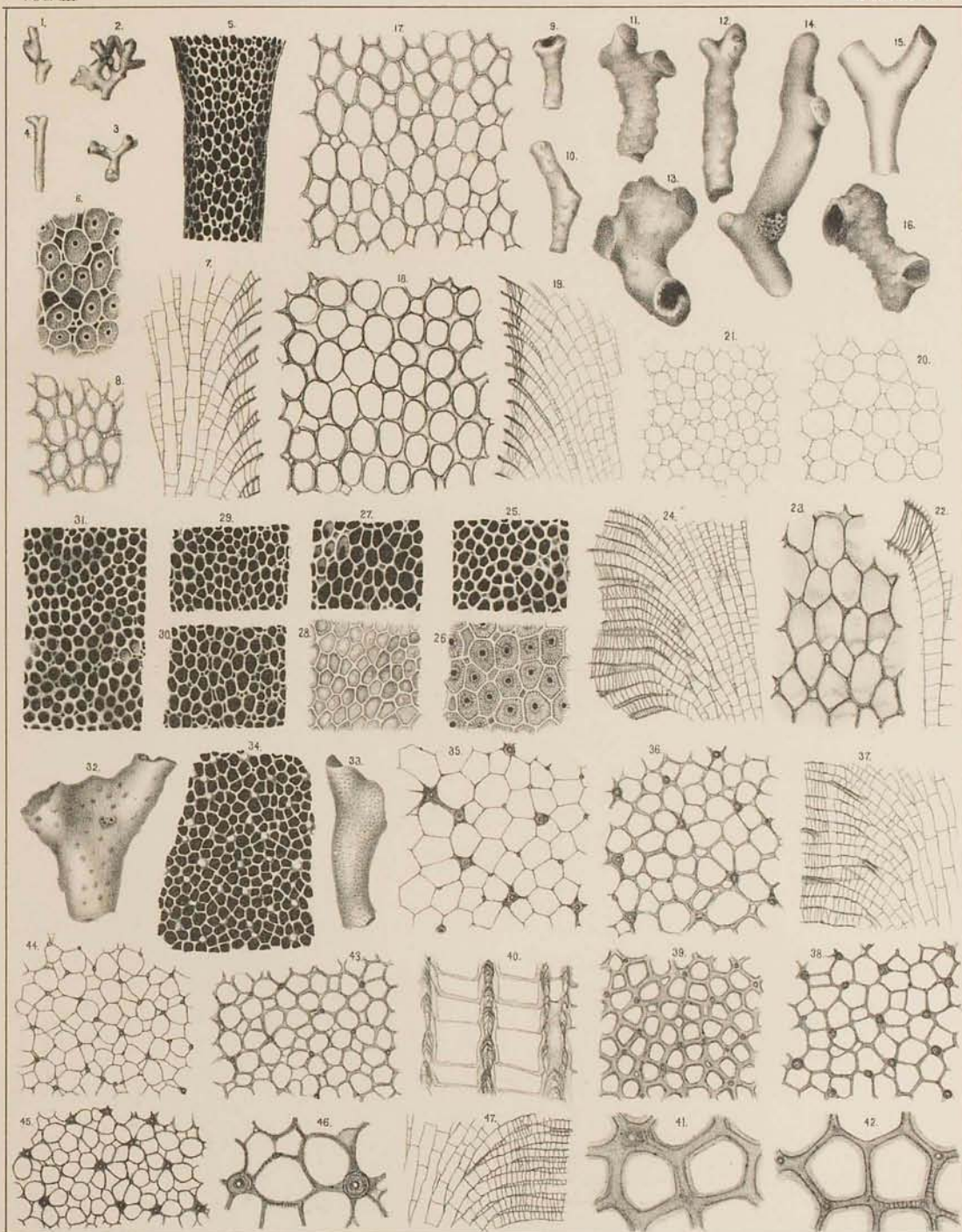
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CEDL. AND NAT. HIST. SURVEY OF MINNESOTA,
[Bryozoa]

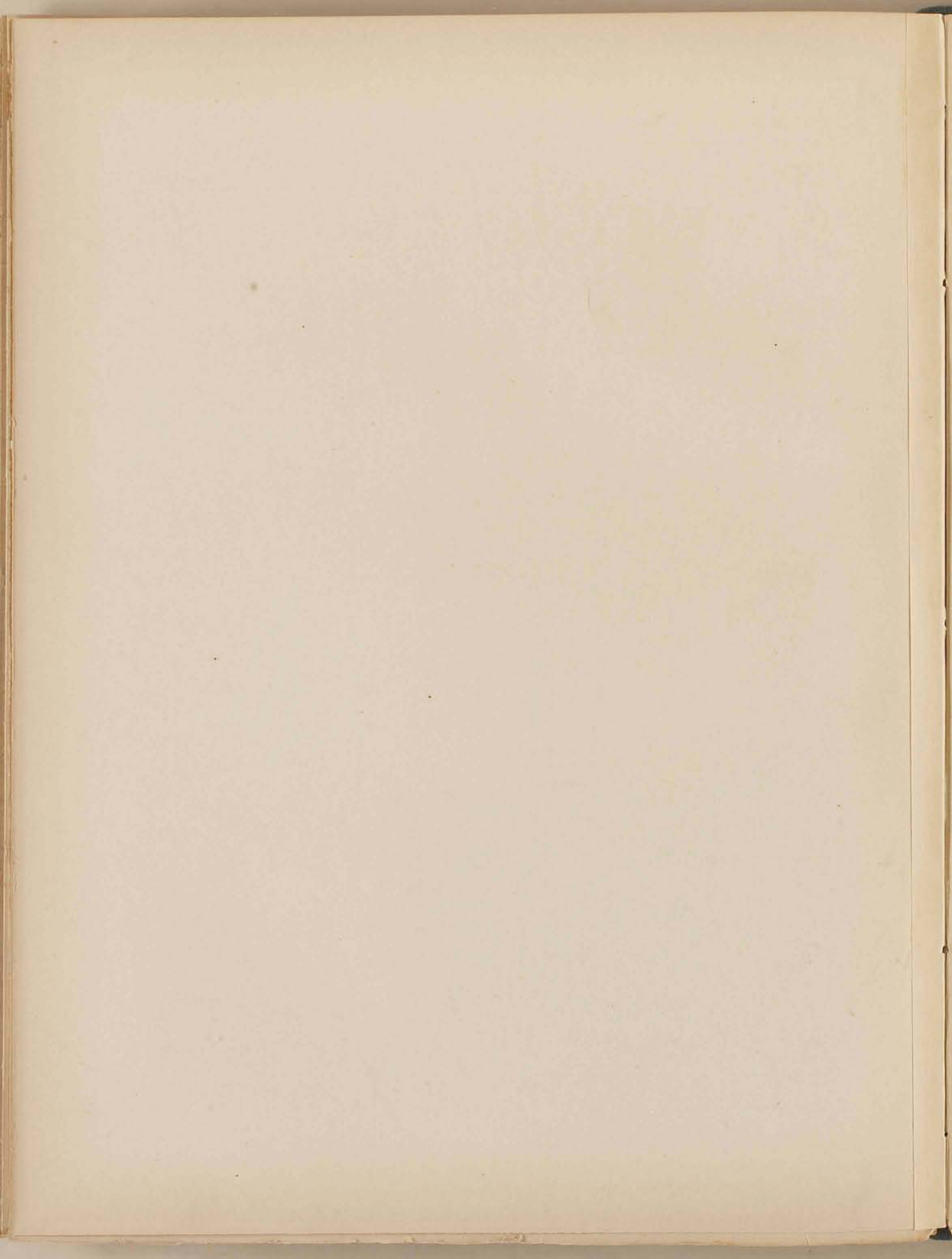
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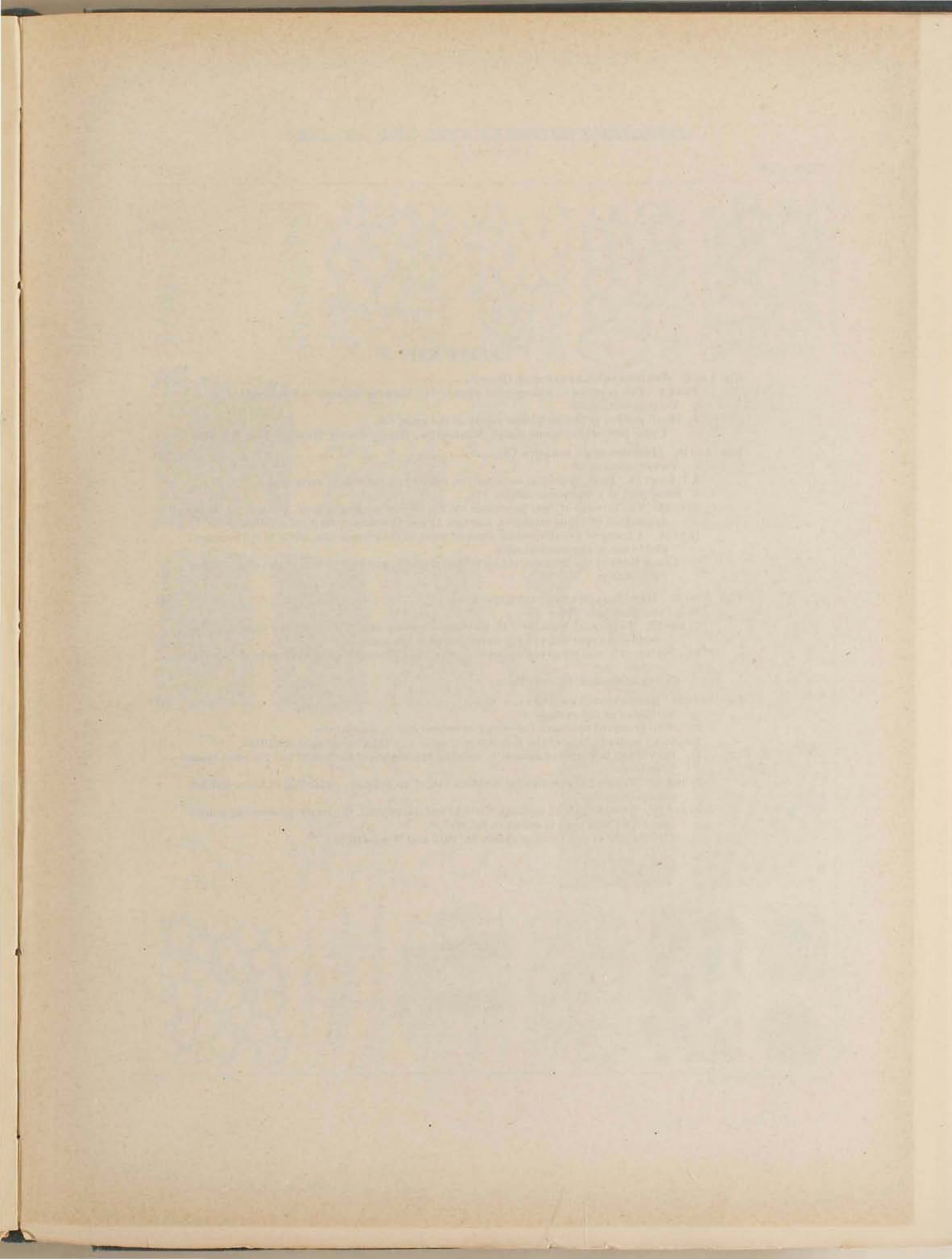


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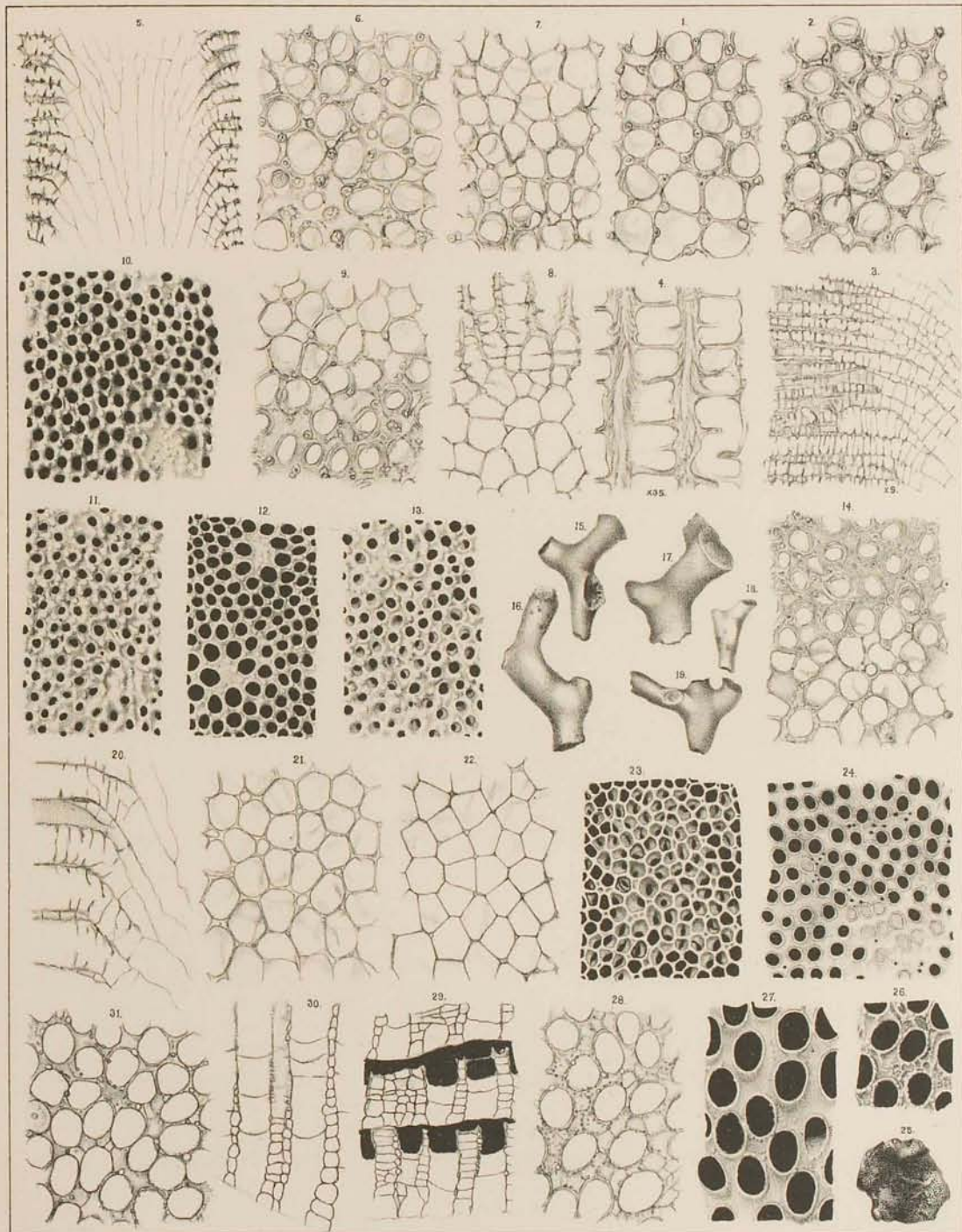
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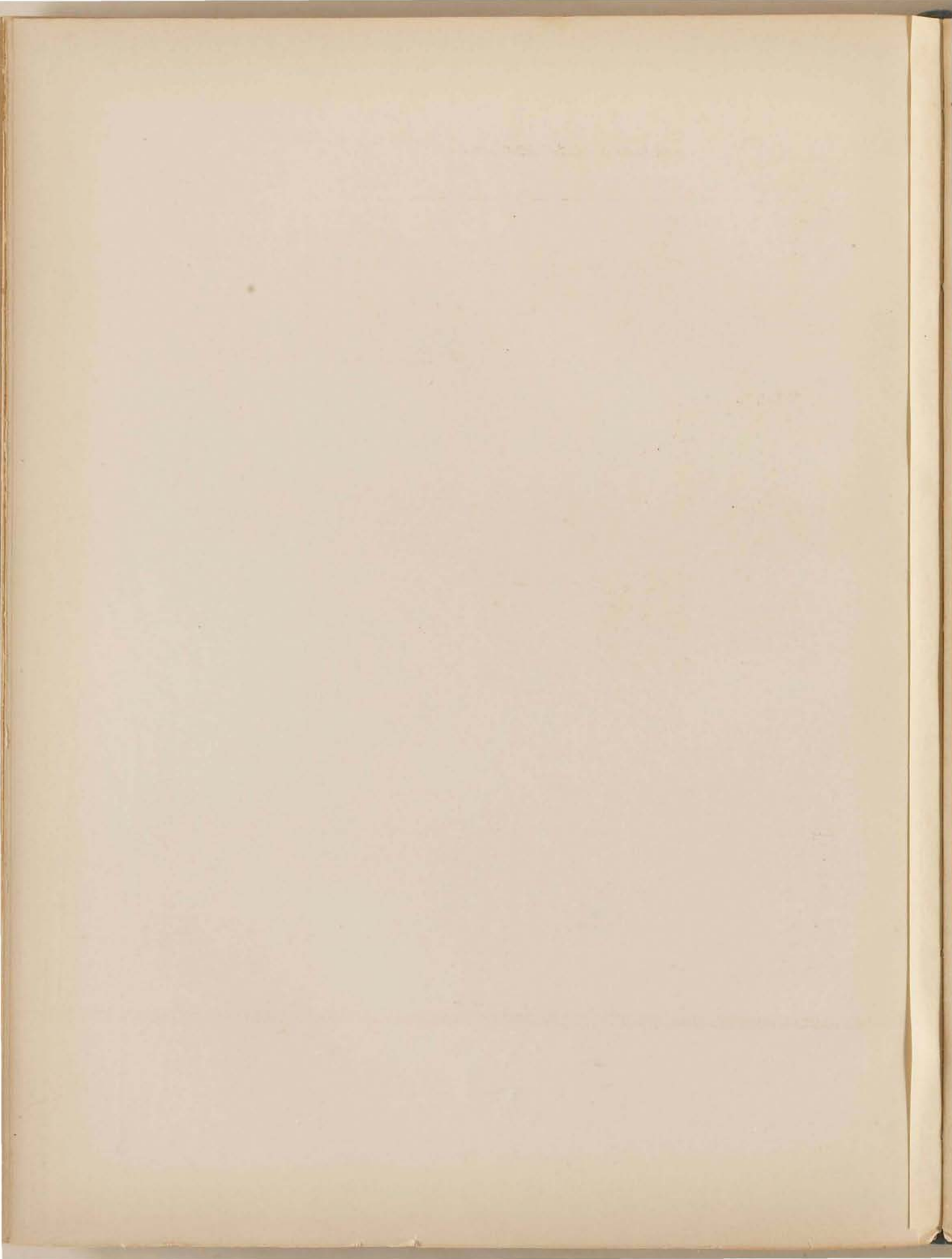
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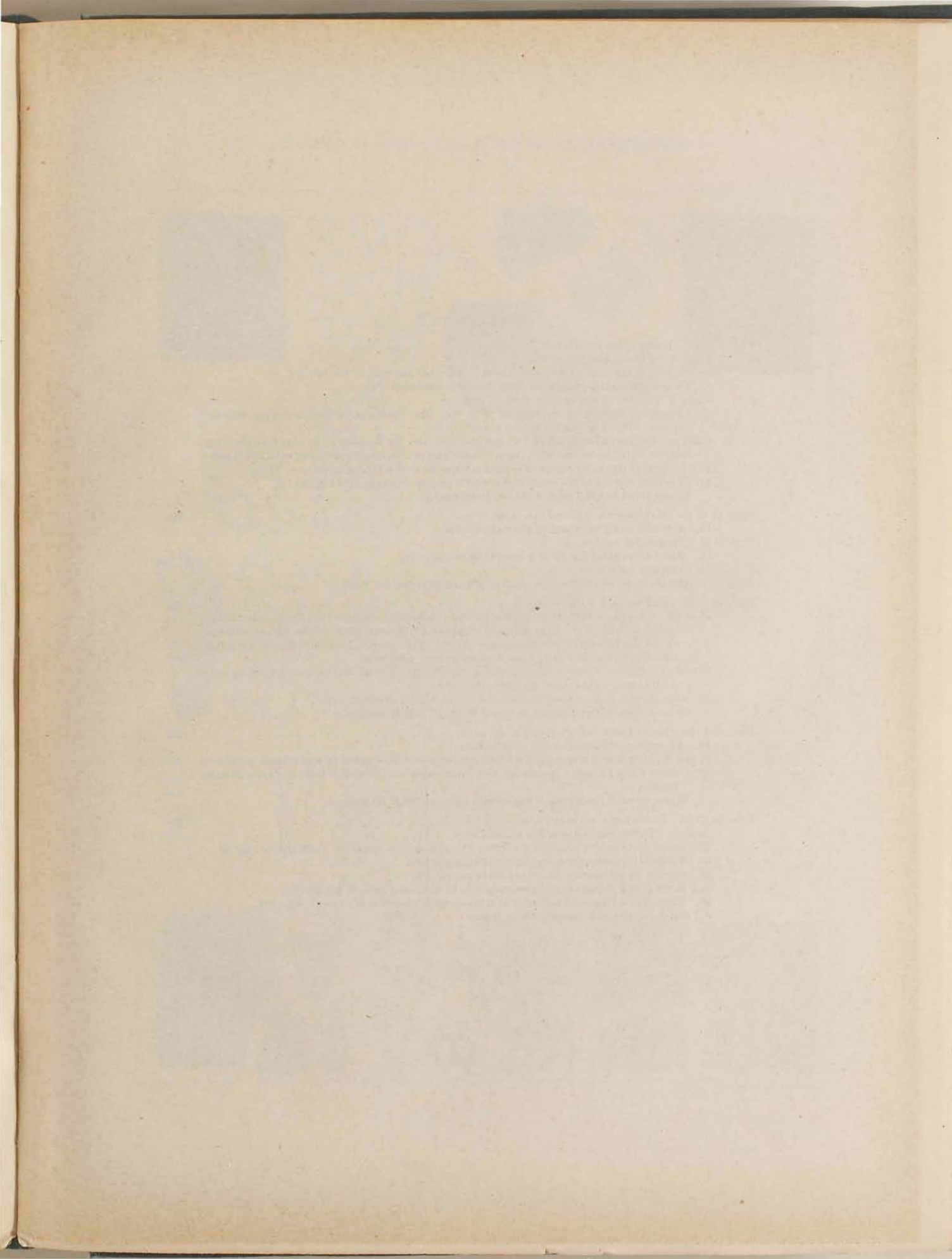
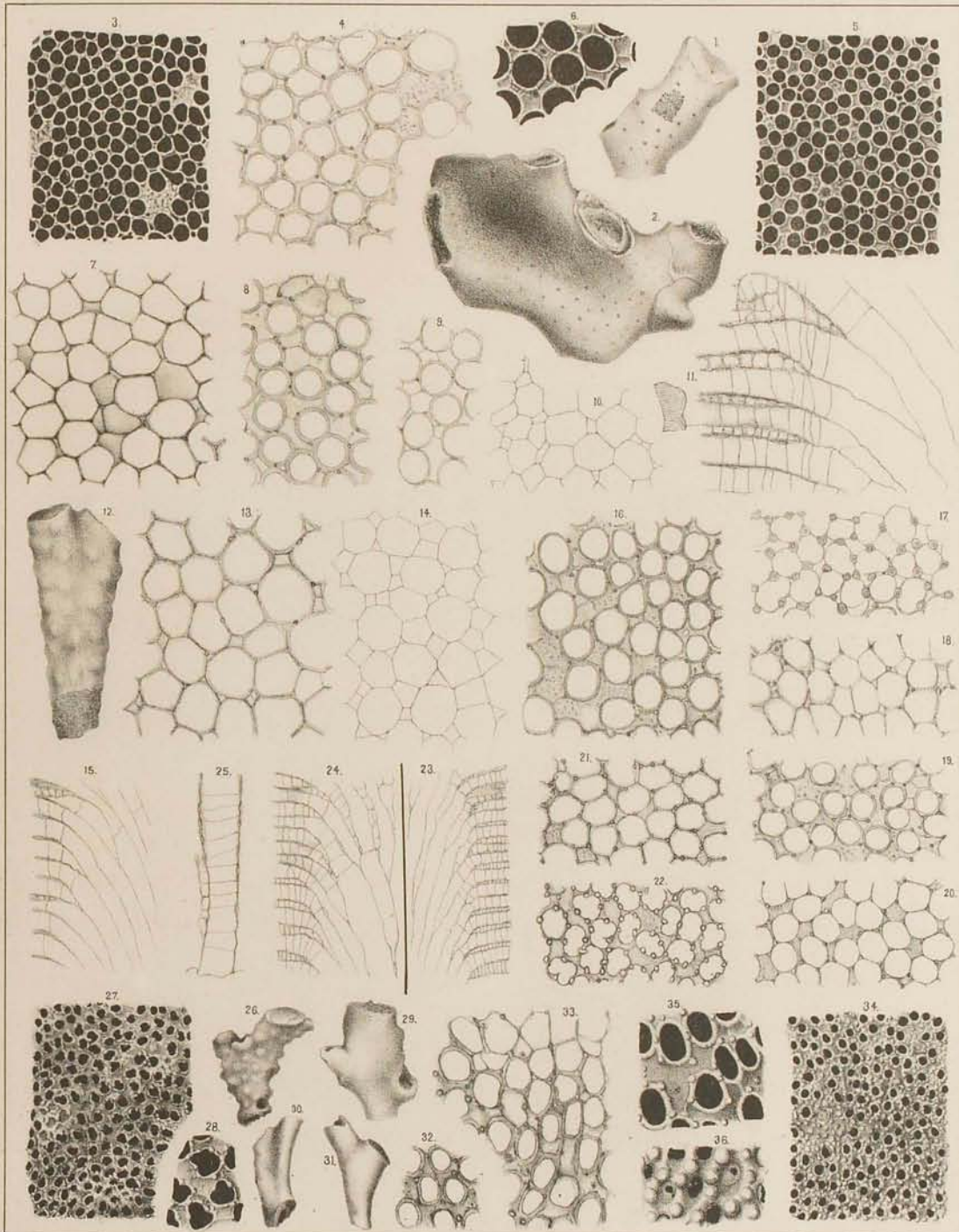


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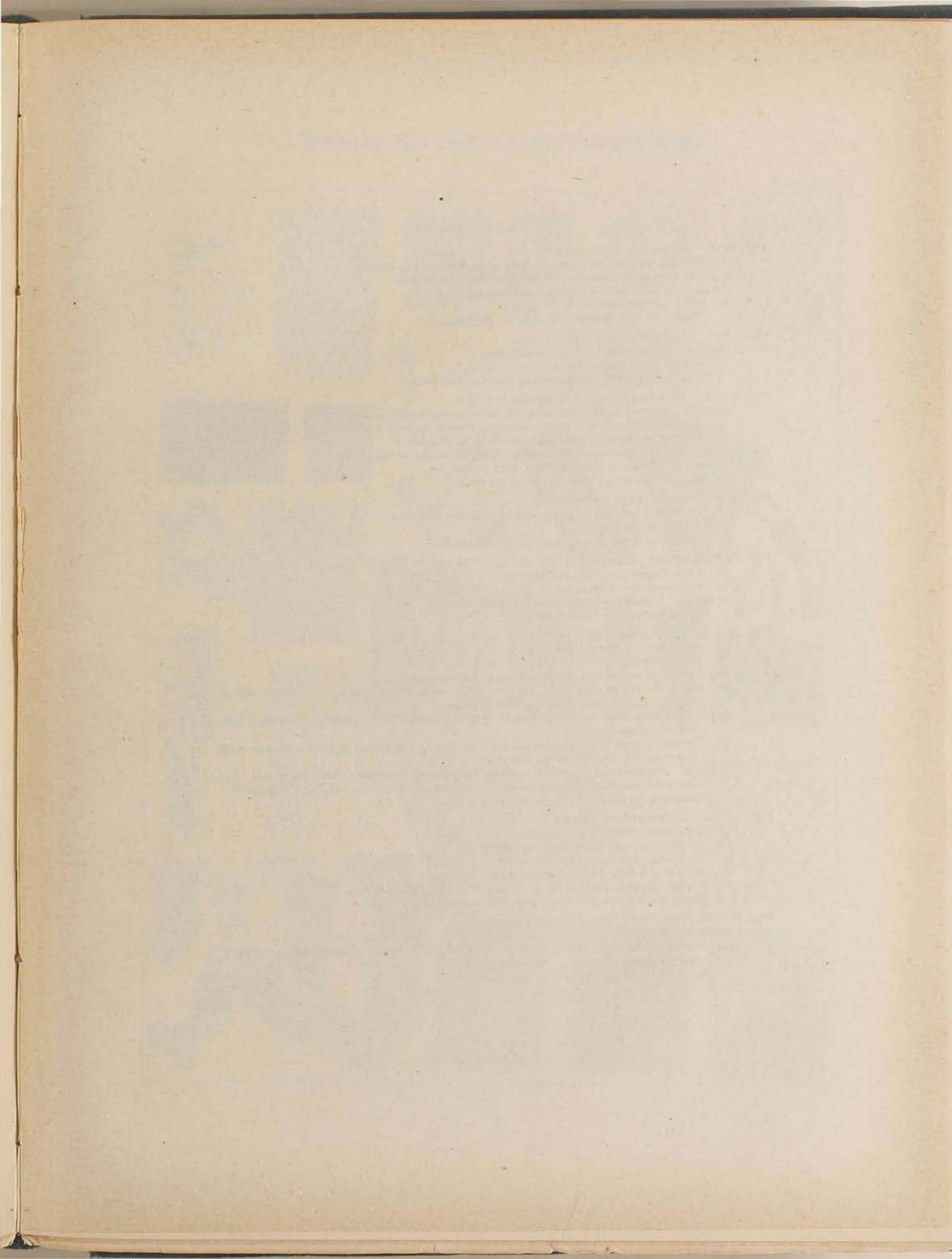
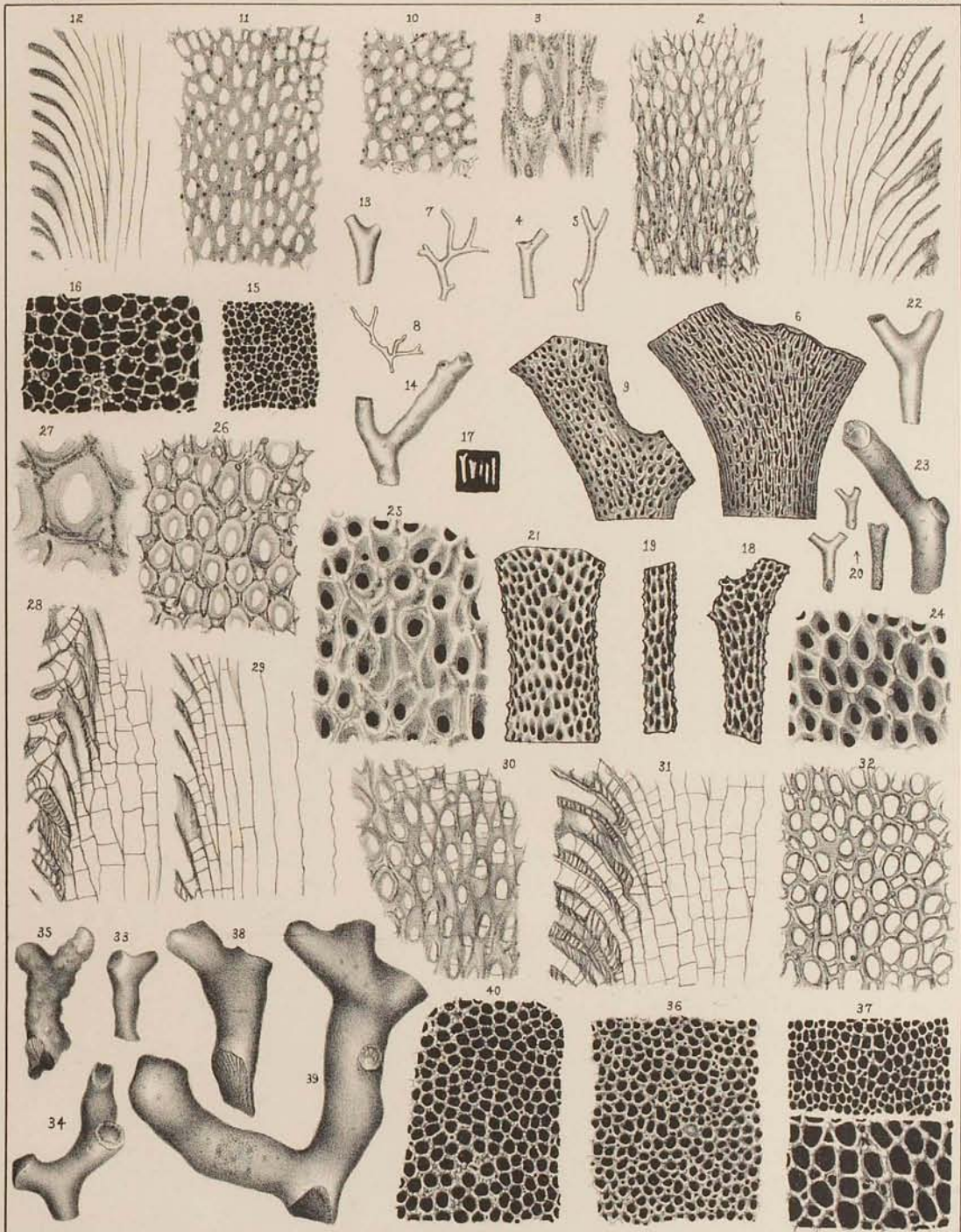


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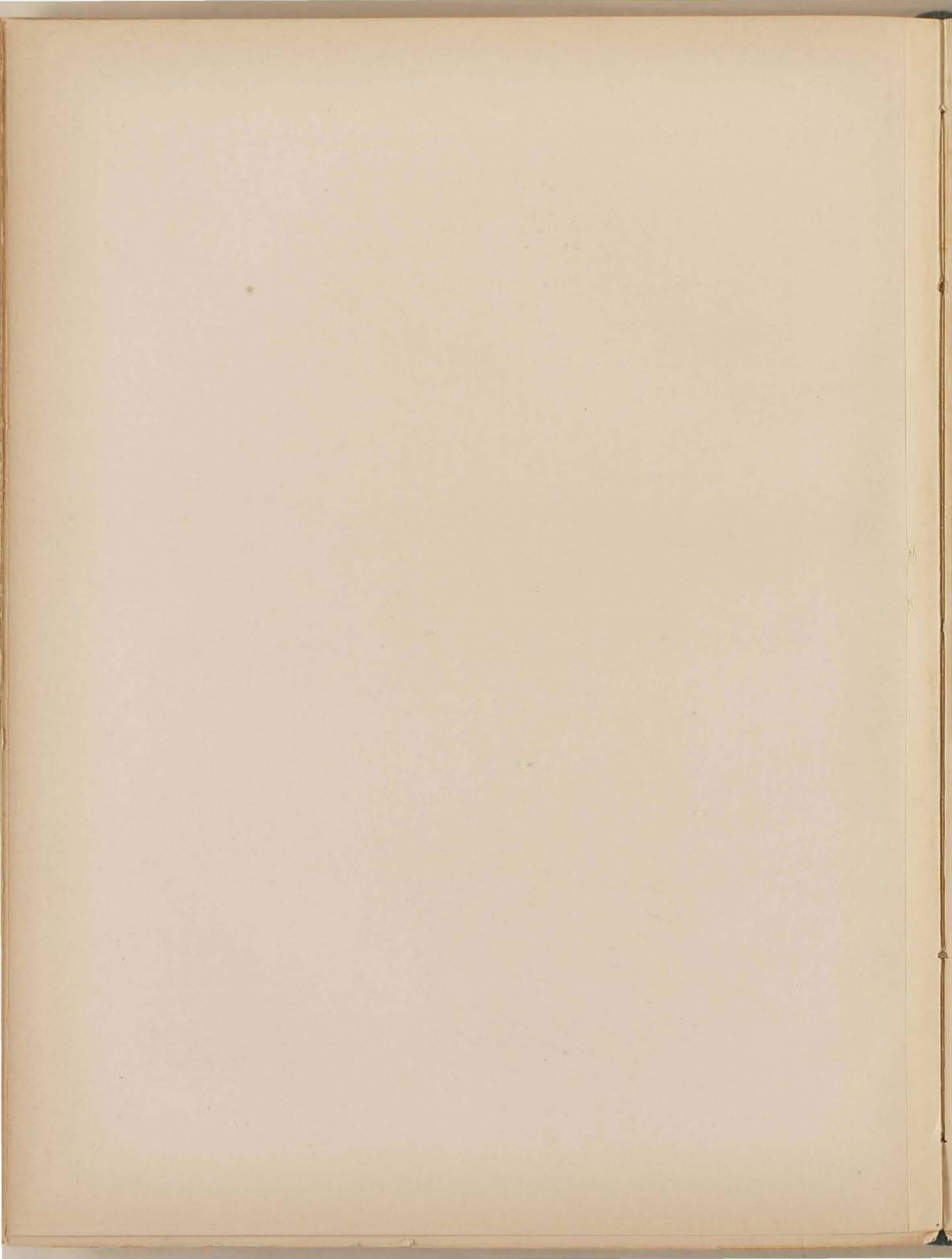
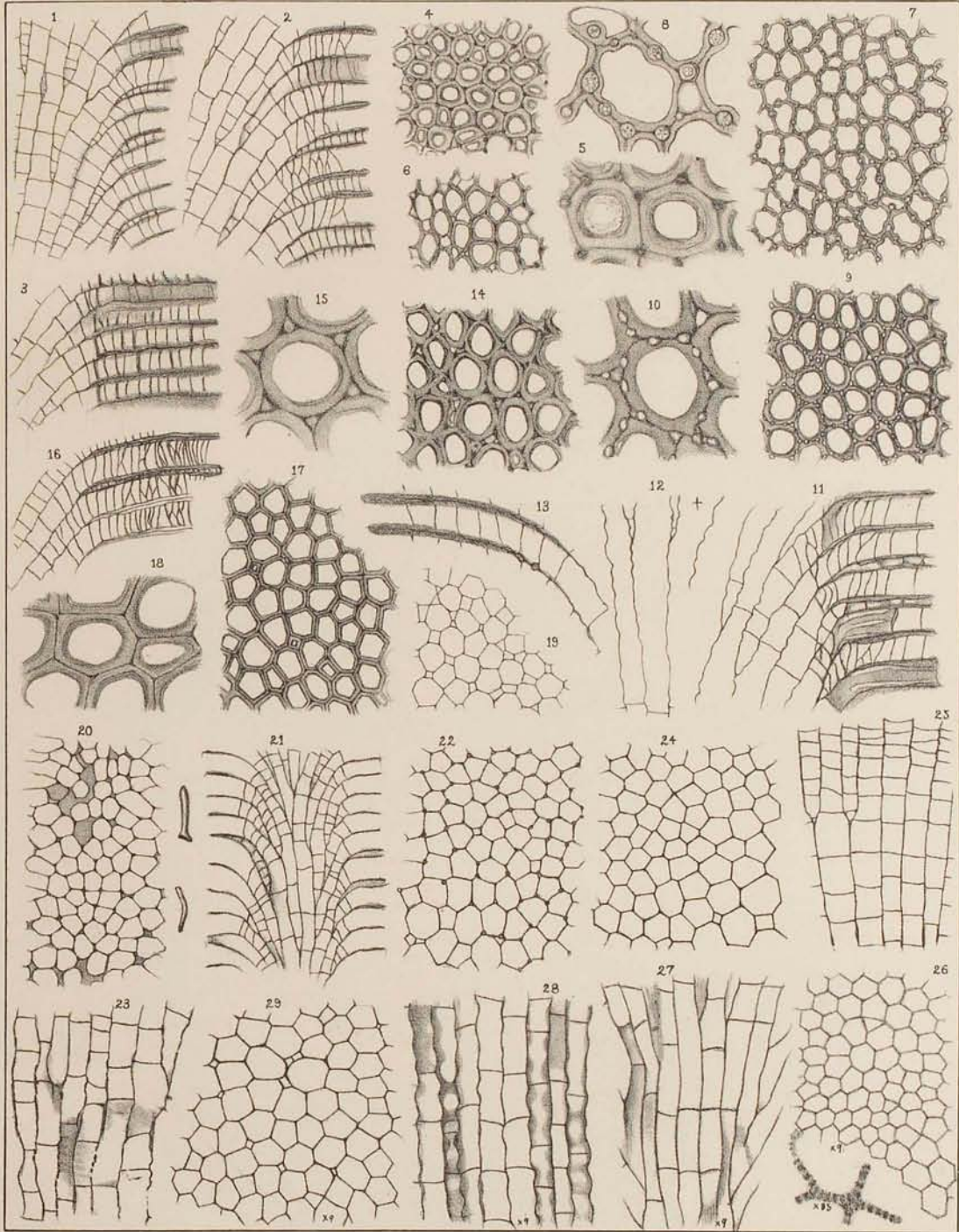


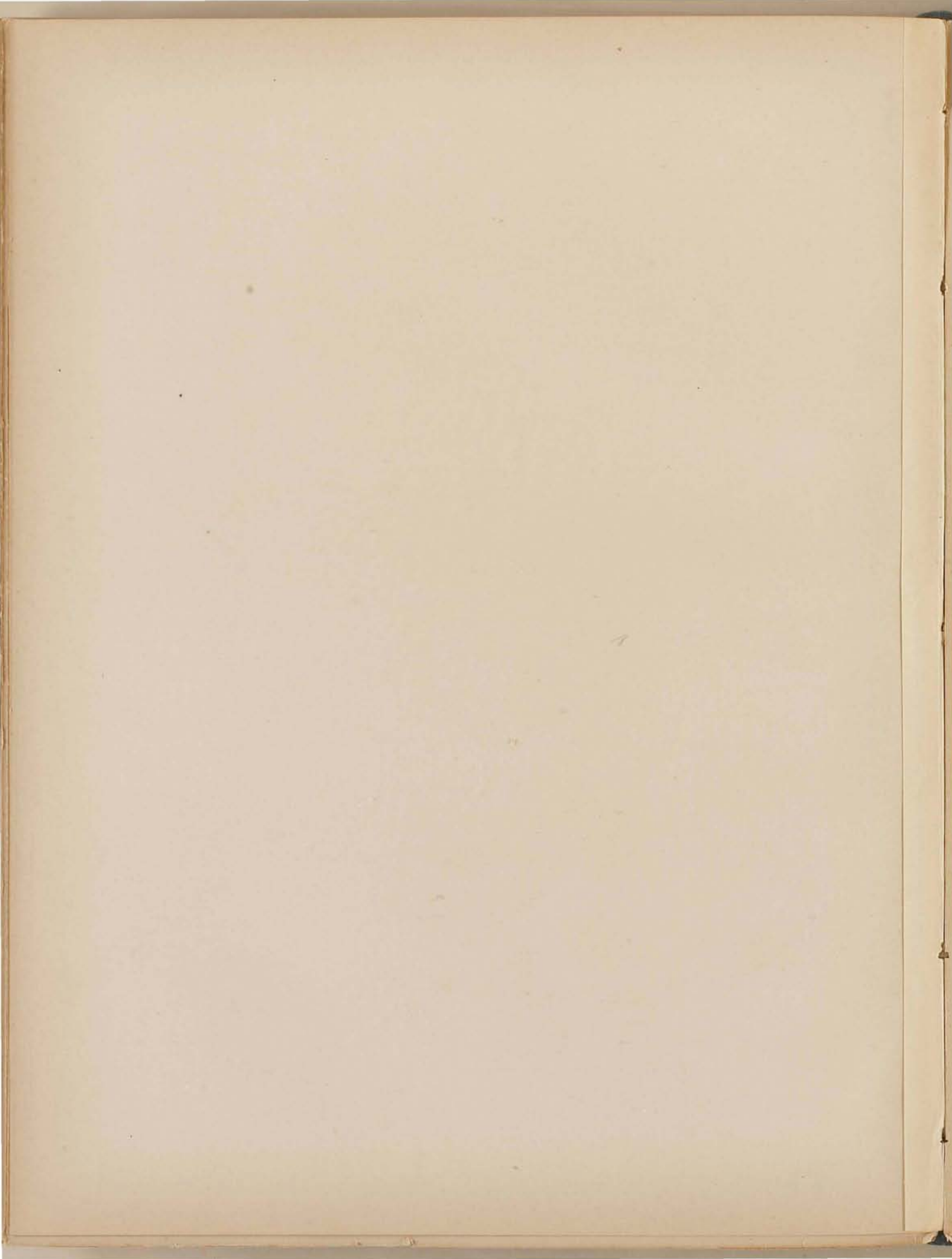
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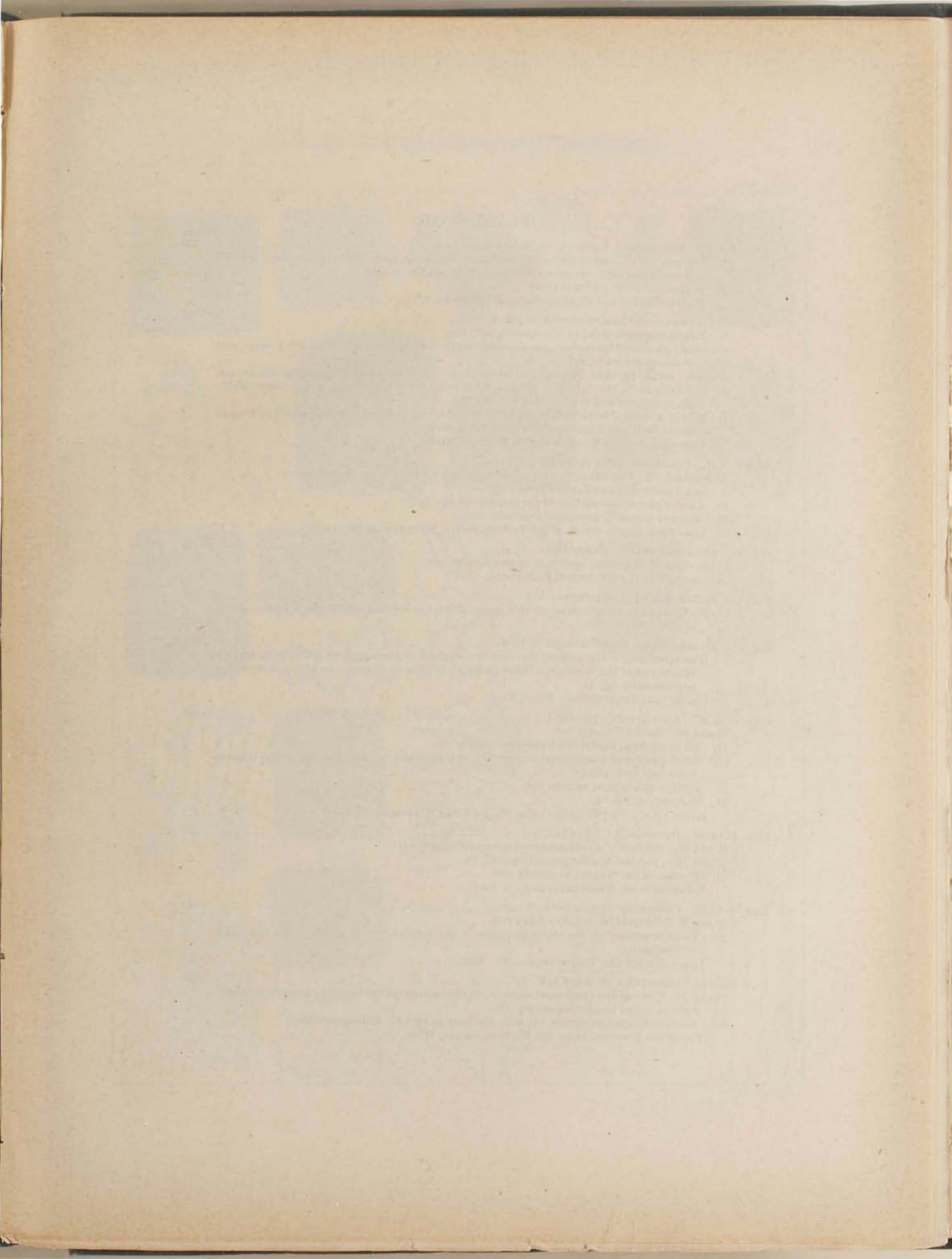
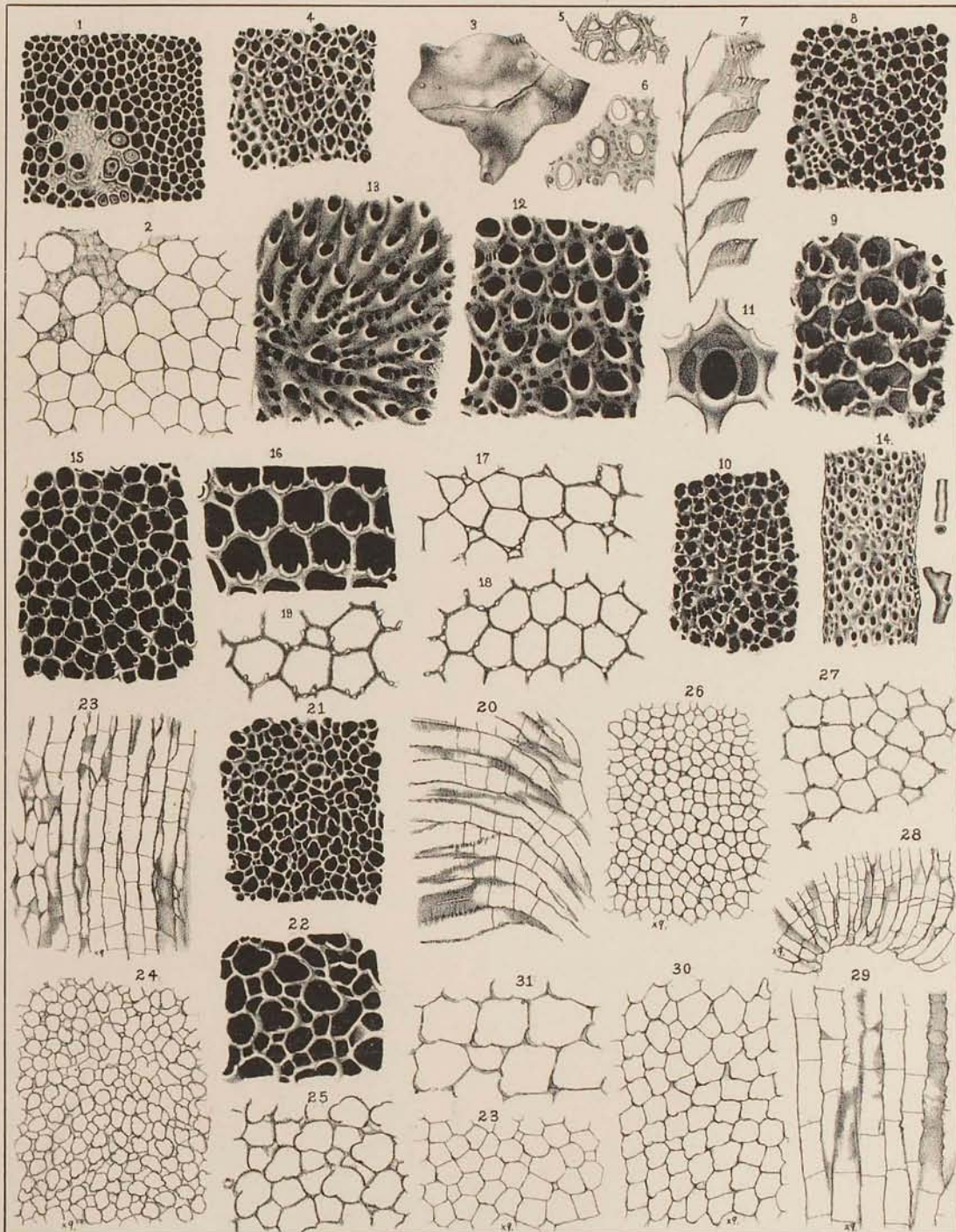


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CHAPTER V.

THE LOWER SILURIAN BRACHIOPODA
OF MINNESOTA.

BY N. H. WINCHELL AND CHARLES SCHUCHERT.

PRESERVATION AND DISTRIBUTION.

In the upper third of the Trenton limestone in the vicinity of Minneapolis, brachiopods are numerous, but usually not very well preserved. This is due mainly to the dolomitic nature of the rock, and the frequent small crystals of calcite and pyrite lining the cavities of the casts. In some of the shaly layers, slabs are found, containing very fine specimens of *Rhynchotrema inaequivalvis*, *Orthis deflecta*, *O. subaquata* var. *conradi*, *Scenidium anthonensis* and *Rafinesquina minnesotensis*. With a few exceptions, all the species of this division also occur in the Trenton shales above.

In the Trenton shales, a great abundance and variety of forms of well preserved fossils can be gathered readily in the immediate vicinity of St. Paul and Minneapolis. The greatest thickness of the shales is about seventy feet, but towards the southern part of the state they rapidly diminish, so that at Preston, which is near the state line in Fillmore county, they are not more than fifteen feet thick. The predominating fossils of this horizon are bryozoans, and next in abundance are the brachiopods. The latter are beautifully preserved, either as entire specimens or separated valves, so that the external and internal structure of nearly all the species can be understood satisfactorily. Much can also be accomplished in the discovery of young specimens 1 mm. in size up to maturity. These small specimens cannot be picked up on the hill sides, nor on the quarry dumps, but usually where adult examples of a species are abundant, there, also, will be found all individuals from the youngest to the mature shells. Collectors discovering such localities should not fail to carry away a small sample of the shale to be washed carefully in a pan until the water is colored no longer by the residuum. After drying, what remains should be sifted into various sizes to facilitate examination with the hand lens. If the sample proves to contain young specimens, it will be only a matter of washing and

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picking to secure of a species a complete series of specimens from less than 1 mm. in length to the adult size. Such series are of great value in classification, and much yet remains to be done in this direction.* A great deal can also be learned by local collectors, in regard to the evolution, introduction and disappearance of the species in these shales.

Near the top of the Trenton shales, new forms are introduced gradually, so that in the overlying Galena deposits the brachiopod fauna is changed. With the introduction of shales containing *Clitambonites diversa*, the marking species of this horizon, the fauna is noticed to disagree more or less in specific expression with that of the underlying Trenton shales. A number of forms are common to both horizons, but there is a perceptible difference in them. Ascending towards the middle Galena, the older species drop out, and new ones take their places more and more rapidly. In connection with this faunal change, there is also a lithological one. The Trenton shales are greenish in color, but change easily to a yellow with a coarser texture, before the *Clitambonites* horizon is introduced. The strata then become more and more sandy in the northern exposures of the Galena, which towards the south is altered into a compact, thin-layered limestone series.

Near the middle of the Galena there is another brachiopod horizon quite distinct from any below it. At some localities the species found here are preserved as casts while in others the shell remains. The characteristic species of this horizon are *Orthis meedsi* var. *germana*, *Rafinesquina deltoidea*, *Strophomena trilobata*, *Plectambonites gibbosa*, *Zygospira uphami*, *Cyclospira bisulcata*, *Schizotreta pelopea*, and *Lingulasma galenensis*. From these beds to the Hudson River group above, the fauna is rather meager, and little collecting has been accomplished.

In the upper member of the Hudson River deposits, the brachiopods are again numerous in individuals and species. Its fauna agrees with that of the upper portion of the Cincinnati group of the Ohio valley. The fossils are preserved in a semi-siliceous condition. Numerous outcrops of this formation occur in the southern portion of the state, but the fauna appears to be localized, and not well preserved nor abundant except in the region of Spring Valley.

Below the Trenton limestone, but one brachiopod (*Lingula morsii*) is known in the St. Peter sandstone; none in the Shakopee formation; but several, as yet unstudied, in the Lower Magnesian. In the St. Croix formation, however, brachiopods are abundant but mainly of inarticulate species.

* See "The Development of some Silurian Brachiopoda," by Beecher and Clarke: Mem. N. Y. State Mus., vol. 1, no. 1, 1889; "Development of the Brachiopoda," pt. 1, by C. E. Beecher, Am. Jour. Sci., vol. xli, 1891; and "Development of Bilobites," by C. E. Beecher, Am. Jour. Sci., vol. xli, 1891.

TERMINOLOGY.

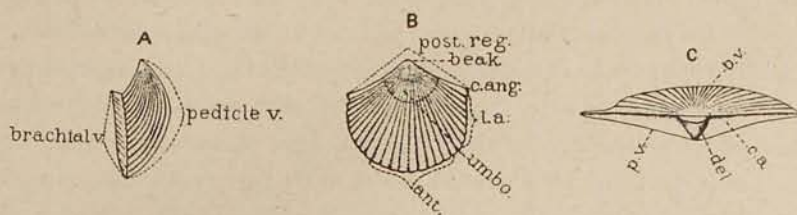


FIG. 21. *a*, profile view of *Orthis tricenaria* Conrad; *b*, ventral view of *Orthis tricenaria* Conrad; *c*, cardinal view of *Strophomena incurvata* Castelnau.

Pedicle=*Ventral valve*. The valve always situated on the ventral side of the animal and having the foramen or pedicle opening, except in *Lingula*, *Obolella*, etc., where the pedicle protrudes between the valves. When the shell is cemented to foreign bodies it is always by the ventral valve. It is usually the larger and deeper of the two valves in which the animal is contained. It was called the "dorsal valve" by Hall, from 1847 to about 1861; since which time "ventral valve" has been used by him. "Pedicle", "neural" and "receiving" valves, are synonymous terms.

Brachial=*Dorsal valve*. The valve to which the arms or the calcified brachial supports are attached. "Ventral valve" of Hall, from 1847 to about 1861. "Brachial," "hæmal" and "entering" valves, are other terms more rarely employed.

post. reg., posterior region; applies to both valves.

beaks, the apexes of valves.

umbo, the elevated portion of the valve immediately in front or anterior to the beaks.

c. ang., cardinal angle, or angle formed by the cardinal plane with the lateral margin.

l. a., lateral margin, or lateral area.

ant., anterior region or margin.

b. v., dorsal valve. *p. v.*, ventral valve.

c. a., cardinal area of the ventral valve.

del., *deltidium*. A plate of one piece which grows over the delthyrium of the *Strophomenida*, and is rudimentary in some species of *Orthis*. This plate begins, in the early larval stage of *Thecidium*, as a secretion from the dorsal side of the body segment, and becomes ankylosed to the ventral valve in the phylembryonic stage, subsequent additions being secreted by the body wall and pedicle. A plate similar in appearance, the "chilidium"

of Dr. Beecher,* is often present in the dorsal valve covering the cardinal process, but its development does not begin until early nealagic or later growth, and is probably secreted by the dorsal mantle lobe. When the delthyrium of the ventral valve contains two pieces growing out from its walls, more or less uniting medially, they are called "deltidial plates", and are deposited by the extensions from the ventral mantle lobe (see d. p., fig. 23*b*). These plates are seen in the rhynchonelloids, spire and loop bearing genera. The pedicle opening in these forms is always situated above the deltidium or deltidial plates.

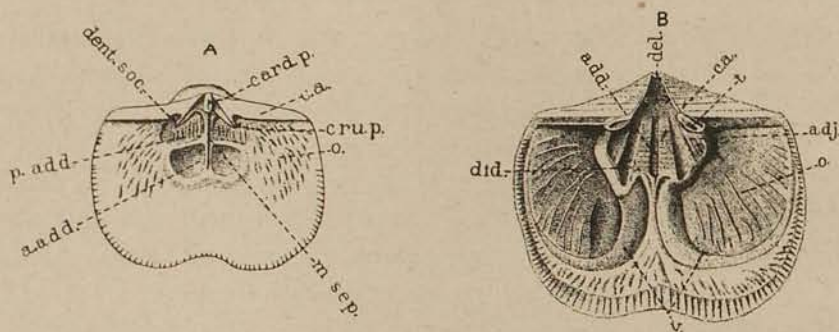


FIG. 22. *a*, interior view of the dorsal valve of *Orthis occidentalis* Hall; *b*, interior view of the ventral valve of *Orthis insculpta* Hall.

- c. a.*, cardinal area.
card. p., cardinal process; this may be a thin, simple plate, or thickened and trilobed, or separated in two processes, as in the strophomenoids.
dent. s., dental sockets; the cavities into which the teeth of the ventral valve enter.
cru. p., crural plates, usually forming the inner walls of the dental sockets, to which the brachia are attached.
p. add. and *a. add.*, posterior and anterior adductor scars.
o., genital [ovarian] spaces.
m. sep., median septum separating the two pairs of adductor scars.
del., delthyrium, a term introduced by Hall (Pal. N. Y. vol. viii) for the triangular space usually covered by the deltidium or deltidial plates; "fissure" and "foramen" have also been used.
c. a., cardinal area.
o., genital [ovarian] spaces.
t., teeth; when they are supported by thin plates, the latter are termed "dental plates."

* For a synopsis of the early embryology of the brachiopods, and a complete discussion of the development of the deltidium and deltidial plates, and on the term chlidium, see "Development of the Brachiopoda, part II, On the Stages of Growth and Decline." American Jour. of Science, August, 1892.

- v.*, vascular sinuses.
add., adductor muscle scars.
did., diductor muscle scars.
adj., adjustor muscle scars. When the *pedicle muscular scar* is present, it appears in the apex of the rostral cavity, posterior to the other scars, and is indicated by transverse striae.

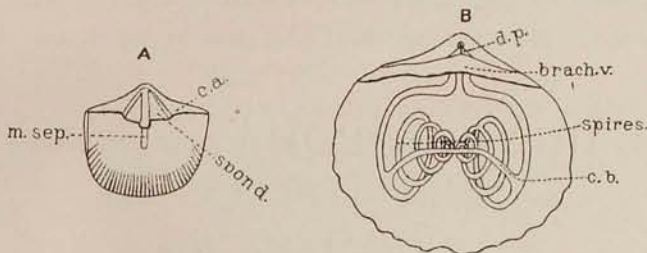


FIG. 23. *a*, interior view of the ventral valve of *Clitambonites diversa* Shaler; *b*, dorsal view of *Zygospira modesta* (Say) Hall, from which the greater portion of the dorsal valve has been removed to show the calcified brachial supports.

- spond.*, spondylium, a plate formed by the junction of the dental plates, to the upper surface of which were attached the adductor, diductor, and adjustor muscles. This plate is also present in the *Pentameridae*.
- m. sep.*, median septum supporting the spondylium.
- d. p.*, deltidial plates. See *deltidium*.
- spire*, the spiral cones or calcified brachial supports. The spires may be directed toward the center of the dorsal valve or with their apices toward the lateral margins. The lamellæ are usually single, but a number of genera have two bands in each spiral cone. The brachial supports also may be short or long hooks or crura to which the fleshy arms are attached, as in *Rhynchonella*, or they may form a more or less complicated "loop," as in the terebratuloids. For an illustration of a loop, see the species of *Hallina* of this report.
- c. b.*, connecting band or loop; it is variously disposed, and of a great variety of forms growing out from each spiral cone, and may or may not join medially. In *Atrypa* and *Spirifer*, the band is represented by two prongs.
- Protegium*, Beecher. The initial shell of brachiopods. It is smooth and of microscopic size, in outline semicircular or semielliptical, with a straight or arcuate hinge line and without a hinge area. Homologous to the "protoconch" of Owen in cephalopods, and to the "prodissoconch" of Jackson in lamellibranchs.

Nepionic, Hyatt.* The smooth shell stage succeeding the protegulum.

Nealagic, Hyatt. Youthfulness, or the stage in which specific characters begin to develop.

Ephibolic, Hyatt. The mature shell.

Geratologic, Hyatt. Old age. It is indicated in many species of brachiopods by extreme thickness of the valves, obesity, or by numerous, crowded growth lines near the anterior margin, a condition which sometimes produces truncation and absence of striae at the margin.

Class BRACHIOPODA, (Cuvier) Dumeril.

Subclass LYOPOMATA, Owen.

Order ATREMATA, Beecher.

Family LINGULIDÆ, Gray.

Genus LINGULA, Bruguière.

1789. *Lingula*, BRUGIERE. Histoire naturelle des Vers Testacés.

1892. *Lingula*, HALL. Palæontology of New York, vol. viii, pt. 1, p. 2.

Description: "Shells subequivalve, equilateral; elongate-ovate, subquadrate or subtriangular in outline; broad over the pallial region, cardinal slopes more or less conspicuous; slightly gaping at both extremities. Brachial or dorsal valve somewhat the shorter, and with a slightly thickened hinge-line. Surface of the shell smooth, or concentrically and radiately striated. Animal attached by a long, muscular pedicle protruding from between the beaks of the two valves.

"Muscular impressions numerous, but usually indistinct. In the recent species they are twelve in number upon each valve, and are somewhat unsymmetrical in their arrangement. They may be designated as follows: The *umbonal* impressions, produced by a single muscular band passing directly across the cavity of the shell near the beaks, and by their contraction opening the valves; the *lateral* impressions, which are produced by three pairs of muscles, the *anterior*s passing from near the lateral boundaries of the visceral area on the pedicle [ventral] valve, forward to the anterior extremity of this tract on the brachial [dorsal] valve; the *middles* passing in just the opposite direction, from the anterior region of the pedicle-valve to the lateral region of the brachial; the *externals* passing from the ante-lateral region of the pedicle valve to the post-lateral region of the brachial valve; these muscles serving to move the valves forward and backward. The *central* impressions are

* Values in classification of the stages of growth and decline, with propositions for a new nomenclature," by Alpheus Hyatt; Am. Nat., vol. xxii, p. 872, 1888. Also "Genesis of the Arrietidae." Mem. Mus. Comp. Zool., vol. xvi, no. 3, 1889.

produced by a single pair of muscles extending across the ante-lateral region of the visceral area, and by the contraction of these, the valves are closed. The *transmedian* impressions, are made by a triple muscle, one band of which is on one side of the visceral area, the other two on the other side, the two lateral components crossing each other in passing from the posterior region of the pedicle-valve to the medio-lateral region of the opposite valve. By the action of these muscles the animal is able to slide apart the anterior and posterior extremities of its valves. The muscular region in each valve is surrounded by the *parietal* bands, which leave more or less distinct impressions upon the shell.

"The anterior internal surface of each valve bears traces of two strong pallial sinuses, which nearly meet in the axial line before reaching the anterior margin. In front and behind are radiating vascular markings.

"Shell substance composed of alternating lamellæ of chitinous and calcareous material.

"Type *Lingula anatina* Lamarck." (Hall, *op. cit.*)

Species of this genus had their origin in the St. Croix formation,* and thence lived through all geologic times. Several species are still living, usually in shallow water, of which *L. anatina*, the type of the genus, is the most abundant and widely distributed.

LINGULA ELDERI Whitfield.

PLATE XXIX. FIGS. 1-4

- 1875-77. *Lingula quadrata* WINCHELL (non EICHWALD). Fourth Annual Report of the Geological and Natural History Survey of Minnesota, p. 49.
 1880, June. *Lingula elderi* WHITFIELD. American Journal of Science, third ser., vol. xix, p. 472, figs. 1, 2.
 1880, July. *Lingula minnesotensis* N. H. WINCHELL. Eighth Annual Report of the Geol. and Natural History Survey of Minnesota, p. 61.
 1882. *Lingula elderi* WHITFIELD. Geology of Wisconsin, vol. iv, p. 345, pl. xxvii, figs. 1-5.
 1892. *Lingula elderi* HALL. Palæontology of New York, vol. viii, pt. i, p. 11, pl. L, figs. 21, 22.

Original description.—"Shell oblong and subquadrangular in outline, with nearly or quite parallel lateral margins, which are but very slightly curved; anterior and posterior extremities subequal, the upper end being slightly angular at the apex and on the shoulders, while the front or posterior end is broadly rounded. Valves rather strongly convex, the dorsal or shorter valve being a little the more convex and the valve, as shown by the cast, frequently marked by a slight flattening, or even by a depressed longitudinal line along the middle of the front half." Surface of the shell nearly smooth and glossy, marked by fine concentric lines of growth

* This statement is based largely on professor James Hall's late investigations as given on p. 6. Palæontology of New York, vol. viii. 1892.

and still finer radiating lines. These give to the surface a minutely crenulated appearance; also several distinct radiating lines over the anterior half of the valves which interfere somewhat with the rounding of the concentric lines.

"In the dorsal valve the impressions of the pallial sinuses [vs] are deeply marked and are widely separated, leaving the area within them very considerable; the central or inner ramifications [v] are very distinct, and the outer ones also for a short distance from the main branches, while the posterior branches show the lateral ramifications only on the outer side. The divaricator [umbonal] muscular scar of the dorsal valve [g] is very large and curved forward at the sides, being situated well back near the apex of the valve. It cannot be positively traced on the ventral side, most of the specimens being imperfect at this point. The anterior adductor [anterior laterals] scars [j] are small and situated near the center of the valve, while the posterior adductors [h, central scars] are large and situated outside of and posterior to them so as to inclose their posterior ends. The adjustor [lateral, middle and transmedian] muscles [l i k] are distant from each other, and placed just within the posterior third of the length of the shell. Two elements can be detected in each scar on some individuals, but they are usually obscure.

"On the ventral valve the lines of the pallial sinuses are nearer together on the anterior half of the shell than on the dorsal, the same as shown in *L. anatina*, but spread out rapidly toward the middle, and, on the posterior half, occupy nearly the same relative position as on the other side. Near the center of the valve are seen a pair of large [central] scars [h], which have advanced from behind their track, forming a strong feature on the cast, as it originates just in front of the position of the divaricator [umbonal] muscular scar [g], and gradually widens as it advances until it occupies fully one-half of the width of the cast near the middle of its length. In the central line of these scars there is an elevated ridge, which terminates in a slightly prolonged tongue, and seems to represent the central adjustors [middle laterals, k]. The large scars outside of these are probably the posterior adductors and external adjustors combined. Posterior to these and distant from the median line are other scars, which are long and narrow, which have also left their track as they have advanced. Two elements are represented on each side, and mark the place of the posterior adjustors and anterior adductors [anterior, laterals and transmedians, j i]. Between the lines formed by the advance of the scars of the adjustor muscles and those of the central area, on each valve, there is a narrow smooth impressed space which unites with the line of the pallial sinuses at the junction of the anterior and posterior branches, seen on all the specimens, and for which I have not been able to satisfactorily account, as it lies within the area of the muscular scar, and consequently within the walls of the perivisceral chamber. The areas of

attachment of the muscular walls of the perivisceral chamber has not been detected, unless it be combined with the scar of the posterior branches of the pallial sinuses, which really seems to be the case. If this is so, the posterior branches of the sinuses can have had ramifications on but one side instead of on both, as in the case of *L. anatina*. This would be a marked specific but not a generic character."

There is considerable variation in the outline of this species, some being short and wide, while others are long and comparatively narrow. Specimens with the shell adhering to the limestone show that the valves near the edges are considerably flattened, giving the shell a greater width than the casts of the interior indicate. These specimens greatly resemble *L. quadrata*, as figured by professor Hall (Pal. New York, vol. i, pl. LXXIX, figs. 1a. 1b), and in several cases we have seen the species labeled in this way. *L. elderi* can be distinguished readily from that species by the absence of a well-developed median septum in the interior of the dorsal valve. In *L. quadrata* Hall=*L. rectilateralis* Emmons, the septum is usually indicated externally by a strong central depression. By washing and picking away the adhering portion of the shell, casts of the interior of *L. elderi* Whitfield, can be made to show the muscular scars, and the delicate detail of the ramification of the vascular trunks.

Formation and locality.—Common in the Trenton limestone at Minneapolis, Wanamingo, Oxford Mills, Fountain, and Rochester. Minnesota; Beloit, Wisconsin. A single example of this species was also found near the base of the Galena* shales on St. Anthony Hill, in the city of St. Paul, Minnesota. In the Salmon River or Cincinnati group at Cincinnati, Ohio, and at Covington, Kentucky.

Collectors—W. D. Hurlbut, Wm. Howling, C. L. Herrick, H. V. Winchell, W. H. Scofield, and the writers.

Mus. Reg. Nos. 291, 786, 3499-3503, 5009, 5010, 5061, 5133, 5668.

LINGULA EVA *Billings*.

PLATE XXIX, FIGS. 5 and 6.

1861. *Lingula eva* BILLINGS. Canadian Naturalist and Geologist, vol. vi, p. 150.

1863. *Lingula eva* BILLINGS. Geology of Canada, p. 141, fig. 73.

Original description: "Shell from one to one and a half inches in length, greatest width near the front margin, thence gradually tapering with nearly straight sides until within one-fourth of the length from the beak, from which point the sides rapidly converge to the beak; apical angle about 90°; both valves rather convex along the middle, thence descending with a flat or gently convex slope to the sides and front margin. Surface with distinct sub-imbricating concentric ridges and fine striæ, and when partially exfoliated obscure longitudinal striæ are visible.

*For a definition of this and other stratigraphic terms consult the introductory chapter.

"The width at one-fourth the length from the beak is usually one-fourth less than it is at one-sixth the length from the front margin. The following are the measurements of a specimen of the ordinary form:

"Length, $12\frac{1}{4}$ lines; width at 3 lines from beak, $6\frac{1}{2}$ lines; width at 2 lines from front, 9 lines.

"The largest specimen found measures nearly one inch and a half in length."

The surfaces of the valves from the mid-length to the anterior margin are marked by a few prominent radiating, continuous, or intermittent striations. The concentric growth lines in passing the radiating striæ are more or less reflexed posteriorly.

Of this species we have seen but a single example in a good state of preservation. It was discovered some years ago by Mr. W. H. Shelton, and is from the Trenton Shales near St. Charles in Winona county, Minnesota. The rather strongly convex valves without indications of a median depression, and the gradually diverging lateral outline, will readily separate it from *Lingula quadrata* Hall,=*L. rectilateralis* Emmons.

Formation and locality.—From the Trenton shales, in section six, Fremont, Winona county, Minnesota. Also in the Black River formation of Murray bay, lower St. Lawrence river, Canada.

Mus. Reg. No. 4973.

LINGULA PHILOMELA *Billings.*

PLATE XXIX. FIGS. 7, 8.

1862. *Lingula philomela* BILLINGS. *Paleozoic Fossils*, vol. i, p. 49, fig. 53.

1863. *Lingula philomela* BILLINGS. *Geology of Canada*, p. 161, fig. 133.

1892. *Lingula philomela* HALL. *Paleontology of New York*, vol. viii, pt. i, pl. 1, fig. 8.

Original description.—"Very elongate oval; width a little less than half the length; front margin rather narrowly rounded with a small space in the middle straight or sinuate; sides for about two-thirds the length straight or very gently convex; the apical extremity appears to be obtusely angular, but this still remains doubtful, as no specimens with this part perfect have been collected. The shell is rather strongly convex, most prominent at or about the mid-length. There is a shallow concave sinus extending all along the median line from near the apex to the front margin. Surface with fine crowded imbricating striæ of variable size, the smaller just visible to the naked eye, and the larger partaking of the nature of squamose interruptions of growth. Color in the black limestone black. A specimen in gray limestone showing the interior in a state of exfoliation is light grayish-brown, but this may be owing to some circumstance in the fossilization of the shell.

"Length 16 lines; width 7 lines."

The figure of this species, as given by Billings, shows a strong median sinus, which does not reach the anterior margin, but in the description, it is said that the "shallow sinus extends all along the median line from near the apex to the front margin," and that the latter is "straight or slightly sinuate" in the middle. Since the example before us agrees with the original description, we do not hesitate to identify this species as occurring in the Northwest. This example and the one figured by professor Hall, like the Canadian specimens, are broken along the cardinal line, and must have been "obtusely angular," as the earlier lines of growth are semicircular in outline, or *Paterina*-shaped, and not much crowded laterally. The shell substance is thick, and composed of many corneous and calcareous layers, with the surface glossy.

Formation and locality.—From the lower portion of the Hudson River group, or Loraine shales, in a small quarry on the north side of the Upper Iowa river, about two miles west of Granger, Minnesota. Mr. E. O. Ulrich reports the species from the same horizon near Wykoff. The original specimens were found in the Trenton limestone, at Montmorenci falls, and Island of Montreal, Canada.

Collector.—The specimen here figured was found by Mr. R. H. Hasse, and kindly donated by him to the survey collection.

Mus. Reg. No. 7671.

LINGULA RICINIFORMIS Hall.

PLATE XXIX. FIG. 9.

1847. *Lingula riciniformis* HALL. Palæontology of New York, vol. i, p. 95, pl. xxx, figs. 2a, 2b, 2c.

1892. *Lingula (Glossina) riciniformis* HALL. Ibidem, vol. viii, pt. i, pl. i, fig. 3.

Original description.—"Oval, convex, slightly attenuated towards the beak, which is obtuse; surface nearly smooth, or with fine nearly obsolete concentric lines. Fine radiating striæ are sometimes visible; and the surface is sometimes slightly ridged, as if from elevated lines beneath the outer lamina of the shell."

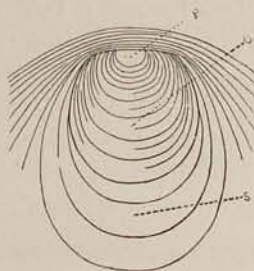


FIG. 24. Stages of *Lingula riciniformis*. p. protegulum; o. obolella; s. nealagic.

Our specimens of this species show three distinct stages of development; the first shelled condition, or "protegulum,"* which is not distinct, owing to its very

*For a definition of this term, and description of the earlier stages of growth in Brachiopoda and their importance in classification, see Dr. C. E. Beecher's valuable papers on "Development of the Brachiopoda," American Journal of Science, April, 1892.

small size; second, a very sharply defined circular stage, which is of a lighter color than the shell surrounding it. This second growth has been appropriately called the *Obolella* stage, and around it the shell begins to assume its specific form, growing most rapidly in the anterior region, and but comparatively little laterally and posteriorly. At maturity, the apex is no longer marginal, as in the *Obolella* stage, but has become submarginal through the addition of shell substance posterior to the protogulum. These stages of growth indicate that the course of development of *Lingula* is through *Paterina*—*Obolella*—*Lingula*.

This species can be separated readily from *Lingula attenuata* Hall (non Sowerby) = *L. daphne* Billings = *L. (Glossina) trentonensis* Conrad, sp., by its oval form and obtuse beaks. The latter is also more attenuated towards the apex, and is now referred to the sub-genus *Glossina*, Phillips. *L. elongata* Hall differs in being twice the size of *L. riciniformis*.

Formation and locality.—Near the base of the Galena shales, associated with *Zygospira recurvirostris* Hall. A single example has been discovered at Minneapolis, while from St. Anthony Hill, a suburb of St. Paul, Minnesota, a number of specimens have been procured. Also in the Trenton at Middleville, New York, and Charlesbourg, Canada.

Collector.—C. L. Herrick.

Mus. Reg. No. 785.

LINGULA RICINIFORMIS, VAR. GALENENSIS W. and S.

PLATE XXIX, FIGS. 10 and 11.

1892, April 1. *Lingula riciniformis*, var. *galenensis* W. and S. *American Geologist*, vol. ix, p. 284.

The conspicuous differences between *L. riciniformis* Hall and this variety are that the former is constantly two-thirds the size of the latter, and that the greatest width is across the center of the length of the valves, while the variety is widest in the anterior third. In the Galena horizon at Oshkosh, Wisconsin, this variety is not rare, and attains twice the size of *L. riciniformis* Hall.

Formation and locality.—From the Galena shales of the north branch of the Zumbro river, at the upper bridge, near Kenyon, and near Fountain, Minnesota. Also from the Galena horizon at Neenah and Oshkosh, Wisconsin.

Collectors.—W. H. Scofield and Charles Schuchert.

Mus. Reg. Nos. 7672, 7673.

LINGULA MODESTA Ulrich.

PLATE XXIX, FIG. 41.

1889. *Lingula modesta* ULRICH. *American Geologist*, vol. iii, p. 382, figs. 4-4b.

Original description: "Shell small, subovate, widest in the anterior half, the width and length, respectively, in four representative cases, 3.5 to 5.2, 5.5 to 8, 7 to 10 and 7 to 11, the figures representing the dimensions in millimeters. Both valves

with exceedingly little convexity, appearing in most cases, perfectly flat. Anterior third or half usually uniformly rounded. Front margin occasionally somewhat straightened. Sides gently convex to near the beak which, in none of the numerous specimens examined, seems ever to have formed an acute termination. Surface with only very faint concentric undulations; even these are quite obsolete, when the shell is preserved in a shaly or impure limestone matrix."

Formation and locality.—Rather rare near the base of the Hudson River group near Granger and Wykoff, Minnesota. It also occurs at Graf, Iowa, and Cincinnati, Ohio. Also in the middle and upper portion of the Trenton at Frankfort and Paris, Kentucky.

Collectors.—E. O. Ulrich and C. Schuchert.

LINGULA CLATHRATA, *n. sp.*

PLATE XXIX, FIGS. 42.

This little *Lingula* is, in form and convexity of valves, much like *L. riciniiformis* Hall, except that it is somewhat wider posteriorly. Like that species, this one also shows plainly the Obolella stage of growth. It is, however, much smaller than that species, besides differing from it and all associated species of *Lingula* in having from twenty-two to twenty-eight wavy, imbricating, transverse lines crossing the marks of growth and restricted to the external shell layer. These lines begin to appear on the medial portion of the valves quite close to the apex, or during early nealagic growth. They are closely arranged and gradually become more distant and extend across the valve from side to side. Those which are continuous from one margin to the other occupy but a small portion of the shell, becoming disunited medially at about one-third the length of the valve from the apex and cease to be developed a short distance beyond mid-length or may be continued to near the anterior margin.

Interior characters not defined beyond a low median septum extending for two-thirds of the length of the shell from the apex.

Length and breadth of an ordinary specimen 4.5 mm. and 2.5 respectively.

The transverse surface lines appear in a number of other forms occurring in older and younger formations. The earliest species with it known to us is *Lingulella stoneana* Whitfield* of the St. Croix formation. The next younger one is the species here described followed by *Lingula teniola* Hall and Clarke† of the New York Clinton. The latter species possesses this feature very strongly developed, obscuring the concentric growth lines, and "are equally visible on the inner side of the shell, a character not seen in the other forms. Of precisely the same character is the ornamentation in *L. zebra* Barrande from the Bohemian Etage E."‡ *L. spathata* of the Lower Helderberg also has these lines sharply developed and more closely arranged than

*Geol. Wisconsin, vol. iv, p. 344, pl. xxvii, figs. 6, 7; 1882. †Pal. N. Y., vol. viii, pt. i, p. 18; 1892. ‡Ibid., p. 18.

the others. In several species of recent *Discinisca* such as *D. strigata* Broderip and *D. levis* Sowerby the same kind of transverse lines are usually present on the ventral valve, originating on each side of the pedicle slit, curving outwardly and terminate on the anterior third of the shell. In the above species of *Lingula* and *Lingulella* it is a constant feature in both valves, while in *Discinisca* it may or may not be developed in the same species and when present is restricted to the ventral valve.

Prof. Whitfield remarks that "the peculiar surface ornamentation of *Lingulella stoneana* seems to be one that characterizes many forms of this genus in the primordial formations." Since *Lingula* is a development from *Lingulella* the presence of the transverse lines in species of the former genus seems to indicate that they have acquired it through heredity rather than its being a sporadic development. If this inference is the correct one it seems to call for some recognition in a future classification of species of *Lingula*.

Prof. Whitfield also calls attention to a homologous growth in *Lucina divaricata* and other pelecypods and thinks this feature to depend "on a series of changes in the mantle of the animal during the formation of the shell." While we do not doubt this growth being due to a deposition from the mantle, yet how shell can be secreted externally, posterior to the anterior edge by a "series of changes in the mantle" is not clear.

Formation and locality.—A number of specimens were found by Mr. Ulrich in the middle third of the Trenton shales at St. Paul associated with *Rhinidictya mutabilis*.

LINGULA COBOURGENSIS *Billings?*

PLATE XXIX, FIG. 12.

1862. *Lingula cobourgensis* BILLINGS. Paleozoic Fossils, vol. i, p. 50, fig. 54.

1863. *Lingula cobourgensis* BILLINGS. Geology of Canada, p. 161, fig. 132.

Original description: "Almost regularly oval; greatest width about the middle; length one-fourth greater than the width; anterior extremity uniformly rounded; apex obtusely angular; both extremities sub-equal; sides gently convex. Both valves are moderately convex, and one of them has sometimes an irregular furrow extending from near the beak along the median line for one-half or three-fourths the length. Color dark brown, with some shades of light brown or yellow; general aspect smooth and shining, with fine concentric undulations of growth, which become fine, elevated, sharp, closely crowded striæ, on each side; longitudinal striæ are visible on some specimens.

"Length, about one inch; width, about three-fourths of an inch; depth of both valves, three or four lines. Smaller specimens occur associated with the larger."

We have two imperfect and exfoliated specimens which appear to be of this species. *Lingula covingtonensis* Hall and Whitfield is sometimes regarded as identical with *L. cobourgensis*. An examination, however, will show that it is more broadly oval and has sharply elevated, rather distant, concentric lines. The striae in *L. cobourgensis* are fine, elevated, sharp and closely crowded on the lateral slopes, while medially there are fine concentric undulations with occasionally some radiating lines.

Formation and locality.—Rare in the Trenton limestone at Minneapolis and Chatfield, Minnesota; Cobourg and Collingwood, Canada.

Collectors.—H. V. and N. H. Winchell.

Mus. Reg. Nos. 309, 3504.

Sub-genus GLOSSINA, Phillips.

1848. *Glossina*, PHILLIPS. Memoirs of the Geological Survey of Great Britain, vol. ii, pt. ii, p. 370.

1892. *Glossina*, HALL. Palaeontology of New York, vol. viii, pt. 1, pp. 5, 6, 15.

Species of this sub-genus differ from *Lingula* in having "an acuminate or sub-triangular form, in which the rostral area is very narrow, with long, sloping post-lateral margins, and a rounded or transverse anterior margin." (Hall, *op. cit.* p. 5.)

This sub-genus is restricted to Palaeozoic rocks.

LINGULA (GLOSSINA) HURLBUTI N. H. Winchell

PLATE XXIX. FIGS. 13 and 14.

1880. *Lingula hurlbuti* N. H. WINCHELL. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 62.

Original description: 'Shell ovate, broadest in the anterior half, and pointed posteriorly; the sides approaching the apex with a gentle convexity; lines tangent to sides at one-third the length from the apex, form an angle of 72°; anterior angles obsolete. The exterior surface of the shell is marked by sharply elevated concentric plications, which stand perpendicular to the shell, and on the anterior third portion five occupy the space of one line, but towards the beak they are reduced in size and increase in frequency so as to become mere striae. Where these are largest and perfectly developed, the intervening grooves are destitute of fine striations. These plications leave corresponding lines on the interior cast when the shell is exfoliated. There are no longitudinal radiations visible on the exterior, but on the cast near the front are exceedingly dim, interrupted lines visible under the lens, that possibly have the same origin, but these do not extend more than a line and a half from the front margin, and they cannot be seen even with the lens except under a favorable angle of reflected light.

"The most elevated portion is at one-third the length from the beak, but the convexity of the valve is moderate and regular.

"Dedicated to Mr. W. D. Hurlbut of Rochester, Minnesota, one of the earliest patrons of the Geological and Natural History Survey."

Recently Mr. W. H. Scofield found two other specimens of this species at the same locality in which the type was discovered. These specimens, however, add nothing to the interior characters, except that, near the anterior portion, the valves are strongly pitted, a feature, moreover, which is visible also on the type specimen.

L. hurlbuti differs from *L. crassa* Hall,* the only species with which it need be compared, in being twice the size, and in having strongly elevated and comparatively widely separated concentric lines of growth. In *L. crassa* Hall, which also is referable to Phillips's subgenus *Glossina*, the surface is described as being "apparently smooth, but, under a magnifier, exhibiting fine concentric and radiating striæ."

Formation and locality.—From the lower portion of the Galena limestone, in the quarries at Mantorville, and at Weisbach's dam near Spring Valley, Minnesota.

Collectors.—N. H. Winchell and W. H. Scofield.

Mus. Reg. Nos. 393, 7674.

LINGULA (GLOSSINA) DEFLECTA *W. and S.*

PLATE XXIX, FIGS. 15-18.

1892, April 1. *Lingula (Glossina) deflecta* W. and S. *American Geologist*, vol. ix, p. 284.

Shell of medium size, subtriangular; lateral margins diverging more or less rapidly from an acute apex, to the broadly rounded and deflected anterior third. Shell substance thick, and marked by strong, irregular, concentric lines of growth, between which are numerous finer ones. In profile the line of junction of the valves is more or less convex, dorsally. Ventral valve flat or slightly concave medially, and strongly convex transversely. On the interior of the ventral valve there is a distinct but slightly elevated median septum, which originates near the apex, and terminates somewhat beyond the center of the valve, in front of which are the small, middle lateral muscular scars. Upon each side of the median septum are the scars of the progressive central muscles, which gradually expand anteriorly, and terminate just above the middle lateral impressions. The vascular trunks bound the limits of the central scars, and meet just in front of the middle lateral impressions, where they are no longer defined. In front of these scars there is a low median elevation, with a broad shallow depression on each side, the latter being anterior to the vascular trunks and slightly pitted. Numerous irregularly radiating obscure lines back of the anterior margin.

* Pal. New York, vol. 1, p. 98, pl. xxx, fig. 8; 1847.

Dorsal valve strongly convex, both transversely and longitudinally. In the interior of this valve, the cardinal margin is broadly flattened, striated, and divided centrally by a well defined, narrow depression, which terminates at a point one-fourth the length of the shell from the posterior edge. Near the posterior end of this depression are faint traces of the umbonal scar. The vascular trunks are discernible on each side and anterior to the rostral depression, and having the same curve as the outer margin of the valve, thence proceed to a point somewhat beyond the posterior half of the shell, where they gradually converge and meet near the anterior margin. Vascular branches originate only from the outer side of the vascular trunks. The enclosed space seems to represent the tracks of the anterior and central muscular scars.

The outline of this species and the convexity of the dorsal valve are variable. The broadly subtriangular specimens have more strongly convex dorsal valves than the narrow and less triangular form. There is no other species of *Lingula* from Lower Silurian strata having the peculiarly deflected anterior portion of the shell so characteristic of this species. *Lingula linguata* Hall* from the Clinton group is the only other American species with this peculiarity, and differs from *L. deflecta* in having parallel lateral margins.

Formation and locality.—From the shales near the base of the Galena group on the farm of Ole Hansen, near Fountain, and in the Hudson River group near Spring Valley, Minnesota.

Collectors.—E. O. Ulrich and C. Schuchert.

Mus. Reg. Nos. 7675, 7676.

LINGULA IOWENSIS Owen.

PLATE XXIX. FIGS. 19-22.

1844. *Lingula iowensis* OWEN. Geol. Rep. Iowa, Wisconsin and Illinois, p. 70, pl. xv, fig. 1.

1851. *Lingula quadrata?* OWEN (not Eich.). Geological Report of Wisconsin, Iowa and Minnesota, pl. II B, fig. 8.

1862. *Lingula quadrata* HALL. Geology of Wisconsin, vol. i, p. 46, fig. 1, and p. 435.

1868. *Lingula quadrata* MEEK and WORTHEN. Geological Survey of Illinois, vol. iii, p. 305, pl. II, fig. 4.

1882. *Lingulella iowensis* WHITFIELD. Geology of Wisconsin, vol. iv, p. 242, pl. IX, fig. 1.

1892. *Lingula iowensis* HALL. Palæontology of New York, vol. viii, part i, p. 8, pl. I, fig. 14.

Original description: "Resembles *L. lamellata* H., of the Niagara group, but is larger and straighter on the lateral edges. It differs from *L. rectilateris* [probably meant *L. rectilateralis* Emmons], in being flatter and not so pointed at the apex."

From the figure given by Owen, we cannot be positive in the identification of this species, but since comparison is made with *L. rectilateralis* Emmons, in the

* Pal. New York, vol. viii, p. 173, pl. IVK, fig. 5; 1892.

description, there can be no doubt that the name *L. iowensis* was applied by him to the widely distributed and characteristic *Lingula* of the Galena horizon. Professor Whitfield was the first to make use of Owen's name; the following is a copy of his description, with our additions: "Shell large, broadly ovate, elliptical or subquadrate in outline, generally a little narrower above the middle of the length than below; upper end very obtusely angular, the cardinal slopes forming an angle with each other of about one hundred and twenty degrees; sides of the shell gently rounded, and the basal line more sharply rounded, but never truncate. Valves convex, the ventral most strongly so, and generally subangular along the middle. Ventral beak projecting a short distance beyond the dorsal, and more pointed. The cardinal margins of the ventral [as well as the dorsal] valve are infolded along their border, forming an imperfect cardinal area of a very perceptible width on well-preserved specimens." These areas are striated, and immediately below the apex of each valve, the arched striae meet, forming in the ventral valve a very slight linear elevation.

Gutta-percha impressions made from natural casts of the interior of the dorsal valve show a pronounced median septum, which is but slightly developed near the posterior end of the valve, and extends somewhat beyond the center of the shell, where it is strongly elevated, and terminates abruptly. On each side of the septum, for two-thirds of its length, are well-defined, progressive, concrete lateral, and central muscular scars. In the ventral valve, the median septum is faintly indicated, and does not extend beyond the progressive, lateral muscular scars, which are one-third the entire length of the valve. In front of these impressions, at the anterior end of the septum, are the small, middle lateral scars, which extend somewhat beyond the central muscular imprints on each side.

"Surface of the shell marked by strong, irregular lines of growth at irregular distances, the outer margins of which are slightly raised and free, presenting a strongly lamellose appearance under a magnifier; the spaces between being smooth and often polished. On exfoliated specimens, and more distinctly on internal casts, the surface is very strongly radiated by fine flattened, but irregular striae for from one-third to one-half the length of the shell, and on nearly the entire width along the basal line; but a little higher on the sides they lose their regularity and become broken and wrinkled as well as more strongly divergent." The striae are confined to the internal surface of the valves.

Lingula cincinnatiensis Hall and Whitfield is a closely related species, and may be a direct descendant from *L. iowensis* Owen. It differs from the latter in being usually more robust, the valves deeper or more convex, and in having the posterior portion of the shell more pointed.

Lingula quadrata, as identified by Hall,* and Billings,† we regard as identical with *L. rectilateralis* Emmons.‡ This species occurs in the Trenton, Utica slate and Loraine groups of New York and eastern Canada, and differs but slightly, if any, from *L. iowensis* Owen. The characteristic striated hinge areas of *L. iowensis* Owen and *L. cincinnatiensis* Hall and Whitfield have not been observed in *L. rectilateralis* Emmons. Should these parts eventually be discovered in the latter species, *L. iowensis* Owen will then give place to *L. rectilateralis*, as the latter has two years' priority over the former. Professor Hall in 1847** regarded Emmons' species as a synonym of *L. quadrata* Eichwald, while Whitfield†† regarded this form as identical with *L. iowensis* Owen.

We have seen four specimens of typical *Lingula quadrata* Eichwald from Esthonia in the collection of Mr. Ulrich, and these prove beyond a doubt that none of the American forms identified with this species are correctly named. The Russian species is larger, with very strongly convex valves and a more narrowly rounded anterior margin than in *L. iowensis*, *L. rectilateralis*, or *L. cincinnatiensis* Hall and Whitfield.

Formation and locality.—Throughout the Galena horizon of Wisconsin, Iowa and Minnesota. Some of the more prominent localities of Minnesota are Fountain, Mantorville, Kenyon, Aspelund and Hader.

From the Hudson River group near Wykoff and Spring Valley, Minnesota, Mr. Ulrich has collected four specimens which apparently cannot be separated from this species. They may, however, prove to be dwarfed or young individuals of *Lingula beltrami*, since this species also occurs in the above mentioned region.

Collectors.—W. H. Scofield, A. D. Meeds and the authors.

Mus. Reg. Nos. 2372, 3389, 7677-7680.

LINGULA BELTRAMI, *n. sp.*

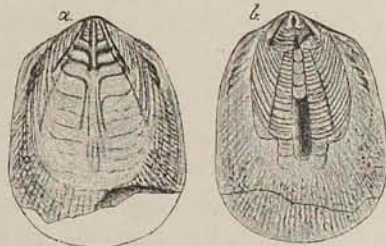


FIG. 25. *Lingula beltrami*.

In form and convexity of valves this species closely resembles *L. iowensis*, but attains a larger size with greater convexity of valves and a more subquadrate anterior margin. From *L. cincinnatiensis* Hall and Whitfield§ it can readily be distinguished in being wider, with valves not quite so convex and the cardinal slopes

*1847. Pal. New York, vol. 1, p. 96, pl. xxx, fig. 4; p. 285, pl. LXXIX, fig. 1.

†1856. Canadian Naturalist and Geologist, vol. 1, p. 319, fig. 8.

‡1842. Geology of New York; Report of the Second District, p. 309, fig. 6.

** Loc. cit., p. 285. †† Loc. cit., p. 242.

§ *Lingulella (Dignomia) cincinnatiensis* Hall and Whitfield, Pal. of Ohio, vol. II, p. 67, pl. 1, figs. 2, 3; 1875.

more obtuse. The ventral valve in *L. iowensis* and *L. beltrami* is also less convex than the dorsal, while in *L. cincinnatiensis* and *L. quadrata* Eichwald (non Hall) they are equally deep, but the latter is more so than the former. In all of these species there is on the lateral slopes in the anterior half of the interior a more or less conspicuous wrinkling of the shell which may represent the vascular markings of other species of *Lingula*.

Formation and locality.—Four specimens have been found by Mr. Ulrich in the Hudson River group between Wykoff and Spring Valley, Minnesota.

LINGULA CANADENSIS *Billings?*

1862. *Lingula canadensis* BILLINGS. Palæozoic Fossils, vol. i, p. 114, fig. 95.
 1863. *Lingula canadensis* BILLINGS. Geology Canada, p. 210, fig. 209.
 1889. *Lingula?* (*Lingulasma?*) *canadensis* ULRICH. American Geologist, vol. iii, p. 384.

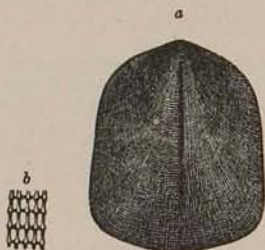


FIG. 26. Copy of Billings' original figure of his *Lingula canadensis*.

Original description: "Shell large, oblong, subpentagonal; front margin gently convex or nearly straight; anterior angles narrowly rounded; sides straight and nearly parallel for about two-thirds the whole length, then converging to the beaks; apical angle about 130°; cardinal edges on each side of the beak nearly straight. The valves are moderately convex, most tumid in the upper half, descending to the sides and front margin with three flat slopes. Surface with fine, thread-like, elevated, longitudinal ridges, five or six in the width of one line at the front margin; these are crossed by much finer concentric ridges, ten or twelve in one line, which are continued over the longitudinal ridges and give to the surface a minutely nodulose appearance."

The material upon which the above identification is based is rather fragmentary, consisting of two small broken individuals, and a piece of the lateral portion of a large specimen. These are not altogether identical in outline with the figure given by Billings, but since the surface ornamentation of *L. canadensis* is like that of the Minnesota specimens it has seemed best to refer them provisionally to this species

rather than separate them under a new name. *L. tenuigranulata* McCoy* is another closely related species, but it and *L. canadensis* have three flattened slopes, another character not seen in the Minnesota material.

Formation and locality.—Lower portion of the Galena limestone, in the quarries at Mantorville and near Hader, Goodhue county, Minnesota. The type specimens are from the Hudson River group of Anticosti.

Collectors.—W. H. Scofield, E. O. Ulrich and C. Schuchert.

Mus. Reg. Nos. 7681, 7682.

Family LINGULASMATIDÆ, n. fam.

Genus LINGULASMA, Ulrich.

1889. *Lingulasma*, ULRICH. American Geologist, vol. iii, p. 383.

1889. *Lingulelasma*, MILLER. North American Geol. and Pal., p. 350.

1892. *Lingulasma*, HALL. Palæontology of New York, vol. viii, pt. 1, pp. 24, 46.

Shell subquadrate, linguliform, inequivalve; the dorsal valve considerably the deeper. Beaks apical, that of the ventral somewhat extended beyond the dorsal; cardinal margins gently sloping to the sides. Surface with the concentric striae raised at irregular intervals into points, these being arranged in radiating lines.

Interior of the ventral valve with a low concave or concavo-convex platform occupying from less to more than one-half the length of the shell; the anterior wall may or may not be profoundly excavated. The ventral area has been enclosed more or less within the shell, making a distinct sheath or shelf, beneath which is the umbonal scar. Platform occupied by the progressive anterior, external and middle lateral scars. Transverse scars present underneath the platform at its antero-lateral angles. Crescentic scars scarcely defined.

The dorsal valve deep, with a high platform occupying the posterior third or one-half of the valve, centrally produced into a short or very long septum. The anterior walls of the platform are more or less excavated, deepest close to the septum; marked by vascular sinuses laterally directed. The crescent is more or less strongly developed, with its center sharply pointed posteriorly. In front of it is the umbonal scar, and in the type species there is anterior to the latter impression a short, sharp, median septum. Platform occupied by the lateral, transmedian, central and anterior muscular scars. Transverse scars situated at the base of the platform at its antero-lateral angles.

Type: *Lingulasma schucherti* Ulrich.

Lingulasma and *Lingulops* are the only linguloid genera in which interior platforms are developed, and in this remind one strongly of the same parts in the

*See Davidson's British Silurian Brachiopoda, p. 37, pl. II, figs. 9-14.

Trimerellidae. We do not regard these genera, however, as in the direct line of development towards *Trimerella*, but rather as a branch from *Lingula*, probably having its origin during Trenton times, and terminating with the Niagara formation. In the Black River group, at Pauquette Rapids of the Ottawa river, in Canada, we find *Obolus canadensis*, and *O. magnificus* Billings. These species Billings subsequently referred to his genus *Obolellina*, now regarded as synonymous with *Dinobolus*, Hall. In the Galena formation of Wisconsin and Minnesota, there is another form related to the above species, *Dinobolus parvus* Whitfield. These species were in all probability derived from *Obolella*, while *Monomerella* and *Trimerella* had their origin in *Dinobolus*. If this opinion is the proper one, *Lingulops* and *Lingulasma* should be separated from the *Lingulidae* and *Trimerellidae*, and referred to a new family, the *Lingulasmatidae*. This family will then follow the *Lingulidae*.

LINGULASMA GALENENSIS.

PLATE XXX. FIGS. 1-4.

1892, April 1. *Lingulasma galenensis* W. and S. American Geologist, vol. ix, p. 285.

Shell large, oblong, subpentagonal. Anterior margin slightly convex, and somewhat produced in the center; anterior angles narrowly rounded; lateral margins straight, nearly parallel, rounding rapidly into the more or less convex postero-lateral margins. Ventral beak somewhat extended beyond that of the dorsal valve. Valves strongly convex, dorsal more than the ventral; point of greatest convexity, in the former at one-third the entire length of the valve from the posterior margin, in the latter nearly central. Surface of each valve with three slopes in the anterior half; the central one flat or very slightly convex, with two broad and shallow depressions, causing a small central extension of the anterior margin; lateral sides very rapidly descending and somewhat convex. Surface concentrically striated; at irregular intervals the striæ rise into small pointed pustules radially arranged. These radial series of granulations are most prominent on the flattened, central, anterior portion of the valves; thirteen to fifteen of them in 5 mm., while twenty-eight pustules occupy the same length, measuring along a series.

Interior of ventral valve with a diamond-shaped concavo-convex platform, strongly elevated, and excavated anteriorly. Posterior margin of the specimen slightly broken; an internal arched deltidium not present. Umbonal scar (*g*) close to the posterior broken edge, and upon each side of it is a diverging excavated ridge. In front of the umbonal scar, and occupying the lateral portions of the platform, are the progressive tracks of the lateral (*l*) scars. At the posterior end of the platform are two slightly diverging, linear depressions, which terminate near the mid-length of the platform; and here originate two linear and parallel median elevations.

On each side of these are large shallow depressions, the middle lateral (*k*) scars. Transverse scars present at the base of the platform, at its antero-lateral angles. A broadly rounded, slightly elevated, median septum has its origin underneath the anterior end of the platform, and terminates at a point two-thirds the entire length of the valve from the posterior margin. The inner surface of both valves not occupied by the platform is marked by faint concentric undulations and radiating striations; the latter are conspicuous on the lateral portions.

Interior of dorsal valve with a concave platform occupying the posterior third, more or less defined laterally, profoundly elevated, and excavated anteriorly. Anterior edge of the platform produced in the center and supported by a short septum, which terminates at about the center of the valve. Underneath the platform, on each side of the septum, are well-defined vascular sinuses, laterally directed. Near the apex of the posterior margin is situated a small crescent (*ct*), and in front of it is a well-defined umbonal (*g*) scar, the anterior edge of which is strongly raised above the platform. Sides of the platform occupied by the lateral (*l*) scars. On the inner sides of the latter are situated the central (*h*) scars, leaving between them a median triangular space. The anterior produced portion of the platform occupied in part by the anterior (*j*) muscles. At the antero-lateral angles of the platform, and indenting it, are situated the strongly defined transverse (*t*) scars.

Length of the largest specimen, 35 mm.; width 28 mm.; thickness, 19 mm.; another specimen measures respectively 27x22x14 mm.

This species differs from *L. schucherti* Ulrich, the only other species of the genus, in that the dorsal valve is deeper, platform and median septum shorter, and the crescent smaller. In the ventral valve, the platform is also shorter and is of an entirely different shape. The muscular scars of this species are likewise more distinct than in *L. schucherti*, while the interior ventral area is absent in *L. galenensis*.

The posterior margin of the ventral valve in the two specimens of this species is somewhat broken, but it is certain that this valve extended beyond the dorsal, since the outline of the latter is distinctly visible. If an enclosed ventral area had been developed in this species, such as is present in *L. schucherti*, there should be evidence of it in these specimens. Since there is no proof of this nature, we are of the opinion that the ventral area was mainly external in *L. galenensis*, and that during the succeeding geological horizon, the Hudson River group, it receded more and more internally.

Formation and locality.—Near the top of the Galena limestone on Bear creek, just south of Hamilton, Fillmore county, and near the middle of this formation near Mantorville, Minnesota. Also in the Galena limestone at Decorah, Iowa, and at Neenah and Oshkosh, Wisconsin.

Collector.—Charles Schuchert.

Mus. Reg. Nos. 7683-7686.

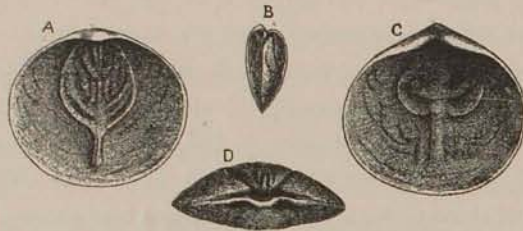
DINOBOLUS (?) *PARVUS* Whitfield.1882. *Dinobolus* (?) *parvus* WHITFIELD. Geology of Wisconsin, vol. iv, p. 347, pl. XXVII, figs. 8-10.

FIG. 27. *Dinobolus* (?) *parvus* Whitfield. A, interior of the dorsal valve as seen in a gutta-percha impression, $\times 2$; B, profile view of a cast of the interior, with the thickness and form of the shell indicated by the outer line, natural size; C, gutta-percha impression showing the internal characters of the ventral valve, $\times 2$; D, cardinal view of the cast of the interior, $\times 2$.

Description: Shell small for the genus, subcircular in outline, lenticular in profile, with the dorsal side somewhat more convex than the other, and both more ventricose posteriorly than anteriorly. Posterior margin broadly triangular, curving rapidly in the lateral portion to the broadly rounded anterior edge. Each valve with a narrow false cardinal area, that of the ventral valve larger and slightly produced beyond the dorsal into a small, acute and but little incurved beak, beneath which there appears to have been a narrow, concave triangular depression.

A gutta-percha impression of the dorsal side of a cast of the interior shows a large concave muscular area or platform, oval in outline and produced anteriorly into a narrow but slightly elevated mesial septum which terminates near the anterior margin. Upon this platform, and occupying the greater portion of it, are the progressive scars of the lateral muscles, except antero-medially where the anterior scar is present; the posterior portion is occupied by two well-defined, parallel, narrow, elongate elevations, separated by a narrow sinus, the front of which may be homologous with the cardinal scars, and the latter with the anal depression of *Obolella*. A crescent so characteristic of *Dinobolus* does not appear to have been developed in either valve. Platform of the ventral valve but slightly elevated, subquadrate in outline, widest anteriorly, occupied by broad progressive tracks of the lateral muscles, and separated medially by the faintly elevated median scars. Anterior edge of platform not excavated. Within the cardinal margin of the ventral valve are two short, narrow, rapidly diverging ridges, probably cardinal scars, separated by a broad but short pedicle muscle impression.

Shell substance originally not very thick, apparently smooth and now replaced by a coarsely crystallized calcite, a feature common to many species of the Trimerellidæ.

Of this species we have but a single specimen from Minnesota, found by Mr. E. O. Ulrich, which is in an excellent state of preservation. The interior characters are shown in greater detail than appears to have been the case in the material from Wisconsin upon which Prof. Whitfield based the species, otherwise the example agrees with his description and illustrations. In size and form it is nearer to *Dinobolus schmidti* Davidson and King,* from the Lyckholmer Schicht at Kirna, Esthonia, a horizon nearly equivalent to the Trenton limestone of New York, than to *Obolellina canadensis* and *O. magnificus* Billings** from the Black River group of Canada. The latter, of which only the exterior is known, are also much larger species than *D. ? parvus*.

The interior of *D. ? parvus*, as revealed in the Minnesota specimen, is highly instructive, since it appears to have characters both of the *Obolidæ* and *Trimerellidæ*. The structure of the cardinal region is similar to that of *Obolella*, while the platform and its muscular scars are as in *Dinobolus*. The crescent so characteristic of *Dinobolus* is, however, absent in *D. parvus*. The diverging elevations on each side of the pedicle muscle scar in *Obolella crassa*, (the cardinal scars), are also present in *D. ? parvus* and occupy a position equivalent to the crescent of *Dinobolus*. It may be that here is indicated the line of development of the crescent from the cardinal scar of *Obolella*. The combination of these characters in *D. ? parvus* seems to require its separation from *Dinobolus*, but until the interior is known of the species referred by Billings to *Obolellina* it is better to leave it provisionally in the former genus. Lower Silurian species of *Dinobolus* are also known from Esthonia (*D. schmidti*) and Brittany (*D. brimonti* Rouault†), but these have well-developed crescents.

Formation and locality.—Middle Galena, Wykoff.

Collector.—E. O. Ulrich. Type in the collection of C. Schuchert.

*Quart. Jour. Geol. Soc. London, vol. xxx, p. 164, pl. xix, figs. 5, 6, 1874.

**Canad. Nat. Geol. vol. III, p. 441, 1858; vol. vi, n. ser., p. 329, 1872.

†See Davidson's paper in the Geol. Mag., vol. vii, decade II, p. 349, 1880.

Order NEOTREMATA, Beecher.

Sub-order DAIKAULIA, Waagen.

Family SIPHONOTRETIDÆ, Kutorga.

Genus SIPHONOTRETA, De Verneuil.

1845. *Siphonotreta*, DE VERNEUIL. Géol. de la Russie d' Europe et des mont. de l'Oural, p. 286.

1892. *Siphonotreta*, HALL. Palæontology of New York, vol. viii, pt. i, p. 110.

Description.—"Shell elongate-oval, inequivalve; valves inarticulated. Pedicle-valve the more convex, with a straight, elevated, conical, and perforated beak, the circular foramen opening at the apex and communicating with the interior of the shell by a tubular canal, which narrows slightly as it passes inward. No cardinal area or deltidium is present, the growth-lines passing between the beak and the posterior margin as elsewhere on the shell. Brachial valve depressed-convex; beak marginal; posterior margin regularly arched and thickened. Interior of pedicle-valve with muscular impressions confined to the umbonal region. Close alongside the opening of the siphon, just within the cardinal margin, lie two elongate scars which are accompanied on either side by broader somewhat expanded or flabellate, simple and less distinct impressions. Directly in front of the middle pair lies a small central scar, in the axis of the shell, and at either side of it a transversely elongate impression. These latter impressions are distinctly separated from the former by a transverse ridge.

"In the brachial valve the impressions are equally concentrated, the entire muscular area being bounded on the posterior margin by a prominent ridge which, at the sides, merges into a compound lateral scar. The central portion of the area is much depressed and is divided axially by a narrow ridge or septum.

"Shell ornamented with concentric lines and ridges, the epidermal layer bearing hollow spines, which are distended at the base. Shell-substance calcareo-corneous, the layers beneath the epidermis being punctured by radiating and branching tubules, these layers are concentric and not parallel to the internal surface.

"Type *Siphonotreta unguiculata* Eichwald sp." (Hall, *op. cit.*)

SIPHONOTRETA? MINNESOTENSIS Hall.

PLATE XXIX. FIGS. 23 and 24.

1892. *Siphonotreta? minnesotensis* HALL. Palæontology of New York, vol. viii, pt. i, pp. 112, 177, pl. 4, figs. 37, 38.

Original description: "Shell subovate in outline. Pedicle-valve more convex than the brachial, slightly flattened along the median line, sloping with equal

convexity toward the lateral and anterior margins. Foramen apical(?). Brachial valve depressed-convex, somewhat elevated about the umbo. Surface covered, in the umbonal region, with fine, anastomosing and gently undulating concentric lines, which, in the latter portions of the shell, are finely granulose or serrated; at about one-third the length coarser varieties of growth appear, between which the finer lines are retained. Surface covered with hollow spines of various sizes, which appear to have been mostly set over the umbonal region of the pedicle valve. Here, where the growth lines are absent, the spine-bases in the original specimen are large and all of about the same size, and are disposed without order. Over the other portions of the shell the spines are set along the edges of the varices, small and large being indifferently mixed. The bases of the spines make annular swellings on the interior of the valve. The length of the original specimen is 15 mm., width, 12 mm."

Since no additional material has been discovered other than that used by professor Hall, we give in addition his observations on the species, with its relations to a similar form which is tentatively referred by him to *Schizambon*. "The American palæozoic faunas have yet furnished no thoroughly satisfactory representative of *Siphonotreta*. Before us are two specimens of a form allied to, but probably distinct from the Canadian representatives of *Schizambon* (?), referred to on a following page [*Siphonotreta scotica* Whiteaves—*Schizambon fissus* var. *canadensis* Ami (Hall)], which have been collected by Mr. Charles Schuchert and Mr. E. O. Ulrich, from the Trenton limestone at Minneapolis, Minnesota. One of these is an exterior mould, the other retains both valves, though the umbonal part of the pedicle valve has been broken, leaving no indication of the character of its foraminal aperture. The shell differs somewhat from the Canadian specimens in outline, being broader over the pallial region; the brachial valve shows a low longitudinal depression, the shell substance is very thin, while in the other species referred to, it is remarkably thick, and its lamellose structure conspicuously developed; the ornamentation of the surface consists, not of sharp, concentric lines, broadening to ridges toward the margin, but of fine, concentric, anastomosing wrinkles, which are interrupted over the body of the shell by the edges of the spiniferous lamellæ; the spines are comparatively short and sparse. Though recognizing the difficulties in the discrimination of species of *Siphonotreta*, we are nevertheless disposed to regard the above mentioned features as of specific value; and in the absence of evidence determining the character and position of the pedicle passage, it seems judicious to leave the species for the present under the genus *Siphonotreta*, with the designation *Siphonotreta minnesotensis*."

Formation and locality.—From the Trenton limestone near the University of Minnesota, Minneapolis, Minnesota.

Collectors.—E. O. Ulrich and Charles Schuchert.

Family LINGULELLIDÆ, Schuchert,

LEPTOBOLUS OCCIDENTALIS Hall.

1871. *Leptobolus occidentalis* HALL. Description n. sp. Foss. from the Hudson River group. p. 3, pl. III, fig. 18.
 1872. *Leptobolus occidentalis* HALL. Twenty-fourth Report N. Y. State Cab. Nat. Hist., p. 227, pl. VII, fig. 18.
 1892. *Leptobolus occidentalis* HALL. Pal. N. Y., vol. viii, pt. i, pl. III, fig. 7.

This species will probably be found in the lower portion of the Hudson River group of Minnesota, since it occurs in abundance in Iowa and Wisconsin. Mr. E. O. Ulrich has collected one specimen which may prove to belong to this species, but its position is such as to leave its identity in doubt.

Formation and locality.—In the lower portion of the Hudson River group at Hawley's mills or Graf, Iowa; Plattville and Clifton, Wisconsin; Ottawa, Canada (Ami). The specimen from Minnesota was found three miles north of Spring Valley.

Genus SCHIZAMBON, Walcott.

1884. *Schizambon*, WALCOTT. Monograph U. S. Geological Survey, vol. viii, p. 69.
 1887. *Schizambonia*, CHELERT. Manuel de Conchyliologie, Fischer's, p. 1266.
 1892. *Schizambon*, HALL. Palaeontology of New York, vol. viii, pt. i, p. 113.

Original description: "Shell ovate or oblong-oval, inequivalve; valves inarticulate; larger or ventral valve most convex, with a short obtuse beak at the cardinal margin. Foramen oblong and opening on the summit of the valve; no area nor deltidium; cardinal edge thin; smaller or dorsal valve nearly as convex as the larger, slightly flattened along the median line.

"Structure calcareo-corneous, consisting of a nacreous outer layer with a closely attached inner calcareous layer. Both layers are thought to be punctured by scattering spines apparently on the outer edges of the laminae or lines of growth.

"The interior of the larger valve shows the oblong foramen in a slight elongate depression and a pair of muscular scars just in front of it on each side of a slight longitudinal depression; from near the beak on each side of the foramen, a shallow sharply defined depression extends obliquely outward. No other markings were observed. In the interior of the dorsal valve a pair of anterior central muscular scars terminate their path of advance from the beak, a slight rounded ridge rising on the central line; posterior to these a large pair occur, and still beyond and more posterior a third pair, a narrow rounded edge extending obliquely down from the beak on each side between the central and lateral scars."

Type *Schizambon typicalis* Walcott.

Since the interior characters are unknown in *Schizambon? dodgii*, n. sp., and *S.? lockii*, n. sp., these forms are placed in this genus provisionally. *S. typicalis* is

said to have a short, obtuse beak at the cardinal margin, and judging from the illustration, it seems that little growth took place posterior to the protogulum, or initial shell. While no mention is made in *S. typicalis* and *S. ? fissus* var. *canadensis* Ami, of shell growth posterior to the protogulum, yet undoubtedly this feature will be found when looked for in specimens preserving these parts.

The line of development was probably as follows: From *Paterina* to a form having an open pedicle notch at the posterior end as in *Schizocrania* and *Trematis*, next to one where this notch is closed, leaving a more or less circular excentric pedicle opening, as in *Acrothele* or *Acrotreta*; thence to *Schizambon*.

SCHIZAMBON(?) DODGII, *n. sp.*

PLATE XXX, FIGS. 5-7.

Shell broadly oval, or nearly circular in outline. Dorsal valve evenly convex laterally and anteriorly; deeper than the ventral valve; point of greatest elevation about mid-length; centrally it has a shallow, concave, narrow sinus, which has its origin at the beak, thence slowly expanding in width, and traversing the entire length of the valve. Surface with numerous, concentric, variously terminating growth lines. Near the beak these lines indicate a *Paterina*-shaped nepionic stage. They are very delicate, the shell appearing smooth and shining, and gradually assume the contour of the mature outline of the valve, becoming stronger and stronger as full development is attained. Every second, third, or fourth line prominent, strongly imbricating, wavy along the edges, and terminating in long, slender, hollow(?), radiating spines. The intermediate concentric lines between the spiniferous ones are sharply elevated and finely crenulated. The spines begin to develop at a very early age, are remote, but become more and more crowded toward the anterior margin, where there are about sixteen in 3 mm., with an average length of 2 mm.

Ventral valve somewhat larger than the dorsal; curvature along the center not very marked, with the lateral slopes broadly convex. Beak marginal, slightly produced, elevated, with a small, false cardinal area beneath it. Pedicle furrow originating at the beak, narrowly triangular, 4 mm. in length, becoming deeply concave, with an opening into the interior of the shell, probably at its inner end. The nature of this opening and the interior characters of both valves are unknown. At the apex, the concentric lines are first *Paterina*-shaped; then growth obtains all around the initial shell, being more rapid anteriorly than posteriorly. It is during this second stage that the false cardinal area is formed, and the position of the pedicle opening changed. After the initial shell, the first few lines of growth

along the posterior margin do not pass over nor around the pedicle, but stops on each side; therefore during this period, there is an open pedicle slit, which is afterwards closed posteriorly by the addition of shell matter underneath the pedicle. As the pedicle opening advanced, the shell was resorbed anteriorly, and a deposit formed posteriorly, as indicated by the strong convex lines in the pedicle furrow.

Schizambon? dodgii differs from *S.? fissus*, var. *canadensis* Ami*, in being smaller, more broadly oval, in having a dorsal sinus, and the spines shorter, thicker, and therefore less numerous. If *Siphonotreta? minnesotensis* Hall should prove to belong to *Schizambon*, it will still be found to differ from *S.? dodgii* in the much thicker spines and the many large openings in the shell on the posterior portion of the dorsal valve.

Formation and locality.—Two specimens and fragments of others were collected by Mr. W. W. Dodge, of Cambridge, Massachusetts, for whom the species is named, in a dark, compact limestone near the top of the Trenton at Sandy Hill, New York. Associated fossils are *Trematis terminalis* Emmons, and *Trinuclaus concentricus* Eaton. The types were kindly presented to one of the writers.

SCHIZAMBON (?) LOCKII, *n. sp.*

PLATE XXX, FIGS. 8-10.

Shell large, very thin and broadly oval in outline. Dorsal valve shallow, not as deep as the ventral, and evenly convex laterally and anteriorly. Surfaces shining, nearly smooth, marked by fine, concentric growth lines and delicate, radiating striae. At the apex the former are Paterina-shaped, but after this stage growth takes place more strongly anteriorly than laterally, which soon gives to the shell its specific form. At about two-thirds the length of the shell from the beak to the anterior margin, the fine, radiating striae have numerous, very small, elongate, but distinct pustules, which probably did not terminate in spines.

Ventral valve most elevated at the beak, with gradual slopes laterally and anteriorly, and abrupt ones posteriorly. Apex obtuse, situated at about one-sixth the length of the shell from the posterior margin, with the pedicle furrow originating at the highest point, and gradually widening and extending forward not quite to the center of the valve in the smaller specimens; while in the larger it terminates at one-third the length of the shell from the posterior margin. Surface marked by concentric, slightly elevated growth lines, a number of which continue around posterior to the apex, and gradually become more distant and prominent as growth progresses. On each side of the pedicle furrow are a few radiating striae, while in front of the former the concentric growth lines have numerous, very small but distinct tubercles, about ten in 3 mm., which are probably the bases of former spines.

*Ottawa Naturalist, Dec. 1887; see also Pal. N. Y., vol. viii, p. 1, p. 115, pl. 4, figs. 32-36, 1892.

This species is readily separated from all other American species now referred to the genus by its thin valves, and particularly by the absence of all spines and imbricating growth lines on the posterior two-thirds of the dorsal valve. This species may prove to be the type of a new genus with relations nearer to the *Discinidae* than with the *Siphonotretidae*.

Formation and locality.—Two specimens have been procured, one of which, showing more of the detail, was recently collected by Mr. F. W. Sardeson on top of the hill just north of the Cincinnati University, in beds XIIIb of Mr. Ulrich's subdivision of the Cincinnati group. The specific name is given in remembrance of the pioneer geologist, John Locke, of Ohio.

Family DISCINIDÆ, Gray.

Genus ORBICULOIDEA, d'Orbigny.

1850. *Orbiculoidea*, d'ORBIGNY. *Prodrome de Paleontologie*, vol. i, p. 44.

1890. *Orbiculoidea*, HALL. *Paleontology of New York*, extract vol. viii, pt. i, p. 129.

Description: "Shells subcircular or subelliptical in outline, inequivalve. Apices eccentric. Pedicle-valve depressed convex, or flattened, with the apex slightly elevated and inclined posteriorly. On the exterior of the valve a narrow pedicle-furrow, abruptly intercepting the ornamentation, but not penetrating the substance of the shell, begins just below and behind the apex, extends over a greater or less portion of the radius of the valve, and, at its distal end, is produced into a short tubular siphon, which traverses the substance of the shell obliquely backward, emerging on the interior surface, where it produces a narrow groove, and usually terminates before reaching the margin of the valve. On the interior, the position of the external groove is marked by a thickened ridge extending from the apex, and this is continuous with the thickened margins of the internal groove, which, in advanced age, may become so developed as to envelop this groove, except at its outer end.

"The larger or brachial valve is depressed-conical, with the apex more strongly directed backward than in the opposite valve. The interior shows a fine longitudinal ridge or septum extending from the apex forward. Otherwise the internal markings are not satisfactorily known.

"Shell-substance composed of alternating lamellæ of corneous and mineral matter, the latter often removed in fossilization, making the shell appear essentially phosphatic. Surface ornamentation usually consisting of fine, crowded or distant, sometimes lamellose concentric lines, occasionally crossed by radiating lines or ridges.

"Type: *Orbicula morrisoni* Davidson." (Hall, *op. cit.*)

The species now referred to this genus were formerly regarded as congeneric with the recent species *Discina striata* Schumacher, the type of *Discina*. So far as known that genus is restricted to a single species, all the other recent forms formerly referred to *Discina* now belonging to *Discinisca*, Dall. Other Palæozoic subgenera of the same type of structure as *Orbiculoidea* are *Schizotreta*, Kutorga, *Ehlertella*, *Lindstroemella* and *Römerella*, Hall.

ORBICULOIDEA LAMELLOSA Hall?

PLATE, XXIX, FIG. 25.

1847. *Orbicula lamellosa* HALL. Paleontology of New York, vol. i, p. 99, pl. xxx, fig. 10 (not *Orbicula lamellosa* Broderip, 1833=*Discinisca lamellosa*).
1855. *Orbicula truncata* EMMONS. American Geology, part ii, p. 200, fig. 62.
1860. *Discina truncata* EMMONS. Manual of Geology, p. 99.
1862. *Discina circe* BILLINGS. Palæozoic Fossils, vol. i, p. 51, fig. 125.
1890. *Orbiculoidea lamellosa* HALL. Paleontology of New York, extract of vol. viii, pl. 1vE, fig. 12.

Original description: "Orbicular, depressed; apex small, but little elevated, situated about one-third the breadth of the shell from the margin; surface marked by elevated lamelli-form concentric lines or ridges."

The following is Mr. Elkanah Billings' description of *Discina circe*, a species now regarded as a synonym of *O. lamellosa*:

"Circular; lower [ventral] valve with the apex central or nearly so; peduncular groove acutely oval, extending from the apex about two-thirds the distance to the margin. The foramen is probably situated at the outer extremity of the groove, but it cannot be seen in the specimen examined. The upper [dorsal] valve (supposed to be that of this species) has the apex situated about one-third the semi-diameter from the margin. In both valves the apex is smooth.

"Surface with rather strong, sublamellose concentric striae, which become more distant and coarser from the apex outwards. At the margin there are four or five ridges in one line, but next to the apex double that number in the same space. The ridges are somewhat irregular, being in some places slightly undulated, and occasionally branched, two or more running into one. The grooves are rather wider than the ridges, and the lamellose aspect of the latter appears to be due to their being more abruptly elevated on the inner side, or the side towards the apex, than on the outside.

"Width of the specimens of the lower valves examined, nine lines; length of peduncular sulcus, three and one-fourth lines; width of the same, one-half line. Another specimen (an upper valve) is seven lines wide.

"The lower [ventral] valve is depressed, conical and appears to have been about two lines in height, but as it is somewhat distorted by pressure, the true elevation cannot be determined. The upper [dorsal] valve seems to be less convex than the lower."

The single specimen which is here referred, with some doubt, to this species is a dorsal valve about 4 mm. in height. The apex is nearly central, with the anterior slope strongly convex, while the posterior slope is slightly concave.

Formation and locality.—From the Salmon River (Hudson River) group or Loraine shales near Spring Valley, Minnesota. Also in the Trenton formation at Middleville and Lowville, New York; Bellville and Ottawa, Canada.

Collector.—Charles Schuchert.

Genus SCHIZOTRETA, Kutorga.

1848. *Schizotreta*, KUTORGA. Verhandl. der russ.—Kais. Mineral. Gesellsch. zu St. Petersburg, pp. 272, 273.

1890. *Schizotreta*, HALL. Palæontology of New York, vol. viii, abstract, p. 135.

This subgenus is readily distinguished from *Orbiculoidea* "in having the perforated valve very convex and the imperforate one depressed-conical or flat.

"The pedicle-groove has essentially the character seen in *Orbiculodea*, d'Orbigny, but is usually much more distinctly retained on account of the greater thickness of the shell.

"Muscular impressions of the brachial or imperforate valve in *Schizotreta conica* Dwight, consist of two strong excavated anterior adductors approaching toward the center of the shell, and separated by a prominent septum which is continued from a somewhat thickened posterior muscular area." (Hall, *op. cit.*)

Interior of ventral valve with the posterior adductor scars situated on each side of the walls of the pedicle groove.

SCHIZOTRETA PELOPEA Billings, *sp.*

PLATE XXIX. FIGS. 26-28.

1862. *Discina pelopea* BILLINGS. Palæozoic Fossils, vol. i, p. 52, fig. 56.

1863. *Discina pelopea* BILLINGS. Geology of Canada, p. 159, fig. 124.

1892. *Discina concordensis* SARDESON. Bulletin of the Minnesota Academy of Natural Science, vol. iii, p. 328, pl. iv, figs. 13, 14.

Original description: "Upper valve circular, depressed-conical. Apex about half the semi-diameter from the posterior margin. Surface with fine concentric striae when perfect, but when partially exfoliated, smooth and places shining. Color black; width, six lines. Lower valve unknown.

The following emended description is prepared from a series of specimens obtained from the quarries at Mantorville, Minnesota, in the Galena limestone horizon: Shell circular, biconvex, with the apex of the dorsal valve situated at about one-third the entire length of the shell from the posterior margin; apex of the ventral valve somewhat more excentric. Surface with numerous concentric, strongly elevated lines of growth, with the intermediate spaces wide and concave;

thirteen to fifteen in the space of 2 mm. Dorsal valve depressed-convex. Ventral valve strongly elevated at the apex, perforate; posterior slope rapid, convex; anterior slope flat, or slightly concave. Pedicle opening short, narrow, oval and surrounded by an elevated margin. In the interior, on each side of the pedicle area, are situated the very narrow posterior adductor scars. The margin of this valve is distinctly, but slightly reflexed, producing a broad, shallow groove along the outer margin of the natural casts.

This species differs from *Discina circe* Billings—*Orbiculoidea lamellosa* Hall, in having the ventral valve more elevated, while in the latter it is the shallower valve that has the pedicle opening. The apices of the valves also are much more excentric in *S. pelopea* than they are in Hall's species, being very nearly central in the latter. From *Schizotreta conica* Dwight, and *S. ovalis* Hall, it differs in being in outline and not narrowly oval.

Formation and locality.—Not uncommon in the Galena limestone, just above the Galena shales, in the quarries at Mantorville and at Old Concord, Minnesota. Also from the same formation at Dubuque, Iowa, and Neenah, Wisconsin. From the Salmon River (Hudson River) formation at Spring Valley, Minnesota. Also in the Trenton limestone at Montreal, Canada.

Collectors.—A. D. Meeds and the authors.

Mus. Reg. Nos. 263, 296, 7688-7690.

SCHIZOTRETA MINUTULA, *n. sp.*

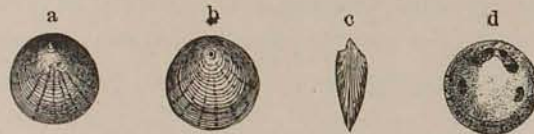


FIG. 28. *a*, dorsal valve; *b*, ventral valve; *c*, profile view; *d*, interior of dorsal valve; all $\times 18$.

Description: Shell minute, nearly circular in outline, marked by numerous, delicate concentric lines of growth and sometimes a few radii, in the anterior region; valves about equally convex. Ventral valve with a minute circular pedicle opening in the apex of the shell. Area posterior to the dorsal beak more excavated than that of the other valve.

Interior of the dorsal(?) valve apparently with two pairs of muscle scars, the posterior pair the larger, diverging forward and situated one on each side of the beak cavity; the other pair is placed medially near the lateral margin.

Dimensions, $\frac{1}{6}$ of a millimeter in length.

This little species is the smallest adult brachiopod from paleozoic rocks known. Individuals occur in abundance associated with stems of *Diplograptus*, to which they were probably attached. This may account for their small size.

Formation and locality.—From the lower portion of the Hudson River group near Granger, Minnesota, *Mus. Reg.* No. 8392.

Genus TREMATIS, Sharpe.

1847. *Trematis*, SHARPE. Quarterly Journal Geological Society, vol. iv, p. 66.

1892. *Trematis*, HALL. Palæontology of New York, vol. viii, pt. 1, p. 138.

Description: "Shell subcircular or transversely oval in outline. Pedicle valve unevenly convex, more or less depressed over the posterior region; apex at or behind the center; directly beneath it begins the pedicle-fissure, which transects the shell, vertically widening to the posterior margin with straight or outwardly-curving edges. Brachial valve evenly convex, with its apex marginal and slightly projecting. On the interior, the pedicle-valve shows a faint median furrow extending from the angle of the fissure to the apex of the shell; this groove widens at its apical termination and may represent a point of muscular attachment. The sides of the fissure are often thickened by callosities similar to those sometimes seen in species of *Orbiculoides*. From the apex of the valve extend radiating and branching vascular sinuses.

"In the brachial valve the posterior margin is much thickened and broadly grooved to allow the extension of the pedicle. This thickening does not take the form of a cardinal area or shelf, but is rather a callosity closely appressed against the interior surface of the shell, the central portion being projected beyond the margin of the pedicle-valve. Directly below and in front of this area are two transversely elongate scars, adjustors or posterior adductors, which are usually partly concealed by the progressive overgrowth of the cardinal thickening. A faint median septum begins between these scars and passes forward, becoming more prominent over the tongue-shaped median elevation which separates the large central scars. These impressions are oblique and are not simple, each appearing to be composed of two, if not three distinct scars, making a posterior, a median and an anterior pair. What appears to be the posterior pair is small, and sometimes quite sharply defined, the central pair very much larger, and the anterior pair narrow, situated at either side of the angle of the median callosity and separated by the apex. The specialization of the first of these scars is not satisfactorily established; the entire impression is deeply excavated. In some well preserved specimens there is also evidence of external marginal scars lying just in front of the outer end of the posterior adductors.

"Surface of both valves more or less completely covered by a beautiful ornamentation consisting of punctures or small pittings of varying depth, arranged either in quincunx (*T. terminalis*) or in radiating rows; in the latter case they may be distant from one another without intervening ridges (*T. umbonata*), or lie in radiating furrows, when they are either circular (*T. punctostriata*) or subrectangular (*T. ottawensis*).

"Shell-substance composed of an outer calcareous layer with a series of inner corneous lamellæ. The outer layer varies in thickness in different species and is coarsely punctated by the pittings constituting the surface ornamentation. The corneous layers are impunctate." (Hall, *op. cit.*)

Type: *Trematis terminalis* Sharpe (not Emmons)—*T. millepunctata* Hall.

TREMATIS HURONENSIS *Billings?*



FIG. 29. Billings' original figure of *T. huronensis*. *a*, lower valve. *b*, longitudinal section, showing the curvature of both valves; *c*, a portion of the surface enlarged.

1862. *Trematis huronensis* BILLINGS. Palæozoic Fossils, vol. 1, p. 53, figs. 59a, 59b, 59c.

1863. *Trematis huronensis* BILLINGS. Geology of Canada, p. 159, figs. 130a, 130c.

1892. *Productella minneapolis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 332, pl. iv, figs. 11, 12.

Of *Trematis* we have seen but four imperfect specimens. Since they preserve only the dorsal valve, no direct comparison can be made with the ventral valve of *T. huronensis* Billings, and therefore this identification is provisional. The surface pittings in these specimens are similar to those in *T. huronensis*, *i. e.*, they are arranged in radiating lines, not in quincunx, and in this respect differ from *T. terminalis* Emmons, *T. millepunctata* Hall, and *T. quincuncialis* Miller and Dyer. Our specimens vary somewhat from Billings' species, in that the radial surface depressions become obsolete towards the anterior margin.

The "ventral valves" of *Productella minneapolis* Sardeson are identical with the upper or dorsal valve of the shells identified by the writers with *Trematis huronensis*. Moreover, *Productella* is not known below the Devonian.

Formation and locality.—From the Trenton limestone in the quarries along the river bluffs, and near the base of the Trenton shales at Minneapolis, Minnesota. The Canadian specimens are from the Black River limestone of Pallideau islands, lake Huron.

Collectors.—C. L. Herrick and C. Schuchert.

Mus. Reg. No. 7691.

TREMATIS OTTAWENSIS *Billings.*FIG. 30. Billings' original figure of *T. ottawensis*.1861. *Trematis ottawensis* BILLINGS. Paleozoic Fossils, vol. i, p. 53, fig. 58.1892. *Trematis ottawensis* HALL. Paleontology of New York, vol. viii, pt. i, pl. IVG, figs. 15-17.

Original description: "Nearly circular; length a little greater than the width; upper valve moderately and uniformly convex, most elevated about the middle; apex small, obtusely pointed, slightly elevated, marginal. Surface with fine, radiating striae, which increase by interstitial addition, sometimes closely crowded together, in which case there are ten or twelve in the width of one line; occasionally more distant, or from four to eight in one line. The intermediate grooves are divided into square compartments by cross-ridges, which connect the radiating ridges, but are not continuous, those in one groove not corresponding in position with those in the adjacent grooves, so as to form uninterrupted concentric lines. In specimens with the striae closely crowded together only the radiating lines are distinctly visible, but the others can always be detected in good specimens, on close examination.

"Length from twelve to fifteen lines; width a little less than the length. Lower valve unknown."

Formation and locality.—Rare in the Galena beds at St. Anthony hill, St. Paul. Also in the Trenton limestone, Ottawa, Canada, and at Frankfort, Kentucky.

Collector.—E. O. Ulrich.

Genus SCHIZOCRANIA, Hall and Whitfield.

1875. *Schizocrania*, HALL and WHITFIELD. Paleontology of Ohio, vol. ii, p. 73.1892. *Schizocrania*, HALL. Paleontology of New York, vol. viii, pt. i, p. 142.

Description: "Shells subcircular in outline, inequivalve, unarticulated. Pedicle valve flat or concave; apex subcentral. A deep triangular notch extends from just behind the beak to the margin, where its arc is equal to about one-sixth of the periphery. The apex of this broad pedicle-notch is occupied by a triangular transverse plate varying in size with the age of the shell, but extending for one-fourth to one-third the length of the opening. Surface marked by concentric-growth lines. On the interior no muscular impressions are visible. Brachial valve more or less

convex, with the beak marginal. The interior bears a pair of strong posterior adductor scars, lying close together in the umbonal region; their outline is elongate-ovate, indicating a progressive increase in size, and they frequently appear to be divisible into anterior and posterior elements. In front of them, at about the center of the valve, are the small and faint anterior adductor impressions. A low median ridge extends from the apex to beyond the center of the valve. External surface marked by elevated striæ radiating from the beak.

"Substance of the shell composed of perlaceous calcareous laminae which constitute the most of the shell. The inner layers appear to be corneous. All are impunctate?" (Hall, *op. cit.*).

Type: *Orbicula? filosa* Hall.

Species of this genus are found in the Trenton, Utica and Hudson River groups of America. *S. helderbergia* Hall, from the Lower Helderberg, and *S. superincretata* Barrett, of the lower Oriskany, are other American species.

SCHIZOCRANIA FILOSA Hall,

PLATE XXIX. FIGS. 29-31

1847. *Orbicula? filosa* HALL. Palæontology of New York, vol. i, p. 99, pl. xxx, figs. 9a-9d.
 1863. *Trematis filosa* BILLINGS. Geology of Canada, p. 159, fig. 126.
 1873. *Trematis filosa* HALL. Twenty-third Rep. N. Y. State Cab. Nat. Hist., pl. XIII, figs. 21, 22.
 1875. *Trematis (?) filosa* MILLER. Cincinnati Quart. Jour. Sci., vol. ii, p. 15.
 1875. *Schizocrania filosa* HALL and WHITFIELD. Palæontology of Ohio, vol. ii, p. 73, pl. I, figs. 12-15.
 1892. *Schizocrania filosa* HALL. Palæontology of New York, vol. viii, pt. i, p. 143, pl. IV G, figs. 22-30.

Original description: "Orbicular; one valve more or less convex; apex marginal; surface radiated with numerous fine elevated thread-like striæ which are more or less prominent, depending on exfoliation of the shell; intermediate striæ coming in between the others as they recede from the beak, but the striæ are not bifurcate."

This species was subsequently more fully described by Hall and Whitfield from material obtained at Cincinnati, Ohio. The description is as follows; "Shell orbicular, or very slightly ovate, the beak of the upper or free valve [dorsal] projecting a little beyond the limits of the circle, giving a somewhat greater diameter along the median line than in a transverse direction. Free valve moderately convex, the central region being the most prominent. Attached valve [ventral] discoid, very thin, deeply and broadly notched on the posterior side; the notch not extending quite to the center of the valve; occupying nearly one quarter of the circumference of the valve on the outer margin; border of the notch thickened, especially at the base, which is rounded and the center marked by a slightly projecting point. Interior of the free valve [dorsal] marked by two proportionally large, elongate, ovate, diverging muscular prominences [posterior adductor scars], leaving corresponding pits on the casts of the shell, or on exfoliated specimens; situated just below the

beak, and extending nearly or quite one-fourth of the length of the valve from the apex. There are also two other muscular impressions [anterior adductor scars] smaller in size, circular in form, and situated near the middle of the valve below the extremities of the ovate imprints, and slightly more distant from each other. Beneath the beak there is a slight thickening of the cardinal border. The muscular markings of the lower valve have not been observed.

"Surface of the shell of the convex valve [dorsal] marked by fine, even, thread-like radiating striae; increased both by division and implantation, and gradually increasing in strength toward the border of the shell; the interspaces where the shell is perfectly preserved are flattened, the striae appearing as raised lines on the surface. The attached valve [ventral] is strongly marked by irregular concentric undulations circling the valve parallel to the margin, but interrupted at the border of the notch."

When the dorsal valve is broken away so as to show the ventral valve beneath, it is seen that the first overlaps and completely surrounds the latter, and it may, as believed by Hall, (*op. cit.* 1892, p. 143), have served as "an important accessory means of attachment" to foreign bodies. This species is usually found attached to brachiopods, particularly to *Rafinesquina alternata*, but is occasionally found on gastropods, as in the case of the Minnesota specimens before us.

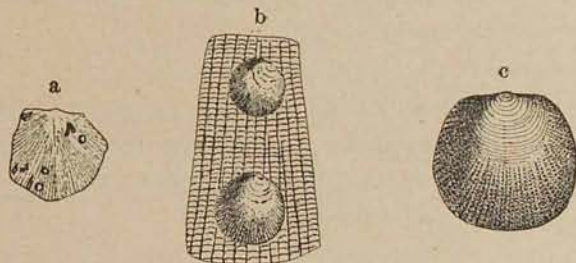


FIG. 31. a, three immature specimens attached to *Strophomena*, natural size; b, two of the same $\times 7$; c, same $\times 18$. Middle third of the Trenton shales, Minneapolis. Collection of C. Schuchert.

These figures are introduced to show various stages of the nepionic and early nealogue condition of *Schizocrania*. The "Paterina stage," with its straight hinge-line, continues throughout the nepionic growth and is succeeded in the early nealogue stage by the development of series of radially arranged pits strongly resembling those of *Trematis*. This is followed by the striated or specific stage. *Schizocrania*, therefore, seems to be phylogenetically related to *Trematis*.

Formation and locality.—In the Trenton shales at Cannon Falls, Chatfield and Minneapolis, Minnesota. This species also occurs in the Trenton formation of New York and Kentucky; in the Utica formation at Utica, New York, and Ottawa, Canada; and in the Utica horizon at Cincinnati, Ohio.

Collectors.—W. H. Scofield, E. O. Ulrich and C. Schuchert.

Suborder GASTEROPEGMATA, Waagen.

Family CRANIIDÆ, King.

Genus CRANIA, Retzius.

1781. *Crania*, RETZIUS. Schriften der Berliner Gesellsch. Naturf. Freunden, vol. II, p. 72.

1892. *Crania*, HALL. Paleontology of New York, vol. VIII, pt. I, p. 145.

Description: "Shell inequivalve, inarticulated, without perforation for a pedicle; subcircular in outline, generally somewhat transverse across the posterior margin; attached by the apex or the entire surface of the lower valve. Ventral or lower valve depressed-conical or conforming to the surface to which it is attached. Dorsal or upper valve more or less conical, with a subcentral, posteriorly-directed apex. External surface of the valves usually smooth, sometimes spinose or with concentric or radiating striae. In the interior of both valves are two pairs of large adductor scars, the posterior of which are close upon the margin and widely separated, the anterior near the center of the shell and close together, more approximate in the lower than in the upper valve. These posterior scars are often strongly elevated on a central callosity which surrounds their anterior margins. The margin of the lower valve is usually broad and thickened. Impressions of the pallial genital canals coarsely digitate.

"Shell substance calcareous; strongly punctated by vertical canals which become subdivided toward the epidermal surface.

"Type: *Crania craniolaris* Linné." (Hall, *op. cit.*)

This genus had its origin in the Trenton formation and thence has existed through all geological time up to the present. One species is reported from the Chazy and another from the middle Primordial, neither of which have furnished undoubted evidence of their belonging to this genus.

CRANIA SETIGERA Hall.

PLATE XXIX, FIGS. 32 and 33.

1866. *Crania setigera* HALL. Description of new species of Crinoidea and other Fossils, p. 12.

1872. *Crania setigera* HALL. Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., p. 220, pl. VII, fig. 15.

1892. *Crania setigera* HALL. Paleontology of New York, vol. VIII, pt. I, pl. IVH, figs. 14-16.

Original description: "Shell small, suborbicular; length greater than width; cardinal margin nearly straight. Dorsal valve convex; beak elevated, pointed, situated nearly one-third the length of the valve from the cardinal border.

"Surface marked by comparatively coarse pustules or setæ, which are more distant [distinct] near the margin of the shell."

The individuals of this species from the thin-bedded Trenton limestone have the surface pustules strongly elevated, appearing more like short spines. Those from

the Trenton shales often attain a greater size, and have the setæ usually less pronounced, while the beak is obtuse, the outline variable, and the cardinal margin only in rare instances straight. Free dorsal or upper valves are common, and but few specimens have been secured in which the valves conjoin, and are attached to an *Orthis* or *Rafinesquina*. These attached specimens are marked more or less with their host, causing the characteristic surface pustules to become obsolete, while the striæ of those growing upon smooth surfaces have developed the setæ. In specimens where these pustules have been removed by weathering or other causes, it is very difficult to decide whether they are individuals of *C. setigera* or *C. trentonensis*. Such specimens are usually referred to the latter species, but they commonly preserve a few pustules near the margin.

A specimen of *Monticulipora*, with an individual of this species* attached, also has a parasitic species of bryozoan growing on it, which grew towards the *Crania*. Its growth, however, was limited towards the anterior portion of the *Crania*, leaving between it and the encroaching bryozoan a space 3-4 mm. in width. This limiting of the growth of the bryozoan may have been caused by the frequent extension of the arms of the *Crania* during life.

Formation and locality.—In the Trenton limestone at Minneapolis; Trenton shales at Minneapolis, St. Paul, Cannon Falls, Fountain, Chatfield and Preston, Minnesota. Also from the Trenton at Decorah, Iowa; Mineral Point and Beloit, Wisconsin. In the Salmon River group or Loraine shales at Wilmington, Illinois.

Collectors.—C. L. Herrick, W. H. Scofield and the writers.

Mus. Reg. Nos. 718, 5500, 7692-7696, 7958.

CRANIA GRANULOSA N. H. Winchell.

PLATE XXIX. FIGS. 34 and 35.

1880. *Crania granulosa* N. H. WINCHELL. Eighth Annual Rep. Geol. and Nat. Hist. Survey of Minnesota, p. 63.

Original description: "Shell small, but prominently elevated at the beak; orbicular or somewhat widened between the antero-lateral margins; no concentric striæ or undulations visible on the exterior of the shell, nor radiations; the whole surface of the dorsal valve uniformly fine-granulated or pustulose; these granulations not disposed in any apparent order. The lower valve unknown."

Crania scabiosa Hall, when growing on a bryozoan, usually has the upper valve strongly pitted. Specimens of this nature have received the name *C. multipunctata* Miller and Dyer. The outer surface of *C. granulosa*, however, is not pitted, but is crowded with small pustules irregularly arranged.

Formation and locality.—Trenton limestone at Minneapolis, Minnesota.

Mus. Reg. No. 708.

*This specimen is figured in Pal.-N. Y., vol. viii, pl. ivH, fig. 14, 1892.

CRANIA TRENTONENSIS *Hall*.

PLATE XXIX. FIGS. 36 and 37.

1866. *Crania trentonensis* HALL. Description of new species of Crinoidea and other Fossils, p. 12.
 1872. *Crania trentonensis* HALL. Twenty-fourth Rep. N. Y. State Cab. Nat. Hist., p. 219, pl. VII, figs. 11, 12.
 1892. *Crania trentonensis* HALL. Palæontology of New York, vol. VIII, pt. I, pl. IVH, figs. 21, 22.

Original description: "Shell medium size, strongly convex on the upper valve; width a little greater than the length, greatest width below the middle of the shell. Beak of dorsal valve small, pointed towards and situated near the cardinal border.

"Surface marked by strong concentric lines of growth. No striæ or radiating lines are visible. Transverse diameter eleven-twentieths of an inch; length half an inch."

This species differs from *C. setigera* Hall, in not having the upper or dorsal valve covered with elongate pustules. The shell of the dorsal valve of *C. trentonensis* is thick, and in this differs from *C. scabiosa* Hall, which is thin and usually partakes of the ornamentation of its host. Outline of the shell and position of the apex are variable features, and of little specific value among species of *Crania*.

Formation and locality.—In Minnesota this species has been found only in the Galena shales near Cannon Falls. One of the writers has found it in the "Lower Blue beds" of the Trenton at Janesville, Wisconsin, and Dixon, Illinois. The type specimens are from the Trenton at Middleville, New York.

Collectors.—W. H. Scofield and C. Schuchert.

Mus. Reg. No. 7697.

Genus CRANIELLA, Ehlert.

1888. *Craniella*, EHLERT. Bull. de la Soc. d'Etudes Scientif. d'Angers, p. 37.
 1892. *Craniella*, HALL. Palæontology of New York, vol. VIII, pt. I, p. 153.

Description: "Shell somewhat irregular, outline subcircular or subquadrangular. Ventral valve thin, adhering by its entire surface; dorsal valve conoidal, more or less elevated; apex subcentral, posterior; interior of the dorsal valve without a well-defined border; impressions of the adductors large, very distinct, four in number, of which the posterior two are quite distant, the two subcentrals somewhat smaller, closely approximate or even confluent; from near each of the posterior impressions starts a vascular sinus, which is broad, strongly sinuous near its point of departure, narrowing gradually in following the contour of the valve, emitting from its marginal side dichotomizing secondary branches.

"Type: *Craniella meduanensis* Ehlert." (Hall's translation of the original diagnosis.)

The known species of this genus are *C. ulrichi* Hall of the Trenton, *C. hamiltonia* Hall of the Hamilton, and *C. meduanensis* Ehlert of the Devonian of France.

CRANIELLA? ULRICHI Hall.

PLATE XXIX, FIGS. 38 and 39.

1892, July. *Craniella ulrichi* HALL. Palaeontology of New York, vol. viii, pt. 1, pp. 153, 181, pl. IVH, figs. 1, 2.Compare *Crania halli* SARDESON.* Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 328, pl. IV, figs. 8-10; April, 1892.

Description: "Shell moderately large. Outline normally circular. Apices sub-central, slightly posterior, inclined backwards. Upper valve with the posterior scars large and the adjustors well defined; anterior scars subdivided, the outer or posterior portion possibly representing the insertion of the brachial muscles. The vascular sinuses make a 3-shaped curve on the lateral portion of the valve, with the crest of the double arch towards the center; narrowing rapidly, becoming indistinct over the anterior region. Lower valve regularly curved, evidently unattached at maturity. Anterior adductors very large, situated on a thickened posterior area. Posterior adductor and adjustor scars very faint, lying just within the margin. The vascular sinuses are a series of low grooves extending forward in subparallel lines from the anterior and lateral margins of the central muscular area. External surface of the valves smooth or covered with concentric sublamellose growth-lines. Length of an upper valve, 16 mm." (Hall, *op. cit.*)

The specimens which can be referred to this species are free, separated, strongly convex valves, and are usually overgrown by bryozoans. Associated with them are numerous dorsal valves of *Crania setigera* Hall, also usually occurring as free valves. These can be separated from *Craniella? ulrichi*, when the interior is not shown, only by their outer spinose surface.

The material of *C. ulrichi* examined by Prof. Hall is identical with that which we have. All of the attached specimens on which he bases the statement, (p. 153) "is sometimes attached," have proved to be *Crania setigera*. Among the many specimens of *Crania* and *Craniella* observed in Minnesota, not a single attached ventral valve with the dorsal valve removed has been found. When the ventral valve is present it is attached to some other brachiopod and has the dorsal valve covering it. Such specimens have invariably proved to be *Crania setigera*. That we have both valves among the large and free specimens of *Craniella? ulrichi* is probable, since the muscular scars and vascular markings are quite different in the two type specimens described and illustrated by professor Hall. This species is, therefore, biconvex and probably attached by the apical portion of the ventral valve.

Formation and locality.—Rare in the Trenton shales at Minneapolis, St. Paul and near Fountain, in the Galena shales, six miles south of Cannon Falls, Minnesota.

Collectors.—E. O. Ulrich, W. H. Scofield and C. Schuchert.

Mus. Reg. Nos. 7698-7700.

*Mr. Sardeson's name may really apply to this species, but neither his description nor figures are sufficiently diagnostic to enable us to determine this point satisfactorily. On the other hand, it would seem that his specimens must be distinct, because he had on several occasions been informed by one of us that Prof. Hall had named and described the present species in the work above cited. As is well known, part 1 of that volume was printed nearly two years before it was published.

Genus PHOLIDOPS, Hall.

1859. *Pholidops*, HALL. Palaeontology of New York, vol. iii, pp. 489, 490.

1892. *Pholidops*, HALL. Ibidem, vol. viii, pt. i, p. 155.

Description: "Shells small, patelliform, equivalve, equiconvex, inarticulate, unattached. Outline oval or subelliptical; apex subcentral, excentric or marginal, sometimes terminal and produced. Surface marked by strong, concentric, often lamellose lines of growth, which are crowded on the posterior and distant on the anterior portion of the valves; these are sometimes crossed by faint, interrupted radiating lines. In the interior the surfaces of contact make a broad, smooth, flat or slightly convex border, somewhat broader in front than behind. The muscular and visceral area occupies a sharply-defined and very limited space in the apical portion of each valve. In both it is of essentially the same size and subtriangular in outline, the apex of the triangle pointing forward and usually surrounded by a conspicuous callosity.

"The ventral(?) valve bears two well-defined central adductors occupying the same relative position as in *Crania*; these impressions are usually simple, but appear to be sometimes complicated by association with ill-defined scars of the anterior muscles. The posterior adductors or divaricators are situated at the basal angles of the muscular triangle and are distant from the posterior margin. The linear parietal scars are very strong, the posterior being more or less distinctly lobate, the anterior generally straight or rounding about the central adductors. In the opposite or dorsal(?) valve the scars have essentially the same arrangement; the anterior adductors, however, are separated by elongate median scars (anterior) which traverse the elevated callosity surrounding the anterior margin of the area. The posterior scars are often more widely divergent than in the other valve. Shell substance calcareous and impunctate(?)." (Hall, 1892, *op. cit.*)

Type: *Orbicula ? squamiformis* Hall.

PHOLIDOPS TRENTONENSIS Hall, var. MINOR, n. var.

PLATE XXIX, FIG. 40.

The original description of *P. trentonensis* Hall* is as follows: "Shell small, broadly oval, very depressed-convex. Apex situated near the cardinal extremity. Surface marked by strong, concentric, lamellose lines of growth."

The Minnesota specimens in outline, convexity of valves, position of the apex and the strong lamellose lines of growth, agree with these parts as described and illustrated in *P. trentonensis* Hall. They are, however, one-half, but more often less

* Descript. of new species of Crinoidea and other Fossils, p. 14, 1866. Twenty-fourth Rep. N. Y. State Cab. Nat. Hist. p. 221, pl. VII, fig. 8, 1872.

than one-half the size attained by this species as found at Middleville, New York, and since they are constantly smaller, the varietal name *minor* is here applied to them. The growth lines are conspicuous in some specimens, while in others they are nearly obsolete. The muscular markings are undefined, owing to the tenuity of the valves.

Formation and locality.—Not uncommon near the base of the Galena shales at St. Paul; associated with *Clitambonites*, three miles south of Cannon Falls and at Kenyon, Minnesota. Also in the upper part of the Trenton shales at Chatfield.

Collectors.—A. D. Meeds and C. Schuchert.

Mus. Reg. No. 7279.

Subclass ARTHROPOMATA, Owen.

Order PROTREMATA, Beecher.

Family CLITAMBONITIDÆ, n. fam.*

Genus CLITAMBONITES, Pander.

1830. *Clitambonites*, PANDER. Beitrage zur Geognosie des russischen Reiches, p. 70.

1892. *Clitambonites*, HALL. Paleontology of New York, vol. viii, pt. i, p. 233.

Orthisina, d'ORBIGNY (1847) and subsequent authors.

Description: "Shells with a subsemicircular marginal outline; convex or subpyramidal in the typical group. Hinge-line straight and forming the greatest diameter of the shell. Pedicle [ventral] valve elevated, cardinal area high, vertical, or sometimes incurved and crossed by a broad delthyrium, which is normally covered by a convex, perforate deltidium. On the interior of the valve the dental lamellæ are very strongly developed, converging and uniting in the median line before reaching the bottom of the valve, thus forming a spondylium, which with the deltidium encloses a conical subrostral vault. This plate is supported by a median septum extending for about one-half the length of the valve. [Adductor, diductor and adjustor scars occupy the upper surface of the spondylium.] In the brachial [dorsal] valve the cardinal area is considerably developed and the delthyrium filled by a conspicuous callosity, against the inner side of which the simple orthoid cardinal process abuts. The dental sockets are large, the crural plates low and continuous with the edges of the delthyrial callosity. A thickened transverse area is formed in the umbonal region by the union of the inner portions of the crural plates with the cardinal process, and thence a broad median ridge is continued forward through the muscular area, which is sharply defined and quadripartite. External surface covered with radiating striae. Shell substance impunctate.

*This family will contain *Protorthis*, Hall, *Clitambonites*, Pander, *Hemipronites*, Pander, and *Scenidium*, Hall. Waagen (Pal. Indica, vol. i, p. 576, 1884,) proposed the sub-family *Orthisina* for the genus *Orthisina*. D'Orbigny's family *Orthisidae* contains *Strophomena*, *Orthis*, and *Orthisina*—*Clitambonites*, genera now referred to three distinct families.

"Type: *Pronites adscendens* Pander." (Hall, *op. cit.*)

In well-preserved specimens of *C. diversa* the upper surface of the spondylium is transversely striated, these striae having three distinct curvatures in passing over it. Since their position and the area occupied agree with the muscular scars of this valve in *Orthis*, they are here regarded as homologous with the adductors, diductors and adjustors of that genus. In *Lingulelasma*, *Lingulops* and the trimerellids the muscular scars are not found in front nor underneath, but on the "platform" of those genera. The platform, therefore, is homologous with the spondylium of *Clitambonites* and *Pentamerus*. In *Pentamerus galeatus* Dalman, of the Lower Helderberg group of New York,* the adductors and diductors occupy nearly the entire spondylium, while the adjustors were probably situated on narrow flanges of the walls of the delthyrium. The portion of the valve immediately beneath the spondylium, and occasionally the sides of the septum, are strongly marked by the genital sinuses. Since there is no space posterior to these markings for the attachment of the muscles, this clearly indicates that they were situated on the upper surface of the spondylium.

CLITAMBONITES DIVERSA *Shaler, sp.*

PLATE XXX. FIGS. 11-17.

1865. *Orthisina diversa* SHALER. Bulletin of the Museum of Comparative Zoology, no. 4, p. 67.
 1866. *Orthisina verneuili* BILLINGS. Catalogue of the Silurian Fossils of Anticosti, pp. 43, 74.
 1877. *Hemipronites americanus* WHITEFIELD. Annual Report of the Geological Survey of Wisconsin, p. 72.
 1882. *Hemipronites americanus* WHITEFIELD. Geology of Wisconsin, vol. iv, p. 243, pl. x, figs. 15-17.
 1889. *Streptorhynchus americanus* MILLER. North American Geology and Paleontology, p. 378.
 1892. *Clitambonites americanus* HALL. Paleontology of New York, vol. viii, p. 239, pl. xvA, figs. 1-8.

Original description: "Toothed [ventral] valve, usually pentagonal; socket-valve quadrate; hinge-line usually equal to the greatest width of the shell. Toothed valve very strongly projecting; depth about one-half the width; deepest point about the height of hinge-line; umbo somewhat laterally compressed, usually rising high above the plane of the hinge-line, but very variable in this respect; umbo always laterally inclined indifferently towards either extremity of the hinge-line. Surface near the extremities of the hinge-line a little depressed and slightly recurved; area very large, nearly half as wide as long. Fissure from one-fourth to one third the width of the hinge-line; deltidium large, massive, rarely central, with distinct circular or oval foramen. Socket-valve with a broad and shallow mesial fold."

Shell of medium size; subquadrangular in outline; hinge-line straight, rarely shorter, and usually as long as, or slightly longer, than the greatest width of the shell; cardinal angles often mucronate; lateral margins straight or nearly so, sloping

* Pal. New York, vol. III, p. 267, pl. XLVI and XLVII, 1859.

more or less abruptly into the broadly-rounded and centrally somewhat sinuous, anterior edge. Surface marked with numerous, subangular, prominent, sometimes tubulose striæ, increasing in number by interpolation and bifurcation; from seventy to eighty-eight in adult examples along the margin and crossed by crowded, delicate, concentric growth lines some of which imbricate near the outer margin.

Ventral valve strongly and evenly convex, with the point of greatest elevation near the beak. Cardinal area very wide, broadly triangular, flat or elevated, and slightly convex, distinctly striated longitudinally and finely transversely; deltidium broadly triangular, strongly convex, with a large oval pedicle opening in the apical portion; anterior margin broadly excavated and, when perfect, completely occupied by the chilidium of the dorsal valve. On the interior the dental processes are not very large and are attached to the strong lamellæ, which converge and join centrally before reaching the bottom of the valve, forming the spondylium, which is supported by a well-developed septum terminating in the anterior third of the valve. The upper surface of the spondylium has a narrow median depression, which is sometimes faintly divided by a fine line; the lateral limits of this plate are also slightly depressed, and the whole is crossed by numerous transverse lines of growth. The lines have a constant curvature in the median depression, with another over the area on each side and are strongly reflexed along the edge of the delthyrium. These markings are believed to be due to the adductor, diductor and adjustor muscles, which were attached to the upper surface of the spondylium, as not the slightest trace of any scar can be seen on the under surface of this plate, nor on the valve immediately beneath it. Genital markings numerous, delicate, originating underneath the spondylium, radiating towards the antero-lateral margins and surrounded by the vascular sinuses. Outside of the latter there is a smooth space, while the anterior margin of both valves is slightly marked by radiating lines.

Dorsal valve slightly concavo-convex, or almost flat; point of greatest elevation at the apex, where a shallow, narrowly-expanding medial depression has its origin and extends to the anterior margin. Cardinal area conspicuous but not wide, centrally occupied by a broad, short and strongly elevated chilidium. Underneath the latter, and attached to it, is what may be termed a simple cardinal process. The muscles are not attached to the top of this process, as in species of *Orthis*, but to the striated thickening of the rostral cavity and slightly to the basal portion of the process, the whole being covered by the chilidium. Dental sockets prominent, situated at the point of union of the cardinal area with the chilidium. The crural plates form the inner edges of these sockets, are much elevated and continuous with the deltidium. The rostral thickening extends forward as a broad, low septum to near the center of the valve, and on each side are two strongly excavated, separate pairs

of adductor scars. The antero-lateral edges of these are drawn out into short ridges, probably the bases of the vascular trunks. Outside the muscular scars are a number of small tubercles, indicating the genital spaces.

This widely-distributed species was first described by Shaler as *Orthisina diversa*. A year later Billings identified it as *O. verneuili* Eichwald, at the same time regarding Shaler's species as synonymous with it. On the other hand, Shaler has since referred *Orthisina verneuili* Billings to his species, in which he is correct. On comparison with the European species, as illustrated by de Verneuil,* it is seen that the American species is wider along the hinge-line, the ventral area much less incurved and elevated, with finer striae and a narrow sinus in the dorsal valve. These differences are sufficient to distinguish the two species. Specimens of *Hemipronites americanus* Whitfield have been collected at Oshkosh, Wisconsin, and are found to agree with *O. diversa* Shaler of the Hudson River group of Anticosti. Castelnau,** as early as 1843, however, described as *Terebratala borealis* a shell derived from the "magnesian limestone of Green bay, Wisconsin," which may prove to be this species. The only illustration given is of a ventral valve, and this is not satisfactory for positive determination. These type specimens are probably in the collections of the Academy of Sciences at Paris, France.

C. diversa must have been quite often the prey of other animals, probably gastropods, as valves of this species are found with a single, large circular hole in them, such as are often seen in recent shells. Others have been partially crushed, generally near the anterior margin. That such injury was received during life, but was occasionally not sufficient to kill the animal, is shown by the fact that in some shells the damage was repaired. Such specimens are irregular in growth, the place of injury being indicated by more or less of a depression and great irregularity of the striae.

Formation and locality.—Very common in the yellow shales here designated as *Clitambonites* beds of the Galena shales. With this species many forms are introduced which extend upward, while a number of species of the Trenton shales below do not pass into the *Clitambonites* horizon. A single specimen has been found in the uppermost layer of the shales on St. Anthony hill, St. Paul. Common at many localities south of Cannon Falls, Kenyon and Warsaw, Goodhue county; Eyota, and near Fountain, Minnesota. In the Galena at Oshkosh, Wisconsin. In the Trenton group, Ottawa, Canada. Also in division I of the Anticosti group, Anticosti. Some fragments of what appear to be a new species have been found by Mr. Ulrich one mile south of Burgin, Kentucky, in the middle Trenton beds.

Collectors.—Miss C. E. Seymour, W. H. Scofield, A. D. Meeds and the writers.

Mus. Reg. Nos. 5308, 5586, 5847, 5853, 6765, 7951-7957.

* Russia and the Ural Mts., vol. II, pls. XI and XII.

** Essai sur le Système Silurien de l'Amérique Septentrionale, p. 40, pl. XIV, fig. 14.

Clitambonites diversa, var. altissima.]

CLITAMBONITES DIVERSA, VAR. ALTISSIMA, *n. var.*

PLATE XXX, FIGS. 18 and 19.

1892. *Clitambonites americanus* var. HALL. Palaeontology of New York, vol. viii, pl. xvA, figs. 7, 8.

This variety is readily distinguished by the exceeding elevation of the cardinal area of the ventral valve. This feature is so striking that its recognition seems to be demanded.

Formation and locality.—Several specimens of this variety have been found by Mr. W. H. Scofield associated with *C. diversa* in the Galena shales south of Cannon Falls, Minnesota.

Genus SCENIDIUM, Hall.

1860. *Skenidium*, HALL. Thirteenth Report N. Y. State Cabinet of Natural History, p. 70.1892. *Scenidium*, HALL. Palaeontology of New York, vol. viii, pt. i, p. 241.

Description: "Shell subpyramidal, somewhat semicircular, with or without median sinus and elevation. Area large, triangular, divided by a narrow fissure, which is sometimes closed at the summit by a concave deltidium [spondylium]. Valves articulating by teeth and sockets, which are often obscure or obsolete. Dorsal valve flat, or varying from depressed-convex to concave. Beak entire, or indented by the foramen; cardinal line straight and usually equalling the width of the shell; cardinal plates broad and well developed, marked by the imprints of the peduncular muscles, and produced in the middle in a pointed process; the cardinal process extends, as a median septum, through the length of the shell, and may be simple or divided at its anterior extremity. Ventral valve elevated, subpyramidal; beak straight or slightly arched; muscular impressions undetermined. Exterior surface covered with radiating striae." (Hall, 1892, *op. cit.*)

Type: *Orthis insignis* Hall.

The ancestral stock from which *Scenidium* was developed is very uncertain, though it seems to have had its origin in the *Clitambonitidae*. The genus appears in the Trenton, but it is not until the Lower Helderberg formation is reached that the greatest development of its generic character is attained. It is also known in the Middle Devonian of Europe.

SCENIDIUM ANTHONENSIS *Sardeson.*

PLATE XXX, FIGS. 20-23.

1869. *Skenidium halli* SAFFORD. Geology of Tennessee, p. 287 (undefined).1892. *Skenidium anthonensis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 333, pl. IV, fig. 7.1892. *Scenidium halli* HALL. Palaeontology of New York, vol. viii, pt. i, p. 242, pl. viiA, figs. 33-39.

In its external characters this little species is much like the young of *Orthis tricenaria*, but the concentric growth lines show it to be an adult form. The hinge-

line is longer, and the cardinal area of the ventral valve is wider, as compared with that species, while a more conspicuous mesial sinus and fold are present in *S. anthoniensis*. Further in the apical portion of the delthyrium there is a small spondylium, and in the dorsal valve the space between the crural plates is thickened by shell deposit and is medially divided by a sharp, but low, cardinal process, the whole being drawn out into a long, angular, medial septum.

Formation and locality.—Rare in the Trenton limestone and shales at Minneapolis, St. Paul and near Cannon Falls, Minnesota. In the Trenton at Dixon, Illinois. Common in the "Glade limestone" at Lebanon, Tennessee.

Collectors.—E. O. Ulrich, W. H. Scofield and C. Schuchert.

Mus. Reg. No. 8252.

Family PENTAMERIDÆ, McCoy.

Genus ANASTROPHIA, Hall.

ANASTROPHIA ? HEMIPLICATA *Hall, sp.*

PLATE XXX, FIGS. 29-31.

1847. *Atrypa hemiplicata* HALL. Palæontology of New York, vol. i, p. 144, pl. XXXIII, fig. 10.
 1856. *Atrypa hemiplicata* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 208, figs. 20-23.
 1859. *Pentamerus hemiplicatus* BILLINGS. Canadian Journal, vol. iv, p. 316.
 1859. *Pentamerus hemiplicatus* HALL. Twelfth Report N. Y. State Cabinet of Natural History, p. 66.
 1863. *Camarella hemiplicata* BILLINGS. Geology of Canada, p. 168, fig. 154.
 1892. *Camarella bernensis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 328, pl. iv, figs. 4-6.

Original description: "Subglobose, pentagonal, wider than long, thickness often equal to the length; cardinal line distinct, short, with (in some specimens) the appearance of a small area on the dorsal [ventral] valve; dorsal [ventral] valve depressed-convex, with an abrupt, broad, not deep sinus, which commences nearly half way from the beak to the base, the beak very small and closely incurved [with a small triangular delthyrium underneath]; ventral [dorsal] valve very convex, becoming gibbous with a broad mesial elevation, commencing one-third of the distance from beak to base, more gibbous towards the beak; sinus marked by two or three strong plications, with three or four upon the mesial lobe, and two or three on each side, all of which reach from one third to one-half the distance from the base to the beak of the shell, leaving the upper half entirely free from these markings; entire surface ornamented by fine, concentric, filiform, subimbricating lines, which are more conspicuous towards the base of the shell and beautifully undulated in crossing the plications."

In Minnesota this species occurs not uncommonly near the base of the Galena and differs from New York examples in having the umbo of the dorsal valve more tumid and elevated beyond that of the ventral valve. The transverse diameter in the former is also shorter, while the individuals are commonly smaller than those from eastern localities.

Anastrophia (?) *hemiplicata*, var. *rotunda*.]

The generic position of *Anastrophia*? *hemiplicata* and *A.*? *scofieldi* is left open for the present until more is known of the interior of those Lower Silurian shells with a camarelloid exterior.

Formation and locality.—Not uncommon in the upper part of the Galena shales eight to thirteen miles south of Cannon Falls; and more rarely at Weisebachs' dam near Spring Valley, Fountain and Preston, Minnesota; Decorah, Iowa; Neenah, Wisconsin. In the Trenton at Middleville, Watertown and Turin, New York; Center county, Pennsylvania; Ottawa, Canada.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 8232 to 8236.

ANASTROPHIA? *HEMIPLICATA*, var. *ROTUNDA*, *n. var.*

PLATE XXX, FIGS. 32-35.

This variety is distinguished in having the length and width nearly equal, the valves more convex and the plications somewhat more pronounced on the fold and sinus, and less numerous on the lateral portions of the shell. The figured specimen is strikingly distinct from typical *A.*? *hemiplicata* in its greater convexity. Younger specimens, however, are less pronounced in this respect, but are still distinguished by their shorter transverse diameter.

Formation and locality.—The specimen figured is from the middle portion of the Galena formation; other smaller individuals have been secured from near the base of the same formation associated with *A.*? *hemiplicata* near Cannon Falls, Minnesota, and at Decorah, Iowa.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. No. 8231.

ANASTROPHIA? *SCOFIELDI*, *n. sp.*

PLATE XXX, FIGS. 24-28.

This species seems to be a local development of *A.*? *hemiplicata*, and differs from it in having attained a larger growth, in being rounder in outline and in having the valves less gibbous, while the smooth or non-plicated portion of the shell is comparatively greater. The fold and sinus also are less marked features, while the number of plications, not only here but on the lateral parts of the shell as well, is greater, there being on the fold and on each side respectively five to seven and three to six in *A.* (?) *scofieldi* to three to seven and three to four in *A.*? *hemiplicata*.

In the interior of the ventral valve there is a long, triangular and very narrow spondylium, supported by a septum, and in the dorsal valve are the long crural plates not unlike those in *Anastrophia verneuili* Hall.* When the shell is distorted so that the posterior margins gape, it is seen that the dorsal valve has a very distinct cardinal area, which is more conspicuous than that of the other valve. This feature reminds one of species of *Stricklandinia*.

Formation and locality.—A cluster of thirty specimens was found by Mr. W. H. Scofield near the base of the Galena at a locality eight miles south of Cannon Falls, Minnesota.

Mus. Reg. No. 8230.

*Pal. N. Y., vol. iii, p. 260, pl. XLVIII, fig. 1.

Family STROPHOMENIDÆ, King.

Genus STROPHOMENA, Rafinesque (de Blainville).

1820. *Strophomena*, RAFINESQUE. Annales Gen. Sci. phys. Bruxelles, tom. v, p. 232.
1825. *Strophomena*, de BLAINVILLE. Manuel de Malacologie et Conchyliologie, vol. I, p. 513, pl. LIII, figs. 2-2a.
1892. *Strophomena*, HALL. Palæontology of New York, vol. viii, pt. I, p. 245.

Description: "Shells transversely subsemicircular or semielliptical; greatest width along the hinge-line. Surface concavo-convex and covered with fine radiating striæ, which are equal or alternate in size. The pedicle valve is slightly convex about the umbo, but becomes rapidly concave toward the middle, with the apex perforated, except in old age. The cardinal area is conspicuous and nearly vertical and the delthyrium closed by a convex plate or deltidium [which is internally much thickened medially]. The teeth are widely divergent and are supported by plates which are produced into elevated ridges nearly surrounding the muscular area. The latter is relatively short, subcircular in outline, deeply excavated and divided medially by a more or less distinctly defined longitudinal ridge which is often continued over the pallial region. [Upon each side of this ridge in the posterior half are situated the small, narrow adductor scars, and these are surrounded by the large diductors. It is probable that the adjustors are also present outside the latter, but so poorly defined as not to be recognizable.]

"The brachial valve is concave at the umbo, becoming strongly convex with growth; it has a much narrower cardinal area and the chilidium is rudimentary or incomplete. Dental sockets deep and continued as narrow grooves or indentations across the cardinal area. The crural plates are extended laterally with a slight curve, but are not supported by septa; at their inner margins they unite to form a callosity, upon which rests the short, bilobed cardinal process, which scarcely extends beyond the hinge-line. The muscular surface of this process is cordate in outline and is placed at a low angle to the plane of the area. A low median ridge extends forward from the hinge-plate separating two large adductor scars, in front of which are two narrow elongate impressions. Vascular and ovarian markings frequently well defined. Shell substance fibrous, strongly punctate.

"Type: *Strophomena rugosa* Rafinesque (de Blainville), 1825=*Leptæna planumbona* Hall, 1847." (Hall, *op. cit.*)

The well known species of *Strophomena* can be separated readily into two natural groups; (1) those in which the shell is concavo-convex, and (2) where the valves are biconvex. The interior features are very similar in the two sections and are not available for grouping. The external form of the valves, however, easily

allows any of the species mentioned below being referred to either one of the groups. There are, besides these species, a few others, but they are not sufficiently understood by the writers for positive classification.

GROUP I.—Valves concavo-convex.

- S. incurvata* Shepard, Trenton.
S. thalia Billings, Trenton.
S. trentonensis, n. sp., Trenton.
S. septata W. and S., Trenton.
S. neglecta James, Hudson River.
S. naglecta, var. *acuta*, n. var., Hudson River.
S. vetusta James, Hudson River.
S. rugosa Rafinesque (de Blainville), Hudson River.
S. rugosa, var. *subtenta* Conrad, Hudson River.
S. planoconvexa Hall, Hudson River.
S. planodorsata W. and S., Hudson River.
S. wisconsinensis Whitfield, Hudson River.
S. trilobata Owen, Galena.
S. fluctuosa Billings, Hudson River.
S. nutans (James Ms.) Meek, Hudson River.
S. hecuba Billings, Hudson River.

GROUP II.—Valves biconvex.

- ? *S. minor* Walcott, Upper Pogonip.
S. scofieldi W. and S., Galena Shales.
S. billingsi, n. sp., Trenton and Galena.
S. emaciata W. and S., Galena.
S. halliana Miller, Lower Hudson River.
S. sinuata (James Ms.) Meek, Hudson River.
S. sulcata de Verneuil, Hudson River.
S. cardinalis Whitfield, Hudson River.

STROPHOMENA INCURVATA *Shepard, sp.*

PLATE XXX, FIGS. 36-40.

1838. *Producta incurvata* SHEPARD. American Journal of Science, vol. xxxiv, p. 144, figs. 1, 2.
 1843. *Orthis incurvata* CASTELNAU. Essai sur le Système Silurien de l'Amérique Septentrionale, p. 38.
 1844. *Strophomena convexa* OWEN. Geological Exploration of Iowa, Wisconsin and Illinois, p. 70, pl. xvii, fig. 2.
 1847. *Leptena filitexta* HALL. Paleontology of New York, vol. i, p. 111, pl. xxxiB, figs. 3a to 3f.
 1856. *Strophomena filitexta* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 203, figs. 1, 2.
 1859. *Strophomena filitexta* HALL. Twelfth Report N. Y. State Cabinet of Natural History, p. 70.
 1863. *Strophomena filitexta* BILLINGS. Geology of Canada, p. 164, fig. 142.
 1883. *Streptorhynchus filitexta* HALL. Second Annual Report New York State Geologist, pl. xxxix, figs. 1-7; pl. xlii, figs. 11-14 (not figs. 10 and 15—*S. neglecta* James).
 1892. *Strophomena filitexta* HALL. Paleontology of New York, vol. viii, pt. 1, p. 251, pl. ix, figs. 1-17; pl. ixa, figs. 11-14.

Original description: "The extent of the magnesian limestone in Wisconsin, Upper Illinois and Missouri struck me with surprise. I observed it, in addition to the country already noticed between Chicago and Ottawa, as the prevailing formation about the northern extremity of Michigan, the islands about Michillimacinae,

the mouth of Green bay, as well as near Navarino [now Green Bay city,] Wisconsin], at the head of the bay. In the last mentioned region it abounded in a species of *Producta*, which I take to be undescribed and shall, therefore, denominate the *incurvata*. Specific character: Semi-circular; hinge nearly straight and the length of the shell; with fine longitudinal striae; flattish; edge crenated; shallow valve, concave, basal margin incurved; muscular impressions and hinge-process very distinct. The space between the valves is very small in this species."

Shell moderately large, more or less strongly concavo-convex, semi-oval, wider than long, with the greatest breadth along the hinge-line; cardinal extremities acutely angular and deflected, lateral and anterior margins regularly rounded. Surface marked by numerous, fine, subequal, crowded and rounded, radiating striae, increasing by intercalation, with every second, third or fourth one more prominent. This alternation in the size of the striae is variable; it is nearly obsolete in some, while in others it is a prominent feature, the whole surface being crossed by numerous and crowded, very delicate, raised, concentric lines and a few stronger marks of growth. Sometimes there are some oblique wrinklins along the cardinal margin on each side of the beaks.

Ventral valve slightly convex in the umbonal region, but otherwise more or less deeply concave; point of greatest elevation at the beak, which is minutely perforated for the passage of the pedicle. Cardinal area variable in width and elevation, slightly retrorse in very gibbose specimens or strongly elevated in flattish specimens; deltidium conspicuous, broadly convex, as wide as, or wider, than long, broadly excavated anteriorly and entirely occupied by the chilidium. The teeth are divergent, not very prominent and attached to the much elevated outer margin of the large, strongly striated, suboval muscular area. In the center of the posterior half of this area there are two slender, short adductor scars, which are separated by a septum attaining its greatest development toward the anterior margin, upon each side of which are the large impressions of the diductors, and probably also of the adjustors. On either side of the muscular area there are numerous, elongated tubercles, arranged in more or less regular radiating series, the genitalia markings. Near the outer margin of the valve is a more or less strongly defined, concentric, irregular thickening, crossed in the anterior region by a number of short, irregular, vascular sinuses. The whole of the interior is minutely granulose.

Dorsal valve flattened or slightly concave in the umbonal region, and more or less strongly convex laterally and anteriorly; sometimes there is a shallow, narrow sinus present, becoming obsolete before reaching the anterior margin. Cardinal area narrow, vertical, centrally occupied by a very broad but short convex chilidium. Dental sockets] conspicuous, rapidly narrowing and continued as grooves over the

cardinal area along each side of the chilidium, with the thin, erect, crural plates forming their inner walls. The space between the crural plates is slightly thickened and occupied by a short, strong, bilobed cardinal process. Its upper surface is transversely striated and has a shallow median depression along each lobe. The rostral thickening is continued forward but a short distance and converges to a low median ridge which separates the two large, shallow scars of the adductor muscles. In front of the latter are sometimes seen two, linear, slightly diverging ridges, probably the markings of the main trunks of the vascular system. Genital markings on each side of the muscular scars, consisting of series of tubercles of various sizes radially arranged. Surface near the periphery more or less distinctly marked by numerous, short, irregular, radiating striæ, much the strongest in the medial region.

The variations of this species are mainly those of convexity, thickness of shell and alternation of striæ. In the "Lower Blue beds" of Wisconsin, where this species is abundant, the alternation of striæ is a very persistent character and the valves are usually flatter than specimens from other regions.

In the Trenton shales of Minnesota *S. incurvata* is also a common species, often preserving the delicate markings of the interior. The variation in convexity here attains its maximum, and while the striæ likewise alternate in size, this feature is never so conspicuous as in Wisconsin.

This species is usually known as *S. filitexta* Hall. It is thought that to this form Shepard applied the name *S. incurvata* nine years prior to that given by Prof. Hall. One of the writers, through Mr. John M. Clarke, has endeavored to find the types at Amherst College, but Prof. Emerson states that no specimens of it with Shepard's label attached exist at present in that collection. While the original description and illustrations are not very satisfactory, yet sufficient is shown, combined with the locality, to warrant the conclusion that the above specimens were of this widely distributed species. *Strophomena convexa* Owen, proposed three years earlier than Hall's name, is undoubtedly a specimen of the same species, which was derived from the "Blue and Grey limestone of Wisconsin and Iowa." Probably Owen subsequently regarded it as identical with some other form, for in a subsequent report (1852) no mention is made of it.

This species is commonly stated to occur in the Hudson River group, but a comparison of specimens from that horizon with those from the Trenton will show the interior of the dorsal valve of the former to be entirely different in its prominent vascular ridges, while the space beneath the cardinal area on each side of the teeth in the ventral valve is filled up by a deposit of shell matter. Since Mr. U. P. James has applied the name *Strophomena neglecta* to one variation of the species identified by Meek in 1873 as *S. filitexta*, it is advisable to refer to the specimens from the

Hudson River deposits under that name. The literature treating of *S. neglecta* is given below, for the convenience of those having occasion to study this species.

Formation and locality.—Somewhat rare in the Trenton limestone at Minneapolis and Fountain, Minnesota. Common in the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Fountain, Preston, near Caledonia and elsewhere in Minnesota; Decorah and McGregor, Iowa. One of the common species in the "Lower Blue beds" at Mineral Point, Beloit, Janesville and Green Bay city, Wisconsin. In the Trenton limestone at Dixon and Dunleith, Illinois; Auburn, Lincoln county, Missouri. In the Black River, and at the top of Birdseye limestone near High Bridge, Kentucky. Glade limestone at Lebanon and Lavergne, Tennessee. Trenton limestone at Middleville and elsewhere in New York; at Ottawa and county of Renfrew, Canada.

Collectors.—C. L. Herrick, W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 669, 2147, 3733, 3734, 6771, 6773, 6795, 8167-8178.

STROPHOMENA NEGLECTA James, sp.

1873. *Strophomena filitexta* MEEK (non Hall). *Palaontology of Ohio*, vol. i, p. 83, pl. VI, figs. 5a to 5d.
 1875. *Strophomena filitexta* WHITE. U. S. Geological and Geographical Survey west of the 100th Meridian, vol. iv, p. 69, pl. IV, fig. 8.
 1875. *Hemipronites filitextus* MILLER. *Cincinnati Quarterly Journal of Science*, vol. ii, p. 43.
 1881. *Streptorhynchus neglecta* JAMES. *The Palaontologist*, no 5, p. 41.
 1883. *Streptorhynchus filitextus* (partim.) HALL. *Second Annual Report New York State Geologist*, pl. XLII, figs. 10 and 15 (not figs. 11-14); pl. XXXIX, figs. 1-7.
 1892. *Strophomena filitexta* HALL. *Palaontology of New York*, vol. viii, pt. i, pl. IXA, figs. 10 and 15 (not figs. 11-14); pl. XIA, fig. 3.

This species is not known to occur in Minnesota, and is restricted to the Hudson River group. For further remarks see *S. incurvata* Shepard.

Formation and locality.—Oxford, Clarksville, Waynesville and elsewhere in southwestern Ohio. Richmond, Versailles and Weisburg, Indiana; Savannah, Illinois; ?Silver City, New Mexico.

STROPHOMENA NEGLECTA, var. ACUTA, n. var.

PLATE XXXI, FIGS. 6 and 7.

Shell of moderate size, resupinate, concavo-convex, the postero-lateral angles mucronate and deflected. Hinge-line wider than any part of the shell in front of it; cardinal area in the ventral valve three to four times as wide as that of the dorsal valve and somewhat elevated beyond it; cardinal margins more or less strongly wrinkled, the elevations being directed medially at various angles. Outer margin semi-ovate, narrowly rounding anteriorly, more broadly laterally, and terminating on the cardinal line in more or less prominent extensions. Dorsal valve plano-convex medially and regularly convex laterally; convexity varying with age, strongest in the larger specimens; point of greatest elevation about mid-length. Ventral valve convex from the beak to nearly mid-length, from here to the anterior margin, and laterally as well, strongly concave, with the postero-lateral portions somewhat deflected. Surface striæ distinctly alternating, from three to five smaller lines between the sharply elevated larger ones. The alternation of the striæ most distinct in the posterior half.

This variety in general appears to be closely related to *Strophomena wisconsinensis* Whitfield,* but is readily distinguished in being less convex and in the very distinct alternation of the striae. That species is clearly related to *S. rugosa* Blainville, while *S. neglecta*, var. *acuta* belongs to the *S. incurvata* group of strophomenas. *Strophomena vetusta* James** is probably also closely related, but it is more evenly convex, never has a flat central disc in the dorsal valve, while the outline is subquadrate.

Formation and locality.—Not rare in the upper portion of the Hudson River group at Spring Valley, Minnesota.

Collectors.—E. O. Ulrich, W. H. Scofield and the writers.

Mus. Reg. No. 5550.

STROPHOMENA TRENTONENSIS, *n. sp.*

PLATE XXX, FIG. 41.

1847. *Leptæna subtenta* (partim.) HALL. Palæontology of New York, vol. i, p. 115

1883. *Streptorhynchus subtenta* HALL. Second Annual Report, New York State Geologist, pl. XXXIX, fig. 18.

1892. *Strophomena subtenta* HALL. Palæontology of New York, vol. viii, pt. i, p. 251, pl. IX, fig. 18.

This species is closely related to *S. rugosa* var. *subtenta*. The valves are, however, thinner, the striae more delicate and the oblique wrinkling along the cardinal margins a more constant feature than in that species. The interior characters of *S. trentonensis* are also less strongly developed than in *S. rugosa*. Whether from New York, Minnesota, Kentucky or Tennessee, they exhibit the same undefined internal markings when compared with the Hudson River group specimens of the latter species. It is deemed also advisable to indicate this line of development towards *S. rugosa* of the Hudson River group by separating the Trenton specimens on the above characters with the name *S. trentonensis*.

Prof. Hall (*op. cit.*, 1847) found among the drawings of Mr. Conrad the figure of a *Strophomena* with the name *S. subtenta* attached. The specimen from which this drawing was made Prof. Hall says "is from a western locality" of the upper portion of the Hudson River group of Ohio or Indiana. This form was again described and figured by Meek† as *S. plicata*. As the essential difference between this form and *S. rugosa* is only in the oblique wrinkling of the shell along the cardinal margins we do not consider it of greater importance than varietal.

Formation and locality.—Not common in the Trenton shales at several localities to the south of Cannon Falls, Minneapolis and Fountain, Minnesota. In the "Lower Blue beds" at Janesville and Beloit, Wisconsin. Near the top of the Trenton at Frankfort, Kentucky, and Nashville, Tennessee; Trenton Falls, New York. A few examples apparently of this species have also been found in the Galena shales in Goodhue county, Minnesota.

Collectors.—C. L. Herrick, W. H. Scofield and the writers.

Mus. Reg. Nos. 677, 8179, 8182, 8183.

*Geol. Wis., vol. iv, p. 263, pl. xii, figs. 11-13; 1882.

**Cincinnati Quart. Jour. Sci. vol. i, p. 241; 1874.

†Pal. Ohio, vol. i, p. 81, pl. vi, figs. 4a-4b.

STROPHOMENA SEPTATA *W. and S.*

PLATE XXX, FIGS. 1-3.

1892, April 1. *Strophomena septata* W. and S. American Geologist, vol. ix, p. 285.

This species appears to be a local development of *S. trentonensis* W. and S., and as far as external characters are concerned, no distinguishing features can be pointed out. Compared with *S. rugosa*, a still closer resemblance, both externally and internally is seen. However, when the interior is shown it can be separated readily from both by the strong mesial septum of the ventral valve. This originates between the diductor scars and continues to increase in strength to near the anterior margin, where it often coalesces with one or two of the vascular ridges. In *S. trentonensis* the thickening of the interior near the anterior margin of the ventral valve is obsolete or entirely undeveloped, constituting another distinguishing feature between it and *S. septata*. The cardinal process of both species is also more elevated, while the rostral thickening upon which it rests is developed less strongly than in *S. rugosa*, these parts being much as in *S. incurvata*. *S. trentonensis* and *S. septata* never attain the thickness of shell nor the abundance of individuals of *S. rugosa*. The septum of the ventral valve in *S. septata* will also distinguish it from *S. incurvata*, in addition to its smaller size and comparatively greater width than length.

Formation and locality.—Common in the upper third of the Trenton shales at St. Paul, Minneapolis and near Rochester, Minnesota.

Collectors.—C. L. Herrick, E. O. Ulrich and the writers

Mus. Reg. Nos. 345, 676, 4936, 6795, 6798.

STROPHOMENA RUGOSA (Rafinesque Ms.) *Blainville*.

PLATE XXXI, FIGS. 4 and 5.

1825. *Strophomena rugosa* (RAFINESQUE) BLAINVILLE. Malacologie et Conchyliologie, vol. i, p. 513, pl. LIII, figs. 2, 2a.
1827. *Strophomenes rugosa* DEFRANCE. Dictionnaire des Sciences Naturelles, vol. i, p. 151 and atlas.
1847. *Leptæna planumbona* HALL. Palæontology of New York, vol. i, p. 112, pl. XXXI, figs. 4a to 4e.
1850. *Strophomena rugosa* KING. Permian Fossils, p. 103.
1862. *Strophomena planumbona* HALL. Geology of Wisconsin, vol. i, p. 54, fig. 7.
1873. *Strophomena (Hemipronites) planumbona* MEEK. Palæontology of Ohio, vol. i, p. 79, pl. VI, figs. 3a-3h.
1874. *Streptorhynchus (Strophomena) elongata* JAMES. Cincinnati Quarterly Journal of Science, vol. i, p. 240.
1875. *Hemipronites planumbona* MILLER. Ibidem, vol. ii, p. 45.
1877. *Streptorhynchus planumbonus* MILLER. American Palæozoic Fossils, p. 134.
1878. *Streptorhynchus elongata* MICKELBOROUGH and WETHERBY. Journal Cincinnati Society of Natural History, vol. i, p. 76.
1880. *Strophomena planumbona* WHITE. Second Annual Report, Indiana Bureau of Statistics and Geology, p. 483, pl. II, figs. 13, 14.
1881. *Strophomena planumbona* WHITE. Tenth Report, Indiana State Geologist, p. 115, pl. II, figs. 13, 14.
1883. *Streptorhynchus planumbona* HALL. Second Annual Report New York, State Geologist, pl. XXXIX, figs. 15-17; pl. XLII, figs. 8, 9.

Strophomena rugosa (Rafinesque Ms.)

1887. *Strophomena planumbona* (partim) SHALER. Memoirs, Kentucky Geological Survey, p. 13, pls. IV, V.
 1892. *Strophomena rugosa* HALL. Palæontology of New York, vol. viii, pt. 1, p. 247, figs. 13, 14.
 1892. *Strophomena planumbona* or *rugosa* HALL. Ibidem, p. 251, pl. IX, figs. 15-17; pl. XI A, figs. 8, 9.

From the examination made by Prof. Hall (*op. cit.*, 1892,) it appears that this widely-distributed species was never described by Rafinesque. Undoubtedly the latter sent to Blainville or DeFrance, or both, specimens of it, with the name *Strophomena rugosa* attached. The species is now well known as *S. planumbona* Hall. Blainville, 1825, was the first to give a diagnosis of *Strophomena* (*loc. cit.*), using as the type "*S. rugosa* Rafinesque," of which he gives two good figures. These have been reproduced by Prof. Hall (*op. cit.*, 1892). In 1827 a description was given of this species in the "Dictionnaire des Sciences Naturelles" by "D. F.," probably DeFrance. King, 1850, (*op. cit.*) called attention to the fact that *Strophomena rugosa* (Rafinesque) Blainville and *Leptaena planumbona* Hall are one and the same species. A similar conclusion was also reached by Meek in 1873 (*op. cit.*, p. 73). The following is the description of *S. rugosa* of DeFrance, which is copied from Palæontology of New York, vol. viii, pt. i, p. 247: "Strophomène rugueuse; *Strophomenes rugosa* Rafinesque. Coquille bombée en dessous, et dont la valve supérieure est un peu concave et chargée de petites stries rayonnantes. Largeur, un pouce. Fossile de l'Amérique septentrionale. On voit une figure d'une coquille de cette espèce dans l'atlas de ce dictionnaire, planche de fossiles. Des coquilles de ce genre, qu'on trouve à Dudley en Angleterre, ont de très-grands rapports avec cette espèce; elles en diffèrent pourtant en ce que le bord ce celles d'Amérique se retrouse un peu en dessous, tandis que c'est le contraire pour celles d'Angleterre, dont le bord s'abaisse en dessous. On trouve à l'embouchure de la rivière des Alleghanys près de Pittsborough (Amérique septentrionale), dans un grès rougeâtre, des empreintes de coquilles qui ont beaucoup de rapports avec cette espèce, mais qui sont plus aplaties."

"Shell of medium size, concavo-convex, semi-oval or more than semi-circular in outline; hinge line generally a little longer than the breadth of the valves at any point farther forward; lateral extremities, in most examples, somewhat less than rectangular, or sometimes rather acute, more or less compressed and deflected; lateral margins a little contracted posteriorly and rounding to the front, which forms a regular semi-circular curve.

"Dorsal valve flat [or somewhat depressed] in the umbonal region, and rather strongly and evenly convex in the central and anterior regions, from which it rounds off abruptly to the front and lateral margins; beak very small or not distinct from the edge of the narrow or sublinear area, which is inclined nearly directly backward, but not incurved. Interior showing the cardinal process to be small, depressed, divided to its base into two diverging tooth-like parts, a little flattened [or concave and

striated] on their posterior faces and directed very obliquely forward and outward; socket ridges short and oblique [but much thickened, and upon them are placed the linear and but slightly elevated crural plates]; mesial ridge low [in some specimens, usually strongly elevated and rounded], extending but a little distance forward, while the space between it and the socket ridge, on each side, is occupied by a moderately distinct muscular scar. [Vascular trunks and genital markings faintly indicated and similar to those in *S. incurvata*.]

"Ventral valve broadly and rather deeply concave in the central and anterior regions, and slightly convex at the beak, which is very small, abruptly pointed, scarcely projecting beyond the edge of the area, and usually [always] minutely perforated; area moderately high, extending the whole length of the hinge, generally but little sloping laterally, flattened and inclined more or less backward, foramen [delthyrium] closed by a prominent, rounded deltidium, that is transversely striated and rather broadly sinuous on its inner edge, for the reception of the [chilidium, which partially covers the posterior portion of the] cardinal process of the other valve. Interior showing hinge-teeth to be well developed, trigonal and striated on their posterior sides, while from their inner bases the dental laminae extend forward so as nearly to encircle the usual saucer-shaped depression for the [diductor and probably very small adjustor] muscular scars, which is sometimes [always more or less] divided by a small linear mesial ridge [upon each side of which are situated the narrow adductor scars]; cardinal margin prominent and sharp within, on each side of the hinge teeth; anterior and lateral regions more or less thickened within and roughened by the crossing of the vascular markings, which are scarcely visible on any part within this zone.

"Surface of both valves ornamented by numerous fine, closely-crowded, radiating striae that are often alternately a little larger and smaller or, on some parts, with several of the smaller ones between each two of the larger; the smaller being always shorter than the larger, or ending at various distances between the free margins and the beaks without coalescing with those between which they are intercalated. Striae and furrows minutely crenulated by extremely small, very regular, closely-arranged, concentric lines, invisible without the aid of a magnifier; a few subimbricating marks of growth are likewise seen near the free margins." (Meek, *op. cit.*)

The comparative length and width of the shell vary considerably in this species, the latter being in some cases equal to two-thirds, in other cases only about one-half of the former. The narrow specimens with the long hinge-line have received the name *S. elongata* James, but a large collection will show every gradation between this and *S. planumbona* or *rugosa*. Some specimens are nearly as long as wide and are often difficult to separate from *S. nutans* (James' Cat.) Meek. The latter, however, in its typical condition, is very distinct and approaches *S. fluctuosa* Billings.

Strophomena rugosa, var. *subtenta*.]

S. incurvata Shepard, of the Trenton, became *S. neglecta* James, of the Hudson River group. *S. trentonensis* likewise was changed into *S. rugosa* Blainville, and *S. winchelli* developed into *S. nutans*. In the Trenton formation of Minnesota *S. septata*, a local variation of *S. trentonensis*, is found, and in the Hudson River group of the Northwest, *S. rugosa* and *S. wisconsinensis* are representatives of the latter.

Formation and locality.—Common in the Hudson River group in Ohio, Indiana and Kentucky; Anticosti; Iron Ridge, Wisconsin, and Spring Valley, Minnesota. At Graf, Iowa, and Iron Ridge, Wisconsin, a variety occurs in which the concentric growth lines are very conspicuous and farther apart than in *S. rugosa*, and this may prove, when more material is at hand, to be specifically distinct.

Collector.—C. Schuchert.

Mus. Reg. Nos. 8184, (? 8185, 8186).

STROPHOMENA RUGOSA VAR. SUBTENTA (*Conrad Ms.*) Hall.

1841. *Strophomena subtenta* CONRAD. Fifth Annual Report, New York Survey, p. 37 (undefined).

1847. *Leptaena subtenta* HALL. Palæontology of New York, vol. 1, p. 115, pl. xxxiB, figs. 9-9b

1862. *Strophomena subtenta* BILLINGS. Palæozoic Fossils, vol. 1, p. 132, fig. 109 on p. 130.

1873. *Strophomena (Hemipronites) plicata* (JAMES) MEEK. Palæontology of Ohio, vol. 1, p. 81, pl. vi, figs. 4a, 4b.

Conrad's specimens of *Strophomena subtenta* were found in the Hudson River group of the Ohio valley, and can be distinguished from *S. rugosa* Blainville only by the oblique wrinkling of the shell along the cardinal margins. This character we do not regard as of greater value than varietal. For further remarks see *Strophomena trentonensis*.

Formation and locality.—Rare in the Hudson River group at Spring Valley, Minnesota. Other localities as for *Strophomena rugosa*.

STROPHOMENA PLANODORSATA *W. and S.*

PLATE XXXI, FIGS. 8-10.

1892, April 1. *Strophomena planodorsata* W. and S. American Geologist, vol. ix, p. 286.

Shell large, semicircular or subquadrate in outline, concavo-convex, wider than long, greatest width along the hinge-line, or immediately in front of it. Surface with fine, radiating striæ, every second or third one somewhat stronger than those intermediate, crossed by exceedingly delicate, closely crowded concentric lines, and towards the anterior margin by a few larger subimbricating lines of growth. Dorsal valve flat or very slightly concave for more than half the length and breadth of the shell from the cardinal margin, thence sloping rapidly towards the lateral and anterior edges. Cardinal area linear, slightly reflexed and centrally occupied by an inconspicuous deltidium. Interior unknown.

Ventral valve slightly concave, except near the lateral and anterior margins, where it is strongly bent. Cardinal area 5 mm. or more in width in adult examples, more or less elevated, but never very strongly so; deltidium depressed convex,

about as wide as long and distinctly limited laterally by linear elevations, with a depression outside of the latter; internally much thickened; apical perforation or pedicle opening exceedingly minute. Teeth not large for a shell of the size of this species; unsupported. Muscular depression very large, subquadrate in outline, with a sharply elevated outer margin, which has its postero-lateral limits outside the hinge teeth; medially divided by a more or less prominent ridge, upon each side of which are the large, longitudinally striated, diductor scars, enclosing the small adductors situated centrally in the posterior half. Space underneath the cardinal area filled up with shell matter. Near the outer margin there is occasionally a slight elevation, which is crossed medially by a few, not very prominent, vascular ridges. Entire interior surface covered with more or less radially arranged, delicate, oblique granules, which become more pronounced immediately outside the muscular margin.

The size, large flattened area of the dorsal valve, and the subquadrate form of the muscular area of the ventral valve, distinguish this species from all others having the structure of *S. rugosa*.

Formation and locality.—Rare in the Hudson River group near Spring Valley and Wykoff, Minnesota; Iron Ridge, Wisconsin, and Wilmington, Illinois. The interior characters are described from specimens from the last named locality.

Collectors.—E. O. Ulrich, C. Schuchert.

Mus. Reg. No. 8191.

STROPHOMENA WINCHELLI Hall.

PLATE XXXI. FIG. II.

1883. *Streptorhynchus* (*Strophonella*?) *delloidea* HALL (not *Leptaena delloidea*, 1847). Second Annual Report, N. Y. State Geologist, pl. XXXIX, figs. 10, 12-14 (not fig. 11 = *S. nutans*.)

1892. *Strophomena winchelli* HALL. Palaeontology of New York, vol. viii, pt. i, p. 344, pl. ix, figs. 10, 12-14; pl. xx, fig. 26.

This species, though quite as large, differs from *S. trentonensis* in being more commonly longer than wide, and is probably the parent stock of the later appearing species *S. nutans* and *S. fluctuosa*. From these it is separated readily by its thinner, less convex shell, finer and more numerous striae, the central disc also being without corrugations and less depressed than in *S. nutans*. A large collection would probably show intermediate variations between *S. trentonensis* and *S. winchelli*, as are found to occur between *S. rugosa* and *S. nutans* of the Hudson River group. These transitional specimens are, however, rare and should therefore not be used to unite the species. If this were done, to be consistent, all the above mentioned forms, together with *S. incurvata* and *S. neglecta* should be referred to one common, widely distributed and variable species.

Formation and locality.—Rare in the "Lower Blue beds" at Janesville and Clifton, Wisconsin. In the Galena at Oshkosh, Wisconsin. It has not been observed in Minnesota.

Collector.—C. Schuchert.

Mus. Reg. Nos. 8180, 8226.

STROPHOMENA TRILOBATA *Owen, sp.*

PLATE XXXI. FIGS. 12 and 13.

1852. *Leptæna trilobata* OWEN. Geological Survey of Wisconsin, Iowa and Minnesota, p. 584, pl. II, figs. 17, 18.
 1877. *Strophomena trilobata* MILLER. American Palæozoic Fossils, p. 138.

Original description: "This species was at first referred to the species *deltoidea*, but the form is so decidedly different in several respects that it seems to constitute a distinct species. Dorsal valve broadly trilobate, very gibbous in front and depressed towards the hinge-line; margin undulating, semioval; ventral valve concave; hinge-line extended; fine and equally radiating striæ, partaking of the curvature of the surface of the shell.

"The outline of this shell is much more undulating, shell more gibbous and broader, and more distinctly trilobate than the *deltoidea*.

"It occurs in the shell-beds F. 3A, near the Agency, on the Turkey river, Iowa."

Owen's illustrations, and his statement that the shell is "very gibbous in front and depressed towards the hinge-line," leaves very little doubt that *S. trilobata* is identical with a species occurring in the middle beds of the Galena in Minnesota. It is true that associated with these specimens are also very gibbous examples of *Rafinesquina deltoidea*. These, however, are never as flat on the central disc nor have they the nasute anterior margin of *S. trilobata*. To *S. fluctuosa* this species is closely related, but can be distinguished by the following features: The flat central disc is comparatively smaller, the shell anteriorly is twice as long and incurved, while in *S. fluctuosa* it is always flat, and the ventral cardinal area is strongly retrose. The interior characters and the corrugation of the flat central disc are, as far as can be determined, essentially as in *S. fluctuosa*.

Formation and locality.—The species is abundant in the middle beds of the Galena horizon, but since it usually occurs as natural casts it is not often gathered by collectors. It occurs at Kenyon and elsewhere in Goodhue county, Mantorville, Old Concord and near Rochester, Minnesota. Turkey river Iowa. Probably also in the Galena of Wisconsin.

Collectors.—A. D. Meeds, W. H. Scofield, M. W. Harrington and N. H. Winchell.

Mus. Reg. Nos. 208, 293, 369, 371, 391, 7253, 8189, 8190.

STROPHOMENA FLUCTUOSA *Billings.*

PLATE XXXI. FIGS. 14-17.

1860. *Strophomena fluctuosa* BILLINGS. Canadian Naturalist and Geologist, vol. v, p. 57, fig. 6
 1862. *Strophomena fluctuosa* BILLINGS. Palæozoic Fossils, vol. I, p. 123, fig. 102.
 1863. *Strophomena fluctuosa* BILLINGS. Geology of Canada, p. 209, fig. 207.
 1892. *Strophomena fluctuosa* HALL. Palæontology of N. Y., vol. VIII, pt. I, p. 251, pl. XI A, figs. 4, 5.

Original description: "Triangular or semioval, usually widest at the hinge-line and more or less narrowly rounded, pointed, trilobed or nasute in front.

"Dorsal valve convex, the visceral disc being in general equal to one-third the superficies of the whole valve, nearly flat, the remainder abruptly curved down all around so that the lower half of the length of the shell is sometimes at right angles with the upper half. The cardinal angles more or less compressed and often a little reflected, usually forming angular or narrowly rounded ears. Ventral valve concave, the curvature corresponding to that of the dorsal valve.

"Area of dorsal valve lying in the plane of the lateral margin, about one-third of a line high. Area of ventral valve forming a right angle with the marginal plane, in large specimens one line or a little more in height at the beak, and gradually decreasing towards the extremities of the hinge-line.

"Foramen of ventral valve triangular; the width at the base somewhat exceeding the height, completely closed by a convex deltidium, the basal margin of which is rendered a little concave by the convex margin of the similar deltidium [chilidium] which closes the foramen of the dorsal valve.

"Surface with a set of fine, rounded, elevated, radiating striae, distant from each other usually about half a line, sometimes a little less, and occasionally one line. Between each two of these there are from two to ten much finer striae; the whole crossed by fine, crowded, concentric lines. In most of the specimens the whole of the upper half of the shell is covered with short undulating wrinkles, which sometimes have a concentric arrangement and often form concentric rows converging from the hinge-line towards the center of the shell, crossing each other. The specimens from the Trenton limestone are usually without these undulations, [probably *S. winchelli*], but in those from the Hudson River group this character is prominently exhibited." Interior of both valves very much as in *S. nutans* (James) Meek, or *S. rugosa* Blainville.

This species has been confounded with *Rafinesquina deltoidea* Conrad, sp., as figured by Prof. Hall (Pal. New York, vol. i). The types now in the American Museum of Natural History, in New York city, have been carefully examined by Prof. Hall, Mr. Clarke and one of the writers. After considerable difficulty, owing to the thinness of the shells and the limestone matrix, it was proved that *R. deltoidea*, when compared with *S. fluctuosa*, has the convexity of its valves reversed and is, therefore, a species of *Rafinesquina*. *R. deltoidea* must therefore be restricted to the specimens figured by Hall in 1847. Trenton shells from Canada and Wisconsin, devoid of the corrugated surface, and usually referred to this species, are removed from *S. fluctuosa* and *R. deltoidea* and used as the type of a new species, *S. winchelli* Hall (*op. cit.*, pl. ix, figs. 10, 12-14). *S. fluctuosa* thus becomes a well marked

species, restricted to the Hudson River group, and takes the place of *S. nutans* of the Ohio valley, in the deposits of this formation on Anticosti and in Minnesota.

Formation and locality.—Common in the Hudson River group at Spring Valley, Wykoff and near Granger, Minnesota: Anticosti.

Collectors.—E. O. Ulrich, W. H. Scofield and the writers. Also in the collection of Dr. C. H. Robbins, of Wykoff, Minnesota.

Mus. Reg. Nos. 232, 430, 4077, 8187, 8188.

STROPHOMENA BILLINGSI *n. sp.*



FIG. 32. Billings' original illustration of *Strophomena recta*. a, side view; b, ventral view; c, portion of face enlarged.

1862. *Strophomena recta* BILLINGS (non Conrad). Palæozoic Fossils, vol. i, p. 130, figs. 108a-108c.

Original description: "Semielliptical, both valves nearly flat, hinge-line equal to, a little greater or a little less than, the width; sides somewhat straight for about half the length, and either parallel or slightly converging forwards; all of the front half of the shell uniformly rounded, sometimes only gently convex or somewhat straight in the middle of the front margin. Ventral valve slightly convex in the umbonal region, and elsewhere flat or gently concave; beak scarcely distinct from the cardinal area, slightly depressed below the umbo; area of medium size, flat, extending the whole length of the shell, forming an obtuse angle of from 110° to 135° with the plane of the lateral margin; foramen triangular, width at the base greater than the height, closed by a convex deltidium which does not quite reach the hinge-line, but has its lower margin concave. Dorsal valve uniformly very depressed convex or nearly flat, slightly concave at the cardinal angles and with a barely perceptible mesial depression along the middle, which commences very near the beak and extends one-third or one-half the length of the shell; beak very small and minutely elevated above the cardinal edge; area varying in size from less than one-half to nearly equal that of the ventral valve.

"Surface with fine, rounded, slightly crenulated, radiating striae of different sizes, the smaller coming in by implantation at various distances from the beak. In some specimens the striae are more nearly of one uniform size than in others; at the front margin there are usually four of the larger and four or five of the smaller striae in the width of one line. When the surface is perfectly preserved it is seen to be

beautifully cancellated by fine, apparently squamose striæ, which are undulated slightly upward in passing over the ridges. There appear to be from ten to twelve concentric striæ in the width of one line.

"Width of largest specimen collected, one inch; length, nine lines; height of ventral area, one line."

Strophomena recta Conrad we regard as founded on young specimens of the same author's *Strophomena deflecta*, which is no longer referred to *Strophomena*, but belongs to Prof. Hall's subgenus *Dinorthis* of *Orthis*. Even if the above conclusion is not accepted the specimens of Billings cannot be retained under Conrad's name, since they clearly belong to *Strophomena*, while *Strophomena recta* Conrad must be referred to *Dinorthis*. This leaves Billings' species without a name and we propose therefore to designate it as above.

S. billingsi belongs to our group II of *Strophomena* and is related to *S. scofieldi*. The former differs in having a far less defined sinus and fold, finer radiating striæ and the concentric growth lines more delicate and closely crowded.

Formation and locality.—In the Galena shales at St. Paul, near Cannon Falls and Fountain, Minnesota. In the upper beds of the Trenton limestone, Ottawa, Canada.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. No. 8192.

STROPHOMENA SCOFIELDI *W. and S.*

PLATE XXXI, FIGS. 18-21.

1892, April 1. *Strophomena scofieldi* W. and S. *American Geologist*, vol. ix, p. 286.

1892, April 9. *Streptorhynchus subsulcatum* SARDESON. *Bulletin of the Minnesota Academy of Natural Sciences*, vol. iii, p. 335, pl. iv, fig. 39.

Shell small, semicircular in outline, biconvex, with a more or less prominent fold and sinus towards the anterior margin: hinge-line a little shorter than the greatest width; area of ventral valve forming an angle of about 140° with the plane of the lateral margin, centrally occupied by a convex, perforated deltidium, which fits closely against the chilidium of the other valve. Surface marked by numerous, crowded, rounded, radiating striæ, increasing in number by implantation, with from 110 to 120 along the outer margin in adult shells, crossed by delicate, crowded, concentric lines and a few larger growth marks.

Dorsal valve not deep, evenly convex, or with a fold near the anterior margin. Cardinal area very narrow and slightly reflexed. Crural plates prominent, very oblique, coalescing medially; upon this thickening at its base originate two low ridges, which continue upward and outward into the small, low cardinal process, about half of which is covered by the chilidium. Immediately underneath the crural plates are two pairs of small adductor scars, separated by a low, rounded

and short septum, which bifurcates anteriorly. Near the anterior margin of the posterior pair of scars two other ridges arise, making four in all, probably the main trunks of the vascular system. Very small genital spaces indicated outside the muscular scars and in front of the crural plates.

Ventral valve somewhat deeper than the other, evenly convex, or with a broad, shallow sinus near the anterior margin. Hinge teeth prominent and joining the outer elevated margin of the short, suboval, muscular area. This is centrally divided by a low ridge, separating the two pairs of adductor and diductor scars.

This species is of the type of *S. sinuata* (James) Meek.* *S. scofieldi* can readily be distinguished from the latter by its smaller size and greater number of striae, having about sixty. The profound fold and sinus, greater size, and less numerous striae of *S. sulcata* de Verneuil,† will distinguish it from *S. scofieldi*. Another related species is *S. cardinalis* Whitfield.‡ The more elevated cardinal area, very convex dorsal valve and greater width of the shell, distinguish this form from *S. scofieldi*.

Formation and locality.—Rare near the base of the Galena shales at Minneapolis and St. Paul; common in association with *Clitambonites diversa* at several localities south of Cannon Falls, Minnesota. A single specimen of it has been collected near the top of the "Lower Blue beds" north of Beloit, Wisconsin.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. Nos. 8193-8195.

STROPHOMENA EMACIATA *W. and S.*

PLATE XXXI, FIGS. 22-24.

1892, April 1. *Strophomena emaciata* W. and S. American Geologist, vol ix, p. 287.

Shell small, depressed, biconvex, semicircular in outline; hinge-line usually somewhat smaller than the greatest width of the valve. Surface marked by numerous angulated striae, increasing in number by interpolation, having from sixty to seventy-five of the large and small ones along the anterior margin.

Ventral valve depressed-convex, subangulated medially, greatest point of elevation about mid-length. Cardinal area narrow, less than 1 mm. in width, strongly elevated, with a very convex, apically-perforated deltidium, which is somewhat wider than long and excavated for the reception of the chilidium.

Dorsal valve slightly convex, with or without a shallow sinus, having its origin near the beak and rapidly widening to the anterior margin, which is more or less sinuous, according to the depth of the medial depression. Cardinal area linear, with a short, broad chilidium partially covering the cardinal process. Interior unknown.

This little species was at first regarded as the young of some form of *Strophomena*. There are two species associated with it—*S. scofieldi* and *S. trentonensis*. If

* Pal. Ohio, vol. 1, p. 87, pl. v, figs. 5a-5f.

† Ibidem, p. 85, pl. v, figs. 4a-4e.

‡ Geol. of Wisc., vol. iv, p. 261, pl. XII, figs. 9, 10.

immature examples of the latter of the same size as adult individuals of *S. emaciata* be examined, it will be seen that a greater number of less conspicuous striae are present, that the shell near the anterior margin is decidedly more convex, and that the umbo is not depressed as in *S. emaciata*, the last feature being more or less strongly developed in all the concavo-convex *Strophomenas*. The subcarination of the ventral valve of *S. emaciata* is also present in *S. trentonensis*, but in the former the shell is evenly convex from the cardinal line to the anterior margin, while in the latter it is concavo-convex. With these constant differences there is no ground for assuming that *S. emaciata* is the young of *S. trentonensis*. In *S. scofieldi* it is seen that the hinge line is somewhat shorter, that the valves are more convex, and that the fold and sinus are just the reverse of those in *S. emaciata*.

Formation and locality.—Several specimens have been collected by Mr. W. H. Scofield near the base of the Galena in the *Clitambonites* beds south of Cannon Falls, Minnesota.

RAFINESQUINA, Hall, 1892.

Strophomena of most American authors.

1892. *Rafinesquina*, HALL. *Palaentology of New York*, vol. viii, pt. i, p. 280.

Description: "Shells normally concavo-convex. Surface ornamented by radiating striae of alternating size, crossed and crenulated by finer concentric striae. Cardinal margins without denticulations. Interior of the pedicle valve with the muscular area not strongly limited; consisting of two broad, flabellate, diductor scars enclosing an elongate, more distinctly defined adductor. The faintness of the limitation of this area is in marked contrast to the sharply defined muscular area in the corresponding valve of *Leptaena*. In the brachial valve the cardinal process is more closely sessile than in *Leptaena*, and there is frequently a linear callosity between the branches. The posterior adductor scars have the arborescent markings of *Leptaena rhomboidalis*, and these impressions are the only ones well defined, the anterior scars being narrow and rarely retained with distinctness. From the anterior margin of the muscular area radiates a series of irregular furrows and nodose ridges, which are, to some extent, of vascular origin.

"Type: *Leptaena alternata* Conrad. Trenton and Hudson River groups."

Rafinesquina had its origin in the Calciferous and died out in the Clinton group.

RAFINESQUINA MINNESOTENSIS N. H. Winchell.

PLATE XXXI. FIGS. 25-29.

1844. *Strophomena deltoidea* OWEN (not CONRAD). Geological Exploration of Iowa, Wisconsin and Illinois, pl. XVI, fig. 8; pl. XVII, fig. 6.
 1852. *Leptæna deltoidea* OWEN (not CONRAD). Geological Report of Wisconsin, Iowa and Minnesota, p. 620, tab. 2B, fig. 10 (not the middle figure).
 1862. *Strophomena incrassata* HALL (not 1847). Geology of Wisconsin, vol. i, p. 42, fig. 16.
 1873. *Leptæna deltoidea* N. H. WINCHELL. First Annual Report of the Geological and Natural History Survey of Minnesota, p. 101; Ibidem, Fifth Report, p. 148; Ibidem, Eighth Report, p. 62.
 1881. *Strophomena minnesotensis* N. H. WINCHELL. Ibidem, Ninth Report, p. 120.
 1883. *Strophomena incrassata* HALL (not 1847). Second Annual Report New York State Geologist, pl. XXXVIII, figs. 1-5.
 1892. *Rafinesquina incrassata* HALL. Palæontology of New York, vol. viii, p. 281, pl. VIII, figs 1-5. Compare *Leptæna incrassata* HALL. Palæontology of New York, vol. i, p. 19, pl. IV bis, figs. 2a-2d, 1847.

Original description: "Shell semioblong or semioval, with the cardinal angle about 90°, or less than 90°; diameter from six to nine lines transversely, and from four and a half to eight lines perpendicularly [Wisconsin specimens attain a greater size]; the receiving [ventral] valve convex, sometimes more suddenly deflected after passing the visceral area; entering [dorsal] valve gently concave, but reflexed more rapidly about the margin; the exterior of the convex [ventral] valve marked by fine, radiating striæ, every third, fourth or fifth one being larger than the intervening ones; interior of the convex [ventral] valve, which is best known from its frequent casts, shows a large muscular impression much resembling that of *S. alternata* as figured by Meek in vol. i, Pal. Ohio, plate VII, fig. 3c, but somewhat bilobate in front and larger in proportion to the size of the valve; scars of adductor muscles closely approximate, small and in many casts of this valve undistinguishable; behind they are separated (on the casts) by a short mesial ridge, which between them becomes a narrow mesial furrow and then a deep furrow, terminating at the sinus between the outer larger scars; the outer larger scars [diductors] are radiately striated from the beak [at the base of the dental lamellæ small adjustors are occasionally indicated]; their margins are strongly marked (on the cast) along their posterior sides by distinct grooves formed by the dental plates, which diverge at once from the foramen at an angle of 100-120°, running nearly straight to the outer margins of the muscular scar, when they curve slightly towards the front; the anterior and lateral margins of the general muscular impression are slightly marked on the casts; outside of the muscular scar is a shallow marginal impressed line which is most evident at the cardinal angles as it converges toward the beak; interior edge of the cardinal line is carinate from the teeth to the cardinal angles; the details of the markings in the apex of the beak are seen on the valve itself to consist of two short, distinct, diverging ridges extending not much beyond the hinge teeth [enclosing the adductor

scars], between the anterior ends of which rises a short mesial ridge of about the same size and length, with faint linear ridges parallel with it on each side, which extend a little further forward than the mesial ridge. The mesial ridge first gives place to a flat, unmarked interval, when it again rises more conspicuously, but narrower and sharper, extending nearly to the sinus separating the lobes of the outer muscular scar. The cardinal area of the convex valve slopes from the hinge-line obliquely backward, instead of being in plane with the lateral edges, thus differing from *S. alternata*. From three to five short undulations of the shell transverse to the cardinal line, are seen often between the umbo and the cardinal angles, the heavier ones being near the cardinal angles. The cardinal process is bifid and prominent, the two parts being short, smooth, dentate protuberances that stand prominently exposed about parallel with the plane of the cardinal area.

"The interior of the entering [dorsal] valve is very different from that of the entering valve of *S. alternata*. The general visceral disc is nearly flat, surrounded by a suddenly flexed margin, inside of which is a shallow impressed broad line, most evident round the front; inside the cardinal angles are a few scattered, radiately-interrupted, short ridges or elevations [genital markings], but these do not prevail along the side nor in front, the surface there being smooth or finely granulated instead; in the center of the valve are five smooth, abrupt, digitately-spreading ridges, the middle one of which is a little larger and longer than the others; these rise more abruptly at their anterior extremities than behind, but none of them reach the beak, or even the umbonal region, though the exterior pair of lateral ones are placed further back than the others, converging at an angle of about 70° [and often pass through the large pair of adductor scars]. Socket [crural] ridges very short and widely divergent; behind them are small, doubly-grooved sockets." The beak of the ventral valve is often perforated by a minute, circular, pedicle opening.

R. incrassata Hall* seems to be a closely allied species, of which a few examples from the typical locality have been examined, but they are too poor for detailed comparison. These specimens and Prof. Hall's figures of the species are constant in size and always smaller than *R. minnesotensis*. Billings,† however, found *R. incrassata* "in the Chazy limestone at the Mingan islands, and in the Black River limestone at the Fourth Chute of the Bonnechère, Canada. Specimens from the latter locality agree precisely with those sent me from Tennessee by Prof. Safford." Of the Tennessee specimens referred to by Billings, the writers possess a complete series, and find them to be identical with *R. minnesotensis* Winchell. It is probable that *R. minnesotensis* is only a larger development of the eastern *R. incrassata*.

* *Leptæna incrassata* Hall. Pal. N. Y., vol. i, p. 19, pl. iv bis, figs. 2a-2d.

† Canadian Nat. and Geol., vol. iv, p. 443, 1859.

Formation and locality.—Very common in the upper portion of the Trenton limestone at Minneapolis, St. Paul, Cannon Falls and Fountain, Minnesota. Also abundant in the "Lower Blue beds" at Janesville and Beloit, Wisconsin; Rockton, Illinois. Very rare in the Trenton shales at St. Paul and Cannon Falls, Minnesota; Decorah and McGregor, Iowa. Also at Dixon, Illinois, in the Trenton; in the Birdseye limestone at High Bridge, Kentucky, and in the "Glade limestone" at Lebanon, Tennessee.

Collectors.—C. L. Herrick, H. V. Winchell, Wm. Howling, W. H. Scofield and the writers.

Mus. Reg. Nos. 671, 673-675, 681, 685, 704, 705, 2192, 3521-3523, 3731, 5059, 5097, 5673, 7919, 8143-8148.

Variety *INQUASSA Sardeson*.

PLATE XXXI. FIGS. 27, 28.

1892. *Strophomena inquassa* SARDESON. Bulletin of the Minnesota Academy of Natural Science, vol. iii, p. 334, pl. v, figs. 22-24.

This name is applied to large convex shells with a wide ventral hinge area which otherwise strongly resemble *R. alternata*. In Minnesota specimens are rare. They occur in the upper third of the Trenton shales and continue upward into the Galena, passing into a very gibbose form, *R. deltoidea* Conrad. In Wisconsin variety *inquassa* is quite abundant near the base of the "Upper Buff limestone" and has been identified by Hall as *Strophomena incrassata* (*op. cit.*, 1862). It is not always easy to distinguish between *R. minnesotensis*, var. *inquassa*, *R. deltoidea* and *R. alternata*. This is particularly the case between var. *inquassa* and the latter species when the exterior alone is visible. The thickening of the shell, however, near the anterior margin on the interior of the dorsal valve in *R. alternata* is much stronger, while the four ridges of *R. minnesotensis*, var. *inquassa*, two on each side of the median septum, are reduced to two in the former species. The tendency in the progressive line of development from *R. minnesotensis* seems to be towards larger growth (var. *inquassa*) and greater convexity (*R. deltoidea*), while another series tends to flatter shells and maximum of size (*R. alternata*).

Formation and locality.—Rare in the Trenton shales at Minneapolis, St. Paul and elsewhere in Minnesota. Common near the base of the "Upper Buff beds" at Mineral Point, Wisconsin.

Mus. Reg. Nos. 8141.

RAFINESQUINA DELTOIDEA Conrad, *sp.*

PLATE XXXI. FIGS. 30 and 31.

1839. *Strophomena deltoidea* CONRAD. Third Annual Report of the New York Geological Survey, p. 64; Fifth Report, p. 37, 1841.
 1842. *Strophomena deltoidea* VANUXEM. Geology of New York; Report Third District, p. 46, fig. 2.
 1842. *Strophomena deltoidea* EMMONS. Ibidem, Report Second District, p. 389, fig. 2.
 1842. *Strophomena camerata* CONRAD. Journal of the Academy of Natural Sciences of Philadelphia, vol. viii, p. 254, pl. XIV, fig. 5.
 1847. *Leptæna camerata* HALL. Palæontology of New York, vol. i, p. 106, pl. XXXIA, figs. 2a, 2b.
 1847. *Leptæna deltoidea* HALL. Ibidem, p. 106, pl. XXXIA, figs. 3a-3e.
 1863. *Strophomena deltoidea* BILLINGS. Geology of Canada, p. 163, fig. 141.
 1883. *Streptorhynchus* (*Strophonella*) *deltoidea* HALL. Second Annual Report N. Y. State Geologist, pl. XLII, figs. 1, 2, 4 (not fig. 3).
 1892. *Rafinesquina deltoidea* HALL. Palæontology of New York, vol. viii, pt. i, pl. IXA, figs. 1, 2, 4.

Original description: "Shell deltoid, with numerous radiating striæ and concentric rugose undulations, obsolete on the inferior half of the valves; inferior valve slightly convex above, gibbose, abruptly rounded and flattened at the base; striæ small and crowded; one or two lines in the middle of the valve larger and more prominent than the others; angles of the cardinal line slightly prominent. Length, one inch. *Locality*, Trenton Falls."

This species is closely related to *Rafinesquina alternata*, and differs from it both in its greater convexity and in the corrugations of the central disc. The latter feature is never very well developed in Minnesota specimens, while the convexity may be very great as in *camura*, with all variations to those nearly flat. These depressed convex specimens, especially when the concentric corrugations are obsolete, approach *R. alternata* so closely that it is difficult or impossible to separate them. Such forms are, however, rare. This same difficulty is also met with in New York specimens. Prof. Hall writes,* "it is certainly often very difficult to draw the line of distinction between this species [*R. deltoidea*] and *L. alternata*, and more particularly so between this and *L. camerata*."

R. deltoidea is associated with *Strophomena trilobata*, a species with about the same curvature and corrugations of the central disc. The latter can be readily distinguished by the reversed convexity of the valves, the upper, or strongly rounded valve being the dorsal, while in *R. deltoidea* this is the ventral valve. The nasute anterior portion of the shell and the small, flat, or even slightly concave, central disc will also assist in separating *S. trilobata* from *R. deltoidea*.

Formation and locality.—From the top of the Trenton shales at St. Paul and Cannon Falls, Minnesota, examples have been found which probably belong to this species. Near the middle of the Galena formation at Mantorville, it occurs commonly as casts and retains more or less of the shell at several localities in Goodhue county, and at Weisbach's dam near Spring Valley; close to the top of the formation near Hamilton, and in the lower portion of the Hudson River group at Granger, Minnesota. In the Galena at Oshkosh, Wisconsin, and near the top of the hills at Dubuque, Iowa. Prof. Whitfield gives it as occurring in the Trenton, Galena and ?Hudson River group of Wisconsin. In the Trenton of New York and Canada. Davidson† mentions it as occurring in the Caradoc or Bala period in England, Scotland and Ireland, also "at Paggart, in Esthonia, and at Reval; in Norway and elsewhere." It is believed by the writers, however, that a direct comparison of the British examples referred to *R. deltoidea* will prove them to be different from American specimens in their muscular markings and crural plates.

Collectors.—M. W. Harrington, W. H. Scofield and the writers.

Mus. Reg. Nos. 174, 182, 204, 261, 387, 389, 394, 3395, 8157-8164.

RAFINESQUINA ALTERNATA (*Conrad Ms.*) *Emmons.*

PLATE XXXI, FIGS. 32-34.

1838. *Leptæna alternata* CONRAD. Second Annual Rep. N. Y. Geological Survey, p. 115 (undefined)
 1838-41. *Strophomena alternata* CONRAD. Ibidem, Third Report, p. 63; Fourth Report, p. 201;
 Fifth Report, p. 37 (undefined).
 1842. *Strophomena alternata* EMMONS. Geology of New York; Report Second District, p. 395, fig. 3.

*Pal. N. Y., vol. 4, p. 107.

†Monograph of British Silurian Brachiopoda, p. 202.

[*Rafinesquina alternata*.]

1843. *Orthis huronensis* CASTELNAU. Essai sur le Système Silurien de l'Amérique Septentrionale, p. 37, pl. XIV, fig. 6.
 1843. *Orthis plana* CASTELNAU (not PANDER). Ibidem, p. 38, pl. XIV, fig. 1.
 1844. *Strophomena angulata?* OWEN. Geological Explorations in Iowa, Wisconsin and Illinois, pl. XVIII, figs. 1, 3.
 1847. *Leptæna alternata* HALL. Palæontology of New York, vol. i, pp. 102, 286. pl. XXXI, fig. 1; pl. XXXIA, fig. 1; pl. LXXXIX, fig. 2.
 1856. *Strophomena alternata* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 204, figs. 3, 4.
 1858. *Leptæna alternata* ROGERS. Geology of Pennsylvania, vol. ii, pt. 1, p. 818, fig. 600.
 1860. *Strophomena alternata* BILLINGS. Canadian Naturalist and Geologist, vol. v, p. 51.
 1862. *Strophomena alternata* BILLINGS. Palæozoic Fossils, vol. i, p. 117.
 1863. *Strophomena alternata* BILLINGS. Geology of Canada, p. 163, fig. 140.
 1865. *Strophomena anticostiensis* SHALER. Bulletin of the Museum of Comparative Zoology, vol. i, p. 62.
 1873. *Strophomena alternata* MEEK. Palæontology of Ohio, vol. 1, p. 88, pl. VII, fig. 1.
 1875. *Strophomena alternata* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 51.
 1880. *Strophomena alternata* WHITE. Second Annual Report of the Indiana Bureau of Statistics and Geology, p. 481, pl. 1, figs. 6, 7.
 1881. *Strophomena alternata* WHITE. Tenth Report State Geologist of Indiana, p. 113, pl. 1, figs. 6, 7.
 1883. *Strophomena alternata* HALL. Second Annual Report N. Y. State Geologist, pl. XXXVIII, figs. 6-11.
 1887. *Strophomena alternata* SHALER. Fossil Brachiopoda of the Ohio Valley, p. 4, pls. II, III.
 1892. *Rafinesquina alternata* HALL. Palæontology of New York, vol. viii, p. 281, pl. VIII, figs. 6-11.

Conrad did not define nor describe this species, but gave it the Ms. name *Leptæna* or *Strophomena alternata*, under which it became known to the geologists of the New York survey. Emmons published a figure of it in 1842, but Prof. Hall, in 1847, was the first to describe it as Conrad's species. In 1843, however, Castelnau described and illustrated the same species as *Orthis huronensis*, and were it not for the previously published figure of Emmons this name would have to be adopted. *S. angulata* Owen is probably a misprint for *S. alternata*, since the identification is queried, and his initial is not added to the name, as was Owen's custom with all new species.

The following detailed description is that of Meek, from which a few paragraphs relating to varieties have been omitted: "Shell attaining a large size, semioval, the breadth being nearly always greater than the length; hinge-line as long as the breadth of the valves at any point farther forward, or somewhat longer; lateral extremities rectangular, sometimes compressed and moderately deflected; lateral margins a little convex, or slightly sinuous posteriorly, and rounding forward to the front, which is semicircular in outline.

"Dorsal valve flattened in the umbonal and cardinal regions, and gently or more or less strongly concave in the central and anterior portions, and curved upward around the anterior and lateral margins; beak small, but projecting slightly beyond the edge of the area, which is very narrow or sublinear, and directed nearly backward. Interior with cardinal process strong, directed obliquely forward, with its two divisions distinctly diverging, and flattened and longitudinally striated on their posterior faces; sockets for the reception of the teeth of the other valve rather well

defined; socket [crural] ridges very small and uniting behind the cardinal process to form a deltidium; [adductor] muscular scars comparatively small, but deeply impressed near the cardinal process on each side of a small, short, mesial ridge, and nearly surrounded by a low obtuse ridge formed by a thickening of the adjacent internal surface of the valve; anterior and lateral margins more or less thickened and geniculated within (especially in adult shells), the thickened zone being transversely furrowed [by the vascular sinuses], and sometimes granular, while outside of it the immediate edge of the valve is suddenly flattened and minutely striated and granulated.

“Ventral valve a little convex at the umbo, but generally much compressed over the whole visceral region in the adult (which includes the whole surface of the young and half-grown shell), but becoming more convex (sometimes strongly so) anteriorly, or antero-centrally and laterally, and thence more or less curved up to the anterior and lateral margins; area of moderate height, flat and directed obliquely backward nearly at right angles to that of the other valve; beak very small, scarcely distinct from the margin of the area, and minutely perforated; foramen broadly triangular and arched over above by the deltidium, which is very deeply sinuous on its inner edge, the sinus being nearly or quite closed by the dental process and deltidium [chilidium] of the other valve.

“Interior with cardinal margin somewhat carinate within; hinge teeth moderately prominent, remote and widely divergent; dental ridges obscure and extending obliquely outward and forward, but not produced or curving to surround a saucer-shaped cavity for the muscular scars; scars of the adductor muscles narrow, long and closely approximated, or almost in contact; those of the cardinal [diductor] muscles on each side very large, fan-shaped, but shallow, separated sometimes by a small ridge in advance of the adductor scars, and marked by radiating furrows and ridges, while the anterior and lateral regions are usually marked by striæ and scattering granules.

“Surface of both valves ornamented by numerous radiating striæ, that increase in number, on the ventral valve, mainly by intercalation, and are usually arranged with one to six or eight smaller and shorter ones between each two larger and more prominent ones, the largest one of which often occupies the mesial line, while on the dorsal valve they more frequently increase by division and are generally of more uniform small size. On well preserved specimens all the radiating lines are crossed by numerous very minute, regular, closely arranged concentric striæ, that are invisible without the aid of a magnifier; a few moderately distinct subimbricating marks are also seen near the free margins of adult shells.”

A comparison of the interior of Trenton specimens with those from the Hudson River group shows that the latter have all the parts more strongly developed, owing,

in great measure, to the larger size attained and the greater thickness of the shell. Still, these differences are so conspicuous that it may prove desirable to distinguish the Hudson River forms by a varietal name. According to Hall,* the large thick-shelled variety occurring at Cincinnati is known to collectors there as *Leptæna ponderosa*. This name is very appropriate and if a separation is to be made it should be used, unless the objection is made that it was not defined; still, if the species is ascribed to Hall, there could be no doubt as to what form is meant. In England and Ireland this shell is commonly represented in the Caradoc and Lower Llandovery by *Orthis expansa* Sowerby, which is abundantly illustrated by Davidson in his monographs.†

In the Trenton shales *R. alternata*, when the exterior alone is shown, is not always easily distinguishable from large and not very convex individuals of *R. minnetontensis*. Usually, however, the stronger convexity and smaller size of the latter form and the five internal ridges of the dorsal valve will serve to separate them.

Formation and locality.—A few specimens have been found in the Trenton limestone at St. Charles and it also probably occurs elsewhere in these beds in Minnesota. From the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Lanesboro and Preston, Minnesota; not rare at the base of the Galena in the shales at several localities south of Cannon Falls, and at Kenyon and Fountain. Near the top of the "Lower Blue beds" at Mineral Point, and probably elsewhere in Wisconsin. It also occurs in the Trenton at Dunleith, Illinois; Kentucky; Tennessee; New York, and Canada. Very common in the Hudson River group in Ohio, Indiana, Kentucky, Tennessee, New York and Anticosti.

Collectors.—C. L. Herrick, H. V. Winchell, W. H. Scofield and the writers.

Mus. Reg. Nos. 181, 287, 3396, 4037, 5859, 6761, 8151-8154.

RAFINESQUINA ALTERNATA, VAR. LOXORHYTIS Meek.

PLATE XXXI. FIGS. 35-37.

1873. *Strophomena alternata*, var. *loxorhytis* MEEK. Palæontology of Ohio, vol. i, p. 91.

1875. *Strophomena alternata*, var. *loxorhytis* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 53.

Original description: "Attains a larger size [than *R. alternata*], moderately convex antero-centrally, or rather depressed; much extended on the hinge-line, with lateral extremities acutely angular, flattened and scarcely deflected; area very narrow; both valves marked near the cardinal margin, toward the lateral extremities, by six to eight distinct, very oblique wrinkles on each side."

The shells referred to this variety agree in all essential features, except that the convexity is somewhat greater than in the Ohio specimens. *R. kingi* Whitfield‡ is a closely related species, also occurring in the upper portion of the Cincinnati group, but it can be distinguished at once from *R. alternata*, var. *loxorhytis* by its fine and equal striæ.

*Pal. N. Y., vol. i, p. 104, pl. xxxi, figs. 1a, 1b, 1c, 1d, 1e, 1f, 1g, 1h, 1i, 1j, 1k, 1l, 1m, 1n, 1o, 1p, 1q, 1r, 1s, 1t, 1u, 1v, 1w, 1x, 1y, 1z.

†British Silurian Brachiopoda, p. 312, pl. xlv, figs. 1-10.

‡*Strophomena kingi*, Geol. Wisc., vol. iv, p. 261, pl. xii, figs. 15, 16.

Formation and locality.—Common in the Hudson River group at, and two miles east of, Spring Valley, Minnesota. Rather rare in the middle and upper portion of the same formation in Ohio and Indiana.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers. Also in the collection of Dr. C. H. Robbins, Wykoff, Minnesota.

Mus. Reg. Nos. 4098, 8155.

Genus TRIPLECIA, Hall.

1858. *Trip'esia*, HALL. Twelfth Report New York State Cabinet of Natural History, p. 44, figs. 1-3.
1892. *Triplecia*, HALL. Palæontology of New York, vol. viii, pt. 1, p. 269.

Description: "Shell trilobate, transverse, unequally biconvex. Hinge-line straight and quite short. Pedicle valve shallow, convex about the beak, but depressed anteriorly by a broad and deep median sinus; cardinal area low, erect and well defined; delthyrium covered by a narrow convex [or flat] plate, with a circular foramen at the apex. In the interior the teeth are well developed and supported by short dental lamellæ longitudinally dividing the umbonal cavity near the apex. Muscular area small, comprising two lateral scars, separated by a longer central adductor impression. The brachial valve is very convex and bears a strong median fold. The cardinal area is very narrow and the beak closely incurved. In the interior is an erect cardinal process, which is deeply bifurcated, the distal extremity of each branch bearing a single deep groove. This process is supported on a subrostral callosity, which also bears two short spiniform crural points at its base. Shell substance fibrous, impunctate(?). Surface with obscure concentric growth lines, and fine radiating striæ on the inner laminae; in rare instances there are radiating lines on the exterior.

"Type: *Atrypa extans* Emmons." (Hall, 1892, *op. cit.*)

Plicated species of this genus are unusual, *Triplecia* being characterized mainly by smooth forms. *T. radiata* Whitfield and the following new species are the only ones known in America. In Britain there is but one, *Triplecia sporiferoides* McCoy, sp., from the Upper Llandeilo and Caradoc, and another, *T. cava* Barrande, sp., from Etage D₂ of Bohemia. One is unwilling at first to regard these plicated species as congeneric with the smooth forms, but upon examination it is seen that the generic characters common to the one section are also present in the other. They were derived from smooth forms, since all of the nepionic and early neologic growth is without a trace of plications, they being first introduced during the later neologic stages.

Species of *Triplecia* are known from the Calciferous to the Upper Silurian.



FIG. 34. *Triplecia ulrichi*, n. sp. *a* and *b*, slightly restored dorsal and profile views of an entire specimen; *c* and *d*, two views of the cardinal region of a dorsal valve, $\times 2$; *e*, cardinal region of the ventral valve, $\times 2$, showing the area, apical perforation, and other features. Lower part of the Hudson River shales, Fillmore county, Minnesota. Collection of E. O. Ulrich.

T. ulrichi is distinguished from all other American forms of the genus, except *T. radiata* Whitfield, in having rounded, rather distinct, radiating striae, of which there are from thirteen to eighteen on each side of the fold and sinus, the median region having seven or eight, making in all from thirty-three to forty-four on each valve. The fold and sinus are well developed, but less than is usual with species of *Triplecia*, and the deltidium is flat, never convex. All of the specimens seen are more or less compressed, but the form in general seems to be near that of *T. nucleus** Hall. Interior characters as in *T. extans*† Emmons, sp., the type of *Triplecia*.

The other American striated species of *Triplecia* is *T. radiata*‡ Whitfield from the Calciferous horizon at Beekmantown, New York, differing from *T. ulrichi* in being much smaller and less tumid. *T. spiriferoides*** McCoy, sp., of the Caradoc sandstone of Wales, has a much longer cardinal line and a more sharply elevated fold of the dorsal valve.

The condition of the specimens of *T. ulrichi* may lead collectors to regard them as species of *Orthis* near *O. borealis* or coarsely striated specimens of *O. subaequata*, var. *gibbosa*, but the covered delthyrium of the ventral valve, or the tumid umbo of the dorsal valve, will distinguish them from all orthoids. The forked cardinal process is always broken in separated valves, appearing simple, but preparations from specimens with the valves in place show it to have two delicate branches.

Formation and locality.—Ten specimens were found by Mr. E. O. Ulrich in the Hudson River group at Wykoff and three miles north of Spring Valley, Minnesota.

Genus LEPTÆNA, Dalman.

1828. *Leptæna*, DALMAN. Kongl. Svenska Vet.-Acad. Handl., för år 1827, pp. 94–96, 106, 107 pl. i, figs. 1, 2.
1892. *Leptæna*, HALL. Palaeontology of New York, vol. viii, pt. i, p. 276.

In its relations this genus is nearest to *Rafinesquina* Hall, from which it differs in its greater transversity; more or less strongly corrugated and geniculated valves; internal strongly elevated ridges near the outer margin of the dorsal valve, in which

* Pal. New York vol. i, p. 138, pl. xxxiii, figs. 2a–2c; 1847.

† See above report, p. 137, pl. xxxiii, figs. 1a, 1b; 1847.

‡ Bull. American Mus. Nat. Hist., vol. ii, no. 2, p. 43, pl. vii, figs. 5–8; 1880.

** See Pal. New York, vol. viii, pt. i, p. 271, pl. xic, figs. 10, 11; 1892.

the muscular area is also more elevated, and in the short, deeply impressed muscular area of the ventral valve. The surface corrugations are also developed among species of *Rafinesquina* and *Strophomena*. In the former, however, this character is never strongly marked, while the quadrangular outline and internal features will readily indicate their generic affinities. *Strophomena* can be distinguished at once from *Rafinesquina* or *Leptæna* by the reversal of the relative convexity of the valves.

For a detailed diagnosis of this genus, and for the reasons for restricting *Leptæna*, *Strophomena*, *Rafinesquina* and *Plectambonites* to the characters of their type species, see Pal. N. Y., vol. viii, pp. 245, 276, 281.

Type: *Leptæna rugosa* Dalman=*Producta rugosa* Hisinger=*Conchites rhomboidalis* Wilckens.

The following American species are of this genus:

- L. charlotta* W. and S., Trenton Shales.
- L. tenuistriata* Sowerby, Trenton to Hudson River.
- L. unicostata* Meek and Worthen, Hudson River.
- L. rhomboidalis* Wilckens, sp., Niagara to Waverly.
- L. rhomboidalis*, var. *ventricosa* Hall, Oriskany.

Leptæna incrassata Hall, of the Chazy (Pal. N. Y., vol. i, p. 19), and *Strophomena nitens* Billings of the Hudson River group (Pal. Fos., vol. i, p. 118) may also belong here.

LEPTÆNA CHARLOTTÆ W. and S.

PLATE XXXII. FIGS. 1-5.

1892, April 1. *Leptæna charlotta* W. and S. American Geologist, vol. ix, p. 288.

1892, April 9. *Strophomena halli* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 334, pl. iv, figs. 36-38.

Shell small, transversely semioval, plano-convex, geniculate, with the sides slightly convex and converging to the broadly rounded front, or drawn out tongue-shaped; hinge-line as long as, or somewhat shorter, than the greatest width of the shell. Surface marked by fine, closely crowded, alternating striæ, as in *Rafinesquina alternata*, crossed by exceedingly delicate concentric lines and over the central flat disc of each valve by more or less continuous zigzag undulations or wrinkles.

Ventral valve depressed-convex over the greater portion of the shell and more or less suddenly bent downward or geniculated along the margin, especially anteriorly. Cardinal area wide, broadly triangular, with a convex deltidium, wider than long, apically perforated by a rather large pedicle opening, posteriorly excavated and completely occupied by the chilidium of the other valve. Crenulated hinge teeth prominent and supported by short dental plates, which are attached to the elevated outer margin of the small, transversely oval muscular area. Within this area, in the center of the mesial thickening, are placed the short and narrow adductors, surrounded by the large diductors, and outside these, at the base of the

dental plates, are the distinct scars of the small adjustors. Surface marked by delicate, crowded papillæ, strongest in front of the muscular area, and in the thin shells by the wrinkling of the outer surface.

Dorsal valve nearly flat, with the anterior margin more or less reflexed downward. Cardinal area narrow, about one-third that of the other valve, with a broad and strongly convex chilidium. Dental sockets deep; crural plates slender, very oblique and merging into the median thickening, upon which is situated the small, bilobed, cordate cardinal process; in front of this is a short, low septum separating the small adductor scars; in the central portion of the valve there are three other inconspicuous septa. Just inside the outer margin of the valve is situated a prominent, rounded ridge of the same nature as that in *L. rhomboidalis*.

L. charlottæ differs from any other American species of *Leptæna* in its zigzag, concentric, surface corrugations and in other minor features, which can be more readily seen in the illustration than by written comparisons.

Formation and locality.—This species, in a dwarfed condition, is first met with in the upper portion of the Trenton limestone, and is not uncommon in the upper part of the middle third of the Trenton shales in the Bryozoa layers at Minneapolis and St. Paul, Minnesota.

Collectors.—E. O. Ulrich and the writers.

Mus. Reg. No. 8142.

LEPTÆNA UNICOSTATA *Meek and Worthen, sp.*

PLATE XXXII. FIGS. 6-9.

1868. *Strophomena unicostata* MEEK and WORTHEN. Geological Survey of Illinois, vol. iii, p. 335 pl. IV, fig. 11.

1882. *Strophomena unicostata* WHITFIELD. Geology of Wisconsin, vol. iv, p. 262, pl. XII, fig. 14.

Original description: "Shell transversely subsemicircular, the greatest breadth being on the hinge margin, which terminates in rather acutely angular extremities; lateral margins generally nearly straight, or more or less concave in outline and converging from the extremities of the hinge to the front, which is rounded, a little straightened or slightly sinuous in the middle; geniculation of both valves from the ventral side, very abrupt all around the anterior and lateral margins to near the extremities of the hinge. Ventral valve almost perfectly flat [or slightly convex for a short distance anterior to the beak] and without any traces of concentric wrinkling on the disc between the hinge and geniculated front and lateral margins [in large Minnesota specimens there is more or less concentric wrinkling present in both valves, strongest along the cardinal line on each side of the beak and nearly obsolete medially]; beak very small or scarcely distinct from the cardinal margin and showing the usual minute [pedicle] perforation; area narrow, but a little wider than that of the other valve, and slightly arched and provided with a rather wider triangular fissure, closed by the convex deltidium [chilidium] and the cardinal process of the

other valve. Interior with the hinge teeth not prominent; rostral cavity with a pair of small depressions, in front of which are two elongate and well marked scars of the adductor muscles; surrounding these, with their lateral margins strongly elevated, are the large bilobed and striated diductor scars, which continue forward for two-thirds the length of the valve; surface outside the muscular area covered with strongly elevated, oblique and minutely perforated pustules, more or less radially arranged; space underneath the cardinal area, on each side of the teeth, filled up with shell matter which, towards the extremities, is reflexed and becomes obsolete on the lateral portions of the valve.

"Dorsal valve with the disc or visceral region flattened and, like that of the other valve, without any traces of concentric undulations; deflected anterior and lateral margins conforming nearly to those of the other valve; beak nearly obsolete; area linear and provided with a marginal furrow for the reception of the edge of the other valve; cardinal process rather small, cordate or bilobed, with the [crenated] socket on each side for the reception of the teeth of the other valve well defined; interior with [a pair of medially divided adductor] muscular scars generally moderately distinct and separated by a small mesial ridge [which is nearly obsolete a little posterior to the mid-length, with a small, shallow scar on each side, the septum then again becoming prominent and continuing to the geniculated margin]; other parts of the visceral region occupied by rather crowded [oblique and rather large] granules. Surface of both valves ornamented by fine, crowded, radiating striæ, which increase by intercalation and division, while one of those on the middle of the ventral valve is generally five or six times as large as the others, and really forms a distinct rib."

Adult Minnesota specimens referred to this species have concentric corrugations on the central flat disc, the latter being more convex than in Illinois examples. Associated with the large shells are also numerous smaller ones, which are comparatively narrower, more mucronate and without wrinkles. Since these specimens are immature, and certainly of the same species as the larger ones, there is no hesitation in extending the specific description of *L. uncostata* so as to contain the corrugated examples. From *L. rhomboidalis*, var. *tenuistriata* Sowerby, this species can be distinguished only by the obsolete or inconspicuous wrinkling, the large mid-rib and, when the interior is shown, by the very large, bilobed, diductor scars of the ventral valve.

In the upper portion of the Hudson River group of the Ohio valley *L. rhomboidalis*, var. *tenuistriata* is a very common form, but is replaced by *L. uncostata* in the same formation in northern Illinois, Wisconsin, Iowa and Minnesota. The latter species, it seems, must be regarded as a branch of the line leading to *L.*

rhomboidalis, which so persistently recurs with more or less numerical strength throughout all formations from the Trenton of New York to the base of the Lower Carboniferous.

In Anticosti *Strophomena nitens* Billings* occurs, which, as far as external characters are concerned, appears to be identical with specimens from Wilmington, Illinois, examined by one of the writers. The interiors of these show them to be a species of *Leptæna* Dalman, and they are apparently closely related to *L. unicostata*.

Formation and locality.—Abundant in the upper portion of the Hudson River group at Spring Valley, and rare in the lower portion of the same formation at Granger, Minnesota. Common at Graf, Iowa; Iron Ridge and Delafield, Wisconsin; Savannah and Wilmington, Illinois.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers. Also in the collection of Dr. C. H. Robbins, Wykoff, Minnesota.

Mus. Reg. Nos. 275, 8138-8141.

Genus PLECTAMBONITES, Pander.

1830. *Plectambonites*, PANDER. Beiträge zur Geognosie des russischen Reiches, p. 90, pl. III, figs. 8, 16; pl. XXVIII, fig. 19.

Leptæna of authors, not DALMAN.

1892. *Plectambonites*, HALL. Palæontology of New York, vol. VIII, pt. I, p. 295.

Description: "Shells usually small, normally concavo-convex. Surface covered with very fine striæ, often alternating in size. Hinge-line making the greatest width of the shell, the extremities often subauriculate. Cardinal area narrow in both valves, crenulated on the margins. On the pedicle valve there is a moderately broad delthyrium partly closed by a convex plate, but mostly occupied by the cardinal process of the opposite valve. Apical foramen sometimes retained. Teeth prominent and supported by thickened plates, which are continued in broad outward curves for more than half the length of the valve, returning and uniting in the umbonal cavity, thus limiting two linguiform [diductor] muscular scars, enclosing a more or less clearly defined adductor impression.

"In the brachial valve the dental sockets are deep and often appear to transect the cardinal area. The cardinal process is simple and erect, but by its coalescence with the short, prominent, crural plates the posterior face appears trilobate. The crural plates end abruptly as in *Orthothes*, becoming thickened at about the middle of their length and giving origin to two low ridges or septa, which at first approach each other and thence continue forward with a slight divergence, thus forming the inner boundaries for two elongate [adductor] muscular scars, which are less sharply defined in their outer margins. The muscular area is rendered quadripartite by two short transverse or oblique posterior furrows. Vascular impressions radial, sometimes digitate. Shell substance fibrous, sparsely punctate.

* Pal. Foss., vol. I, p. 118, fig. 97, 1862; Canadian Nat. and Geol., vol. V, p. 53, fig. 1, 1869.

"Type: *Plectambonites planissima* Pander. Lower Silurian of Russia." (Hall, *op. cit.*,)

The following American species are referred to this genus:

- P. (?) decipiens* Billings, sp., Calciferous.
P. (?) sordida Billings, sp., Calciferous.
P. sericea Sowerby, sp., Trenton to Clinton.
P. gibbosa W. and S., Middle Galena.
P. plicatella Ulrich, sp., Hudson River.
P. glabra Shaler, sp., Anticosti.
P. transversalis Wahlenberg, sp., Clinton and Niagara.
P. transversalis, var. *alabamensis* Foerste, Clinton.
P. transversalis, var. *prolongata* Foerste, Clinton.

PLECTAMBONITES SERICEA *Sowerby, sp.*

PLATE XXXII, FIGS. 10-12.

1839. *Leptaena sericea* SOWERBY. Murchison's Silurian System, pl. XIX, figs. 1, 2.
 1840. *Strophomena sericea* CONRAD. Third Annual Report, Geological Survey of New York, p. 201.
 1842. *Strophomena sericea* EMMONS. Geology of New York; Report, Third District, p. 47.
 1847. *Leptaena sericea* HALL. Paleontology of New York, vol. i, pp. 110, 287, pl. XXXI B, fig. 2; pl. LXXIX, fig. 3.
 1852. *Leptaena sericea* HALL. Ibidem, vol. ii, p. 59, pl. XXI, fig. 1.
 1856. *Leptaena sericea* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 41, fig. 2.
 1858. *Leptaena sericea* ROGERS. Geology of Pennsylvania, vol. ii, pt. ii, p. 818, fig. 599.
 1863. *Leptaena sericea* BILLINGS. Geology of Canada, p. 163, fig. 139.
 1873. *Leptaena sericea* MEEK. Paleontology of Ohio, vol. i, p. 70, pl. v, fig. 3.
 1874. *Leptaena aspera* JAMES. Cincinnati Quarterly Journal of Science, vol. i, p. 151.
 1875. *Leptaena sericea* MILLER. Ibidem, vol. ii, p. 57.
 1875. *Leptaena sericea?* WHITE. U. S. Geological and Geographical Survey west of the 100th Meridian, vol. iv, p. 70, pl. IV, fig. 7.
 1883. *Leptaena sericea* HALL. Second Annual Report, N. Y. State Geologist, pl. XLVI, figs. 25, 29.
 1890. *Leptaena sericea* FOERSTE. Proceedings of the Boston Society of Natural History, vol. XXIV, p. 293.
 1892. *Plectambonites sericea* HALL. Paleontology of New York, vol. VIII, pt. i, pl. XV, figs. 25-29.
 1892. *Leptaena minnesotensis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. III, p. 329, pl. IV, figs. 24, 25.
 1892. *Leptaena praeconsis* SARDESON. Ibidem, p. 329, pl. IV, figs. 26-28.
 1892. *Leptaena recedens* SARDESON. Ibidem, fig. 330, pl. IV, figs. 29-32.
 1892. *Leptaena sazea* SARDESON. Ibidem, p. 330, pl. IV, figs. 33-35.

Description: "Shell small, transverse, semioval, approaching semicircular, concavo-convex; hinge-line equaling or more frequently a little longer than the breadth of the valves at any point farther forward; lateral extremities varying from somewhat acutely angular to nearly or quite rectangular and not properly reflexed; anterior and lateral margins forming together nearly a regular semicircular curve.

"Dorsal valve concave, its deepest concavity being near the middle; beak not distinct from the cardinal margin; area narrow or nearly linear, and ranging at right angles to the plane of the valves. Interior showing cardinal margin to be minutely [in Minnesota, lower Hudson River specimens, strongly] crenate towards the lateral extremities; cardinal process moderately prominent [smooth] and trifid [simple, the lateral divisions are portions of the incomplete chilidium or crural plates], the middle division being most prominent, with a deep pit at its inner base;

brachial process short, appressed and widely divergent; muscular impressions [adductors] generally obscurely defined, occupying an obcordate area and separated from each other by two subparallel, narrow ridges that sometimes coalesce near the base of the cardinal process [and are strongly elevated and broadly thickened anteriorly] each impression usually nearly equally divided by a slender linear [sometimes thickened and much elevated], straight ridge; anterior and lateral regions more or less roughened by minute, granular, radiating striae. [These are the markings left by the vascular and genital organs, anterior to which, in the thick shells, there is a well developed ridge just inside the front margin.]

"Ventral valve moderately convex, being nearly evenly, but gently, arched along the middle from the beak to the front, and thus following so nearly the curve of the other valve as to leave but a very thin visceral cavity within; beak very small, or scarcely, if at all, distinct from the cardinal margin; area twice to three times as high as that of the other valve, inclined backward or more or less nearly parallel to the plane of the valves; foramen arched over near the beak by a small deltidium, and [nearly] closed between this and the hinge margin by the prominent cardinal process [and chilidium] of the other valve. Interior showing hinge margin to be obscurely [sometimes prominently] marked by minute pits for the reception of the crenulations of that of the other valve; teeth small; [diductor] muscular impressions long, narrow, separated behind by a short, linear, mesial ridge [upon each side of which are slender, shallow depressions of the adductor muscles], and diverging and extending forward beyond the middle of the valve, with a moderately distinct dental ridge along the lateral margin of each; anterior and lateral regions granulo-striate." (Meek, *op. cit.*)

Surface of both valves marked by numerous, very minute, closely arranged, equal, radiating striae, or with every fourth, fifth or sixth one a little larger or more prominent than those between.

Plectambonites sericea varies considerably in size, convexity, outline and in the strength of its muscular markings. The largest specimens observed were collected in the lower portion of the Hudson River group near Granger, Minnesota, and one of these is 28 mm. in width. Similar large examples occur at Cincinnati, Ohio, and have received the name *Leptaena aspera* James. The crenulations along the lateral margins of the hinge-line are a very marked character in specimens from the former locality, and the muscular scars of the ventral valve are often not as divergent as in others on the same slab. As a rule, shells from the Galena horizon are smaller than those from the Hudson River or Trenton formations, to which Mr. Sardeson has given the name *P. minnesotensis*. Specimens are usually abundant at most localities. *P. sericea* is one of the few species extending through the Lower Silurian, and is replaced in the Niagara by *P. transversalis* Wahlenberg. As stated in the

discussion of *Orthis testudinaria*, there can be little advantage to the geologist or biologist in applying to the numerous local variations of *P. sericea* specific or varietal names.

Formation and locality.—Common in the Trenton formation of New York, Canada, Pennsylvania, central Kentucky, Tennessee, and Dixon, Illinois. From the "Upper Buff beds" of the Trenton at Rockton, Illinois; Mineral Point, Dodgeville and elsewhere in Wisconsin. In the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Fountain and Preston, Minnesota; Decroah and McGregor, Iowa. Very abundant in the Galena at many localities in Goodhue and Fillmore counties, Minnesota; Neenah and Oshkosh, Wisconsin. In the Hudson River group at Spring Valley, Minnesota; Graf, Iowa; Iron Ridge, Wisconsin; Savannah and Wilmington, Illinois; Indiana; Ohio; Kentucky; Anticosti; and Silver City, New Mexico. Clinton group of New York. In the Llandello, Caradoc and Llandovery formations of England. Also in the Lower Silurian of Scotland, Ireland, Russia, Esthonia, Bohemia, Norway and Spain.

Collectors.—C. L. Herrick, W. H. Scofield, E. O. Ulrich and the writers. Also in Dr. C. H. Robbins' collection.

Mus. Reg. Nos. 193, 228, 793, 3494, 3525, 4054, 4084, 4088, 4090, 5854, 5855, 6747, 6795a, 7929-7939, 7947-7950

PLECTAMBONITES GIBBOSA *W. and S.*

PLATE, XXXII. FIGS. 13-17.

1892, April 1. *Plectambonites gibbosa* W. and S. *American Geologist*, vol. ix, p. 288.

Shell small, semicircular in outline, strongly concavo-convex, wider than long, greatest width along the hinge-line. Surface very finely striate, with six or seven stronger lines on each valve, much as in *P. transversalis*.

Ventral valve very gibbous and subcarinate medially, lateral slopes rapid and slightly concave; greatest elevation about mid-length. Cardinal area strongly elevated, slightly concave, somewhat wider than that of the dorsal valve; delthyrium about as wide as long, with a small deltidium in the posterior portion, and more or less occupied by the cardinal process and chilidium of the other valve. Teeth small, supported by strong dental lamellæ, which join the outer, much elevated margin of the muscular area. Diductor muscle pits deep, short, strongly diverging and separated posteriorly by a small septum, on each side of which are slender depressions of the adductor scars. Interior otherwise smooth.

Dorsal valve concave and closely following the curvature of the other valve. Cardinal area wide, flat, retrose; delthyrium with a large, simple cardinal process more or less covered by a chilidium, which is usually imperfect medially. Crural processes short and widely divergent. Adductor scars broadly triangular in outline, lobate, with the outer margin strongly elevated. They are separated medially by a narrow, deep depression, which is interrupted near the anterior margin of the scars by a transverse thickening. Two sharply elevated ridges have their origin at the hinge-line on each side of the muscular area. These curve much laterally for a short distance and then converge, meeting medially quite close to the anterior

margin, where they become obsolete. The depression between this ridge and the outer elevated margin of the muscular area is granulose, while the slope on the outer side of the former is quite abrupt.

This small species of *Plectambonites* is quite distinct from all other American forms. The convexity of the shell, surface ornamentation and the interior characters of the dorsal valve will distinguish it at once from *P. sericea* Sowerby and *P. decipiens* Billings. Its relationship is rather with the latter species, on account of the sharp elevation just inside the margin of the dorsal valve. *P. gibbosa* seems to be closely allied to *P. quinquecostata* McCoy,* but until more is known of the interior characters of the latter further comparisons are impossible. That species is found in the Caradoc and Llandovery of England; also in Scotland, Ireland and Russia.

Formation and locality.—Not uncommon in the Galena at several localities in Goodhue county; also at Mantorville and Old Concord, Minnesota.

Collectors.—M. W. Harrington, A. D. Meeds, W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 147, 423, 8165, 8166.

Family ORTHIDÆ, Woodward.

Genus ORTHIS, Dalman, *emend* Hall.

1828. *Orthis*, DALMAN. Kongl. Vet. Acad.-Hand., pp. 93, 96.

1892. *Orthis*, HALL. Paleontology of New York, vol. viii, pt. i, p. 192.

Description: "The distinguishing features of these shells are the plano-convex contour; the strong, sharp and comparatively few costæ, rarely, if ever, bifurcating; the elevated and somewhat incurved cardinal area on the pedicle valve; the relatively slight development of the dental lamellæ, which do not extend the entire length of the umbonal cavity. The cardinal process on the brachial valve is an elongate, vertical plate, extending from the apex the whole length of the delthyrium, thus longitudinally dividing the deep deltidial cavity. It is usually simple, both on the outer edge and at its distal extremity.

"In this group of orthids [*Orthis* restricted], more frequently than elsewhere, we find a character rarely developed in any stage of growth, viz: the existence of a transverse apical plate in the delthyrium of the pedicle valve [the rudiments of a deltidium]. * * * The greatest development attained by this feature, in any of the numerous species of *Orthis* studied, is to be found in *O. tricenaria* of the Trenton and Hudson River faunas; it has also been observed in *O. calligramma*, var. *davidsoni*, although it does not appear in any of the figures of this species and its varieties given by Mr. Davidson, nor is any mention made of it in his descriptions. Its

* Sil. Foss. Ireland, p. 33, pl. III, fig. 8, 1846; and Davidson's Mono. British Sil. Brach., p. 322, pl. XLVIII, figs. 23-27.

appearance in this genus, and especially in the typical species of the genus, is interesting, but it cannot be embraced in the diagnostic characters, since its presence appears to be largely of a specific value, and the degree of its development dependent upon the stage of growth. - [For further remarks on this plate see *Dinorthis*.]

"The muscular scar of the pedicle valve of *O. calligramma* is a subelliptical area scarcely longer than the cardinal face, faintly impressed, and its components rarely distinguishable.

"The structure of the shell is comparatively fibrous and impunctate. Specimens of *Orthis calligramma*, var. *davisoni*, from Gotland, show openings of oblique tubules on the external surface, always situated upon the keels of the costæ. These are sparse and irregularly scattered, but of similar nature to those seen in the impunctate species *O. subquadrata* and the punctate species *O. subæquata*, *O. michelini*, *O. resupinata* and their allies." (Hall, *op. cit.*)

ORTHIS TRICENARIA *Conrad*.

PLATE XXXII. FIGS. 18-23.

1843. *Orthis tricenaria* CONRAD. Proceedings of the Academy of Natural Sciences of Philadelphia, vol. i, p. 333.
 1843. *Orthis disparilis* CONRAD. Ibidem, p. 333.
 1844. *Orthis testudinaria?* OWEN. Geological Explorations in Iowa, Wisconsin and Illinois, pl. xv, fig. 11.
 1847. *Orthis tricenaria* HALL. Palæontology of New York, vol. i, p. 121, pl. xxxii, fig. 8.
 1847. *Orthis disparilis* HALL. Ibidem, p. 119, pl. xxxii, fig. 4.
 1859. *Orthis disparilis* BILLINGS. Canadian Naturalist and Geologist, vol. iv, p. 440, fig. 20.
 1859. *Orthis tricenaria* SALTER. Canadian Organic Remains, dec. i, p. 39, pl. ix, figs. 1-4.
 1862. *Orthis tricenaria* HALL. Geology of Wisconsin, vol. i, p. 42, figs. 8-11.
 1862. *Orthis disparilis* HALL. Ibidem, p. 435.
 1863. *Orthis disparilis* BILLINGS. Geology of Canada, p. 130, fig. 60.
 1863. *Orthis tricenaria* BILLINGS. Ibidem, p. 167, fig. 151.
 1875. *Orthis plicatella?* WHITE (not HALL). Report of the U. S. Geographical Survey west of the 100th Meridian, p. 72, pl. iv, fig. 10.
 1883. *Orthis tricenaria* HALL. Second Annual Report, N. Y. State Geologist, pl. xxxv, figs. 1-5.
 1884. *Orthis tricenaria* WALCOTT. Monograph of the U. S. Geol. Surv., vol. viii, p. 74, pl. xi, fig. 4.
 1892. *Orthis tricenaria* HALL. Palæontology of New York, vol. viii, pt. i, pp. 191, 193, 221, 228, pl. v, figs. 9-12.
 1892. *Orthis disparilis* HALL. Ibidem, pp. 191, 221, 228.

Original description: "Semioval, with about thirty prominent, very regular, rounded ribs; larger [ventral] valve ventricose; summit elevated; the dorsal margins subrectilinear, very oblique; lesser [dorsal] valve flat or slightly concave in the middle; cardinal area very wide; apex of the larger valve profoundly elevated above that of the opposite valve. Length, three-fourths of an inch."

Shell semicircular in outline; plano-convex; anterior margin somewhat deflected ventrally. Hinge-line equal to the greatest width of the shell, rarely shorter. Cardinal area well developed on each valve, widest in the ventral valve, striated longitudinally and transversely, and divided by a very narrow delthyrium, which is

partially occupied by a deltidium. Surface with thirty to thirty-six radiating, equal, but sometimes unequal, simple, subangular costæ, with a linear elevation occupying the depressions, all crossed by exceedingly delicate concentric lines of growth.

Ventral valve strongly convex, subangular, with the greatest elevation on the umbo. Cardinal area very wide, more or less convex and elevated. Delthyrium in the apical third occupied by a flat, concave or convex deltidium, which extends as well defined linear ridges along the entire length of the walls of the pedicle opening. Hinge teeth strong, supported by well developed, excavated dental plates, which join the outer elevated margin of the rounded muscular area. Diductor muscles occupy the greater portion of the muscular area, the anterior margin of which is slightly thickened and unites with the two large, diverging vascular trunks. The adductor scars are two slender depressions situated between the diductors and separated by a central linear elevation, the whole being drawn out anteriorly into a very narrow and short septum. Genital markings close to each side of the muscular area. Exterior to these are numerous markings of the vascular system. Peripheral margins of valves marked by radiating, short and strongly elevated costæ, each with a central furrow.

Dorsal valve nearly flat, slightly elevated at the beak; from this the point of greatest elevation, the surface slopes gradually into the broad, scarcely perceptible, rarely well defined, median sinus. Cardinal area wide, flat, divided by a triangular delthyrium, as broad as long, and more or less covered by a convex chilidium, the anterior margin of which is concave. Deltidial cavity occupied by a thin, much elevated, smooth cardinal process. Crural plates broad, strongly projecting interiorly, their bases converging and joining a low, broadly rounded, median septum, which becomes obsolete at about the mid-length of the valve. On each side of this septum are two pairs of adductor scars, the posterior pair well defined. Vascular sinuses numerous, occupying the entire postero-lateral surface of the interior.

Orthis costalis Hall,* of the upper beds of the Chazy group of New York, is closely allied to *O. tricenaria*. Remains of the former, however, are always more or less exfoliated, and this condition makes it difficult to point out satisfactory differences between the two. Specimens figured by Mr. Walcott, and identified as *O. tricenaria*, occur in the upper beds of the Pogonip group (probably equivalent to the Chazy group of New York and Canada), but are smaller than this species usually is. Such specimens, however, are also found near the top of the Trenton limestone at Minneapolis, Minn. After a careful examination of these specimens, the writers are unable to point out characters by which they can be separated from *O. tricenaria*. This variety was doubtfully identified by Dr. White (*op. cit.*) as *O. plicatella* Hall; but his illustrations show it to be the species cited above.

*Pat. Ohio, vol. II, p. 78.

O. disparilis Conrad proves to be the young of *O. tricenaria*, as has been suggested by Hall and Whitfield.*

O. davidsoni de Verneuil,† of the Silurian of America, England and Scotland, is another closely related species, but can be distinguished from *O. tricenaria* by its more convex cardinal area and the strongly elevated subangular costæ. The costæ also have a few remote oblique perforations in the shell substance, a feature never seen in *O. tricenaria*.

Formation and locality.—This widely-distributed and characteristic Trenton fossil is often smaller in size in the Northwest than in either the eastern or southern exposures of the horizon. It occurs commonly as natural casts in the Trenton limestone at Minneapolis, St. Paul and Cannon Falls; but in the Trenton shales good shells are not rare at Minneapolis, St. Paul, Cannon Falls, Fountain, near Lanesboro, Eyota, Preston, and near Caledonia, Minnesota; also at Decorah and McGregor, Iowa. In Wisconsin it is very abundant, and is a characteristic fossil of the "Lower Blue beds" at Beloit, Janesville and Mineral Point; at the last locality it was also collected in a siliceous condition near the base of the "Upper Buff beds." It has also been collected by one of the writers in the Trenton formation at Dixon, Illinois; High Bridge and Curdsville, Kentucky; and Watertown, New York. Near Ottawa and Montreal, Canada; Mangan islands; Eureka and White Pine districts, Nevada. In Goodhue county, Minnesota, this species is known to extend upwards for at least fifty feet in the Galena formation at several exposures south of Cannon Falls.

Collectors.—Miss C. S. Seymour, C. L. Herrick, H. V. Winchell, J. C. Kassube, W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 372, 666, 668, 2191, 3509, 4034, 5057, 5091, 5130, 5150, 5582, 6802, 7795-7810, 7916.

Subgenus DINORTHIS, Hall.

1892. *Dinorthis*, HALL. Palæontology of New York, vol. viii, pt. i, p. 195.

1892. *Plexiomys*, HALL. Ibidem, p. 196.

Original description: "This group of shells, in its most characteristic examples, presents a reversal of the relative convexity of the valves as seen in *Orthis calligramma*. The pedicle valve, elevated at the umbo, becomes gradually depressed as growth advances, and in the mature condition is flat or gently concave over the pallial region. The brachial valve, on the other hand, is eminently convex. The surface is marked by strong [and fine], simple, rarely bifurcating costæ, as in *O. calligramma*. The cardinal area of the pedicle valve is well developed, but not greatly elevated. In the interior the dental lamellæ are prominently developed and are extended around a subquadrate muscular area, the strength of which apparently depends upon the age and thickness of the shell. The three pairs of impressions may often be distinguished; the elongate adductors occupying a central position and separated by a faint median ridge, the diductors forming large antero-lateral expansions enclosing the adductors; the adjustors lie outside and behind these [pedicle muscles not always discernible]. Occasionally, in *Orthis pectinella*, there is again seen the gradual closing of the delthyrium of the pedicle valve by an

* Pal. New York, vol. i, p. 20, pl. iv bis, fig. 4, 1847.

† Bull. Soc. Geol. de France, sec. ser., vol. v, p. 341, pl. iv, fig. 9, 1848.

apical callosity, but it is never carried as far as in the forms mentioned in the group of *Orthis callactis*, and, so far as observed, its existence is confined to the species cited. In the brachial or more convex valve the area is narrower, the crural plates stronger than in the preceding groups [*Orthis callactis* and *O. plicatella*], and the cardinal process, instead of being a simple linear ridge lying in the bottom of the deltidial cavity, is an erect apophysis, broadened and frequently bilobed on its summit and posterior face.

"The shell structure, like that of *Orthis callactis* and *O. plicatella*, is compactly fibrous and, in all the species examined, impunctate. No evidence of tubulose plications has been seen."

Type: *Orthis pectinella* Emmons.

In establishing the subgenus *Dinorthis* Prof. Hall was justified in separating the species having a similar contour of the valves, as in *O. pectinella*, but differing in the far greater number of striae. At that time no form was known to connect the subgenera *Dinorthis* and *Plasiomys*, respectively typified by *O. pectinella* and *O. subquadrata*. In the Lower Silurian of Minnesota, beginning with the lowest fossiliferous member of the Trenton limestone, the first species is *O. deflecta*. This has characters common to the strophomenoids, but is clearly referable to *Dinorthis*. From this species to *O. (D.) pectinella*, the one occurring next higher in the series, in the Trenton shales, there is a wide departure in the surface striation. *O. deflecta* has very fine striae, while in *O. pectinella* there are strong plications. From *O. pectinella* we pass to the variety *sweeneyi*, which is a local variation of it. Associated with the latter are specimens in which the strong plications begin to divide near the anterior margin. At the base of the Galena shales the strong, simple, plicated forms become rarer, while those with more numerous striae prevail. Upon reaching the strata containing *Clitambonites diversa* Shaler, provisionally known to the survey as Galena shales, the numerously striated form, here described as *O. meedsi*, is the only one found. Ascending into the Galena formation for thirty or forty feet more we find *O. meedsi* still exhibiting a tendency to increase the number of its striae, and finally assuming characters (variety *germana*) which attain their greatest development in *O. subquadrata* of the Hudson River formation. The change from *O. pectinella* to *O. subquadrata* is thus completed.

The cardinal process is linear and not much elevated in *O. deflecta*, and attains its greatest development in *O. subquadrata* and *O. proavita* of the Hudson River formation. The adjustor scars are conspicuous in *O. deflecta*, while in the other species here referred to *Dinorthis* they are much reduced in size.

In *Orthis (Dinorthis) deflecta* no pedicle muscle exists, but always a more or less large deltidium. *Orthis (Dalmanella) subaequata* has sometimes a short deltidium, the

posterior end of which is drawn inwards, and is transversely striated. When this plate is absent, as is commonly the case, the apical portion of the delthyrium is filled with shell matter which served for the attachment of the pedicle muscle. In *Orthis tricenaria* the apical plate is always strongly developed and may be flat, concave or convex, the latter condition not being common. A small deltidium is also present in *Orthis (Dinorthis) pectinella*. In all the species of *Orthis* observed when a pedicle muscle is present a deltidium is absent; but where this plate is developed the muscle is rudimentary. This evidence leads the writers to the conclusion that the pedicle muscle is attached to the bottom of the valve in the apex of the delthyrium when the deltidium is wanting, but when it is developed the muscle is then more or less attached to the deltidium.

ORTHIS (DINORTHIS) DEFLECTA *Conrad, sp.*

PLATE XXXII, FIGS. 24-30.

1843. *Strophomena deflecta* CONRAD. Proceedings of the Academy of Natural Sciences of Philadelphia, vol. i, p. 332.
 1843. *Strophomena recta* CONRAD. Ibidem, vol. i, p. 332.
 1847. *Leptaena deflecta* HALL. Palaeontology of New York, vol. i, p. 113, pl. XXXIB, fig. 5.
 1847. *Leptaena recta* HALL. Ibidem, p. 113, pl. XXXIB, fig. 6.
 1859. *Strophomena deflecta* HALL. Twelfth Report, N. Y. State Cabinet of Natural History, p. 70.
 1859. *Strophomena recta* HALL. Ibidem, p. 70.
 1877. *Streptorhynchus rectus* MILLER. American Palaeozoic Fossils, p. 134.
 1889. *Streptorhynchus deflectum* MILLER. North American Geology and Palaeontology, p. 378.
 1892. *Plesiomya deflecta* HALL. Palaeontology of New York, vol. viii, pp. 197, 222, pl. VA, figs. 28-34.
 1892. *Plesiomya recta* HALL. Ibidem, pp. 197, 222.

Original description: "Semioval, superior [ventral] valve slightly concave deflected at the angles, the other valve reflected; radii very closely arranged, prominent, subequal, minutely crenulated; inferior [dorsal] valve slightly depressed in the middle; cardinal area wide; superior margin of the concave valve rather elevated. Breadth, half an inch."

Shell semioval or subquadrate in outline; concavo-convex or strophomenoid in form. Hinge-line two thirds, or as long as, the greatest transverse diameter of the shell; width of cardinal areas variable, in some specimens comparatively wide, widest in the ventral valve, and disposed at a right angle to each other; delthyrium of both valves broadly triangular and partly covered by a convex deltidium. Surface marked by fine, equal, sharply rounded striae, which increase in number by interstitial addition and rarely by bifurcation. From 120 to 135 along the anterior margin of adult examples. Striae and intermediate depressions crossed by numerous, elevated, thread-like, concentric lines and a few well marked minor imbrications, the latter indicating periods of rest in shell growth.

Ventral valve carinate medially in the posterior third, with the lateral and anterior portions concave; the latter part is the stronger and forms a broad and undefined mesial sinus; greatest elevation at the beak. Cardinal area flat, broadly

triangular in outline, nearly horizontal, compared with that of the other valve, and marked by a number of parallel lines of growth; delthyrium widely triangular, covered from less than one-half to more than two-thirds its length by a depressed-convex deltidium, which is broadly excavated along the anterior margin. Interior with well developed dental plates, which join the outer elevated margin of the short, more or less quadrate-lobate muscular depression. In the center of this depression are the small, elongate, centrally divided adductors; on the outside of these and occupying the greater portion of the muscular area, are the diductors. At the base of the dental lamellæ are the variously defined adjustors. Immediately beneath the cardinal area, and originating on each side of the muscular depression, are numerous antero-laterally directed genital markings. Vascular sinuses indistinct. Interior surface of the valves along the anterior margin with radiating, centrally channeled striæ occupying the depressions between those of the outer surface.

Dorsal valve evenly convex medially, with a more or less reflexed or concave portion on each side and immediately in front of the cardinal line. A defined narrow depression has its origin at the apex, which is soon merged into the shallow, though sometimes deep, mesial depression. Cardinal area striated, comparatively wide for species of *Orthis*. Delthyrium broadly triangular and covered by a chilidium at the apex, which continues along the walls of the delthyrium as separated plates. Crural plates short, but prominent, originating at the inner ends of the walls of the delthyrium. The entire rostral cavity is occupied by a subhemispheric deposit of shell matter, upon the posterior surface of which is situated an elongate, linear, crenulate cardinal process, the anterior portion terminating in a short, broadly rounded median septum. On each side of the latter are situated the depressions of the adductor muscles, the posterior pair being most conspicuous.

This species has been regarded, until quite recently, as a true strophomenoid shell. The contour of the valves, elongate hinge-line and fine striæ, combined with more or less large deltidia, are doubtless strophomenoid features; yet the cardinal and articulating processes and the muscular arrangements are decidedly orthoid characters. Since these features are regarded as of greater importance than the former, this species should be referred to the subgenus *Dinorthis*. In the line of development between *O. (D.) deflecta* and *O. (D.) pectinella* some links are missing. In the second species there is still a small deltidium in the ventral valve, which has been reduced in the dorsal valve to linear ridges bounding the delthyrium. The cardinal process is larger, the striæ have become plications and have a tendency towards multiplication, while the general form and muscular scars are essentially those of *O. (D.) deflecta*. For further modifications of *O. (D.) pectinella*, see *O. (D.) meedsi* and its variety *germana*, and *O. (D.) subquadrata*.

Orthis platys Billings,* from the Chazy limestone at Montreal, Canada, appears to be a closely related species, but can be separated from *O. (D.) deflecta* by its convex and deeper ventral valve and more delicate striae.

Billings identified *Strophomena recta* Conrad in the Trenton limestone at Ottawa, Canada. His illustrations clearly show that he had specimens of a true *Strophomena* before him, but not the *S. recta* Conrad, which is here regarded as the young of *O. (D.) deflecta*. For further remarks see *Strophomena billingsi*, n. sp.

Strophomena recta Conrad can be seen readily to be an immature condition of *O. (D.) deflecta*, by observing the growth lines on mature individuals of the latter species. The original material of both forms was obtained at Mineral Point, Wisconsin, and specimens of both have been collected by the writers at that locality and elsewhere in that state, all from the same geological horizon, and it is evident that the former is the young of the latter.

Formation and locality.—This common species is widely distributed in the Northwest, and is everywhere observed to hold an identical horizon. In Minnesota it is restricted to the Trenton limestone in beds known as the "upper building stone," occurring as casts at Minneapolis and St. Paul, and as free shells at Cannon Falls and in Allen Hunt's quarries near fountain. In Iowa near McGregor. In Wisconsin it is a characteristic fossil of the "Lower Blue beds" at Mineral Point, Beloit, Janesville, and Dixon, Illinois. In the "Glade limestone" of Central Tennessee a variety of this species is often met with at Lebanon, Murfreesboro and Lavergne. In Kentucky a specimen has been found near the top of the Birdseye limestone at High Bridge.

Collectors.—H. V. Winchell, C. L. Herrick, E. O. Ulrich and the writers.

Mus. Reg. Nos. 672, 682, 5060, 5092, 5095, 7790-7794, 7928.

ORTHIS (DINORTHIS) PECTINELLA (*Emmons*) Hall.

PLATE XXXII. FIGS. 31-34.

1842. *Orthis pectinella* EMMONS. Geology of New York; Report, Second District, p. 394, fig. 2 (not defined).
 1847. *Orthis pectinella* HALL. Palaeontology of New York, vol. i, p. 123, pl. xxxii, fig. 10.
 1847. *Orthis pectinella*, var. *semiovalis* HALL. Ibidem, p. 124, pl. xxxii, fig. 11.
 1856. *Orthis pectinella* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 205, fig. 5.
 1858. *Orthis pectinella* ROGERS. Geology of Pennsylvania, vol. ii, p. 818, fig. 602.
 1863. *Orthis pectinella* BILLINGS. Geology of Canada, p. 165, fig. 147.
 1880. *Orthis charlotte* N. H. WINCHELL. Eighth Report, Geological and Natural History Survey of Minnesota, p. 67.
 1883. *Orthis pectinella* HALL. Second Annual Report, N. Y. State Geologist, pl. xxxiv, figs. 39, 40.
 1889. *Orthis pectinella*, var. *semiovalis* MILLER. North American Geology and Palaeontology, p. 359.
 1892. *Dinorthis pectinella* HALL. Palaeontology of New York, vol. viii, pt. i, pp. 195, 222, 228, pl. v, figs. 27-33.

Original description: "Suborbicular or obtusely semioval, wider than long in the proportion of about nine to twelve; cardinal line extended, equal to, or less than, the greatest width of the shell, slightly deflected at the extremities; area moderately large and well defined; shell resupinate, or the area and foramen being principally on the latter valve, or partially common to both; dorsal [ventral] valve

* Can. Nat. and Geol., vol. iv, p. 438, fig. 15.

subconvex near the beak, with flat sides and a broad depression along the center, which is distinct in front; ventral [dorsal] valve regularly convex, most prominent in the center; beak extending only to the cardinal line; surface marked with from twenty-two to thirty prominent, rounded radii, which are equal to the spaces between; radii simple, or bifid and trifid towards the margin, crossed by small [closely crowded] elevated concentric [growth] lines."

In the interior of the ventral valve the dental lamellæ are well developed and unite with the outer elevated margin of the elongate-quadrangle muscular area. Within this area, occupying the central portion, are the elongate adductors divided by a very faint median elevation. These scars are surrounded laterally and anteriorly by the diductors, while the adjustors lie outside of the latter at the base of the dental lamellæ. Genital spaces faintly indicated on the lateral area, each side of the muscular depression. The apical third of the delthyrium has a convex deltidium. Surface of both valves near the anterior margin more or less strongly marked by plications, each centrally sulcated and opposite the depressions of the outer surface.

Interior of dorsal valve with a well defined, bilobed and striated cardinal process occupying the apical portion of the delthyrium; immediately underneath it is a low, rounded and short median septum separating the adductor scars, which are rarely divisible into four impressions. Crural plates first form the walls of the delthyrium and then extend into the interior as strong projections.

Orthis pectinella is very constant in its characters throughout its geographical distribution, and is restricted to the Trenton group. In Mercer county, Kentucky, the largest growth and number of individuals is obtained, while in Minnesota the tendency is towards dwarfing. The small size and neatness of the majority of individuals of this species led one of the writers to regard them as a distinct form, to which the name *O. sweeneyi* was applied. Recently, however, large specimens showing the interior have been discovered, and these prove to be *O. pectinella*. Since more than two-thirds of the individuals occurring in Minnesota are smaller than those obtained elsewhere, it is considered advisable to retain the name *O. sweeneyi* as a variety of the species. This new material has also shown that *O. charlottæ* Winchell is founded upon an unusually convex ventral valve of *O. pectinella*.

Formation and locality—Rare in the Trenton shales at St. Paul, Minneapolis and near Cannon Falls, Minnesota; Decorah, Iowa. Common in Mercer county, Kentucky; Middleville, Trenton Falls, Turin, Watertown and elsewhere in New York, Pennsylvania and eastern Canada.

Collectors.—W. H. Scofield, C. L. Herrick, E. O. Ulrich and the writers.

Mus. Reg. Nos. 667, 7767.

ORTHIS (*DINORTHIS*) *PECTINELLA*, var. *SWEENEYI* *Winchell*.

PLATE XXXII, FIGS. 35-38.

1881. *Orthis sweeneyi* N. H. WINCHELL. Ninth Report, Geological and Natural History Survey of Minnesota, p. 117.1892. *Dinorthis sweeneyi* HALL. Paleontology of New York, vol. viii, pt. i, pp. 196, 222, 228, pl. v, figs. 34-36.

Original description: "Shell suborbicular, with a straightening along the hinge-line, and having the general aspect of *Orthis pectinella*, but with a shorter hinge-line.

"The receiving [dorsal] valve is convex, with flattened lateral marginal areas and cardinal angles; costæ coarse and simple, numbering about twenty-two, all of which continue to the beak except two or three on each side, which in passing from the margin in front of the cardinal angles, rather terminate on the hinge-line. The costæ and the furrows, which have about the same width, are crossed by fine, crowded, concentric striæ; beak distinct, but not much elevated above the margin of the area; area slightly arched, but directed in the plane of the edges of the valves; area [foramen] triangular, equilateral, containing a simple tooth which rises to the apex, but is not developed so as to appear in the plane of the cardinal area, but is horizontally ribbed on either side.

"The entering [ventral] valve is flat, with a little elevation at the beak and umbo, and a broad, slight concavity between the umbonal region and the front margin; costæ the same as on the convex valve; beak small and more abrupt than that of the other valve; area low and flat, but of nearly the same height as that of the other valve, with which it forms an angle of about 45°; foramen partially closed, but open below, broadly triangular.

"The transverse diameter is seven lines in the single specimen belonging to the survey, and the perpendicular is six."

The specimen described, and others now before us, are essentially but dwarfed individuals of *O. pectinella*. Their shells, however, are smaller and thinner than in the typical form of that species, while the costæ are usually simple, and the muscular scars undefined. Since these features are constant in the specimens observed, it is considered advisable to recognize them as a variety of *O. pectinella*.

Formation and locality.—Not rare in the upper portion of the Trenton shales at St. Paul, near Cannon Falls and Mineola, Minnesota; Decorah and McGregor, Iowa.

Collectors.—W. H. Scofield, F. W. Sardeson and the writers.

Mus. Reg. Nos. 3510, 3520, 5001, 6791, 7768, 7769, 7785.

Orthis (Dinorthis) meedsi.]

ORTHIS (DINORTHIS) MEEDSI *W. and S.*

PLATE XXXII. FIGS. 30-42.

1892, April 1. *Orthis meedsi* W. and S. American Geologist, vol. ix, p. 289.1892, April 9. *Orthis minnesotensis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 332, pl. v, figs. 14-17.

Shell of medium size, suborbicular in outline; biconvex; anterior margin broadly deflected dorsally; hinge-line about one-fourth shorter than the greatest width. Surface marked by strongly elevated, sharply rounded striæ, from forty-five to seventy on each valve along the anterior margin, crossed by numerous thread-like lines of growth; striæ arranged in bundles of two or three, those of the ventral valve bifurcating, while on the dorsal valve increase takes place by interpolation. Exfoliated specimens show two or three rows of small black spots, which may represent perforations in the shell substance.

Ventral valve slightly convex, with a broad, shallow sinus; greatest elevation near the apex; cardinal area of moderate width, slightly concave, somewhat elevated beyond or depressed below that of the dorsal valve, perforated by a small triangular delthyrium, which is bounded on each side by a thread-like elevation; beak slightly incurved. Internal characters of valves as in *O. (D.) pectinella*, but less sharply defined.

Dorsal valve strongly convex centrally, with the lateral-posterior areas somewhat concave; greatest elevation at a point one-third the length of the valve from the posterior margin; cardinal area very narrow, slightly concave, with a broad delthyrium, which is occupied in part by a striated cardinal process.

This common and widely distributed species throughout Minnesota is probably a lineal descendant of *O. (D.) pectinella*, var. *sweeneyi*. At first it appears rarely with that variety, and attains its distinguishing character in less than fifteen feet of shales above the horizon having var. *sweeneyi* in abundance, and which is here no longer met with. The feature distinguishing *O. (D.) meedsi* and *O. pectinella*, var. *sweeneyi* is, that bifurcation and interpolation of the striæ take place at a much younger stage of growth in the former than in the latter, and therefore the species at maturity appear quite different. In some of the localities of *O. pectinella* this tendency towards multiplication of the striæ is very noticeable, but it invariably takes place after the shell has attained more than one-half its growth. In Minnesota specimens it takes place close to the margin, and consequently after maturity has been attained. In *O. (D.) meedsi* the first increase in number of striæ occurs when the shell has attained but one-third its growth, and after this period bifurcation and interpolation are irregular. There is, moreover, a tendency towards a more convex ventral valve than in *O. (D.) pectinella*, but every now and then a specimen occurs with the characteristic flattened valve of that species.

The specific name is after A. D. Meeds of the University of Minnesota.

Associated with the above species, at its climax of development in number of individuals, a very characteristic and striking variety makes its appearance, which is named *germana*.

Formation and locality.—Rare near the base of the Galena shales at St. Paul, Minnesota, and McGregor, Iowa, a few feet above the horizon of *O. pectinella* and variety *sweeneyi*. It becomes a common and very characteristic fossil in the beds immediately above, and is there associated with *Clitambonites diversa* Shaler; it is known to extend for thirty feet above this horizon.

The following are the most prominent localities at which this species has been collected: Cannon Falls, Kenyon, Warsaw, Fountain and Preston, Minnesota; Decorah and McGregor, Iowa; Neenah and Oshkosh, Wisconsin.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 4055, 5860, 5861, 6746, 7771-7785.

Variety GERMANA *W. and S.*

PLATE XXXII. FIGS. 43-45.

1892, April 1. *Orthis meedsi* var. *germana* W. and S. American Geologist, vol. ix, p. 290.

This variety is distinguished from *O. (D.) meedsi* by the following characters: Smaller in size and squarer in outline; valves more strongly and more evenly convex; hinge areas nearly equal in width and narrower, with the beak of the ventral valve slightly elevated above that of the dorsal; ventral valve with a slight, somewhat angulated fold, while the dorsal has a shallow, but distinct sinus originating immediately below the apex of the valve. The fold and sinus produce a slight sinuosity in the anterior margin, the direction of which is just the reverse of that in *O. (D.) meedsi*.

The largest specimens of this variety observed have the general external expression of small individuals of *Orthis subquadrata*, and no external nor internal parts are known that preclude the form from being viewed as the ancestor of that species which attains its specific development in the upper portion of the Cincinnati group. The beds from which var. *germana* is obtained are fully one hundred feet below those holding *O. subquadrata*. During this interval no specimens of *Dinorthis* have as yet been detected.

Formation and locality.—Not rare in the upper part of the Galena shales at several localities south of Cannon Falls, near Kenyon and Fountain, Minnesota. This horizon is also characterized by *Anastrophia hemiplicata* and a number of small Bryozoa.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. No. 7770.

ORTHIS (DINORTHIS) SUBQUADRATA *Hall.*

PLATE XXXII. FIGS. 46-50.

1847. *Orthis subquadrata* HALL. Palaeontology of New York, vol. i, p. 126, pl. XXXIIA, fig. 1.

1862. *Orthis subquadrata* HALL. Geology of Wisconsin, vol. 1, p. 54, figs. 1, 2.

1863. *Orthis subquadrata* BILLINGS. Geology of Canada, p. 165, fig. 146.

Orthis (*Dinorthis*) *subquadrata*.]

1873. *Orthis subquadrata* MEEK. Palæontology of Ohio, vol. i, p. 94, pl. IX, fig. 2.
 1875. *Orthis subquadrata* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 38.
 1880. *Orthis subquadrata* WHITE. Second Annual Report, Indiana Bureau of Statistics and Geology, p. 484, pl. I, figs. 3-5.
 1881. *Orthis subquadrata* WHITE. Tenth Report, State Geologist of Indiana, p. 116, pl. I, figs. 3-5.
 1887. *Orthis subquadrata* SHALER. Fossil Brachiopoda of the Ohio Valley, p. 22, pl. VII.
 1892. *Orthis (Plesiomys) subquadrata* HALL. Palæontology of New York, vol. viii, pt. i, pp. 194, 197, 222, pl. VA, figs. 17-19.

Original description: "Subquadrate, the cardinal line forming one side, the sides and base being nearly straight, with the angles rounded; cardinal line less than the width of the shell, extremities curved; area small, partially common to both valves; dorsal [ventral] valve nearly flat or slightly depressed near the margin, elevated towards the beak, which is small and well defined; ventral [dorsal] valve regularly convex with a shallow sinus along the center, producing a slight elevation of the dorsal valve in front; surface marked by uniform subangular radii, which bifurcate near the beak and again towards the margin, those near the cardinal line curving upwards; radii crossed by fine, elevated, concentric lines, which are very distinct in the depressions between the rays."

The following more detailed description is that of Meek, drawn up from specimens from typical localities:

"Shell attaining about a medium size, rather distinctly resupinate, somewhat wider than long, subquadrate in general outline; moderately convex; cardinal margin shorter than the breadth of the valves and rounding abruptly at the extremities into the lateral margins, which round and converge forward; front a little sinuous or straightened at the middle.

"Dorsal valve more convex than the other, its most prominent part being near the middle; mesial sinus small and rather shallow, sometimes continued nearly to the umbo, or in other instances scarcely more than reaching the middle; beak very short, or little distinct from the edge of the area, and more or less arched; area narrow, directed obliquely backward and downward. Interior with scars of the adductor muscles moderately distinct, the posterior pair being situated close back under the brachial processes, one on each side of a well defined rounded ridge that becomes suddenly smaller between the anterior pair; cardinal process rhombic, subconical, moderately prominent and having its posterior side marked by deeply impressed, divaricating striæ; sockets well defined; brachial process rather strong and directed obliquely forward and laterally; internal surface, excepting the radiately striated front and lateral margins, nearly smooth.

"Ventral valve a little convex at the umbo and flat or slightly concave between the umbo and the front and lateral margins, but sometimes having a low, very obscure mesial elevation towards the front; beak small and very short or scarcely equalling that of the other valve, arched at the apex, but not strongly incurved; area about

twice as high as that of the other valve, well defined, tapering rather rapidly towards the lateral extremities, arched with the beak, and directed backward and downward at decidedly less than a right angle to that of the other valve. Interior with muscular scars occupying a rather deep, bilobate impression extending nearly or quite to the middle of the valve and usually defined by a low ridge most distinct on each side; scars of adductor muscles small, separated by a mere trace of a raised line; those of the divaricator [diductor] muscles of moderate size, longitudinally striated and having their narrow posterior ends extending backward nearly to a small, triangular, transversely striated space [pedicle muscle scar] occupying the interior of the beak; those of the ventral adjustor muscles smaller and shorter than the divaricators [diductors] and situated nearly under the hinge teeth, which are moderately prominent, subtrigonal and oblique; vascular markings with their lateral divisions curving up backward and sending off several branches, while the other divisions extend forward and bifurcate so as to occupy the anterior region; anterior and lateral margins crenate within by very short striae.

"Surface of both valves ornamented by moderately stout, radiating striae, the posterior lateral of which curve so strongly outward that a few of them run out on the cardinal edge before reaching the lateral margins; striae of ventral valve nearly always increasing by bifurcation [some of them dividing two or three times], while those on the dorsal valve generally increase by the intercalation of shorter ones between the larger. A few distant subimbricating marks of growth are sometimes seen towards the front and lateral margins; while, on perfectly preserved specimens, the radiating striae may sometimes be seen to be roughened by minute, elevated concentric lines, that are more or less interrupted in crossing some of the striae." (Pal. Ohio, vol. i, p. 94.)

This species is so well known that a comparison with other related forms is unnecessary.

It has been shown that *O. meedsi* is a development from *O. pectinella*, var. *sweeneyi*, in which a greater number of striae have their origin at a much younger stage of growth. Moreover, as the tendency is to equalize the space between the ridges, new ones are continually added, so that these species at maturity are quite distinct. The multiplication of striae is carried still further in *O. meedsi*, var. *germana*, and in addition to this, other features are introduced which link it closely to *O. subquadrata*. The latter has all the characters of the former more strongly developed, which is due to its greater size, and the line of development from *O. pectinella* to *O. subquadrata* is thus probably completed.

The following species, *O. proavita*, is closely related to *O. subquadrata* Hall. The striae are simple, and it is rare to find interpolation and bifurcation taking place

beyond the early nealagic stage. Here, then, is a reversion to ancestral characters, which is carried still further in *O. flabellulum* Hall* (non Sowerby)—*O. flabellites* (Hall) Foerste,** a species from the Niagara formation much resembling *O. pectinella* Emmons.

Formation and locality.—This is a very characteristic and common species in America, everywhere marking the upper portion of the Hudson River group. In Minnesota it has been found abundantly at Spring Valley, and is known to be equally common at Wilmington, Illinois; Richmond, Weisburg and Madison, Indiana; Oxford, Clarksville and Waynesville, Ohio; Maysville, Kentucky; and Anticosti. It also occurs rarely at Graf, Iowa, and at Iron Ridge, Wisconsin.

Collectors.—E. O. Ulrich, John Kleckler and the writers. Also in the collection of Dr. C. H. Robbins, of Wykoff, Minnesota.

Mus. Reg. Nos. 274, 396, 4076, 4094, 7786-7788.

ORTHIS (DINORTHIS) PROAVITA *W. and S.*

PLATE XXXII, FIGS. 51-57.

1892, April 1. *Orthis proavita* W. and S. *American Geologist*, vol. ix, p. 290.

1892, April 9. *Orthis petre* SARDESON. *Bulletin of the Minnesota Academy of Natural Sciences*, vol. iii, p. 332, pl. v, figs. 18-21.

Shell of medium size; subquadrate; hinge-line equal to, or less than, the greatest width of the shell; cardinal angles rounded or rectangular; sides gently convex and converging to more or less straightened or slightly concave anterior margin. Surface marked by simple subangular striæ having their origin at the apex of the valves or immediately below it, addition taking place by interpolation on the dorsal, and by bifucation on the ventral valve; one to three striæ terminating on the cardinal margin on each side of the umbo; thirty-seven to forty-two on mature examples, crossed by a variable number of imbricating growth lines near the anterior margin. In some specimens this margin is sharply reflexed, partly indicating old age.

Ventral valve slightly elevated at the umbo, flattened or somewhat concave toward the lateral and anterior margins, with an insignificant mesial elevation. Area comparatively narrow, with a broad, triangular delthyrium, two-thirds of which is occupied by the cardinal process of the other valve; beak slightly incurved. Interior characters as in *O. subquadrata*, with the muscular scars remarkably well defined for a specimen of medium size.

Dorsal valve more or less strongly convex, with the greatest elevation about mid-length. A shallow, or sometimes well pronounced, broad sinus is present, having its origin in the upper third of the valve. Area narrow, perpendicular or slightly inclined forward, with a broad delthyrium entirely occupied by the protruding, striated cardinal process.

O. (D.) proavita differs from *O. (D.) iphigenia* Billings,† in having the fold and sinus reversed; the latter also has a greater number of striæ and is restricted to the

* *Geol. N. Y.*: Rep. Fourth Dist., p. 105, fig. 5, 1843; *Pal. N. Y.*, vol. II, pp. 254, 255, pl. XLII, figs. 6, 7, 1852.

** *Proc. Boston Soc. Nat. Hist.*, vol. xxiv, p. 308, pl. VI, figs. 4, 5, 1890.

† *Pal. Foss.*, vol. I, p. 133, fig. 110, 1862.

Trenton group of Canada. *O. (D.) porcata* McCoy* has deeper valves, while the area of the ventral valve is more than twice as wide. *O. (D.) retrorsa* Salter is a somewhat larger species, but differs from *O. (D.) proavita* in its retrorse ventral area.

For the relation of *O. (D.) proavita* to other species of the subgenus *Dinorthis* see *O. (D.) subquadrata*.

Formation and locality.—Not rare in the upper portion of the Hudson River group at Spring Valley, Minnesota, and Wilmington, Illinois.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 273, 278, 7789.

Subgenus HEBERTELLA, Hall.

1892. *Hebertella*, HALL. Palaeontology of New York, vol. viii, pt. i, p. 198.

Original description: "This division is distinguished both by its external and internal characters; the pedicle valve has a well developed, often much elevated, cardinal area and a long, straight hinge-line; its surface is depressed-convex, always less convex than the opposite valve, which is frequently gibbous or deflected. The surface is covered with a great number of fine, rounded, closely crowded plications which increase rapidly by intercalation, and are crossed by lamellose growth lines and fine concentric striæ. On the interior of the pedicle valve the teeth are large and supported by thick lamellæ, which are continued as a strong ridge around a short, obcordate muscular area. This area is medially divided by a prominent ridge, upon the summit of which lies the linear scar of the adductors. The flabellate lateral impressions are sometimes divisible into their two components, diductors and adjustors, and in old individuals the impression of the pedicle muscle is often distinct.

"In the brachial valve the dental sockets are narrow and are enclosed beneath and on the inner side by the strong crural plates. The cardinal process is elongate and simple, sometimes thickened, often crenulate, but not lobed, at its posterior extremity. This process unites with the inner bases of the crural plates and is produced forward as a median ridge dividing the four muscular scars, which are distinctly developed only in old shells.

"The shell structure is fibrous-impunctate, and the plications of the surface sometimes tubulose."

Type: *Orthis sinuata* Hall.

"Shells of this type of structure are abundant in the Trenton and Hudson faunas and extend upward into the Clinton group, but are not at present known in any later period."

* Sil. Foss. of Ireland, p. 32, pl. III, fig. 14, 1846; and Pal. Foss., vol. i, p. 135, fig. III, 1862.

ORTHIS (HEBERTELLA) BOREALIS Billings.



FIG. 33. *Orthis (Hebertella) borealis* Billings. *a*, dorsal; *b*, ventral, and *c*, profile view of a variety of this species. Upper part of the Galena shales near Wykoff, Minnesota. Collection of E. O. Ulrich.

1859. *Orthis borealis* BILLINGS. Canadian Naturalist and Geologist, vol. iv, p. 436, fig. 14.
 1863. *Orthis borealis* BILLINGS. Geology of Canada, p. 129, fig. 56; p. 167, fig. 148.
 1873. *Orthis borealis* MEEK. Palæontology of Ohio, vol. i, p. 101, pl. viii, fig. 4.
 1875. *Orthis borealis* MILLER. Cincinnati Quarterly Journal of Science, vol. 2, p. 23.
 1889. *Orthis borealis* NETTELROTH. Kentucky Fossil Shells, p. 36, pl. xxxiv, figs. 14-20.
 1892. *Orthis (Hebertella) borealis* HALL. Palæontology of New York, vol. viii, pt. i, p. 222.

The Minnesota specimens of this species are closely related to *Orthis plicatella* of the Galena horizon, so that a detailed description is not necessary. They can be distinguished from each other by the fold and sinus, in *O. borealis*, being on the dorsal and ventral valves respectively, while in *O. plicatella* the conditions are the reverse. These differences are not so pronounced as in specimens from the Ohio valley, where *O. borealis* usually has, in addition, a much deeper dorsal than ventral valve. The latter character is one of the chief distinctions between Prof. Hall's subgenera *Hebertella* and *Plectorthis*, and is developed at its maximum in *O. sinuata* Hall. From the preceding it is readily seen that these subgenera probably had their origin in the Chazy formation, and there and in the Trenton are not easily distinguishable, but in the Hudson River group of the Ohio valley *Hebertella* is one of the characteristic markers of that horizon, there reaching its maximum of growth, diversity and number of individuals. *Plectorthis* also attains its maximum in the Hudson River group, the tendency in the Cincinnati group being towards diminished size, but greater numerical strength and irregularity of plications, while in the north-west the radical form developed into other distinct, large, somewhat localized species. *Hebertella* persists into the Upper Silurian, while *Plectorthis*, which probably originated first, became extinct with the Hudson River group.

Formation and locality.—Rare in the upper Clitambonites horizon of the Galena shales near Wykoff, Cannon Falls and top of West St. Paul bluffs, in Minnesota. Prof. Whitfield mentions its occurrence in Wisconsin. Very common near the top of the Trenton limestone at Frankfort, Burgin, Lexington and elsewhere in central Kentucky. Near Nashville, Tennessee. In Canada Billings cites it from the Chazy to the Trenton at Caughnawaga, St. Genevieve, Isle Bizard and Cornwall.

Collectors.—E. O. Ulrich and C. Schuchert.

ORTHIS (HEBERTELLA?) BELLARUGOSA *Conrad*.

PLATE XXXIII, FIGS. 1-4.

1843. *Orthis bellarugosa* CONRAD. Proceedings of the Academy of Natural Sciences of Philadelphia, vol. i, p. 333.
 1847. *Orthis bellarugosa* HALL. Palaeontology of New York, vol. i, p. 118, pl. XXXII, fig. 3.
 1892. *Hebertella bellarugosa* HALL. Ibidem, vol. viii, pt. i, p. 222.

Original description: "Semioval; valves nearly equally convex; lesser valve with a mesial subangular furrow; ribs prominent, linear, with unequal bifurcations; disk with numerous concentric, prominent, subsquamose wrinkles; apex of larger valve not much elevated above that of the opposite valve; cardinal area rather wide. Length, less than half an inch.

"Locality: Mineral Point, Wisconsin, (Trenton limestone)."

Shell subquadrate in outline; biconvex; anterior margin more or less sharply deflected ventrally. Hinge-line equal to, or a little shorter than, the greatest width of the shell. Cardinal area much the widest in the ventral valve, slightly concave and elevated above that of the dorsal. Delthyrium narrowly triangular in the ventral valve and three times as long as wide. Surface marked by unequal costæ, varying in number from thirty to fifty-two, increase taking place by bifurcation on the ventral valve, and by intercalation on the dorsal, crossed by numerous, strongly imbricating, concentric lines of growth.

Ventral valve strongly and evenly convex, sometimes with a very shallow median sinus, greatest elevation on the umbo, with the beak more or less elevated and slightly incurved. Hinge teeth large, supported by well developed dental plates, which join the lateral elevated outer margin of the more or less obcordate muscular area. This area, in the apical portion, is occupied by the transversely striated pedicle muscle; medially by the expanding adductors, while the diductors are situated on each side of the latter. The short, conspicuous and slightly diverging vascular trunks have their origin at the base of a more or less elevated muscular area and terminate rapidly. Large genital spaces are very faintly indicated on each side of the muscular area. Peripheral margin in the valves marked by prominent radiating striæ.

Dorsal valve convex, with a conspicuous, more or less broad, medial sinus. Cardinal area narrow, erect, slightly concave, divided by the delthyrium, which is as wide as long. Crural plates projecting and having their origin at the base of the walls of the delthyrium, which join the conspicuous, transverse apical thickening; and here the strong and simple cardinal process is centrally situated. Dental sockets deep, situated on the posterior-lateral areas of the crural plates. A stout, but short

and narrowly rounded medial septum has its origin at the base of the apical thickening, and upon each side are placed two pairs of adductor muscles, the posterior ones much the smaller.

The larger specimens of this species occurring in the Trenton shales of Minnesota are difficult to separate from *Orthis insculpta* Hall of the Cincinnati group. Commonly, however, the former is much smaller, has a less convex dorsal valve, with more strongly defined muscular scars; the exterior, concentric, imbricating growth lines are also more prominent.

Formation and locality.—Rare in the Trenton limestone and Trenton shales at Minneapolis and St. Paul; not uncommon in the lower portion of the Galena in many localities in Goodhue county, and at Fountain, Minnesota; and Neenah, Wisconsin. Near the top of the Trenton at Decorah and McGregor, Iowa. In the "Lower Blue beds" of the Trenton at Janesville, Wisconsin, and in the "Upper Buff beds" at Rockton, Illinois. Also in the "Central limestone" of the Trenton near Murfreesboro, Tennessee.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. Nos. 6752, 7806-7812.

ORTHIS INSCULPTA Hall.

1847. *Orthis insculpta* HALL. Palaeontology of New York, vol. i, p. 125, pl. xxxii, fig. 12.
 1863. *Orthis insculpta* BILLINGS. Geol. of Can., p. 167, fig. 150. (Compare with *O. bellarugosa* Conrad).
 1873. *Orthis insculpta* MEEK. Palaeontology of Ohio, vol. i, p. 99, pl. ix, fig. 1.
 1875. *Orthis insculpta* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 40.
 1883. *Orthis bellarugosa* HALL. Second Annual Report, N. Y. State Geologist, pl. xxxv, fig. 22.
 1892. *Hebertella insculpta* HALL. Palaeontology of New York, vol. viii, pt. i, p. 222.

It is peculiar that this prevalent species of the upper beds of the Hudson River formation does not occur in Minnesota, since it is found in Wisconsin and Iowa.

Formation and locality.—A characteristic fossil of the upper beds of the Cincinnati group in the Ohio valley; also at Wilmington, Illinois; Iron Ridge, Wisconsin, and Graf, Iowa.

Mus. Reg. Nos. 7813-7815.

Subgenus PLECTORTHIS, Hall.

1892. *Plectorthis*, HALL. Palaeontology of New York, vol. viii, pt. i, p. 194.

Original description: "This is a persistent form, which in American faunas, so far as known, is limited to the Trenton and Hudson formations. While it retains the strong external ribs of the typical *Orthis*, these are not invariably simple (*O. fissicosta* Hall; *O. triplicatella* Meek; *O. æquivalvis* Hall, not Davidson; *O. jamesi* Hall); the cardinal area of the pedicle valve is comparatively low and the valves are subequally convex. In the interior the character of the muscular scars, dental lamellæ and cardinal process is essentially the same as in Group I [*Orthis callactis* Dalman]; and the minute structure of the shell appears to be in precise agreement with that of *O. calligramma*, though no evidence of tubulose costæ has been observed. In *Orthis jamesi*, which is placed in this association, there is occasionally a deviation toward the resupinate contour, exemplified in Groups IV and V [*Orthis subquadrata* Hall and *Orthis sinuata* Hall].

ORTHIS (*PLECTORTHIS*) *PLICATELLA* Hall.

PLATE XXXIII. FIGS. 5-7.

1847. *Orthis plicatella* HALL. Paleontology of New York, vol. i, p. 122, pl. XXXII, fig. 9.
 1863. *Orthis plicatella* BILLINGS. Geology of Canada, p. 165, fig. 145.
 1873. *Orthis plicatella* MEEK. Paleontology of Ohio, vol. i, p. 108, pl. VIII, fig. 7.
 1875. *Orthis plicatella* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 30.
 1892. *Plectorthis plicatella* HALL. Paleontology of New York, vol. VIII, pt. i, p. 221, pl. v, figs. 18-20.

Original description: "Broadly semioval, nearly equivalve, length and breadth about as three to four; surface marked by strong, radiating plicæ, which are usually simple, about twenty to twenty-eight on each valve, crossed by simple, elevated concentric lines, which are more distinct in the depressions between the costæ, and often obscure or obsolete upon their exposed surfaces; valves nearly equally convex, without sensible depression or elevation on either one, meeting on the edges in a straight line; cardinal lines not extending beyond the width of the shell; area narrow; dorsal foramen not extending to the beak."

This well known species originates in the lower portion of the Trenton group of New York and is also found in the inferior strata of the Galena formation in Wisconsin and Minnesota, attaining its greatest development in numbers and variations in the Cincinnati group, at a horizon about 300 to 350 feet above low water in the Ohio river.

Orthis plicatella is rather a rare species in the Trenton of New York, and Galena of Wisconsin and Minnesota. It attains a larger growth and is fairly constant in its simple plications and has a more depressed and furrowed dorsal umbo than in specimens from the Cincinnati group. The size and number of plications in the specimens from Cincinnati are very variable, several forms having been described as distinct species. These are *O. fissicosta*, *O. dichotoma* Hall,* and *O. triplicatella* Meek.** In large collections of these forms, however, it is often difficult to know where to draw the line between them, and the above names can only be used to indicate the transition from the simple undivided *O. plicatella* to *O. dichotoma* with its numerous interpolated smaller striæ.

In the Cincinnati group of the Northwest, *O. plicatella* is not known to occur, but *O. whitfieldi* Winchell and *O. kankakensis* McChesney take its place. These species have attained a much larger size than *O. plicatella*.

Formation and locality.—Rare in the Trenton limestone of Middleville and Watertown, New York, and Burgin, Kentucky. One individual has been discovered in the Galena shales at St. Paul; it has also been obtained at Kenyon, Cannon Falls and elsewhere in Goodhue county, Minnesota. Prof. Whitfield reports it from about the same horizon in Wisconsin. Very common in the Cincinnati group around Cincinnati, Ohio.

Collectors.—W. H. Scofield, A. D. Meeds and the writers.

Mus. Reg. Nos. 7765, 7766.

* Pal. N. Y., vol. i, pp. 121, 125, pl. XXXI, figs. 7, 8, 1847.

** Pal. Ohio, vol. i, p. 109, pl. VIII, fig. 8, 1873.

ORTHIS (PLECTORTHIS) WHITFIELDI N. H. Winchell.

PLATE XXXIII, FIGS. 8-13.

1881. *Orthis whitfieldi* WINCHELL. Ninth Annual Report of the Geological and Natural History Survey of Minnesota, p. 115.
1882. *Orthis pectinella* WHITFIELD (parti. not EMMONS nor HALL). Geology of Wisconsin, vol. iv, p. 259, pl. XII, fig. 8.
1892. *Plectorthis whitfieldi* HALL. Paleontology of New York, vol. viii, pt. i, p. 221, pl. v, fig. 26.

Original description: "Shell semioval, the hinge-line being a little less than, or equal to, the greatest transverse diameter, the cardinal angles being a little greater than 90° , the edge passing in a regular semioval curve through the antero-lateral angles, but sometimes with a very slight inclination in front toward the side of the receiving [ventral] valve. Size varying from nine and a half to fourteen lines in transverse diameter, and from eight to eleven and a half lines in perpendicular diameter, in the larger size the convexity being, between the umboes, six and a half lines.

"The receiving [ventral] valve has a distinct and full beak and umbo, from which the surface slopes evenly to the margin all round, but having a little flatness at the cardinal angles. The cardinal area is arched, and at its union with the cardinal area of the entering [dorsal] valve forms an angle with it of nearly 90° ; its height is about one-sixth its length; its foramen [delthyrium] is triangular and reaches the beak, the width across the base being somewhat less than the height; plications of the surface are strong, direct and simple, but double their number on the umbo by implantations, and again in the same way before reaching the margin, where they number from thirty-six to forty-eight. Between the plicæ are fine cross ridges which sometimes rise to the tops of the plicæ, but do not cross them so as to be preserved in our specimens. A cast of the interior of this valve shows a distinct general muscular impression, reaching a little more than one-third the perpendicular diameter of the valve from the beak, and divided longitudinally into shallow furrows and ridges converging within the beak, four of the former and five of the latter, with a cross-striation visible on that portion between the teeth and near the foramen. The central ridge in the general muscular impression on the cast does not reach the front margin of the scar, but gradually dies out, giving place to the adjoining parallel furrows which widen and coalesce, and show a longitudinal finer furrowing or striation. The next ridges, on either side, are marked and prominent, extending to the anterior angles of the scar, giving it a nearly straight, elevated front and angular corners, somewhat as in *O. subquadrata*. The two outermost ridges are fainter, but extend to the lateral margins of the scar. Still, outside of all these ridges are traces of a similar furrowing within the beak, embracing that portion between the teeth which

has the fine cross-striation. The outward plications of the valve are strongly marked on the cast for about two and a half lines from the margin, and some of them run faintly even to the edge of the muscular scar.

"The entering [dorsal] valve is much less convex, but cannot be said to be flat, though it has a faint flattening along the center, which widens to the front margin where it is changed, in the large specimen, to a slight concavity and produces a straightening and also a very slight flexure of the margin. In front of the cardinal angles also, on either side, is a flat, depressed area; cardinal angle parallel with the posterior margins of the valve, and a little more than one-half the height of that of the receiving valve; beak indistinct; foramen triangular and about as wide as high, with a small, central, smooth tooth [cardinal process], which does not rise above the plain of the area and only becomes visible, on being cleaned and excavated. A cast of the interior of this valve shows marked internal characters. While the impressions of the individual divaricator and adductor muscles of the same side are not separable with certainty, owing to the faintness of the lines between them, the pairs of each are divided, on the cast, by a deep, sharp furrow that extends from the beak where it divides the divaricately striated cardinal process into two equal lobes, toward the front between the depressions of the hinge teeth, to a point somewhat more than one-third the diameter from the beak, where it dies away or runs into a broad, abrupt, medial depression which produces the flatness in the valve extending to the front margin. The external costæ are deeply impressed on the cast about the margin, some of the lines running faintly within the vascular area. The exterior of this valve is also marked by concentric fine striations, especially between the costæ."

The vascular trunks are often conspicuous in the ventral valve, having their origin at the antero-lateral elevated margin of the muscular area; diverging slightly, they proceed but a short distance forward. Posterior to these and on each side of the muscular area are the faintly marked genital spaces.

* This species is closely related to *O. kankakensis* McChesney,* but is always proportionately less elongated along the hinge-line, and therefore squarer in outline. The plications are also more numerous, there being from sixty to seventy along the margin of one valve in that species, while in *O. whitfieldi* there are usually not more than forty.

The specimen figured by Prof. Whitfield (*op. cit.*) as *O. pectinella* (Emmons) Hall, and found in the Cincinnati group at Delafield, Wisconsin, undoubtedly belongs to this species. It does not occur above the lower portion of the Galena, while *O. whitfieldi* is unknown below the Hudson River group, and always has a greater

* New Pal. Foss., p. 77, 1861; also Trans. Chicago Acad. Sci., vol. 1, p. 20, pl. ix, fig. 3, 1868.

number of plications, with a convex ventral valve. In *O. pectinella* this valve is flatter and its cardinal area is never so strongly elevated as in *O. whitfieldi*.

Formation and locality.—Common in the Hudson River group at Spring Valley and near Granger, Minnesota; Delafield, Wisconsin; Savannah, Illinois, and Graf, Iowa.

Collectors.—E. O. Ulrich, John Kleckler, W. H. Scofield and the writers.

Mus. Reg. Nos. 277, 429, 4094, 5549, 7762-7764.

Subgenus DALMANELLA Hall.

1892. *Dalmanella*, HALL. Palæontology of New York, vol. viii, pt. i, p. 205.

Original description: "Shells plano-convex or subequally biconvex. Pedicle valve usually the deeper, often gibbous, elevated at the umbo and arched over the cardinal area. Hinge-line generally shorter than the greatest width of the shell. In many of the species there is a more or less conspicuous, undefined median fold and sinus on the pedicle and brachial valves respectively. Surface covered with fine, rounded, bifurcating striae.

"In the pedicle valve the teeth are quite prominent, thickened at their extremities and supported by lamellæ which are produced forward circumscribing a rather short suboval or subquadrate muscular area, which is more or less distinctly defined in different species and in different conditions of the shell. In *Orthis meeki* Miller, a somewhat ponderous, biconvex, multistriate variation of *Orthis testudinaria*, it is clearly resolvable into adjustor and diductor scars, the latter bounding, but not altogether enclosing the impression of the adductors; the pedicle scar is also discernable. In the brachial valve the cardinal process extends forward as a ridge to the bases of the crural plates, where it is broadened and continued thence as a median ridge separating the muscular impressions. The inner surface of this process is divided by a faint median furrow which produces two lobes at the posterior extremity, and each of these lobes is again divided, making the process quadrilobate. Sometimes the inner divisions of the two main lobes have coalesced, producing a strong median lobe and thus making the process appear trilobate. In some species at maturity, and in others from abnormal growth, this process becomes a broad plug, which fills the entire delthyrial opening. The dental sockets are small, the crural plates often greatly elevated, especially in the plano-convex forms, and they are not usually produced into a ridge about the muscular area, but end abruptly. Muscular impressions quadruplicate, sometimes with radiating ridges extending from the lateral and anterior margins.

"Shell substance finely fibrous and punctate."

Species of this subgenus probably make their appearance as early as the Calciferous (*O. electra* Billings), but certainly in the Chazy group, and are also known to occur in all the intervening formations up to the close of the Devonian.

ORTHIS (*DALMANELLA*) *HAMBURGENSIS?* *Walcott*.

PLATE XXXIII. FIGS. 14-15

1884. *Orthis hamburgensis* WALCOTT. Monograph of the U. S. Geological Survey, vol. viii, p. 73, pl. II, fig. 5.

Original description: "Shell small, suborbicular in outline, plano-convex; hinge-line a little shorter than the greatest breadth of the valves. Dorsal [ventral] valve moderately convex, most elevated a little behind the center, along a slight ridge formed by two or three strong, slightly raised striae; beak small, depressed about halfway down the cardinal margin. Ventral [dorsal] valve depressed, the slightly convex, mesial depression well defined from the beak to the front margin.

"Surface of both valves marked by from twelve to eighteen strong angular striae, which increase by bifurcation or intercalation towards the margin."

The following description is based on Minnesota material: Shell very small, subquadrate in outline, hinge-line equal to, or slightly less than, the greatest width below; cardinal angles rectangular; sides in the posterior third straight or gently convex; anterior angles and front broadly rounded. Ventral valve convex, subcarinate along the middle, with a flat slope toward the sides; greatest elevation about one-third the length of the shell from the posterior margin. Cardinal area wide, broadly triangular, slightly concave, forming an angle of about 115° with the plane of the lateral margin; delthyrium narrowly triangular, more than twice as long as wide, with a linear elevation along each wall. Beak slightly incurved, raised above that of the dorsal valve. Dorsal valve less convex than the ventral, with a sinus beginning immediately below the beak and rapidly expanding into a broad, shallow depression, which produces a more or less undulated anterior margin. Cardinal area conspicuous, slightly concave, less than half as wide and more erect than that of the other valve; delthyrium about as long as wide, bounded on each side by a linear elevation, and occupied centrally by a narrow and simple cardinal process.

Surface with moderately strong, radiating, bifurcating, angular striae, of which from thirty-two to forty-six may be counted along the anterior margin. In some specimens the striae are nearly equal in size, while in others those originating on the umbones increase rapidly in strength, and the ones coming in later by bifurcation remain smaller, giving to such shells the appearance of striae in bundles. Interior features unknown, except that the dental plates are strong and attached to the bottom of the valve.

Since the cardinal areas, delthyrium and interior characters are unknown in the Nevada specimens, the writers are not satisfied that the Trenton forms are identical with *O. hamburgensis*. A specimen of the latter was sent to Mr. Walcott, who writes that "the cardinal line is a trifle shorter in the Nevada specimens than in those from

Minnesota, otherwise I do not see any difference between the two species. It is to be remembered, however, that the Nevada specimens do not show the cardinal area and that they are not quite as well preserved as the one you sent to me." *O. hamburgensis* is found in the central part of the Pogonip group of Nevada, a horizon probably equivalent to the lower portion of the Chazy group of New York. The great difference, geographically and geologically, between the localities of *O. hamburgensis* and the species here provisionally identified with it leads to the belief that the two may be specifically distinct.

In Minnesota this form is found associated with *O. testudinaria* and is easily confounded with it. Upon examination, however, characters are noticed reminding one of *O. tricenaria* and other species referred to *Orthis* in its strict generic sense. The wide cardinal area, narrow delthyrium, simple cardinal process, and the fact that none of the striæ terminate on the cardinal lines, are features of that genus. In *O. hamburgensis* the surface striæ exhibit a strong tendency towards bifurcation and upon them are series of minute black spots, probably infillings of the punctæ in the shell substance. Since *Orthis* is impunctate and always has simple plications, this species is better placed in *Dalmanella*. If this conclusion is correct, there is evidence to show that *Dalmanella* was derived from *Orthis*.

Formation and locality.—Rare in the Trenton shales at St. Paul, near Cannon Falls, Lanesboro and Fountain, Minnesota. Also from the top of the Birdseye limestone near High Bridge, Kentucky. The typical specimens are from the central part of the Pogonip group of the Eureka District, Nevada, where the species is common.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. No. 7897.

ORTHIS (DALMANELLA) TESTUDINARIA *Dalman.*

PLATE XXXIII. FIGS. 17-22.

1828. *Orthis testudinaria* DALMAN. Kongl. Svenska Vet.-Acad. Handl., för 1827, p. 115, pl. II, fig. 4.
 1839. *Orthis testudinaria* CONRAD. Annual Report of the New York Geological Survey, p. 63.
 1842. *Orthis striatula* EMMONS. Geology of New York: Report of the Second District, p. 394, fig. 3.
 1842. *Orthis testudinaria?* EMMONS. Ibidem, p. 404, fig. 4.
 1847. *Orthis testudinaria* HALL. Palæontology of New York, vol. I, p. 117, pl. XXXII, fig. 1; p. 288, pl. LXXIX, fig. 4.
 1856. *Orthis testudinaria* BILLINGS. Canadian Naturalist and Geologist, vol. I, p. 40, fig. 1.
 1858. *Orthis testudinaria* ROGERS. Geology of Pennsylvania, vol. II, pt. II, p. 818, fig. 601.
 1863. *Orthis testudinaria* BILLINGS. Geology of Canada, p. 165, fig. 144.
 1875. *Orthis testudinaria?* WHITE. Report of the U. S. Geographical Surveys west of the 100th Meridian, p. 72.
 1875. *Orthis testudinaria* MILLER. Cincinnati Quarterly Journal of Science, vol. II, p. 20.
 1882. *Orthis testudinaria* WHITFIELD. Geology of Wisconsin, vol. IV, p. 258, pl. XII, figs. 5-7.
 1883. *Orthis testudinaria* HALL. Second Annual Report, New York State Geologist, pl. XXXIV, figs. 1-4, 6-15.
 1884. *Orthis testudinaria* WALCOTT. Monograph of the U. S. Geological Survey, vol. VIII, p. 72, pl. XI, fig. 10.
 1892. *Dalmanella testudinaria* HALL. Palæontology of New York, vol. VIII, pt. I, pp. 190, 206, pl. VB, figs. 27, 39.
 1892. *Orthis rogata* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. III, p. 331, pl. V, figs. 1-4.
 For other synonymy see Davidson's Monograph of British Silurian Brachiopoda, p. 226.

Original description: "O. testa confertissime striata, costis subalternis elevatioribus; valva minori subplana semiorbiculari; majori basi gibba, nate prominula nutante. Locus. Ostrogothia ad Borenschult, in calce cinera. Longit. 15 mm., latit. testæ 15, lat. valvæ minoris ad basin 12 mm., crass. 7 mm.

"Species quasi media inter *O. elegantulam* et *O. basalem*, ad utraque distincta ambitu magis orbiculari, minime ad cordatum tendente, præsertim vero costarum radiantium ratione, quæ enim duplicis sunt generis, videlicet; *elevatiores* (circiter 30), testæ basin fere attingentes; et *humiliores* plus minus abbreviatæ, quarum 2-3, inter par priorum.

"Valva minor subplana, 1, in medio longitudina liter subimpressa; suborbicularis, basi truncata, apice vero rotundato, minime prominulo. Linea cardinalis quam valvæ longitudo manifeste brevior. Valva major basi gibba, nate prominula, modice curva valvæ minoris convexitatem minime attingente. Subnate areola triangularis impresso-plana, foramine deltoideo brevi.

"Obs. Rostrum quam in *O. elegantula* minus sed quam in *O. basalis* magis curvatum; margo cardinalis quam in utraque specie brevior. Specimina plura consulti similia."

The following description of *O. emacerata* Meek (not Hall)—*O. testudinaria*, var. *meeki* Miller, is given, as it applies to this species in all of its details, except that the former is larger and more robust than in the majority of specimens usually referred to *O. testudinaria*: "Species small, plano-convex, rather depressed, transversely truncato-suboval, the length being about five-sixths its breadth [sometimes as wide as long]; hinge-line perhaps always a little shorter than the greatest breadth of the valves; lateral margins generally rounding to the hinge, most prominent at, or a little behind the middle, and rounding to the front, which is usually somewhat straightened, or very faintly sinuous, at the middle; or presents a regular semi-circular outline.

"Dorsal valve nearly flat, or slightly convex on each side of a shallow mesial sinus, that commences very narrow at the beak and usually widens rather rapidly to the front; beak very small, scarcely projecting beyond the edge of the area, and not incurved; area low at the middle and narrowing off to nothing at the lateral extremities of the hinge, slightly arched, and directed obliquely backward; foramen [delthyrium] very small and filled by the [large trilobed, striated] cardinal process. Interior very shallow and provided with a slender mesial ridge that extends about halfway forward from the hinge, between the muscular impressions, which are not usually well defined; scars of posterior pair of adductor muscles smaller and usually deeper than the anterior and situated close back under the brachial processes; those of the anterior pair three or four times the size of the posterior [commonly not more

than twice the size], suboval in form and extending to near the middle of the valve; cardinal process very small [comparatively large, striated] and trifid; brachial processes comparatively rather stout and prominent; internal surface having the radiating striae of the exterior rather distinctly impressed through, as it were [each with a central furrow], in consequence of the thinness of the shell, and finely granular, the granules being apparently connected with the punctate structure of the shell.

"Ventral valve compressed-convex, the greatest convexity being near, or a little behind, the middle, along a more or less prominent, undefined ridge that sometimes, but not always, imparts a subcarinate appearance to the central and umbonal regions; beak small, projecting somewhat beyond that of the other valve, abruptly pointed and rather distinctly arched, but not strongly incurved; area about twice as high as that of the other valve and with its sharply defined edges sloping to the lateral extremities of the hinge, directed and arched obliquely backward with the beak; foramen [delthyrium] having nearly the form of an equilateral triangle, but rather narrowed upward to the apex of the beak [with a distinct linear ridge along each wall] and partly occupied by the cardinal process of the other valve. Interior showing the teeth to be moderately prominent; concavity for the muscular impressions very shallow, somewhat bifid anteriorly and not defined by a very distinct marginal ridge; at the base of the dental plates are situated the narrow adjustor scars, terminating at the transversely striated pedicle muscle, which occupies the posterior portion of the rostral cavity; on the inside of the former are the large diductors separated by the small, elongate adductors; striae and fine granules of the interior as in the other valve.

"Surface of both valves ornamented by numerous, distinct radiating striae that usually bifurcate about three times between the beak and free margins; posterior lateral striae so strongly curved that a part of them run out on the hinge-line. Numerous very minute, regularly disposed, concentric lines may also be seen by the aid of a magnifier, most distinctly defined in the furrows between the radiating striae, while a few distinct, subimbricating, stronger marks of growth are usually seen in adult shells." Shell structure distinctly punctate.

Size of shell, outline, convexity of valves and number of striae are more or less variable features at all localities of this species. "The shells of this species usually characterize the Trenton and Hudson River beds at nearly all their outcrops, being one of the most persistent, as well as most characteristic fossils of these layers. Still, there are so many varieties of it that it is often difficult to refer it, without some hesitation, to its original place. Very many of these varieties have been described as distinct species, and others as varieties under varietal names, until

collectors have almost lost sight of the original species. Some of these varieties seem to mark given horizons over limited areas, and others apparently characterize special localities; still, I do not believe they are sufficiently distinct or persistent enough to rank as species or to be worthy a varietal name beyond the purpose of the locality where found, or for local preservation." (Whitfield, *loc. cit.*) Specimens of *O. testudinaria* from the Trenton shales and from the lower portion of the Galena formation of Minnesota are slightly smaller and narrower than those from the Trenton of New York, while in central Kentucky they are generally twice the size of the eastern examples. Other specimens from the latter region are very thin-shelled and are referred by local collectors to *O. emacerata* Hall. In the Cincinnati group of the Ohio valley, *O. testudinaria* is abundant in certain horizons. It is, moreover, nearly always present in one form or another throughout the formation and is more or less variable, although constant in its characters in certain beds. Some varieties are known as *O. cyclus* James, *O. multisepta* (James) Meek, *O. emacerata* Hall, *O. jugosa* James and *O. meeki* Miller. The first two are synonymous and cannot be regarded as of greater significance than a local variation; the same is also true of the last two. *O. emacerata* can be distinguished from *O. testudinaria* by its thin, compressed valves and finer and more numerous striae. If, however, a close examination is made between specimens of *O. testudinaria* from various localities it will be apparent to the observer that individuals from one region do not exactly agree with those from another. As long as one restricts himself in his studies of this species to a single horizon of one locality all goes well with the selected varieties, but as soon as the trial is made to apply them to specimens from other regions the chosen varieties drop out for want of constancy of characters.

In some Minnesota specimens there is a tendency to greater convexity of the dorsal valve. The mesial sinus may be obsolete or, as seen in one specimen, narrow and deep, sharply indenting the anterior margin. Probably if the development of the sinus were to become deeper and deeper in successive generations, it would eventually result in a species related to *Bilobites*. The general expression of *O. testudinaria* and species of *Bilobites*, excluding the strongly lobate condition of the latter genus, is essentially the same. While this may be the line of development, still *Bilobites* may have originated from an entirely different stock. Dr. Beecher, in his "Development of *Bilobites*," has suggested its relations to the group represented by *Platystrophia biforata* Schlotheim.*

Formation and locality.—Not common in the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Chatfield, Preston and elsewhere in Minnesota; Decorah and McGregor, Iowa. Very common in the Galena shales at various localities in Goodhue and Olmsted counties, Minnesota. Also from the base of the "Upper Buff beds" of the Trenton at Mineral Point, Wisconsin, and Rockton, Illinois. From the Galena at Decorah and Dubuque, Iowa; Neenah and Oshkosh, Wisconsin. In the Trenton limestone of

*American Jour. Sci., vol. xiii, p. 54. 1891.

Orthis (*Dalmanella*) *testudinaria*, var. *emacerata*.)

central Kentucky, and near Nashville, Tennessee; New York and eastern Canada. In the Salmon River group, or Lorraine shales, at Graf, Iowa; Iron Ridge, Wisconsin; Cincinnati, Ohio; New York; Anticosti, and Silver City, New Mexico; Chazy group of New York and Canada. It is also found in Lower Silurian rocks in England, Scotland, Ireland, Sweden and on the island of Sardinia.

Mus. Reg. Nos. 790, 3511, 4035, 5856, 6766, 6806, 7892-7896, 7898-7909.

ORTHIS (*DALMANELLA*) *TESTUDINARIA*, var. *EMACERATA* Hall.

PLATE XXXIII. FIGS. 23 and 24.

1860. *Orthis emacerata* HALL. Thirteenth Report, N. Y. State Cabinet of Natural History, p. 121.
 1862. *Orthis emacerata* HALL. Ibidem, Fifteenth Report, pl. II, figs. 1-3.
 1862. *Orthis emacerata* BILLINGS. Canadian Naturalist and Geologist, vol. VII, p. 393.
 1874. *Orthis cycclus* JAMES. Cincinnati Quarterly Journal of Science, vol. I, p. 19.
 1875. *Orthis emacerata* MILLER. Ibidem, vol. II, p. 24.
 1883. *Orthis emacerata* HALL. Second Annual Report, New York State Geologist, pl. XXXIV, figs. 14, 15.
 1892. *Dalmanella emacerata* HALL. Paleontology of New York, vol. VIII, pp. 207, 224, pl. VC, figs. 1, 2.
 1892. *Orthis macrior* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. III, p. 330, pl. V, figs. 5-7.

Original description: "Shell semielliptical, length and width about as five to seven; hinge-line nearly equaling the width of the shell. Dorsal valve flat, with a slight depression down the center; area extremely narrow. Ventral valve depressed-convex, slightly elevated at the beak, which is inclined over the area, but scarcely incurved; an undefined elevation, extending from the umbo toward the front and sometimes quite to the margin of the shell; area narrow, almost linear.

"Surface finely striated; striæ bifurcating, curving upwards and running out on the hinge-line. Interior of the dorsal valve with two small teeth and a small cardinal process; valves thin.

"This species has the form and general characters of *Orthis testudinaria*, but the shell is much thinner than that species ordinarily is in the same formation, and the striæ are finer, there being at least twenty more on the margin in shells of equal size. The depression in the center of the dorsal valve and elevation in the center of the ventral valve are far less conspicuous or scarcely marked in some specimens, while the hinge-line is always proportionately longer than in *O. testudinaria*." For further remarks see *O. testudinaria*.

Formation and locality.—Rare in the Hudson River group at Spring Valley and Granger, Minnesota. It is common at Cincinnati at a horizon about 300 feet above the low water mark of the Ohio river; St. Croix, Quebec.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. Nos. 7917, 7934.

ORTHIS (*DALMANELLA*) *TESTUDINARIA*, var. *MEEKI* Miller.

PLATE XXXIII. FIGS. 25-29.

1873. *Orthis emacerata* MEEK (non Hall). Paleontology of Ohio, vol. I, p. 109, pl. VIII, figs. 1, 2.
 1875. *Orthis meeki* MILLER. Cincinnati Quarterly Journal of Science, vol. II, p. 20.

1879. *Orthis jugosa* JAMES. The Palaeontologist, No. 4, p. 31.
 1892. *Dalmanella meeki* HALL. Palaeontology of New York, vol. viii, pt. 1, pp. 206, 224, pl. vC, fig. 3.
 1892. *Orthis corpulenta* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. III, p. 330, pl. v, figs. 8-10.

This variety is restricted to the upper portion of the Hudson River group and can be distinguished from *O. testudinaria* Dalman by the following characters: Attains a larger size; valves thicker and more convex; cardinal areas wider and shorter; striæ coarser in all stages of growth, with a larger number terminating on the cardinal lines; in the dorsal valve the muscular scars are more distinctly defined and often much thickened and elevated around the margin.

Formation and locality.—In the Hudson River group at Spring Valley, Minnesota, this variety occurs in great numbers; also in the upper portion of the same formation at Oxford, Clarksville and elsewhere in Ohio.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers. Also in the collection of Dr. C. H. Robbins, of Wykoff, Minnesota.

Mus. Reg. Nos. 231, 236, 272, 4078-7985.

ORTHIS (DALMANELLA) SUBÆQUATA Conrad.

PLATE XXXIII. FIGS. 30-36.

1843. *Orthis subaequata* CONRAD. Proceedings of the Academy of Natural Sciences of Philadelphia, vol. 1, p. 333.
 1847. *Orthis subaequata* HALL. Palaeontology of New York, vol. i, p. 118, pl. XXXII, fig. 2.
 1862. *Orthis subaequata* HALL. Geology of Wisconsin, vol. 1, p. 42, figs. 1-3, and p. 436.
 1880. *Orthis minneapolis* N. H. WINCHELL. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 63.
 1883. *Orthis perveta* HALL. Second Ann. Rept., N.Y. State Geologist, pl. XXXIV, figs. (? 16,) 17, 18.
 1883. *Orthis subaequata* HALL. Ibidem, pl. XXXIV, figs. 19-24.
 1892. *Dalmanella subaequata* HALL. Palaeontology of New York, vol. viii, pt. 1, pp. 194, 207, 224, pl. vC, figs. 6-11.
 1892. *Dalmanella perveta* HALL. Ibidem, p. 224, pl. vC, figs. 13, 14.

Original description: "Semioval; valves ventricose, subequal; lesser valve with a slight subangulated mesial furrow; larger valve prominent in the middle, with flattened sides; radiating striæ fine, closely arranged, unequal, rounded; cardinal area rather wide; apex of large valve prominent, not profoundly elevated above the opposite beak; the dorsal margin concave. Length, half an inch."

Adult shells vary considerably in size; biconvex, sometimes as wide as long, but generally attaining a greater breadth than length. In very young examples the hinge-line is as long as the greatest width; while in large and obese individuals it is only three-fifths of the breadth. Cardinal angles varying from acute to subacute and sometimes slightly rounded; lateral and anterior margins broadly and evenly rounding, the latter usually broadly, but slightly, deflected dorsally.

Surface with fine striæ, tubulose, bifurcating about twice. In the ventral valve they are less numerous down the middle, but increase in size and have, at varying intervals, very oblique, large openings. At the base of these perforations the striæ

are reduced in size and commonly open again near the anterior margin. On each side of the median area the striæ are finer, more numerous and rarely tubulose. In some specimens, however, the perforations are more prolific near the cardinal margin. In the dorsal valve the arrangement of the larger and smaller striæ is the reverse of that in the other valve. The finer, less tubulose ones are developed medially, while those perforated and larger are situated laterally. Concentric lines excessively fine, with a few coarser lines of growth near the anterior margin. Shell structure finely punctate.

Ventral valve strongly and evenly convex, usually with a broad, shallow sinus; anterior margin slightly prolonged upward to correspond with the concavity in the dorsal valve; point of greatest elevation about mid-length, or somewhat posterior; apex greatly depressed. Cardinal area well developed, broadly triangular, elevated, slightly convex and striated; delthyrium triangular, with straight or slightly convex sides about twice as long as wide, the apex being occupied by a short plate or slightly filled with shell matter. Interior with strong dental processes, supported by well developed plates, which join the more or less strongly elevated postero-lateral margins of the muscular impression. Muscular area elongate, lobate, distinctly limited by a raised margin in thick shells, while in thin ones the anterior edge may be obsolete, the center being occupied by the elongate adductors. The latter are medially divided by a linear ridge, which in some specimens is well developed, separating the scars in front and continuing as a strong septum to near the anterior margin. Outside of the adductor scars are situated the diductors and adjustors, the latter being well defined only in thick shells; pedicle muscle located in the apex of the delthyrium, which may be either a thickening in that part of the shell or a short, transverse, flat plate, similar to a delthyrium, with its anterior portion inwardly directed and transversely striated. Genital spaces indicated on each side of the muscular area in thick shells. In such specimens the anterior margin is slightly thickened and grooved, while in thin valves the entire interior is faintly striated, conforming with the striæ of the outer surface.

Dorsal valve evenly convex, but not as deep as the ventral. In some specimens there is a shallow and narrow medial depression, which has its origin immediately below the beak and becomes obsolete near the mid-length or shortly anterior to it. Cardinal area narrow and concave; delthyrium triangular, as wide as long, with a linear elevation along each wall and centrally occupied by a small, faintly bilobed, sometimes striated, cardinal process, which is anteriorly drawn out into a short, slender septum. Crural processes strong and curving upward; with deep dental sockets situated postero-laterally. The former are supported by strong plates, which also form the walls of the delthyrium and are attached to the bottom of the

valve. The delthyrial cavity is more or less thickened, excavated anteriorly and produced centrally into a low, but distinct, median septum, which terminates at about the mid-length of the valve and separates the two pairs of adductor scars, the posterior pair being slightly smaller. When the scars are more divergent than usual the septum is thickened laterally and fills the space left between the anterior pair. Surface in front of the scars marked with a few faint, short, radiating lines of the vascular system.

This widely distributed species is nearly always prolific in individuals at most localities and varies considerably in outline, number of striae and in the mesial fold and sinus. The writers have several hundred examples, together with the varieties *conradi*, *perveta*, *gibbosa* and *circularis*, the greater number of which were collected in Minnesota, though specimens were also obtained from Canada, Kentucky, Tennessee, Illinois, Iowa and Wisconsin. In southern localities the circular form prevails, while in the northwest the species is commonly wider than long. In the Black River limestone of eastern Canada, a well developed fold and sinus, combined with a more or less short hinge-line, is the local change. These varieties also occur in the Trenton shales between the cities of Minneapolis and St. Paul, and are often not sufficiently constant to permit the positive separation of a large lot of individuals. This, however, is to be expected in any prolific and plastic species. The specimens with coarse striae are separated as var. *perveta*; those with a more or less profound and angulated sinus are referred to var. *gibbosa*, while the circular forms, with fine and equal striae, are placed in the variety *circularis*.

The types of Conrad's *O. perveta* and *O. subaequata*, now preserved in the American Museum of Natural History in New York city, have been compared with similar specimens from Mineral Point, Wisconsin, the original locality, and no specific differences between them have been made out. In Pal. New York, vol. i, *O. perveta* is figured as a small species, but in the Geol. of Wisconsin, Prof. Hall states that it attains a width of one inch. Numerous specimens, however, occur at Mineral Point which agree with the above illustrations of Conrad's type of *O. perveta*. These appear to be adult individuals and were probably so regarded by Conrad, as shown by the specific name. They differ from *O. subaequata* only in having coarser striae, and the name *perveta* is retained for them as a variety. *O. minneapolis* Winchell proves to be identical with *O. subaequata*, while *O. conradi* Winchell, was applied to a small but mature form of the same species occurring in abundance in the Trenton limestone.

Formation and locality.—Rare in the Trenton limestone at Minneapolis and Rochester, Minnesota. Common in the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Lanesboro, St. Charles, Eyota, Fountain, Fremont, Chatfield, Preston and near Caledonia, Minnesota; Decorah and McGregor, Iowa. Near the base of the Upper Buff limestone at Mineral Point, Wisconsin; Auburn, Lincoln county, Missouri. "Of *O. subaequata* I have seen only a single specimen. It was found in an old quarry two miles north of Montreal." (Billings, Can. Nat. Geol., vol. iv, p. 434.)

Collectors.—Miss C. S. Seymour, H. V. Winchell, W. H. Scofield, W. H. Shelton, C. L. Herrick, E. O. Ulrich and the writers.

Mus. Reg. Nos. 321, 346, 374, 644, 648, 707, 720, 737, 739, 766, 789, 794, 3513, 3519, 4032, 4056, 4939, 4943, 4975, 4976, 5058, 5093, 5581, 5671, 6775, 6792, 6801, 6803, 7915, 7959-7968.

Variety CONRADI N. H. Winchell.

PLATE XXXIII, FIGS. 37-39.

1880. *Orthis conradi* N. H. WINCHELL. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 68.

Original description: "Shell having the shape and size of *Orthis disparilis* (Con.), but with a moderately convex entering valve, with from fifty to sixty fine radiating striae on each valve, about half of which disappear before reaching the beak; foramen of the larger valve narrow, of the smaller valve triangular; surface with indistinct growth-bands, but without evident interradiial crenulations; on the center of the smaller valve is a flattening that widens from the beak and disappears before reaching the margin."

In the upper portion of the Trenton limestone at Minneapolis, Minnesota, and Decorah, Iowa, also in the "Lower Blue beds" of Wisconsin at Janesville and Beloit, a small form of *Orthis*, belonging to the *O. perveta* group, is constantly met, and to this the name *O. conradi* has been applied by one of the writers. A similar species has been described by Mr. Billings as *O. electra*,* and was procured in the upper part of limestone No. 2 of the Quebec group at Point Lévis, Canada. Although these specimens are from a much lower horizon than the present material, yet the size and general external expression are strikingly similar. Of this species Billings writes: "The only differences that can be made out from a comparison with specimens [of *O. perveta*] from Tennessee and the figures given by Hall in the Palæontology of New York are, that in *O. perveta* the dorsal valve is more convex than it is in *O. electra*, and the beak of the ventral valve not so depressed, while at the same time it is more extended. At present I have no means of comparing the interior of the two species. When such a comparison can be made, should no greater differences be disclosed than are afforded by the external characters, I would be disposed to unite the two under one name." (Pal. Foss., vol. i, p. 80.) Some northwestern specimens have the beak as much depressed as in *O. electra*. However, it is usually, if not always, more extended than in the latter species, while the dorsal valve seems to be more convex. Dr. White** has doubtfully identified *O. electra* as occurring at Fish Spring, House range, Utah. The greater length of the hinge-line, 16 mm. in these specimens, compared with the figures of Canadian examples, the largest of which are only half that length, precludes the possibility of their being alike. The characters by which the northwestern shells can be separated from *O. electra* are internal. The latter is described as having the dental plates scarcely developed, while no

* Pal. Foss., vol. i, p. 79, fig. 72, and p. 217, 1862.

** Report of U. S. Geog. Surv. west 100th Meridian, vol. iv, p. 55, 1875.

divaricator process was seen in any silicified specimens observed. In *O. subaequata*, var. *conradi*, these parts are comparatively as strongly developed as in any of the larger forms of this species occurring in the shales above.

These small specimens are regarded as mature but dwarfed individuals of *O. subaequata*, and since they hold a constant horizon over a great area, the varietal name *conradi* will serve to distinguish them from the other varieties of this species.

Formation and locality.—Common near the top of the Trenton limestone at Minneapolis, Minnesota; and Decorah, Iowa. Also in the "Lower Blue beds" of the Trenton at Janesville and Beloit, Wisconsin. "In certain beds of the Chazy limestone there are multitudes of a small *Orthis* which have, as nearly as I can judge, precisely the form and dimensions of *O. perveta*, but, in consequence of their being imbedded in a rather compact subcrystalline rock, I have not been able to procure any specimens with the surface well preserved." (Billings, *Can. Nat. and Geol.*, vol. iv, p. 434.) These localities are two miles north of Montreal, Canada, and two or three miles west of Chazy, New York. This same form is believed to be the one identified by Mr. Walcott as *O. perveta*, which also occurs abundantly in the upper beds of the Pogonip group in Nevada. (*Mono. U. S. Geol. Survey*, vol. viii, p. 72.)

Collectors.—C. L. Herrick, E. O. Ulrich and the writers.

Mus. Reg. Nos. 651 (type specimen lost), 753, 5072, 5094, 7978-7982.

Variety *PERVETA Conrad.*

PLATE XXXIII, FIGS. 40-42.

1843. *Orthis perveta* CONRAD. *Proceedings of the Academy of Natural Sciences of Philadelphia*, vol. i, p. 333.
 1847. *Orthis perveta* HALL. *Palaeontology of New York*, vol. i, p. 120, pl. xxxii, fig. 5.
 1859. *Orthis perveta* BILLINGS. *Canadian Naturalist and Geologist*, vol. iv, p. 434, fig. 10.
 1862. *Orthis perveta* HALL. *Geology of Wisconsin*, vol. i, p. 42, fig. 7.
 1863. *Orthis perveta* BILLINGS. *Geology of Canada*, p. 130, fig. 57.
 1880. *Orthis media* N. H. WINCHELL. *Eighth Annual Report of the Geological and Natural History Survey of Minnesota*, p. 64.
 1880. *Orthis kassuba* N. H. WINCHELL. *Ibidem*, p. 65.
 ?1884. *Orthis perveta* WALCOTT. *Monograph of the U. S. Geological Survey*, vol. viii, p. 72, pl. xi, fig. 3.
 1892. *Orthis (Dalmanella) perveta* HALL. *Palaeontology of New York*, vol. viii, pt. i, pl. vC, fig. 12.

Original description: "Transversely oval, wider than the length of the hinge-line; valves slightly ventricose, subequal, with numerous prominent radiating striae, bifurcated on the umbo; larger valve ventricose in the middle, with a slight central depression; sides somewhat depressed; the opposite valve flattened towards the base and depressed to correspond with the elevation of the other valve, forming a sinuous margin when viewed in profile; base truncated; superior lateral margin obliquely truncated, rounded inferiorly. Length, one-third of an inch; breadth, nearly half an inch.

"*Locality:* Mineral Point, Wisconsin, (Trenton limestone)."

This variety can readily be distinguished by its coarser striae. The fold and sinus are also usually more pronounced than in *O. subaequata*, and occasionally are developed equally as strong as in var. *gibbosa*, when it is impossible to separate it from the latter. In Minnesota these shells are much distorted by pressure, a peculiarity at once striking. Well preserved specimens, however, show close relationship

to *O. subaequata*. The specimens illustrated by Mr. Walcott (*loc. cit.*) and occurring abundantly in the upper beds of the Pogonip group—Chazy group of New York, seem to agree better with var. *conradi* Winchell.

Formation and locality.—In Minnesota this form is first met with at the top of the Trenton limestone, where it is fairly abundant, but usually much crushed; thence it extends upward in the Trenton shales. It has been collected at Minneapolis, St. Paul, Cannon Falls, Lanesboro and Fountain, Minnesota; Decorah, Iowa. In Wisconsin it has been found in the "Lower Blue beds" and near the base of the "Upper Buff beds" at Mineral Point, Janesville and Beloit; Dixon, Illinois. In the Glade limestone of middle Tennessee the variety seems to be rare. It is probably this form of *O. subaequata* that also occurs in northern New York and eastern Canada.

Collectors.—C. L. Herrick, W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 186, 322, 336, 643, 3514, 4032, 5147, 5148, 7973-7977.

Variety GIBBOSA Billings.

PLATE XXXIII, FIGS. 43-45.

1857. *Orthis gibbosa* BILLINGS. Geological Survey of Canada; Report of Progress for 1856, p. 296.

1859. *Orthis gibbosa* BILLINGS. Canadian Naturalist and Geologist, vol. iv, p. 434.

1892. *Dalmanella gibbosa* HALL. Palaeontology of New York, vol. viii, pt. i, p. 224.

Original description: "About the size and shape of *Orthis testudinaria*, but with both valves convex; greatest width at the center or a little in front of the center of the length, above which the sides are somewhat straight and converging to the extremities of the hinge-line, the latter about one-sixth shorter than the greatest width; the front margin very broadly rounded; almost straight or even slightly sinuated in some specimens for one-third of the width in the center; front angles well rounded; the ventral valve is depressed, pyramidal, most elevated at about one line from the beak, which is small, pointed and but slightly incurved; a broad shallow [often pronounced] mesial depression occupies the front of this valve, but disappears usually at one-half the distance to the beak; cardinal area triangular at the base, nearly at right angles to the plane of the margin, but curved over above, owing to the backward projection of the beak. Dorsal valve exceedingly convex in most specimens; greatest elevation about the center, often a barely perceptible broad mesial elevation towards the front; cardinal area small, lying in the plane of the margin; beak very small and scarcely projecting from the upper edge of the area; the whole surface is covered with fine striae, which are about twice sub-divided; the cast of the interior of the ventral valve shows that the muscular impressions were bordered by strong lamellae extending downward, slightly converging at three lines from the beak; in a specimen eight lines wide they were separated by a median ridge with a broad base and sharp edge; width of large specimens, eight lines; length, six and a half."

Walter R. Billings has kindly presented to one of the writers specimens of *O. gibbosa* from the Black River limestone near Ottawa. These prove to be very closely

related to *O. subaequata* and *O. perveta* Conrad. E. Billings states that* "it is distinguished from *O. subaequata* by having a broad, shallow, mesial sinus in the front half of the ventral valve. * * * It may be that, by comparison with extensive series of western specimens, these three species might be united. I shall, for the present, keep them separate provisionally." In Minnesota specimens occur which are identical with the *O. gibbosa* before us. The sinus toward the anterior margin is often profound in strongly convex specimens with angular sides, producing a fold in the dorsal valve which is distinctly limited laterally. For such shells we have retained the varietal name *gibbosa*. These and var. *perveta* at times merge into each other to such a degree that it is impossible to separate them.

Formation and locality.—Not uncommon in the Trenton shales at Minneapolis, Chatfield, Lanesboro and Cannon Falls, Minnesota; Decorah, Iowa. One specimen has been found in the "Lower Blue beds" at Mineral Point, Wisconsin. "*O. gibbosa* occurs rarely in the Chazy limestone, island of Montreal; abundantly, but badly preserved, at the Pallideau islands, lake Huron, in rocks which are either Chazy or Black River. At La Petite Chaudière rapids near Ottawa, and at the fourth chute of the Bonne-chère, in the Black River limestone, and in the Trenton limestone at Bellville, Canada." (Billings, Can. Nat. Geol. vol. iv, p. 435.)

Collectors.—W. H. Scofield and the writers.

Mus. Reg. Nos. 4032, 5510, 7969-7772.

Variety CIRCULARIS N. H. Winchell.

PLATE XXXIII, FIGS. 46 and 47.

1880. *Orthis circularis* N. H. WINCHELL. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 66.

Original description: "Shell subcircular, the greatest diameter being from just in front of one cardinal angle to the antero-lateral margin on the opposite side; hinge-line about one-half the greatest diameter; along the front margin is a very slight inclination toward the smaller valve, but the valves are otherwise uniformly convex; umbo of the receiving [ventral] valve prominent and full, but the beak low and arched over the cardinal area; the other valve less elevated in the umbo and the beak less prolonged, but slightly incurved over the hinge-line; the open foramen [delthyrium] of the receiving valve long and narrow, with an obtuse apex, but two or three times as wide at the base as at the top; surface marked by numerous fine rays which, bifurcating once or twice between the umbo and the free margin, are subequal at the middle of the front margin and number six or seven in the space of one line, two or three curving backward from the beak and terminating on the hinge area. These rays are crossed by fine concentric lines, only visible in fresh specimens and under a magnifier, and by distant dim growth bands, which latter begin on the umbo; diameter, about half an inch. Interior unknown."

*Can. Nat. and Geol., vol. iv, p. 434, 1859.

Variety circularis is distinguished by its subcircular outline, usually smaller size and very fine, equal and more numerous striæ, a greater number of which terminate on the cardinal line. The tubulose character of the striæ is also developed, but it is never a conspicuous feature. Occasionally specimens will be found with very fine striæ, which are, however, larger and wider than is usual in this variety.

O. subœquata, var. *circularis*, attains its maximum development in individuals in the "Glade limestone" in Tennessee, and is there somewhat coarser in its striæ.

Formation and locality.—Not rare in the upper part of the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Rochester and Fountain, Minnesota. Rare near the top of the Birdseye limestone two miles south of High Bridge, Kentucky. Common in the "Glade limestone" at Lebanon and elsewhere in middle Tennessee.

Collectors.—W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 279, 346, 3515, 4049, 4935, 5149, 6778, 6804.

ORTHIS (*DALMANELLA*) *AMœNA* N. H. Winchell.

PLATE XXXIII, FIGS. 48 and 49.

1880. *Orthis amœna* N. H. WINCHELL. Eighth Annual Report of the Geological and Natural History Survey of Minnesota, p. 65.

Original description: "Shell transversely oval with a hinge-line that compares to the greatest diameter about as five to nine. Evenly rounded from the cardinal extremities, which hardly disturb the symmetry of the outline, through the front margin; valves nearly equal; umbonal region of the receiving [ventral] valve surrounded by a depressed or somewhat concave border, which in the front margin becomes flat or inclines toward the entering [dorsal] valve; the entering valve having a much less marginal concavity, but being moderately and evenly convex; cardinal areas small; foramen [delthyrium] also small; beak of the receiving valve somewhat incurved; that of the entering valve small, but abrupt and distinct, surface marked by rays which are doubled or tripled in number on the umbo by implantation, but maintain a larger size than the rest in passing to the margin, several of which are also curved so as to run out in the hinge-line; transverse diameter, nine to ten lines; perpendicular diameter from seven and a half to eight and a half lines. Interior unknown."

Two somewhat compressed type specimens are the only ones known of this species. They differ but slightly from *O. subœquata*, as the striæ which originate on the umbo increase in prominence to the anterior margin, between which are two or three smaller ones. A very similar striation is seen in *O. (D.) stonensis* Safford, a species also belonging to the *O. subœquata* section, but always smaller and narrower than *O. amœna* Winchell.

These specimens are supposed to have been derived from the Galena limestone, and no others of the type of *O. subaequata* occurring in this formation are known.

Formation and locality.—Rare in the Galena limestone(?) near Spring Valley, Minnesota.

Collector.—N. H. Winchell.

Mus. Reg. No. 642.

Subgenus PLATYSTROPHIA, King.

1850. *Platystrophia*, KING. Monograph of the Permian Fossils of England, p. 486.

1892. *Platystrophia*, HALL. Palaeontology of New York, vol. viii, pt. 1, p. 200.

Description: "The name *Platystrophia*, proposed by Dr. King, has come into very general use for a group of orthids having a strikingly spiriferoid exterior. The hinge-line and area are long and straight and nearly equally developed on the two valves. Both are very convex, the brachial being the more so and bearing a very strong median fold corresponding to a deep sinus on the opposite valve. The valves are marked by strong, sharp plications which extend over the fold and sinus, and the external surface is finely granulose, the latter feature being rarely well retained. This peculiar exterior, so unlike anything met with elsewhere in the genus *Orthis*, readily deceived earlier writers into referring the species to *Delthyris* or *Spirifer*, and Mr. Davidson was the first to demonstrate* the true generic value of its internal and more essential characters. These are not materially different from those already described in the group of *Orthis occidentalis*. The delthyrium is open in both valves, being somewhat larger in the pedicle valve, and in old and gibbous shells of *Orthis lynx* has often encroached to a considerable extent upon the umbonal region of the valve. The teeth are thick and very prominent, the muscular area comparatively small, but usually deeply excavated in the substance of the shell and not readily divisible into the component scars. In the brachial valve the cardinal process is a simple linear ridge, always small and sometimes nearly obsolete. The dental sockets are comparatively small, the crural plates large and thick, uniting at their inner bases and produced into a prominent median ridge. The muscular area is quadruplicate and indistinct. The shell structure is very compact and finely fibrous, without punctation."

Type: *Terebratulites biforatus* Schlotheim.

"The genus appears in American faunas first in the Chazy and ranges upward into the Clinton and Niagara groups, attaining a great development in individuals and variety in external form in the Trenton-Hudson River fauna. It has also a considerable vertical range in the Silurian of Great Britain, Mr. Davidson citing it from the Caradoc, Upper and Lower Llandeilo and the Wenlock." (Hall, *op. cit.*)

* Bull. Soc. Géol. de France, sec. ser., vol. xxi, 1848.

PLATYSTROPHIA BIFORATA *Schlotheim, sp.*

PLATE XXXIII. FIGS. 40-52.

1820. *Terebratulites biforatus* SCHLOTHEIM. Petrefactenkunde, p. 265.
For other European synonymy see Davidson's Monograph of British Silurian Brachiopoda, pt. vii, p. 268, 1866-1871.
1843. *Spirifer sheppardi* CASTLENAU. Essai sur le Systeme Silurien Septentrionale, p. 42, pl. XIV, fig. 15.
1843. *Delthyris brachynota* HALL. Geology of New York: Report Fourth District, p. 70, fig. 6.
1844. *Orthis* and *Delthyris* OWEN. Geological Exploration of Iowa, Wisconsin and Illinois, pl. XV, figs. 3, 7.
1847. *Delthyris lynæ* HALL (partim) (non EICHWALD). Palæontology of New York, vol. i, p. 133, pl. XXXIII, fig. 1.
1852. *Spirifer biforatus*, var. *lynæ* HALL. Ibidem, vol. ii, p. 65, pl. XXII, fig. 1.
1856. *Orthis biforata* BILLINGS. Canadian Naturalist and Geologist, vol. i, p. 206, figs. 6-10.
1863. *Orthis lynæ* BILLINGS. Geology of Canada, p. 167, fig. 149.
1865. *Platystrophia regularis* SHALER. Bulletin of the Museum of Comparative Zoology, p. 67.
1873. *Orthis (Platystrophia) biforata* MEEK. Palæontology of Ohio, vol. i, p. 112.
1874. *Orthis biforata* NICHOLSON and HINDE. Canadian Journal, vol. XIV, p. 158.
1875. *Orthis lynæ* MILLER (partim). Cincinnati Quarterly Journal of Science, vol. ii, p. 25.
1875. *Orthis biforata* WHITE. Report of the U. S. Geographical Survey west of the 100th Meridian, vol. iv, p. 74, pl. IV, fig. 9.
1883. *Orthis (Platystrophia) biforata*, var. *lynæ* HALL. Second Annual Report, New York State Geologist, pl. XXXV, figs. 11-14 (not figs. 9, 10, 15 of pl. XXXV, and fig. 30 of pl. XXXIV—*P. biforata*, var. *lynæ*).
1885. *Orthis biforata*, var. *lynæ*, forma *reversata* and *daytonensis* FOERSTE. Bulletin of the Denison University, vol. i, pp. 81, 82, pl. XIII, figs. 7, 8.
1889. *Orthis biforata* NETTELROTH. Kentucky Fossil Shells, p. 35, pl. XXIX, figs. 18-29.
1890. *Orthis biforata* FOERSTE. Proceedings of the Boston Society of Nat. Hist., vol. XXIV, p. 312.
1892. *Platystrophia lynæ* HALL. Palæontology of New York, vol. viii, pp. 202, 223, pl. VB, fig. 10.

Description: Since the original description of this species is not accessible, that by Davidson (*op. cit.* p. 269) is here reproduced: "Transversely semielliptical or subquadrate, wider than long, more or less globose, the length, width and depth varying sometimes but little; hinge-line more often rather less than the width of the shell, sometimes slightly exceeding the general breadth, with short, acute mucronate wings, or rounded terminations; in front the ventral valve is abruptly deflected and indents the opposite one; beaks in both valves much incurved and approximating. Ventral valve convex, with a wide, deep medial sinus, commencing at the extremity of the beak and widening as it nears the front. Area triangular of moderate height, fissure [delthyrium] open, beak angular, incurved. Dorsal valve deeper than the opposite one, at times gibbous, with a wide longitudinal fold, commencing at the extremity of the umbonal beak and extending to the front; area a little less wide than in the opposite valve, [erect], fissure [delthyrium] open. Surface of both valves ornamented with a greater or lesser number of radiating triangular ribs; of these from one to five (and in some varieties more) [in American forms usually three] furrow the medio-longitudinal sinus, while from two to six or seven [usually four in this country] compose the mesial fold. The valves are also crossed at intervals by numerous concentric, raised, subimbricating lines; the surface is also marked with small punctures [in well preserved specimens the surface is crowded

with minute granules radially and concentrically arranged, which when worn away presents a punctate exterior]. In the interior of the ventral valve a prominent hinge tooth exists on each side of the fissure [delthyrium] and is supported by strong dental plates, which enclose an elongated, oval, raised [in America, depressed, with an elevated outer margin] muscular cavity of moderate dimensions. In the interior of the dorsal valve no prominent cardinal process is observable, but two short brachial processes deviate from the extremity of the umbonal beak and on the outer side of these are situated the hinge sockets. The quadruple muscle forms four very distinct cavities, strongly margined and divided longitudinally and transversely by prominent cross-like ridges." These adductor scars are not nearly as well defined in American examples.

The writers regret their inability to secure very young specimens of this species for the purpose of determining the ancestors or line of development. In several immature individuals it has been observed that in the early nealagic stage the beaks are strongly elevated, probably erect, and each has a very large open delthyrium, surface smooth at first, but gradually developing eight plications and a mesial sinus in each valve. The sinus in the dorsal valve is bounded by two elevations, which become plications, and between them is soon developed a single costa which immediately bifurcates. The four plications increase in strength and become strongly elevated as they proceed to the anterior margin, producing the conspicuous fold of this valve.

This widely distributed and protean species has its beginning, in North America, in the Chazy group, and is found in all the geological horizons upwards and into the Niagara formation. The earliest individuals are small in size and have but few and simple costæ. Such specimens are found in the Cincinnati group around Cincinnati, Ohio, and are probably to be regarded as the young of *P. biforata*, or of the various forms occurring there and designated by varietal names. In the Ohio valley it attains its maximum in number of individuals, variation and size. In succeeding horizons it becomes less numerous and assumes characters somewhat ancestral.

Adult individuals, occurring at a given horizon and locality, will be found to be fairly constant. However, in younger or older rocks, variations are continually taking place, and if specimens are gathered promiscuously from various horizons at a locality in which the shells are common, it will seem as if there were no constancy whatever in the species. While in a restricted region there is considerable permanence in shape and number of costæ, in the same geological formation other variable characters sufficiently fixed for specific use are wanting. The species is to be regarded as very persistent and capable of readily adapting itself to changes of environment. Among the Brachiopoda such forms appear to be long lived. Others

equally protean are *Leptena rhomboidalis*, which extends from the Trenton into the Waverly, i. e., from the Lower Silurian to the base of the Carboniferous; *Atrypa reticularis*, extending throughout the Silurian and Devonian; *Orthis testudinaria*, from the Chazy to the top of the Lower Silurian; *Plectambonites sericea*, from the Trenton to the Clinton, i. e., from the Lower Silurian to the Silurian.

The references treating strictly of the large and globose variety *lynx*,* as defined by Meek,** are not given in the above synonymy, since that variety is regarded as amply distinct for easy recognition. It is not known to occur in the northwest.

M. de Verneuil, in a foot note appended to the description of *Spirifer sheppardi* Castelnau, states that it is identical with *Spirifer lynx* Eichwald. The above description and figures have been studied by the writers, who find them to agree with examples here referred to *P. biforata*. If desirable to separate American specimens under another specific term, because they have, as a rule, a less number of costæ in the sinus and fold than European examples of *P. biforata*, the name given by Castelnau will have precedence.

Platystrophia biforata is sparingly found near the top of the Trenton shales and becomes one of the characteristic fossils of the Galena shales in Minnesota. Nearly all the specimens seen have three plications in the sinus, with four on the fold, while an individual is rarely found with one more or one less. In other regions, the number in the sinus is also usually three, while occasionally only one, five, or even six are developed. Commonly there are from twelve to sixteen costæ on each side of the fold and sinus. More rarely a specimen is found with ten, while several immature individuals have only from five to seven. Some of the plications are seen to terminate along the cardinal area, and since increase in number of costæ very rarely takes place on the lateral slopes by bifurcation or otherwise, new ones may be added along the postero-lateral margins as the length of the hinge is increased.

Formation and locality.—Chazy group near Montreal, Canada. Common in the Trenton of New York, Canada, Kentucky, Tennessee, and rare in this horizon in the northwest. In the lower portion of the Galena formation it is common at many localities in Goodhue, Olmsted and Fillmore counties, Minnesota; Decorah and Dubuque, Iowa; Neenah and Oshkosh, Wisconsin, and, according to Castelnau, at the mouth of Menominee river, Green Bay. In the Cincinnati group of the Ohio valley; Nashville, Tennessee; Iron Ridge, Wisconsin; Graf, Iowa, and Silver City, New Mexico. In the Clinton and Niagara formations of Ohio, New York, Canada and Anticosti. It is also a common fossil in the Lower Silurian and Silurian in England, Scotland, Ireland, Gotland, Scandinavia, Oeland and Russia.

Collectors.—Miss Cora E. Goode, Dr. Sandberg, W. H. Scofield, A. D. Meeds, E. O. Ulrich and the writers.

Mus. Reg. Nos. 2290, 4948, 5307, 5862, 7816-7828.

**Terebratula lynx* Eichwald. Skizze von Podolis, p. 292, 1830.

**Pal. Ohio, vol. 1, p. 114, figs. 1a-1e, 1872.

PLATYSTROPHIA BIFORATA, var. CRASSA James.

PLATE XXXIII, FIGS. 53-54.

1873. Var. 3. *Orthis (Platystrophia) dentata* ?? MEEK (non PANDER). *Palaontology of Ohio*, vol. i, p. 117, pl. X, fig. 3.
 1874. *Orthis (Platystrophia) crassa* JAMES (non LINDSTRÖM). *Cincinnati Quarterly Journal of Science*, vol. i, p. 20.
 1875. *Orthis dentata* MILLER. *Ibidem*, vol. ii, p. 27.
 1880. *Orthis centrosa* MILLER. *North American Geology and Palaontology*, p. 356.
 1892. *Platystrophia crassa* HALL. *Palaontology of New York*, vol. viii, pt. i, pp. 223.

This variety can be distinguished readily by its short hinge-line, causing the shell to be as wide as long, and its very gibbous valves. This species occurs sparingly in the Hudson River group at Spring Valley, Minnesota, and differs from those found at Cincinnati, Ohio, in having about three more much less elevated costæ on each side of the fold and sinus. The muscular scars and other interior characters are more defined than in southern specimens.

Since this variety is now referred to the genus *Platystrophia*, the name *crassa* James will not conflict with *Orthis crassa* Lindström, 1860.* The latter is said to be related to *O. elegantula* Dalman, and is therefore referable to Prof. Hall's subgenus *Dalmanella*.

Mus. Reg. No. 5543.

Order TELOTREMATA, Beecher.

Family RHYNCHONELLIDÆ, Gray.

Genus RHYNCHOTREMA, Hall.

1860. *Rhynchotrema*, HALL. *Thirteenth Report, New York State Cabinet of Natural History*, p. 68, figs. 7-14.
 1883. *Rhynchotrema*, WAAGEN. *Palaontologica Indica*, ser. xiii, vol. i, p. 410.

Rhynchonella is an extensive genus, if all the species are admitted that are currently referred to it. It then has its beginning at the base of the Lower Silurian, continues through all the subsequent ages, and is represented at present by five living species. Several names have been proposed by authors for the earlier forms, but none of them have come into general use.

Rhynchotrema will be employed for those early rhynchonelloid species having a prominent cardinal process between the crural plates of the dorsal valve. This process is very well developed in all Lower Silurian species of so-called *Rhynchonella* of which the interior has been examined.

* Gotland's Brachiopoden, p. 396, 1860. Also Davidson's Mono. British Sil. Brach., p. 213, pl. XXVII, figs. 17-19.

RHYNCHOTREMA AINSLIEI *N. H. Winchell.*

PLATE XXXIV, FIGS. 1-8.

1886. *Rhynchonella ainsliei* N. H. WINCHELL. Fourteenth Annual Report of the Geological and Natural History Survey of Minnesota, p. 315, pl. II, figs. 5, 6.

This species has the essential characters of *R. inaequalvis*, therefore a detailed description will not be necessary. It differs from the latter in being usually larger, more transverse, and in having from twenty-eight to thirty-four plications, with six to eight on the fold, and five to seven on the sinus, while *R. inaequalvis* has from sixteen to twenty-two plications, with four to five on the fold. Compared with *Rhynchonella altilis* Hall* of the Chazy group of New York, *Rhynchotrema ainsliei* is seen to be more transverse, has a more prominent fold and sinus, is less globose, and on the average has a few more plications.

Formation and locality.—Restricted to the lower portion of the Trenton shales, where it is common at Minneapolis, Cannon Falls, Lanesboro, Fountain, Chatfield and Preston, Minnesota; Decorah and McGregor, Iowa.

Collectors.—C. N. Ainslie, C. L. Herrick, W. H. Scofield, J. C. Kassube and the writers.

Mus. Reg. Nos. 324, 326, 734, 4031, 4938, 4974, 5480, 5489, 5492, 5498, 5505, 5512, 5517, 5521, 7917, 8204-8207.

RHYNCHOTREMA INÆQUALVIS *Castelnau.*

PLATE XXXIV, FIGS. 9-25.

1843. *Spirifer inaequalvis* CASTELNAU. Essai sur le Système Silurien de l'Amérique Septentrionale, p. 40, pl. XIV, fig. 8.
1847. *Atrypa increbescens* (partim) HALL. Palaeontology of New York, vol. I, pp. 146, 289, pl. XXXIII, figs. 13a-13h; ? pl. LXXIX, fig. 6.
1856. *Rhynchonella increbescens* (partim) BILLINGS. Canadian Naturalist and Geologist, vol. I, p. 207, figs. 11-14.
1863. *Rhynchonella increbescens* BILLINGS. Geology of Canada, p. 18, fig. 153.
1875. *Trematospira* (?) *quadruplicata* MILLER. Cincinnati Quarterly Journal of Science, vol. II, p. 60, figs. 6, 7.
1889. *Rhynchotrema quadruplicata* MILLER. North American Geology and Palaeontology, p. 370.
1889. *Rhynchonella increbescens* NETTELROTH. Kentucky Fossil Shells, p. 83, pl. XXXIV, figs. 26-29.
1892. *Rhynchonella minnesotensis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. III, p. 333, pl. IV, figs. 21-23.
- Compare *Atrypa subtrigonalis* HALL. Palaeontology of New York, vol. I, p. 145, pl. XXXIII, figs. 12a-12c, 1847.

The original description of *R. increbescens* was drawn up from specimens now referred to that species and to *R. capax* Conrad. That by Castelnau is not accessible at the present time. The following description is based on material derived from Minnesota, Kentucky and New York: Shell small, varying from narrow to broadly subtriangular in outline, smooth in the nepionic stage, depressed-convex during the nealagic period, and becoming more globose in epheboic and geratologic growth; posterior lateral margins straight or somewhat convex, rounding rapidly into the sinuous anterior edge. Surface with prominent subangular plications, from sixteen to twenty-two on each valve, with from three to five on the fold, and two to four in

*Pal. N. Y., vol. I, p. 123, pl. IVbis, figs. 9a-9d.

the sinus; commonly, however, the number is seventeen or eighteen, four and three, respectively; in Kentucky specimens the tendency is to have fewer plications, there being from thirteen to eighteen on each valve, all crossed by exceedingly delicate concentric zigzag lines, sometimes subimbricating and conspicuous over the anterior half of the shell.

Ventral valve strongly convex in the umbonal region and nearly flat on each side of the deep mesial sinus, sloping more or less abruptly laterally and often angular near the anterior margin; mesial sinus originating on the umbo, often profound anteriorly, with abrupt sides. Beak more or less incurved and always elevated beyond the umbo of the dorsal valve, with a narrow delthyrium partially closed by deltidial plates, which grow out from the walls of the former and, as far as observed, do not join medially. Hinge teeth prominent and supported by thin, short, dental plates. Muscular area much as in *R. capax*, except that in the present species it is very shallow, owing to the shells not being thickened as in *R. capax*.

Dorsal valve more convex than the other, with a mesial fold more or less strongly elevated anteriorly, beginning at the apex of the shell as a slight depression. Beak projecting into the delthyrium of the ventral valve. Crural plates large, separated medially by a depression which is partly occupied by a linear cardinal process strongly curved inward and upward, converging proximally and joining the angular median septum, which terminates at about the center of the valve on the crest of a plication; at the base of the crural plates and separated by the septum are two pairs of adductor scars, the anterior ones being the larger; dental sockets deep, situated lateral to the crural plates.

The variations in this species are numerous, yet are never such as to be of value to the geologist, with one exception, which is described below as variety *minnesotensis*. *R. inaequalis* has often been considered to merge into *R. capax*; this, however, is not known to occur anywhere in the Trenton formation, nor do the specimens of the Hudson River group, in their younger stages, look exactly like adult *R. inaequalis*. The figures given of the two species readily show the differences between them.

In the middle beds of the Trenton limestone a number of free and very well preserved specimens, collected by Mr. Ulrich, have from twelve to fourteen plications on each valve, and are globose and smaller than is usual for this species. Similar but larger shells also occur rarely in the shales above. These specimens approach *Rhynchonella orientalis* of Billings,* from the Chazy group, but differ from it in having three or four more plications, and none of them has the straight, lateral outline shown in the second series of his figures. This is probably the form to which Mr. Sardeson has given the name *R. minnesotensis*.

*Canadian Nat. and Geol., vol. iv, p. 443, 1859.

riety *laticostata*.]

This species is known in America as *Rhynchonella increbescens* Hall, but unfortunately it must give way to *R. inaequalvis*, a name defined and illustrated four years earlier by Castelneau. The latter obtained his specimens from the "Magnesian limestone, Drummond's island."† Of the Trenton brachiopods, this is the most persistent and serves as a good marker of this formation. Associated with *Orthis subaequata*, it at once establishes the outcrop as of Trenton age.

Formation and locality.—In the upper two-thirds of the Trenton limestone at Minneapolis, Minnesota. Very common in the Trenton shales at Minneapolis, St. Paul, Cannon Falls, Chatfield, Lanesboro, Fountain, Eyota, Preston and near Caledonia, Minnesota; Decorah and McGregor, Iowa. Also common in the lower portion of the Galena in Goodhue and Fillmore counties, Minnesota. In the "Lower Blue beds" at Janesville, Beloit and Mineral Point, Wisconsin. In the Trenton at Dixon, Illinois; Auburn, Lincoln county, Missouri; Frankfort, Danville and Lexington, Kentucky; Nashville and elsewhere in Tennessee; Middleville, Trenton Falls, Watertown and other places in New York; Ottawa, Canada, and Drummond's island. In the Galena at Oshkosh and Neenah, Wisconsin. Two specimens have also been collected by one of the writers in the Hudson River group at Savannah, Illinois.

Collectors.—Miss C. L. Seymour, C. L. Herrick, J. C. Kassube, U. S. Grant, H. V. Winchell, W. H. Scofield, E. O. Ulrich and the writers.

Mus. Reg. Nos. 266, 323, 328, 331, 370, 382, 650, 3493, 3516, 3517, 4053, 4925, 4933, 4941, 4999, 5128, 5473-5476, 5478, 5479, 5482, 5484, 5488, 5490, 5491, 5493, 5496, 5497, 5506, 5508, 5509, 5513, 5515, 5516, 5518, 5519, 5522, 5852, 5858, 5883, 6486, 6764, 6777, 6790, 6793, 6799, 6800, 7918, 8209-8218.

Variety LATICOSTATA *W. and S.*

PLATE XXXIV, FIGS. 26-29.

1892, April 1. *Rhynchotrema inaequalvis*, var. *laticostata* W. and S. American Geologist, vol. ix, p. 293.

1892, April 9. *Rhynchonella sancta* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 333, pl. iv, figs. 19-20.

In the lower portion of the Galena south of Cannon Falls *R. inaequalvis* often attains a far greater width than is usual for the species. The four plications of the fold are closely arranged, while the five or six on the side are spread out and are therefore larger than usual. These shells, if found alone, would be regarded at once as a distinct species. Their development begins in the lowest portion of the Galena shales, where specimens are sometimes picked up at St. Paul. However, it is not until this species is found in association with *Clitambonites diversa* Shaler that the variety becomes common and attracts attention. In the Trenton of New York and Kentucky an occasional specimen is found which approaches var. *laticostata*, but none of them is so strongly transverse as Minnesota individuals.

Collectors.—W. H. Scofield and the writers.

Mus. Reg. No. 8219.

†There is probably a slight mistake in referring this species to the "Magnesian limestone" of Drummond's island, which belongs to the Upper Silurian. That limestone constitutes most of the island, and is not likely to hold its fossils in as entire and perfect a condition as the specimen figured by Castelneau. However, there is a low exposure of the Lower Silurian along the north shore, rising about eighteen feet above the water, and these beds probably furnished the specimens described by Castelneau.

RHYNCHOTREMA CAPAX *Conrad, sp.*

PLATE XXXIV. FIGS. 30-34.

1842. *Atrypa capax* CONRAD. Journal of the Academy of Natural Sciences of Philadelphia, vol. viii, p. 264, pl. XIV, fig. 21.
1847. *Atrypa increbescens* (partim) HALL. Palaeontology of New York, vol. i, p. 146, pl. XXXIII, figs. 131, 13k-13y.
1856. *Atrypa increbescens* (partim) BILLINGS. Candian Naturalist and Geologist, vol. i, p. 207, figs. 15, 16.
1860. *Atrypa increbescens* HALL (not 1847). Thirteenth Report, New York State Cabinet of Natural History, p. 66, figs. 6, 7, 9-11.
1862. *Rhynchonella increbescens* (partim) HALL. Geology of Wisconsin, vol. i, p. 55, figs. 5-7.
1863. *Rhynchonella capax* BILLINGS. Geology of Canada, p. 211, fig. 213.
1873. *Rhynchonella capax* MEEK. Palaeontology of Ohio, vol. i, p. 123, pl. XI, fig. 2.
1875. *Rhynchonella capax* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 17.
1880. *Rhynchonella capax* WHITE. Second Annual Report, Indiana Bureau of Statistics and Geology, p. 489, pl. 1, figs. 9-11.
1881. *Rhynchonella capax* WHITE. Tenth Report of the State Geologist of Indiana, p. 121, pl. 1, figs. 9-11.
1882. *Rhynchonella capax* WHITFIELD. Geology of Wisconsin, vol. iv, p. 263, pl. XII, figs. 26, 27.

Description: "Shell attaining about a medium size, varying with age from compressed subtrigonal to subglobose, old examples being often more convex than their diameter in any other direction; posterior lateral margins somewhat straightened and converging to the beaks at about a right angle in young shells, but becoming more rounded in the adult; lateral margins rounding to the front, which is more or less distinctly sinuous, or nearly straight in the middle.

"Dorsal valve generally a little more convex than the other, most prominent in the middle and rounding abruptly or sloping more gently from the central region in all directions; the more elevated part forming anteriorly a depressed mesial ridge that is nearly flat and occupied by four plications on top, and rarely continues two-thirds of the way to the strongly incurved beak, while on young or compressed individuals it is faintly marked even anteriorly; lateral slopes each occupied by four to seven or eight simple angular plications." Interior with the apex much thickened and converging anteriorly into a prominent subangular median septum, which extends about half way to the front margin; bases of the crural processes prominent and drawn out into slender inwardly and upwardly curving hooks, between which there is a thin, but often strongly elevated, cardinal process, while on the outside of the former are the large dental cavities; on each side of the septum in the posterior half are two pairs of deeply excavated adductor scars, the anterior pair being the larger.

"Ventral valve with its beak abruptly pointed and very strongly incurved upon that of the other valve in adult shells, but less distinctly curved and showing a small

opening under its apex [for the protrusion of the pedicle; it is formed by the deltidial plates, which grew from the walls of the delthyrium and joined medially, leaving an oval or circular aperture apically] in young examples; mesial sinus deep and well defined in gibbous specimens and less so in the young and more compressed forms, never quite reaching the front of the beak and always having three simple [sometimes four], rather angular plications in the bottom that extend, like the others, to the apex of the beak in well preserved specimens; lateral slopes each occupied by from five to seven simple plications." Interior with prominent hinge teeth, supported, according to the age of the specimen, by more or less thickened dental plates which join the outer elevated margin of the deeply excavated pear-shaped muscular area. Posterior to the center of this area there is, in old examples, a deep, elongate depression containing the adductor scars, and surrounding these are the large pear-shaped diductors, the adjustors being placed postero-laterally to the latter. Posterior to, and above the muscular area, and between the hinge teeth in old or very obese examples, there is a rather deep rostral cavity, which seems to have been largely produced by the apex of the dorsal valve having been forced in that direction by anterior shell growth. In Wisconsin examples this cavity is often crossed by the coalesced, concave deltidial plates, leaving under it a narrow passage for the peduncle to be extruded through the umbo of the valve.

"Entire surface of both valves marked by numerous very regular, strongly zigzag, prominent, sublaminar marks of growth, that become nearly or quite obsolete, sometimes on old examples." (Meek, *op. cit.*)

Obese specimens of this species are usually found with the apex of the ventral valve more or less worn away. This is nearly always ascribed to imperfect preservation, or due to weathering. Ohio specimens in which the delicate, sublaminar growth lines are well preserved also have the apex more or less broken. The writers, therefore, conclude that, as the pedicle opening was encroached upon by the dorsal umbo, owing to the shell becoming more convex with age, the peduncle was forced back through the beak of the ventral valve. Sometimes portions of the entire beak are worn away from the same cause. This condition is also seen in many species of both fossil and recent terebratuloids and may be due to convexity of the valves or to shortness of the peduncle.

R. capax is often confounded with *R. increbescens*—*R. inaequalis* Castelnau, but the larger size of the former, together with the greater convexity and thickness of the valves, will readily separate it from the latter. Even the young of *R. capax* can be distinguished from the adult of *R. inaequalis* by the obsolete fold and sinus, fewer and larger plications, greater transversity and more prominent subimbricating growth lines.

Formation and locality.—A very characteristic and common species of the upper portion of the Hudson River group; a few specimens have also been secured from the upper portion of the Galena, which as far as can be determined, are referable to this species. In the Hudson River group at Spring Valley and Granger, Minnesota; Graf, Iowa; Iron Ridge, Stockbridge and near Clifton, Wisconsin; Wilmington, Illinois; near Cape Girardeau, Missouri; Ohio; Indiana; Kentucky, and Anticosti. In the Galena near Cannon Falls and near Rochester, Minnesota.

Collectors.—John Kleckler, M. W. Harrington, W. H. Scofield and the writers. Also in the collection of Dr. C. H. Robbins, of Wykoff, Minnesota.

Mus. Reg. No. 177, 4092, 4095, 5547, 8196-8199.

RHYNCHONELLA (?) *ANTICOSTIENSIS* Billings.



FIG. 34. *Rhynchonella anticostiensis* Billings. *a, b, c*, different views of a specimen. From "Palaeozoic fossils of Canada," p. 142.

1862. *Rhynchonella anticostiensis* BILLINGS. Palaeozoic Fossils, vol. i, p. 142, fig. 119A-C.

1863. *Rhynchonella anticostiensis* BILLINGS. Geology of Canada, p. 211, fig. 212.

Compare with *Rhynchonella argenturbica* WHITE. Report of the U. S. Geological and Geographical Survey west of the 100th Meridian, vol. iv, p. 75, pl. iv, fig. 12.

Original description: "Subpentagonal; apical angle about 80°; side nearly straight or slightly convex for rather more than half the length from the beak, then curving to the edge of the mesial sinus; front nearly straight for the breadth of the sinus; side view oblong; front, dorsal and ventral sides nearly straight; umbo of dorsal valve abruptly curved in to the base of the beak of the ventral valve, which is conical, erect and scarcely incurved. Ventral valve with a deep mesial sinus, becoming obsolete at two-thirds the length from the base; dorsal valve with a strong mesial elevation which, on approaching the umbo, disappears and is succeeded by a scarcely perceptible sinus, which continues to the summit. Surface with eighteen or twenty radiating angular ridges, crossed by close zigzag imbricating striae; three ribs in the ventral sinus and four on the dorsal mesial elevation."

The more or less erect beak of the ventral valve, and the conspicuous deltidial plates of *R. anticostiensis*, remind one much of species of *Rhynchotreta* Hall. This form is distinguished from *R. neenah* Whitfield by its greater triangular outline and in the four continuous plications of the less elevated median fold.

Formation and locality.—Common in the upper beds of the Hudson River group at Wilmington and Savannah, Illinois; Graf, Iowa; Wisconsin, and English Head, Anticosti.

Collector.—C. Schuchert.

Mus. Reg. Nos. 8201-8203.

RHYNCHONELLA (?) NEENAH *Whitfield*

PLATE XXXIV. FIGS. 35-37.

1882. *Rhynchonella neenah* WHITFIELD. Geology of Wisconsin, vol. iv, p. 205, pl. XII, figs. 19-22.

This species is distinguished from *R. anticostiensis* in being more tumid and less triangular, while two of the four plications on the strongly elevated median fold usually become obsolete before reaching the anterior margin.

Formation and locality.—Common in the upper portion of the Hudson River group at Iron Ridge and Clifton, Wisconsin; Savannah, Illinois, and probably also at Graf, Iowa.

Collector.—C. Schuchert.

Mus. Reg. No. 8146.

Suborder HELICOPEGMATA, Waagen.

Family ATRYPIDÆ, Dall.

Subfamily ZYGOSPIRINÆ, Waagen.

Genus ZYGOSPIRA, Hall.

1847. *Stenocisma*, HALL (not CONRAD, 1839). Paleontology of New York, vol. i, p. 142.
 1862. *Zygospira*, HALL. Fifteenth Report, N. Y. State Cabinet of Natural History, p. 154.
 1862. *Zygospira*, BILLINGS. Canadian Naturalist and Geologist, vol. vii, p. 393.
 1864. *Stenocisma*, MEEK and HAYDEN. Paleontology of the Upper Missouri, p. 16.
 1867. *Zygospira*, HALL. Twentieth Report, N. Y. State Cabinet of Natural History, p. 267.
 1868. *Zygospira*, MEEK. Geological Survey of Illinois, vol. iii, p. 377.
 1882. *Zygospira*, DAVIDSON. Supplement to British Silurian Brachiopoda, p. 122.
 1882. *Anazyga*, DAVIDSON. Ibidem, p. 128.

Original description: "Shells bivalve, equilateral, inequivalve; surfaces plicate in the typical species; a sinus on the dorsal valve. Internal spires arranged somewhat as in *Atrypa*, with a broad loop passing from the outer limbs of the spiral band entirely across from side to side, near to or above the center and close to the inner side of the dorsal valve." (Hall, 1862, *op. cit.*)

It appears that *Zygospira* is the earliest known spire-bearing genus, and is therefore very instructive. The apices of its spires are medio-dorsally directed, never laterally as in the *Spiriferidæ*; this is the chief character by which the members of the family *Atrypidæ* can be distinguished from all other spire-bearing brachiopods. In the earliest species, *Z. recurvirostra*, the spiral cones are very loosely coiled, each with about three volutions, while the point of attachment of the connecting band is constantly near the base of the outer whorl. In *Z. modesta* there are four or five whorls to each spiral cone, but the point of attachment of the loop is variable. In *Z. headi* there are six whorls to a cone and the connecting band is in the posterior region. In *Atrypa reticularis* there is a very similar arrangement of the spirals, but

with a still greater number of whorls to a cone, while the loop, which is no longer complete in mature individuals, is placed more posteriorly than in *Z. headi*. In the Devonian specimens of *Atrypa reticularis* the greatest number of revolutions to a spiral cone is attained. The evolution of the calcified brachial supports in the family *Atrypidae* has gone on increasing in the number of whorls to a cone, the connecting band has progressed from the anterior to the posterior region, and all has kept pace with the gradual increase in size of the various species, from the Trenton to the Upper Devonian.

The species of *Zygospira* are divisible into two groups—(1) the depressed-convex species with coarse striae in which the ventral valve is more or less carinated medially, and (2) those with the valves globose and finely striated.

Z. RECURVIROSTRA Hall—Trenton.

Group I.

- Z. deflecta* Hall, Trenton.
Z. modesta (Say) Hall, Hudson River.
Z. modesta, var. *cincinnatiensis* (James) Meek,
 Hudson River.
Z. kentuckiensis James, Hudson River.
Z. concentrica Ulrich, Hudson River.
Z. paupera Billings, Anticosti.
Z. mica Billings,* Anticosti.

Group II.

- Z. uphami* W. and S., Galena.
Z. erratica Hall, Hudson River.
Z. anticostiensis Billings, Hudson River.
Z. headi Billings, Hudson River.
Z. headi, var. *borealis* Billings, Hudson River

ZYGOSPIRA RECURVIROSTRA Hall, *sp.*

PLATE XXXIV, FIGS. 38-41.

1847. *Atrypa recurvirostra* HALL. Palaeontology of New York, vol. i, p. 140, pl. XXXIII, figs. 5a-5d.
 1859. *Rhynchonella ? recurvirostra* HALL. Twelfth Report, N. Y. State Cabinet of Nat. Hist., p. 66.
 1863. *Rhynchonella recurvirostra* BILLINGS. Geology of Canada, p. 168, fig. 152.
 1882. *Anazyga recurvirostra* DAVIDSON. Supplement to British Silurian Brachiopoda, p. 129.

Original description: "Elliptical, somewhat ovoid, very symmetrical; breadth about one-fourth of an inch, length a little greater; dorsal [ventral] valve with the middle elevated, regularly convex on the sides, the beak extended and gracefully incurved over the beak of the ventral [dorsal] valve, which is regularly convex, with a slight longitudinal depression; surface of each valve marked by about twenty-four regular, simple, longitudinal striae, which continue entirely to the beak."

Minnesota examples of this species are usually a little shorter, and therefore rounder than eastern examples; otherwise they are identical. Compared with *Z. modesta* the latter is found to attain a larger size, is more transverse and never so gibbous as this species. The beak of the ventral valve is usually less incurved, while the striae bounding the sinus are more prominent. Of interior characters nothing is known beyond the spires and the connecting band.

**Rhynchonella mica*, Cat. Sil. Foss. Anticosti, p. 44, 1866.

In the nepionic stage of this form, in specimens about 1 mm. in length, the shell is depressed-convex without striations and plications, the beak of the ventral valve being erect and perforated by a large triangular delthyrium. This stage agrees essentially with the same age in species of *Rhynchonella** and *Rhynchotrema inæquivalvis*. In some individuals of *Z. recurvirostra* the plications begin to develop along the anterior margin much earlier than in others. During the succeeding stages of growth the valves attain greater gibbosity, the delthyrium of the ventral valve becomes partially closed by the deltidial plates, the beak incurves over that of the dorsal valve and the striæ become larger until a certain size is reached, after which new ones are introduced maintaining their equality.

Z. uphami appears to be a descendant of *Z. recurvirostra*. It differs in having attained a larger growth and greater convexity. The striæ, however, do not increase in size, but numerous new ones are added, so that *Z. uphami* appears more finely striated.

Formation and locality.—This species occurs throughout the Trenton shales, but is very abundant near the base of the Galena shales in association with *Pholidops trentonensis*, var. *minor*, *Orthis pectinella*, var. *sweeneyi*, and *Rhynchotrema inæquivalvis* at Minneapolis, St. Paul, Cannon Falls and Fountain, Minnesota. Also common in the Galena south of Cannon Falls and Kenyon, Minnesota, and at Oshkosh, Wisconsin. Near the top of the Trenton in association with *Orthis borealis* Billings, at Lexington, Daville and Frankfort, Kentucky. Martinsburgh, Lowville and Middleville, New York; Ottawa, Canada.

Collectors.—C. L. Herrick, W. H. Scofield and the writers.

Mus. Reg. Nos. 437, 439, 735, 767, 4069, 5477, 5511, 8220-8223.

ZYGOSPIRA MODESTA (Say) Hall.

PLATE XXXIV. FIGS. 42-44.

1847. *Atrypa modesta* HALL. Palæontology of New York, vol. i, p. 141, pl. xv, fig. 15.
 1859. Genus ? *modesta* HALL. Twelfth Annual Report, N. Y. State Cabinet of Natural History, p. 66. "Related to *Leptocalia*."
 1860. *Atrypa modesta* HALL. Ibidem, Thirteenth Report, p. 69.
 1862. *Zygospira modesta* HALL. Ibidem, Fifteenth Report, p. 154.
 1863. *Rhynchonella ? modesta* BILLINGS. Geology of Canada, p. 211, fig. 211.
 1867. *Zygospira modesta* HALL. Twentieth Report, N. Y. State Cab. of Nat. Hist., p. 267, figs. 1, 2.
 1873. *Zygospira modesta* MEEK. Palæontology of Ohio, vol. i, p. 125, pl. xi, fig. 4.
 1875. *Zygospira modesta* MILLER. Cincinnati Quarterly Journal of Science, vol. ii, p. 58.

Original description: "Suborbicular or plano-convex, with the beak extended; width a little greater than the length; cardinal line distinctly marked and somewhat extended; dorsal [ventral] valve convex, with an elevated ridge along the center, occupied by four plaits which are stronger than the others; beak prominent, incurved and perforated, the perforation [pedicle opening] extending below the beak and occupying a portion of the area; ventral [dorsal] valve depressed-convex, broadly oval or nearly circular, with a broad but ill defined sinus along the middle, the central plication stronger than the others, with a smaller one on each side; each

*The Development of some Silurian Brachiopoda. By Beecher and Clarke. Mem. N. Y. State Mus., vol. i, no. 1, 1880.

valve with about eighteen simple, rounded plications; surface obscurely punctate." Interior structure unknown. Brachial supports large, in the mature stage with about five loosely coiled volutions to each spire and more or less medially directed towards the dorsal valve. On the first or outermost volution on the dorsal side of each spire a band is given off which is more or less backwardly curved, joining medially, and thus forms the "loop" or connecting band. The point at which it is given off from the spires is variable. The band may cross in front of the apices of the spires or above the posterior turn of the second volution.

In the Hudson River group this species is quite distinct from *Z. recurvirostra*. Near the top of the Trenton in Kentucky, however, *Z. recurvirostra* and *Z. modesta* are found together, but these specimens, as a rule, are typically neither the one nor the other. The general expression, however, is more that of *Z. modesta*. In Minnesota the two species are always distinct and hold widely separated horizons. In New York, associated with *Z. recurvirostr* near the middle of the Trenton, is found *Z. deflecta* Hall,* a species in many respects like *Z. modesta*, showing that the tendency of development of the former is toward the latter. For other remarks see *Z. uphami* and *Z. recurvirostra*.

Formation and locality.—Rare in the Hudson River group at Spring Valley, Minnesota. Common in the same formation of the Ohio valley; Savannah, Illinois; New York and Canada. In the upper portion of the Trenton and Utica slate of New York. Whitfield (Geol. Wisconsin) gives it as occurring in the Trenton, Galena and Hudson River groups of Wisconsin.

Collectors.—E. O. Ulrich, W. H. Scofield and the writers.

Mus. Reg. No. 8228.

ZYGOSPIRA UPHAMI *W. and S.*

PLATE XXXIV, FIGS. 45-48.

1892, April 1. *Zygospira uphami* W. and S. American Geologist, vol. ix, p. 291.

This species occurs in the fine-grained portions of the Galena limestone about twenty feet beneath the Maclurebeds and fifty or more feet above the layers containing *Z. recurvirostra* in abundance. Its general expression shows it to be a probable descendant of *Z. recurvirostra*, having attained a larger size, greater convexity and somewhat finer striæ. The latter feature is more apparent than real, owing to the greater size of *Z. uphami*. Some specimens from which the shell has been partially exfoliated show the interior of the ventral valve to have a deep muscular cavity extending from the beak to about one-third the length of the shell. From the antero-lateral margins of this area originate two prominent, diverging ridges, probably the markings of the main trunks of the vascular system; which become obsolete near the front margin. The crural plates of the dorsal valve are very strong and at their bases coalesce with a stout, but rather short, median septum, upon each side of which, posteriorly, are situated two depressions of the adductor scars, the second pair being undefined.

*Pal. N. Y., vol. 1, p. 140, pl. XXXIII, figs. 4a, 4b.

Z. uphami is the transitional species between *Z. recurvirostra* and *Z. erratica* Hall,* and *Z. headi* Billings and its varieties *borealis* and *anticostiensis*.† Its nearest relations are with *Z. erratica*, from which it differs in being narrower, of smaller size, less quadrate in outline and without a sinus near the anterior margin of the ventral valve. *Z. headi* is a large, elongate species, more strongly biconvex, with the sinus of the dorsal valve far less conspicuous; var. *borealis* differs at once in its greater length and tumid umbo; var. *anticostiensis* has a more swollen umbo and its point of greatest convexity is near the mid-length, while in *Z. uphami* it is close to the posterior margin. The latter also has a shallow, rapidly expanding mesial sinus, which is obsolete or not present in var. *anticostiensis*. Named in honor of Mr. Warren Upham, of Somerville, Mass., for several years an assistant on the Minnesota survey.

Formation and locality.—This species seems to be abundant, but is restricted to beds only a few feet in thickness, near the middle of the Galena horizon at Weisbach's dam near Spring Valley, and near Wykoff and Fountain, Minnesota; also in equivalent position in Goodhue county.

Collectors.—W. H. Scofield, E. O. Ulrich and C. Schuchert. Also in the collection of Dr. C. H. Robbins, Wykoff, Minnesota.

Mus. Reg. Nos. 8227.

Family SPIRIFERIDÆ, King.

Subfamily SUESSINÆ, Waagen.

Genus CYCLOSPIRA.‡

The important diagnostic character of *Cyclospira* is the nature of the calcified brachial supports. The primary lamellæ are straight at their point of origin from the crura, thence continuing anteriorly nearly parallel to each other, and recurving somewhat laterally. The Minnesota example in which the brachial supports have been developed does not show a complete revolution of the primary lamellæ, but in a specimen from New York, developed by Mr. John M. Clarke, there are about two and one-half turns to the spiral. This specimen also shows that the second and third turns are somewhat medially directed or introverted. There appears to be a complete loop joining the primary lamellæ near their point of origin with the crura in the Minnesota example, but in the New York example the loop appears to be represented by two prongs or remnants of a loop, as in *Spirifer*. These differences, if correctly ascertained, should be regarded as of generic value; but, since the shells from the two localities are alike exteriorly, we believe that when more material from Minnesota is investigated they will prove to be structurally in harmony with the eastern specimens.

**Orthis erratica* Hall, Pal. N. Y., vol. 1, p. 288, pl. LXXIX, figs. 5a-5f, 1847.

†Pal. Foss., vol. 1, p. 147, figs. 125-127, 1862.

‡The generic description of this genus will be published in Pal. N. Y., vol. VIII, pt. II. The type species is *Orthis bisulcata* Emmons.

In *Zygospira*, *Glassia*, *Dayia* and *Atrypa* of the *Atrypidae* the primary lamellæ diverge widely and have between them the spirals; but in the *Spiriferidae*, to which family *Cyclospira* belongs, the primary lamellæ remain close together and they are between the spirals, except in *Cyclospira*.

This type of calcareous brachial supports has heretofore not been known to occur in rocks older than the Upper Silurian, and it is therefore interesting to find a species possessing them so early as the Trenton of the Lower Silurian. In Upper Silurian genera of the family *Spiriferidae* the number of revolutions in each spiral cone is always numerous, while in *Cyclospira* it never exceeds much more than two turns and is therefore more rudimentary. Since the primary lamellæ remain straight where they join the crural plates in both *Cyclospira* and in the members of the family *Spiriferidae* the genus must be regarded as belonging to that family. It is also geologically and structurally nearer the ancestral stock which gave origin to the entire suborder *Helicopegmata*, or spire bearing families. *Zygospira*, however, is still nearer this ancestral stock, since it is known to occur in the Birdseye and Black River formations; but in this genus the apices of the spirals are dorso-medially directed. The direction of coiling serves well enough for family distinction, but we believe that both types of spirals, and also the *Terebratulidae*, were derived from one stock, which probably is to be looked for in the *Rhynchonellidae*. Waagen,† however, derived the family *Atrypidae*, of which *Zygospira* is a member, from the *Rhynchonellidae*, while all the other forms of spire-bearing genera he considered as developed from the *Terebratulidae*.

CYCLOSPIRA BISULCATA *Emmons, sp.?*

PLATE XXXIV. FIGS. 40-54.

1842. *Orthis bisulcata* EMMONS. Geology of New York; Report, Second District, p. 396, fig. 4 (not described).
 1847. *Atrypa bisulcata* HALL. Palæontology of New York, vol. i, p. 139, pl. xxxiii, fig. 3.
 1859. *Genus ? bisulcata* HALL. Twelfth Report, N. Y. State Cabinet of Natural History, p. 65.
 1877. *Camarella bisulcata* MILLER. American Palæozoic Fossils, p. 107.
 1892. *Camarella owatonnensis* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 328, pl. iv, figs. 1-3.

Original description: "Small, ovoid; dorsal [ventral] valve with a well defined, narrow, mesial sinus, which continues about halfway to the beak, and from there the center becomes much elevated; beak of the dorsal valve strongly incurved over that of the oposite valve; ventral [dorsal] valve depressed-convex, prominent on the umbo, beak very small and abruptly incurved; front with two short, well defined furrows, ending in two plications, which close on each side of the projecting plait formed by the extension of the mesial groove of the dorsal valve." (Hall, *op. cit.*)

†Pal. Indica., ser. xiii, vol. i, p. 550.

Hallina saffordi.]

deltidial plates, characters also common to the *Kampylopegmata*, it seems natural to expect that the earliest members of this suborder should have impunctate shells as their immediate ancestors, the *Rhynchonellidæ*. We find that the species of *Hallina* of the Lower and Upper Silurian are impunctate, but that punctate *Kampylopegmata* are already present in the Lower Helderberg, where the other type of shell structure of this suborder is no longer met with.

HALLINA SAFFORDI *W. and S.*

PLATE XXXIV, FIGS. 55-58.

1892; April 1. *Hallina saffordi* W. and S. American Geologist, vol. ix, p. 292.

Shell very small, rostrate, regularly elongate oval, striate and evenly biconvex. Ventral valve somewhat more convex than the dorsal. Point of greatest elevation about mid-length, slightly carinated, but otherwise evenly convex in all directions. Beak strongly incurved, but not in contact with the umbo of the dorsal valve, with a small pedicle opening in the apex, which is partially surrounded anteriorly by incomplete deltidial plates. Teeth well developed and supported by delicate, strongly oblique, dental plates; other interior characters undefined.

Dorsal valve evenly convex, with a very shallow sinus in the anterior half. Brachial supports straight from the crural plates for a short distance forward, then bend backwards and laterally, turn and proceed anteriorly to within a short distance beyond mid-length and nearly parallel to each other, where they again turn rather abruptly upward and inward, joining medially at a point which is about half the length of the brachia. Thin sections do not show strongly thickened crural plates, nor a median septum amalgamated with the former, as is so common in terebratuloids.

Surface marked with from fifteen to twenty subangular striæ, which terminate on the posterior third of the valves; no concentric lines of growth observable. Shell structure fibrous and impunctate.

This common little shell occurs in association with *Leperditia fabulites*, *Scenidium anthonensis* and *Rafinesquina minnesotensis*. The only species with which it is likely to be confounded, if the exterior alone is taken into account, is *Zygospira recurvirostra*. In the latter, however, the striæ are more prominent and numerous and extend to the beak on each valve, while in *Hallina saffordi* they are obsolete on the posterior third.

Named after Prof. James M. Safford, Nashville, Tenn.

Formation and locality—Common in the "Glade limestone" at Lebanon, Tennessee, where they were discovered by Mr. E. O. Ulrich several years ago. Also near the top of the Birdseye limestone at High Bridge, Kentucky.

Types in the collection of Charles Schuchert.

Mus. Reg. No. 8237.

HALLINA NICOLLETI, *n. sp.*

PLATE XXXIV. FIGS. 59-62.

1892, April 1. *Hallina nicolleti* W. and S. American Geologist, vol. ix, p. 293.1892, April 9. *Zygospira aquila* SARDESON. Bulletin of the Minnesota Academy of Natural Sciences, vol. iii, p. 335, pl. iv, figs. 15-18.

Shell small, rostrate, biconvex, oval or subcircular in outline. Ventral valve convex, point of greatest elevation about mid-length, with a shallow, very narrow sulcus down the center, bordered on each side with a low, rounded ridge, which becomes more prominent toward the anterior margin. The antero-lateral limits of the shell may be smooth or with as many as five low, rounded plications or marginal undulations. Beak strongly incurved, with a small, oval pedicle opening bounded by rudimentary deltidial plates on each side. Dorsal valve evenly convex and trilobed toward the anterior edge; in some specimens the lateral lobes may have as many as six low, rounded plications along the front margin. Calcified brachial supports much as in *Hallina saffordi*, except that the outer bands are curved laterally, while the anterior recurved portion is shorter. Articulating processes and muscular scars unknown.

Hallina nicolleti is easily distinguished from associated species, on account of its small size and camarelloid exterior. It differs from *Hallina saffordi* in its fold and sinus, and the usually obsolete marginal plications. Its associated species are the same as occur with *H. saffordi*.

Named for Jean N. Nicollet, geologist and geographer of the Northwest.

Formation and locality.—Abundant in the upper third of the Trenton limestone at Minneapolis, St. Charles, Rochester and Fountain, Minnesota; Decorah, Iowa, and in the "Lower Blue beds" at Beloit, Wisconsin.

Collectors.—E. O. Ulrich, W. H. Scofield and the writers.

Mus. Reg. Nos. 339, 434, 436, 438, 440, 652, 660, 8238, 8239.

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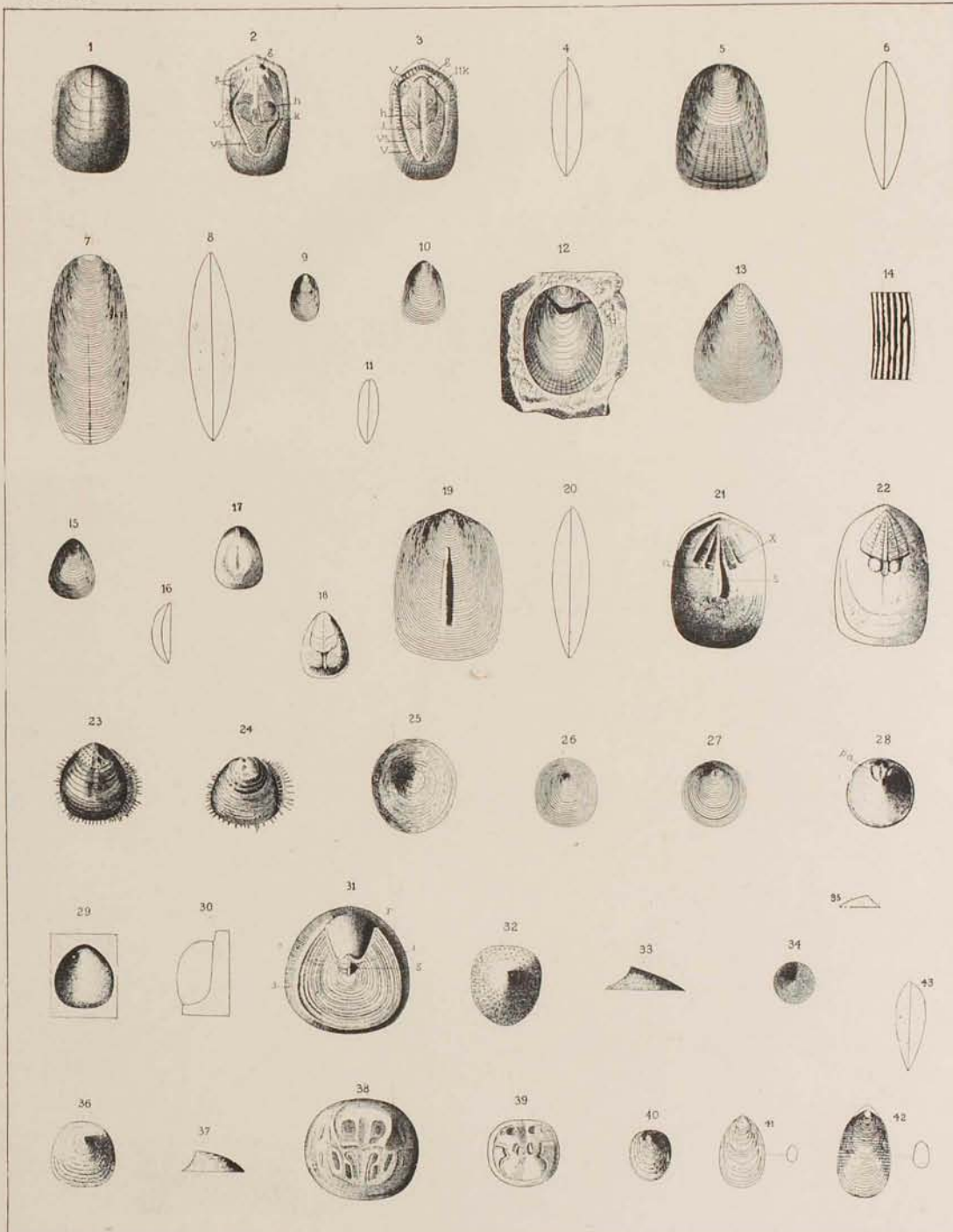
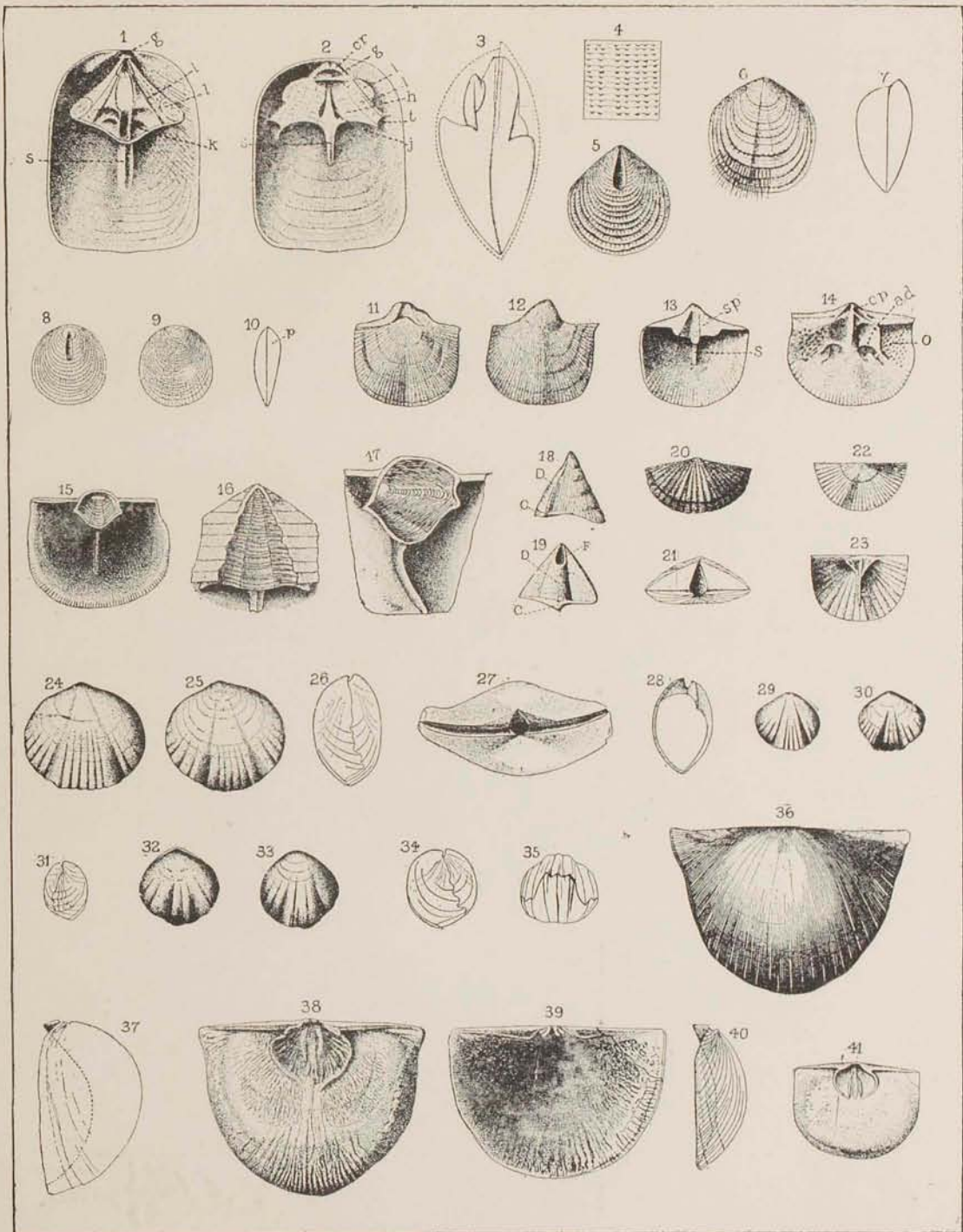


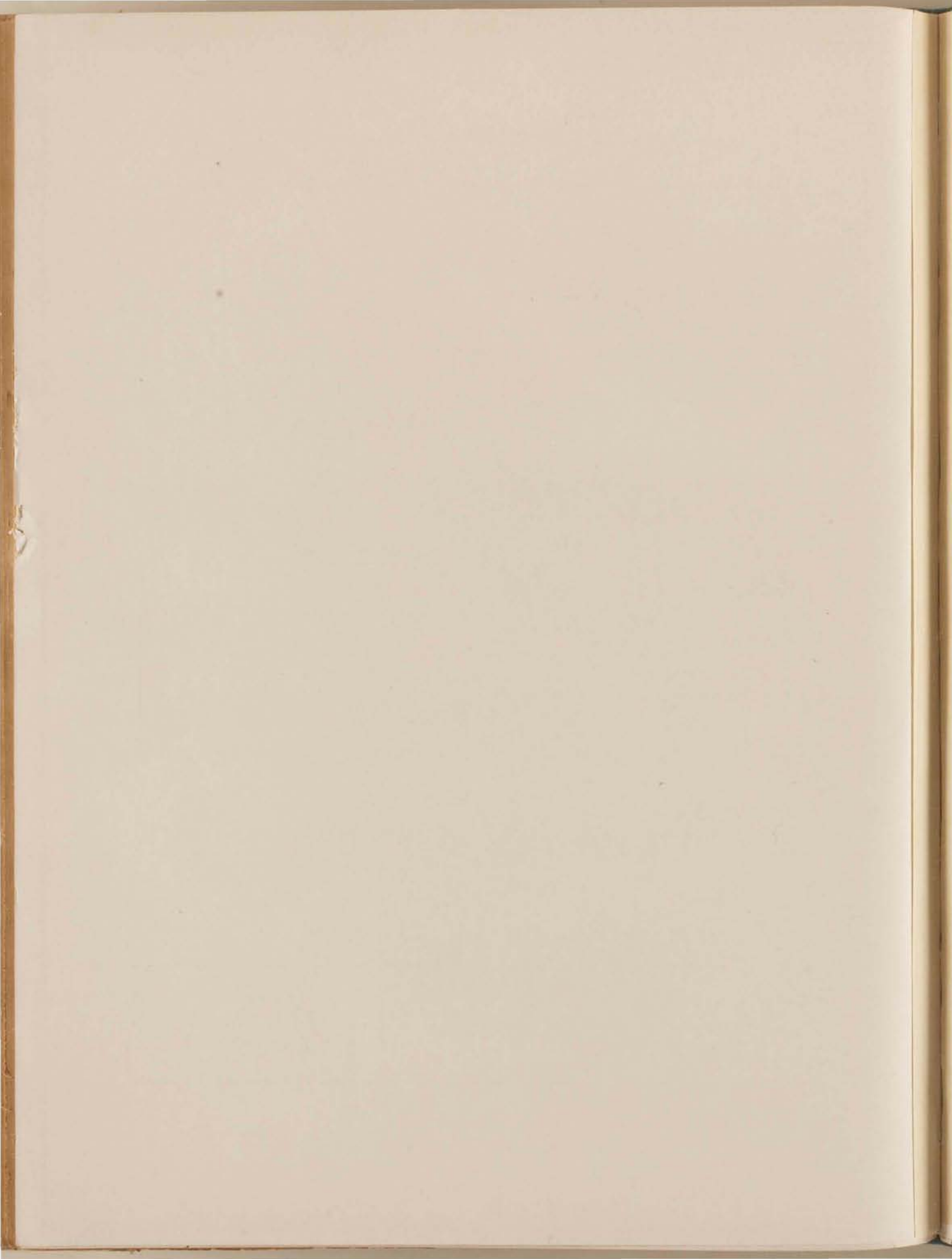


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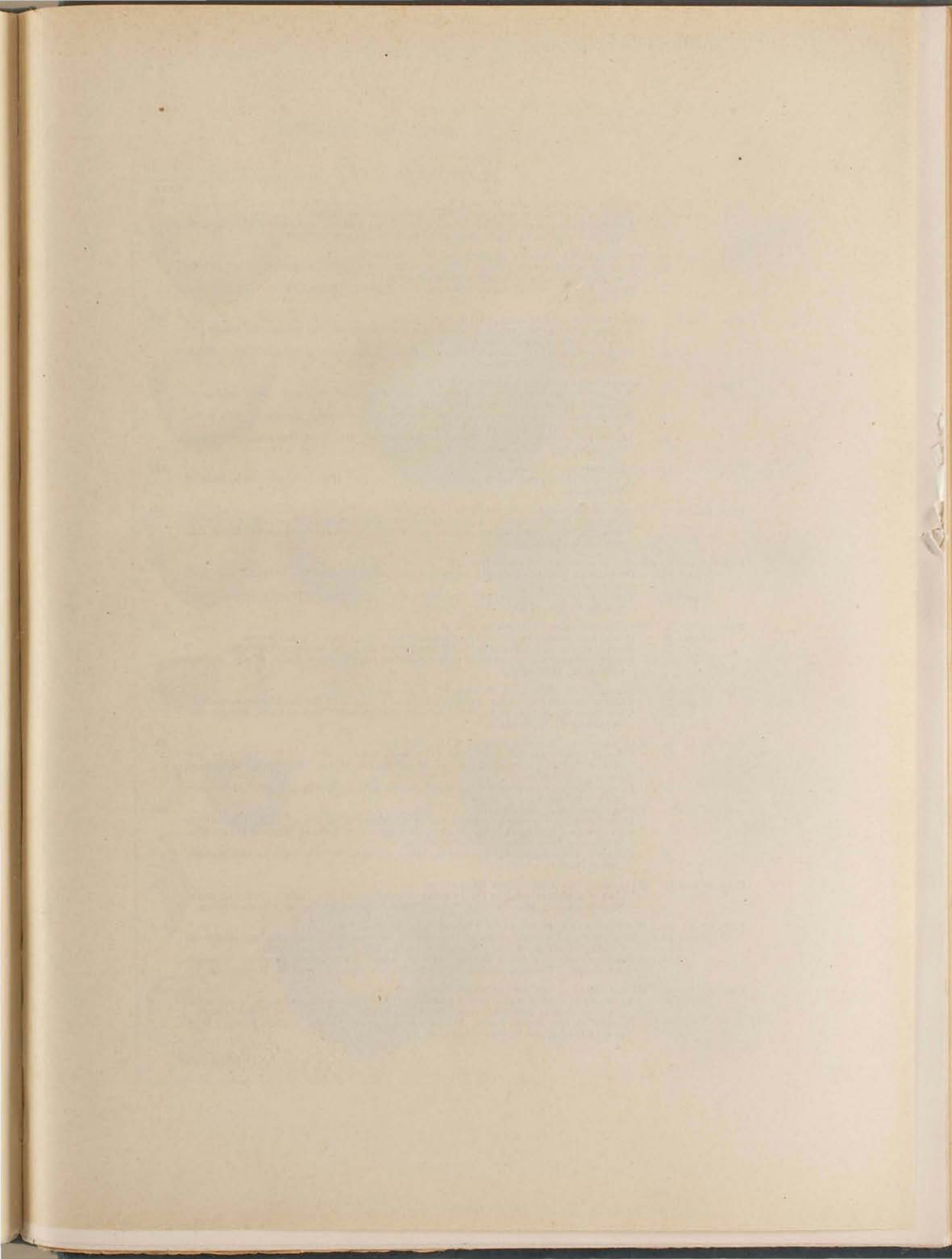


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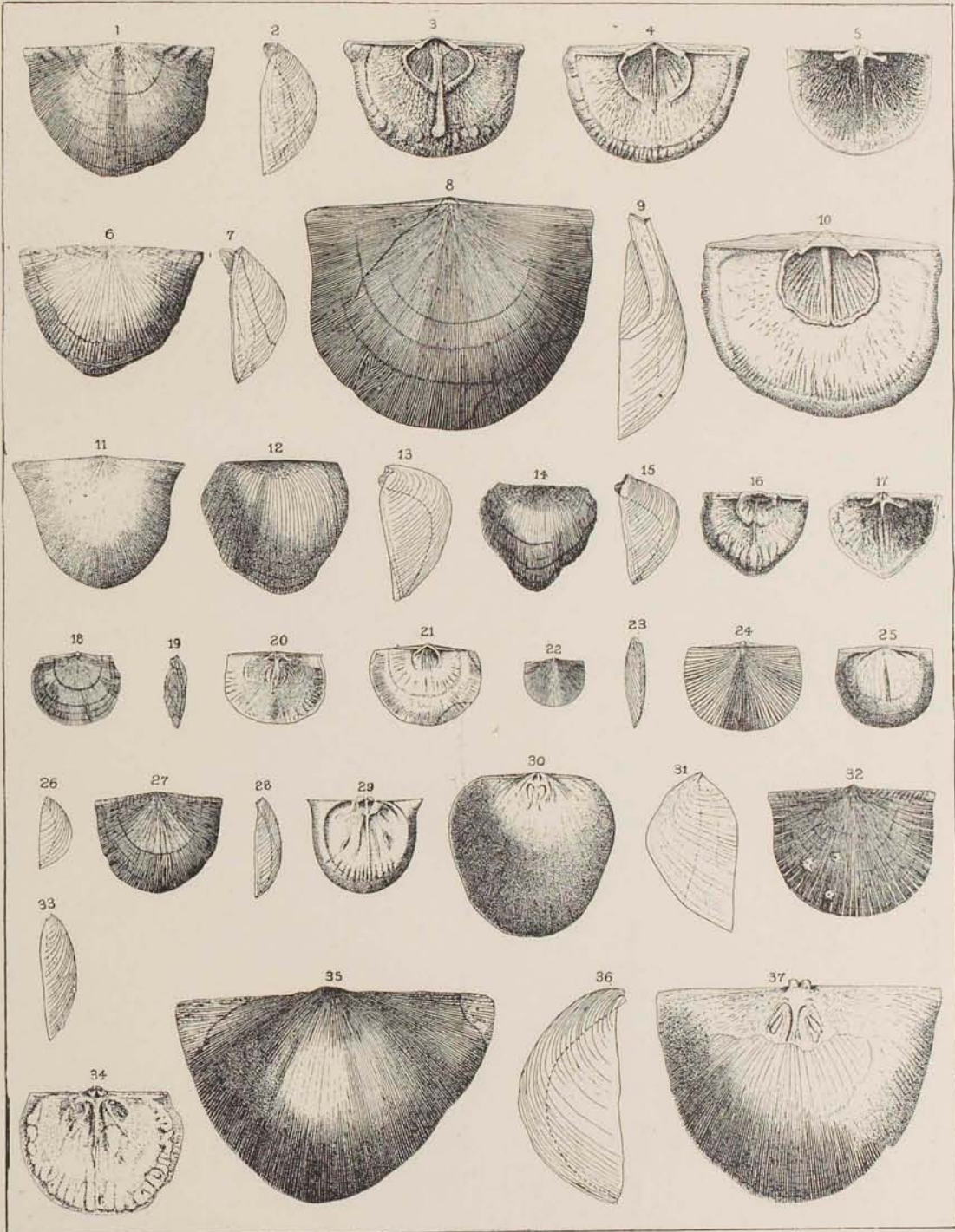


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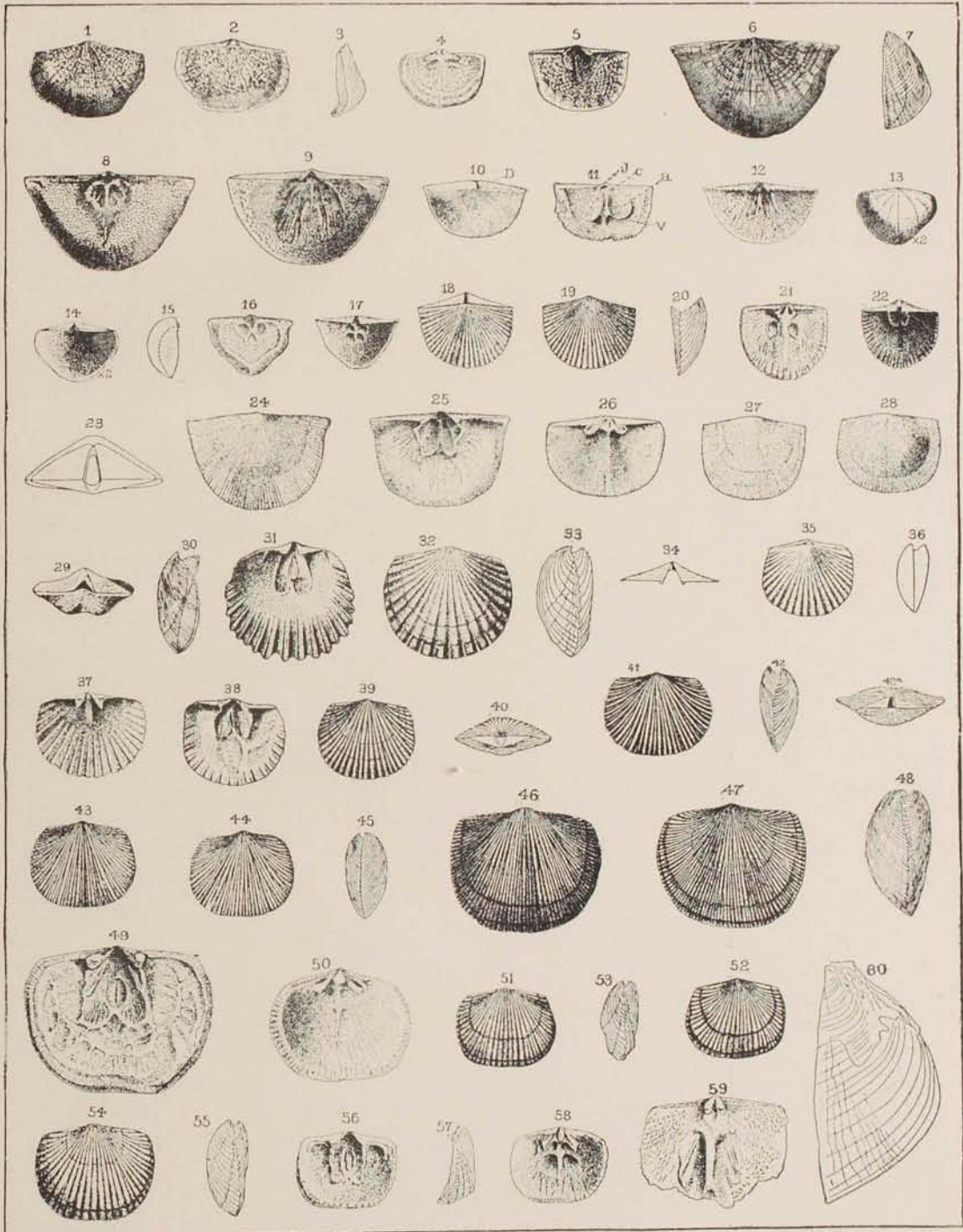
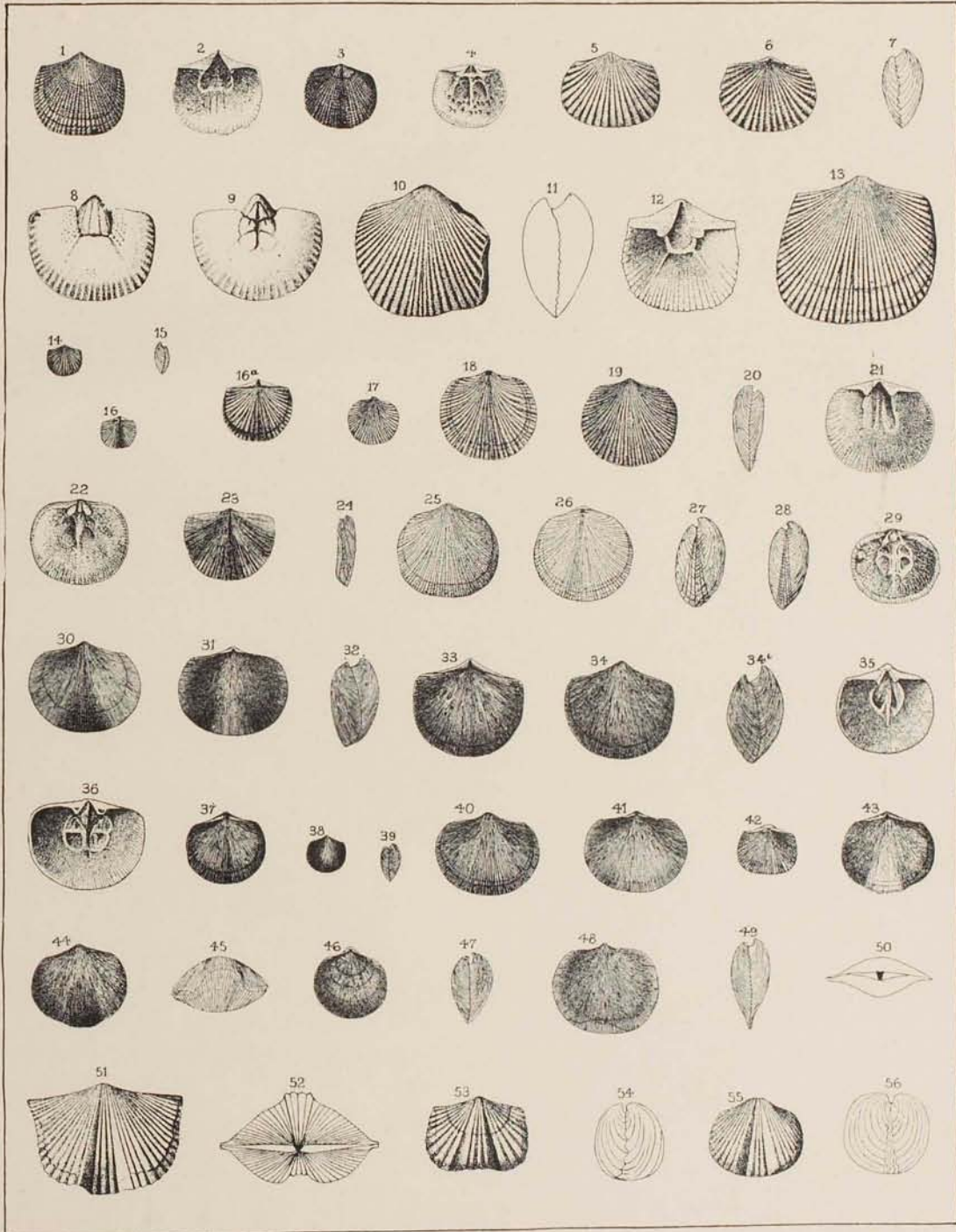
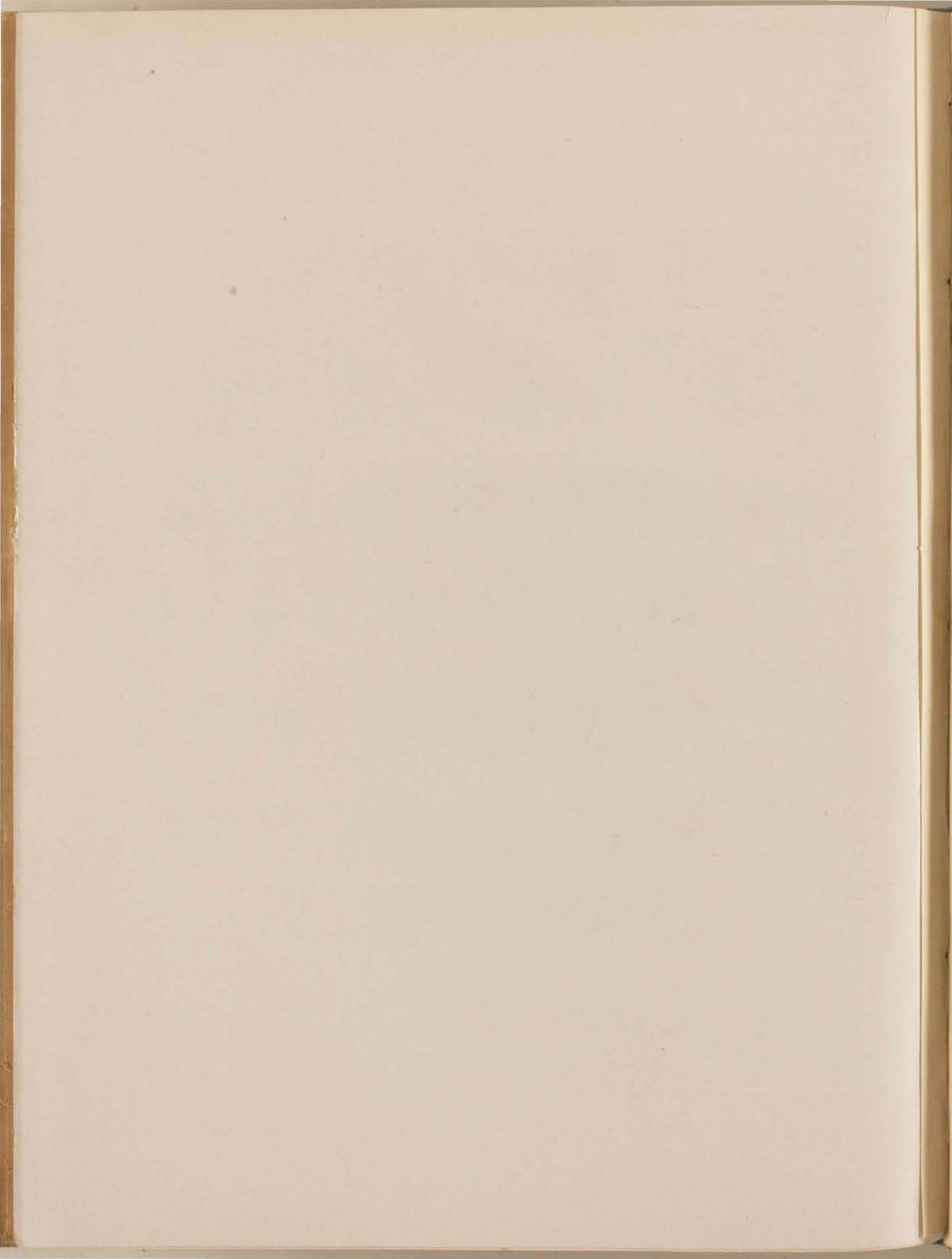


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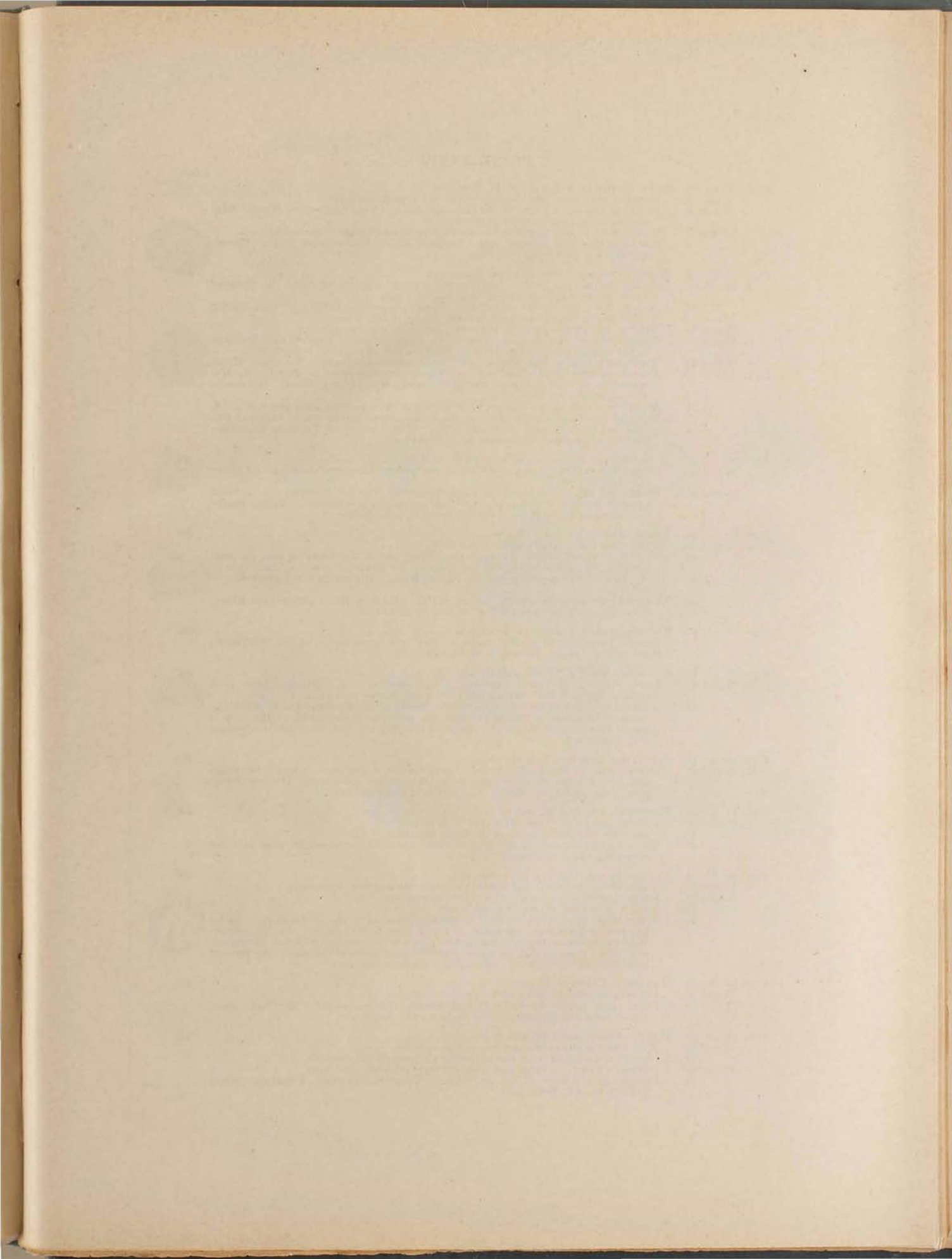


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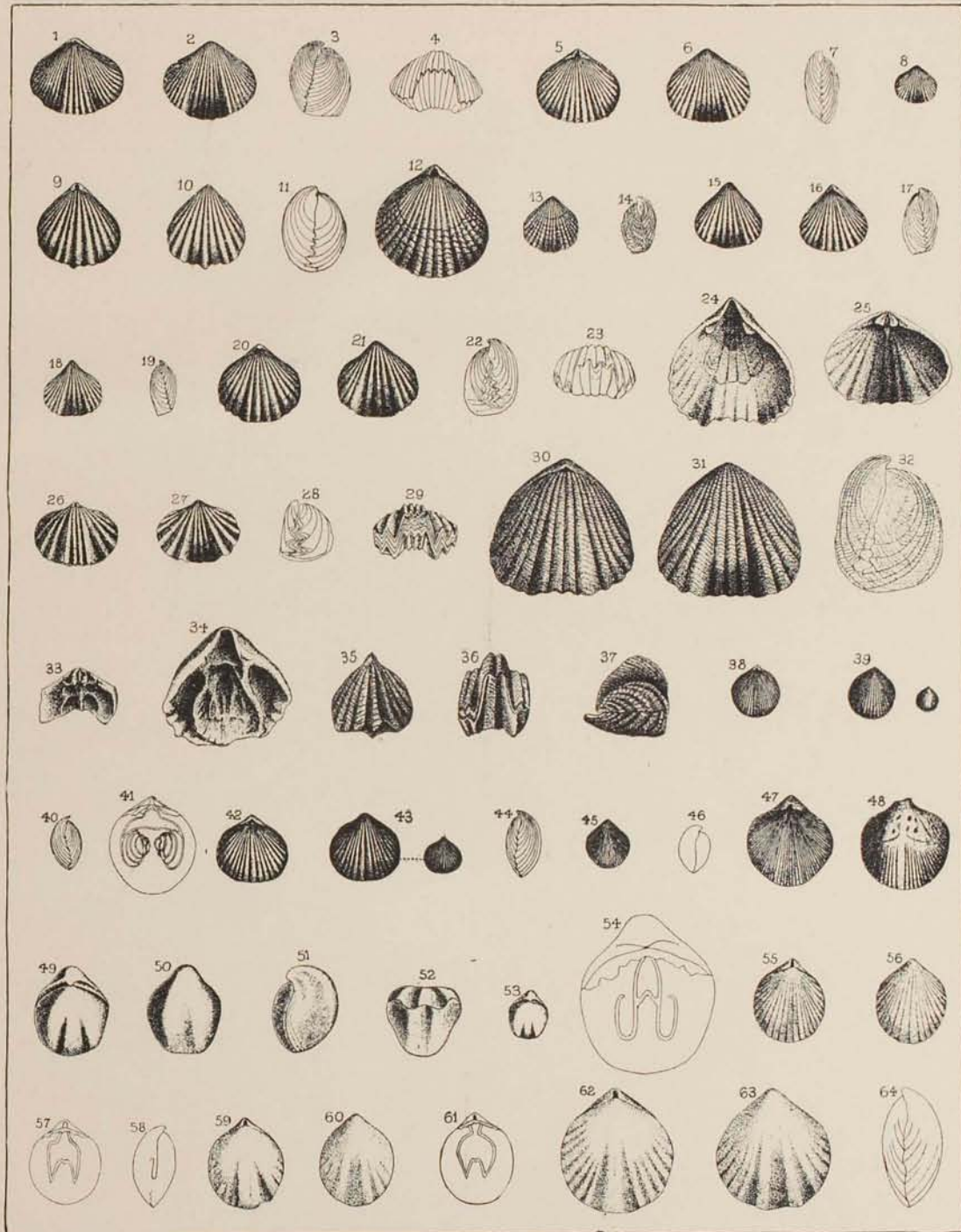
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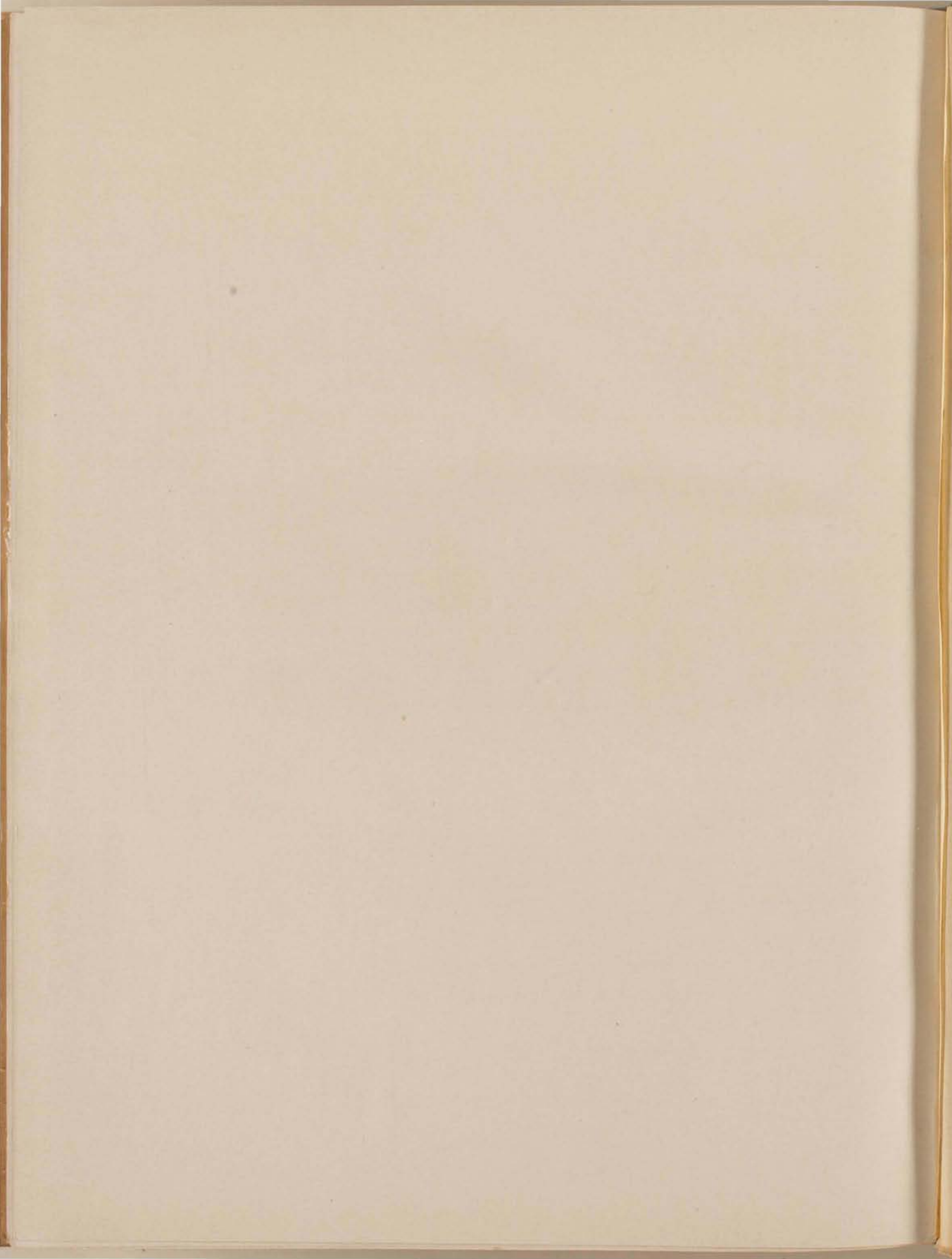
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