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The Saint Peter Sandstone

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[*Paper D.*]

THE SAINT PETER SANDSTONE.*

F. W. Sardeson.

INTRODUCTION.

The name of this formation was written Saint Peter's Sandstone by its author, Dr. Owen, and some geologists still retain that form of the name. The amended form, Saint Peter, has however long been used, and is preferred. The name was adopted by Owen because of the good exposure that is situated at the mouth of the Minnesota river, which last in Owen's time was called the Saint Peter's. The city that was of the same name as the river formerly, is now called Saint Peter.

The type exposure of the formation was chosen because of its situation at the military post, Fort Snelling. It is typical, and a description of it sufficed to enable geologists to recognize the same formation at any other of the many exposures, which occur over a large area. Even the earliest descriptions of this sandstone are free from confusion, both because its very peculiar characters excited close attention, and because those characters are so persistent that recognition of the formation was nowhere difficult. In fact, owing to the persistency of its characters, descriptions of it, although drawn from different regions, are monotonously similar. The little variation that does exist seems to be intended to relieve monotony rather than add to scientific knowledge. The formation is noticeably lacking in mineralogical, petrographical, stratigraphical and palæontological diversity.

* Owing to unavoidable delay in the publishing of this paper, it has been necessary to revise it. It was first delivered to the Society November 13th, 1892. The revised copy was given to the Secretary of the Society November 13th, 1895.

THICKNESS.

The Saint Peter sandstone was supposed by James Hall (9)* to be remarkably uniform in thickness, ranging from 80 feet in its northern (Minnesota) exposures to over 100 feet in the southern (Illinois) ones. In a sense, it *is* remarkably uniform, for the thickness in one area of its great extent averages nearly the same as in any other. But Worthen (12) found this formation to be variable in depth in Illinois, and Chamberlin (21 and 26) has clearly and concisely shown that it is in fact not uniform, but very variable in thickness, even within short distances. This variability is due to the undulated surface of the dolomite upon which it rests, the undulation being so great as to cause the depth to vary from less than one to over 200 feet. The mean thickness has been estimated by Chamberlin (26) to be between 80 and 100 feet. It is more than 100 feet thick in the north.

These estimates are for the Saint Peter itself, exclusive of the Shakopee dolomite and New Richmond sandstone, which two formations McGee (31) Keyes (32) and Norton (33) have, for Iowa, included in the Saint Peter. Such a course is not warranted; when followed, care should be taken to add to the Saint Peter the thickness of the never-failing Shakopee beneath, lest a false meaning be given to already established data, as it has never been shown that Saint Peter and Shakopee taken together are ever reduced to marked thinness. No regularity for the undulations in the underlying dolomite has been observed, hence no explanation for the variability in the thickness of the Saint Peter sandstone is yet known.

GEOGRAPHICAL DISTRIBUTION.

The Saint Peter sandstone is seen in numerous exposures in southeastern Minnesota, in northeastern Iowa, in western southern and eastern Wisconsin, and in northern Illinois. In this wide area it is repeatedly interrupted or reduced to isolated areas by river valleys.

The original extent of the formation we do not know. The general northern edge of its area, presents an eroded, torn and glaciated margin which is very far from being the

* The numbers refer to the bibliography at the end of the paper.

limit of the formation that must have existed at the time of its deposition. It probably extended a considerable distance northward. On the other hand the general southern extent is so deeply buried below the earth's surface that the limits to the southeast, south and southwest are undiscovered. Our knowledge is in fact confined to a relatively small fraction of the Saint Peter. The surface exposures as well as the area in which these exposures are found are narrow, from reasons that will be given below.

GEOLOGICAL DISTRIBUTION.

So far as we know, the Saint Peter was primarily coextensive with the overlying Trenton (Galena) and the underlying Shakopee. The now existing difference in extent is due to erosion, which of course has worked upon the uppermost strata to the greatest degree and it has caused the undermost—Shakopee—to have a few miles widest extent northward, as seen upon maps of the region.

The inequality in extent of these three Lower Silurian (Ordovician) formations is due very often to erosion that is still going on, very much also to glacial and preglacial erosion. In the latter case the once denuded area may be entirely covered with drift. How long ago the preglacial erosion took place is uncertain. An important and interesting addition to our knowledge is afforded, further, by the existence of a small area of Cretaceous clays (28, pl. 3) in Goodhue county, Minnesota, which lie upon the Saint Peter and Shakopee, the Trenton and other formations having been removed before the Cretaceous was deposited.

The situation of this small Cretaceous area at a high elevation, on top of the ridge near deep river valleys suggest that the valleys have been eroded mainly *since* Cretaceous time, and also its position upon an already eroded surface many miles within the present outer limits of the Saint Peter sandstone proves that the latter formation had been greatly eroded even *before* Cretaceous time. We learn from Worthen (12) that in a few exposures in La Salle county, Illinois, the Coal Measures rest immediately upon the Saint Peter sandstone; from this it is to be inferred that the overlying Trenton had been removed during the Devonian or, more probably, the early Carboniferous period.

From the fact that no Saint Peter sandstone has yet been reported from the Upper Peninsula of Michigan, it has been thought probable that a limit to the formation exists in that direction, and one which existed necessarily before the Trenton was deposited, since the Trenton is still there. It is possible that failure to report is due to failure to observe.

The known limits of the Saint Peter sandstone are those that have been produced by erosion, along the northernly and more elevated extent of the formation; the unknown limits are in the direction of the dip of the sedimentary rocks, i. e., in a general southeast and southwest direction. The Saint Peter may be continuous with formations of other adjacent areas but it has not yet been traced, nor as it would seem, satisfactorily correlated.

LITHOLOGIC CHARACTERS.

The Saint Peter sandstone averages about 99 per cent. silica in the form of grains of clear limpid quartz. There is very little cementing material of any kind so that it forms a "very friable stone . . . . . so loosely united that it appears like sand" (Keating, 4). The grains are typically clear white but the sand is often stained yellow or red locally. It is rarely cemented into a firm rock by an infiltration of iron oxide. Rarely also calcium carbonate infiltration has produced large concretions and areas of firm white rock. Normally it is easily eroded.

The sand grains are so much worn that they are nearly round and have a dead polish. Chamberlin (26) describes them as irregularly angular grains like the quartz from eroded acid eruptives and rarely of true crystalline form. The writer has found quartz crystals; but since the zones in which they occur, cross sometimes the sedimentary lamination instead of coinciding with it they are to be considered as originally rounded grains which have been rebuilt to perfect crystals. The rounded grains are the typical ones. In size, they vary from finest dust to coarse sand, 1 to 2 mm. in diameter, intermixed or imperfectly assorted. The dazzling white color gives the appearance of greater uniformity in size of grain than really exists.

An intermixture of argillaceous bands has been described (21) from northeastern Wisconsin; such an intermixture is generally found at the upper and lower limits of the formation. But, the Saint Peter Sandstone proper is a pure, friable, white rock with very little impurities. It is thoroughly pervious to water, so much so that a small stream poured upon the surface of a slab readily goes through it.

STRUCTURE.

Ordinarily the clear whiteness of the sandstone conceals its structure; on the other hand the infiltrated colors bring it out the more strongly. Stratification is always discernible often with fine lamination, crossbedding, and assorted layers of coarse and fine material. Transverse fissures also occur.

PALAEONTOLOGIC CHARACTERS.

Discovery of Fossils.

Owing to the friability of the rock and the total absence of shells, fossils are difficult to find. James Hall writes in 1862, (loc. cit.) that "no vestige of an organism has been observed" and "it is not probable that such remains will be found." Some years afterwards, however, N. H. Winchell (17.) reported shells of a *Lingulepis* from the top shaly strata of Saint Peter at Fountain, Fillmore county, Minnesota. T. C. Chamberlin (21 and 26) found worm burrows and fucoids near Beloit and Waterloo, Wisconsin, and these are reported by him to be not entirely in the uppermost strata of the formation.

Joseph F. James (34 p. 126) reports that he visited Fountain, Minnesota in 1889 and collected specimens of the *Lingulepis* and an *Orthis*. I have myself later collected the same and some other species at that locality in the described upper shaly strata. Species have been collected from similar strata near Dodgeville, Wisconsin. These fossils are all from the transition strata at the top of the formation, i. e. at the base of the Trenton.

Several species do occur in the body of the formation. As a student working under the direction of Professor C. W. Hall, I found in the year 1890, a large fauna in the Saint

Peter Sandstone, near Saint Paul, Minnesota. A notice of the same has been published (29). Fossils can be found still at the same localities. At Dayton's Bluff, the "Carver's Cave" of early writers, fossils were found between 60 to 80 feet below the overhanging Trenton, or Buff Limestone. A second exposure at Highland Park two miles south of the first is in strata lower than any at Dayton's Bluff, and here also fossils were found. At a third exposure, which is near South Saint Paul, there were found by Professor C. W. Hall and by myself a large number of species, in strata that are probably intermediate between those of Highland Park and Dayton's Bluff.

Condition of Preservation.

The fossils are found as casts of shells that have themselves been entirely dissolved without leaving even a stain of color or a trace of calcium carbonate in the sand. The cavities left by the shells are closed up by a consolidation of the sand in some manner so that generally little more than smooth cleavage planes remain to define the fossils. In the strata that are referred to the upper half of the formation, the fossils were nearly always ree from distortion. In the lower half on the contrary, few are not distorted. Here too there were found fossils which are the moulds only, of the casts of shells. The moulds were full of loose sand, which when removed simply by blowing and shaking, left smooth cavities in exact form of the interiors of shells themselves. The loose sand in the moulds was probably once embedded in the casts of shells. The process of fossilization must have been nearly as follows: A shell produced a cast, and was later dissolved away. The inner cast of the shell remained firm while the sand around it was disturbed and pressed around the cast taking the mould of it. The cast itself was then reduced by removal of the calcium carbonate to loose sand, the mould, however, remaining firm because already consisting only of sand.

Similar phenomena are to be observed in dolomitic limestone. The fossilization itself is not strange, but it reveals to us perhaps the reason that Saint Peter sandstone is so generally unfossiliferous, viz.: Because the fossils have been destroyed since the sandstone was deposited. One might dig up many fossils without seeing them unless care be taken to prevent the casts from being crumbled. The most favorable conditions are in the somewhat infiltrated strata where firmness is secured.

In many cases the shells of bivalves are found in such a manner as to prove that the ligament still bound them together at the time they were deposited in the sand. Of course such shells could not have been transported far nor much beaten about otherwise they would be found separated. Many of the shells were undoubtedly very thin and fragile.

LAMELLIBRANCHIATA.

Genus CYPRICARDITES.

Cypricardites (*Vanuxemia*) *fragosus* n. sp.

Plate II, figures 1, 2 and 3.

Cast acutely ovate in outline. Beaks extendfng beyond the anterior end of the hinge, gently curved, gradually expanding, and swelling out dorsally above the cardinal line. Casts concave under the beaks. Cardinal line curved and extended into an alate projection at the anterior end in front of the beaks but rounding evenly into the semicircular posterior margin. Antero-ventral margin slightly curved. The anterior alation contains the cardinal teeth four or five in number and has a very deep muscle scar just below it. Posterior muscle scar and posterior teeth not known. Along the anterior margin the shell is concave, between the beaks and the posterior ventral portion it is convex, end strongly so along the cardinal region. Transverse length of largest specimen 30 mm., breadth greatest at the posterior extremity of the hinge (18 mm.), convexity of single valve 12 mm. Shells probably very thick.

Found at Highland Park and South Saint Paul.

Cypricardites descriptus n. sp.

Plate II, figure 7.

Small, strongly convex, subqfiadrate, length 11 mm, breadth 9 mm. Beaks anterior, acute curved in. The point of greatest convexity is near the umbones, and the slope to the ventral margin is gradual. Cardinal line gently curved. Pallial lime simple and marked. The posterior muscle sears large, situated just below the extremities of the hinge. Surface smooth.

Highland Park.

Cypricardites finitimus n. sp.

Plate II, figure 6.

Shell of medium size, oblique, moderately convex, broadest posteriorly. Beaks broad, a little projecting, and slightly coiled. The point of greatest convexity is central. Anterior muscle sear prominent. Surface of the cast is concentrically marked by growth lines which appear to show the ventral margin a little more convex than on the figure. The only specimen found is a little compressed, and moreover does not show clearly but that it may be a modiolopsis.

Highland Park.

Cypricardites dignus n. sp.

Plate II, figures 4 and 5.

Shell rhomboidal, with the ventral margin longest; length of the largest specimen 18 mm, bredth 12 mm. Beaks anterior, tumid, close together. The hinge line is equal to about two-thirds the length of the shell, is curved and apparently continuous with the anterior margin. In general direction the anterior margin is vertical, but forms a strong even curve, which same is continued, but less strongly, through the ventral margin to the postero-ventral angle. The dorsal margin is more distinctly marked off but is gently curved. The point of greatest convexity is between the umbones and the centre of the shell along the rounded umbonal ridge which extends from behind the beaks obliquely back to the postero-ventral angle. Anterior to this umbonal ridge the shell is evenly and strongly convex, but between it and the dorsal and posterior margins the surface is concave. In general the specimens resemble *Nuculites inflatus* Emmous' Geo. Rep. N. Y., p. 395, fig. 2, but have a more prominent anterior margin and less produced hinge posteriorally. *Edmondia subtruncata* Hall Pal. N. Y., Vol. I, p. 156, and plate 34, fig. 9, (not plate 35, fig. 3, c.) is very much like the specimens from the Saint Peter but is larger and proportionally longer.

South Saint Paul.

Genus MODIOLOPSIS.

Modiolopsis fountainensis n. sp.

Plate IV, figure 7.

The few specimens secured resemble *Modiolopsis plana* Hall, of the Trenton limestone which lies upon the Saint Peter sandstone. The Saint Peter specimens are larger casts, however, and have the beaks situated further back and erect instead of directed forward. The convexity of the shell was not strong but there was a broad deepening between the beaks and the lower posterior curve of the margin, accompanied by a straightening of the ventral margin. The anterior muscle scar is large and close to the anterior margin. The specimens were found with *Lingula morsii* N. H. W. at the top of the Saint Peter formation (see pl. IV, fig. 9, c.) below Fountain, Minn.

Modiolopsis postica n. sp.

Plate IV, figure 8.

Shell about 50 mm. long, width greatest across the posterior half (30 mm.) The hinge line is nearly straight. The beak, of the left valve here described, is obtuse, broad and close down to the hinge. The umbo is high but flattened anteriorally and is continued in a rounded umbonal ridge towards the dorso-ventral margin and in a broad depressed area towards the ventral margin. The posterior margin is broadly rounded and is continuous with the ventral margin, which in turn continues with the anterior forming a sigmoid curve. The surface of the cast is marked by fine concentric lines. All the specimens collected are imperfect and none show the anterior perfectly. The specimen figured is from the transition strata of the Saint Peter about four miles below Dodgeville, Wisconsin, along the Illinois Central railway tracks.

Modiolopsis litoralis n. sp.

Plate II, figures 13, 14, 15 and 16.

The figure represents an interior cast of average size and form of this species. The casts are all strongly convex between the umbones and the lower posterior margin, forming a broad umbonal ridge, and a broad sinus, as well as a straightening of the posterior margin. The beaks are indistinct but extend longitudinally and project above the hinge. One strong anterior muscle scar is situated apparently just at the anterior end of the hinge. Compare *Orthodesma curvatum* H. and W. Pal. O. II, p. 95.

From South Saint Paul and Highland Park.

Modiolopsis contigua n. sp.

Plate II, figure 8.

Shell small, length about 25 mm., bredth at the posterior extremity of the hinge, 15 mm., at the umbones about 9 mm. The hinge is somewhat curved and is in some specimens longer posteriorally than in the one figured, and in these it forms an obtusely rounded angle with the posterior margin. The ventral margin is concave or straight, the anterior margin short and strongly convex. The beaks are somewhat obtuse and are directed forward. Their posterior half swells into a high rounded umborial ridge that extends towards the posterior-ventral margin while the anterior half is flattened continuous with the concave area anterior to the umborial ridge. The greatest convexity is at one-third the distance from the umbones towards the lower posterior margin. The shell has been very thin and marked with growth lines. It differs from *M. plana* Hall, in being proportionately narrower and having a stronger umbonal ridge and more concave ventral margin. From *M. similis* Ulrich it differs by the same characters. The type specimen is a relatively broad one.

Found at South Saint Paul.

Modiolopsis gregalis n. sp.

Plate II, figures 10, 11 and 12.

Length about 25 mm.; bredth 12 mm. and greatest at the middle; beaks less than one fifth the distance from the anterior end, small, incurved and scarcely projecting. Hinge line nearly straight; dorsal margin rounded gently from the hinge but more strongly so near the ventral margin; ventral margin gently arcuate and gradually rounding up continuous with the anterior, which in turn curves abruptly at the antero-dorsal end. Convexity moderate and uniform except for a low broad umbonal ridge which extends from below the beaks towards the lower part of the posterior margin. Point of greatest convexity just above the centre. One reniform anterior muscle scar near the anterior end, close to the pallial line. Pallial line simple, and marked off by a marginal thickening of the shell.

Mopiolopsis subelliptica Ulrich, as described* is the nearest to this species of any known. The difference in size, the position of the muscle scars and the beaks, and the difference in outline and convexity are apparent but the resemblance is great. The specimen is about medium size.

South Saint Paul and Daytons Bluff.

Modiolopsis affinis n. sp.

Plate II figure 9.

Cast of medium size, length 15 mm, bredth 8 mm, beaks about one fifth the distance from the anterior end, not prominent, but strongly curved. The hinge line is curved and runs gradually into the truncate posterior. The ventral margin is arcuate, and the anterior semi-circular. The convexity is greatest anteriorly and along the strong umbonal ridge which extends down and back to the extended end of the shell at the ventral posterior margin. Above the umbonal ridge the shell is gently concave while below and parallel with it the cast is flattened. The pallial line is not distinct.

The above description is of a single specimen which very much resembles *M. gregalis* but is more convex in the anterior portion and has a strong umbonal ridge and some indications that the shell was marked by coarse elevated lines radiating from the umbonal ridge. The general outline of the cast led to the expectation that specimens intermediate in form would link this with *M. gregalis* n. sp. but although a large number of specimens of the latter have been found, the distinctive characters still remain.

South Saint Paul.

Modiolopsis senecta n. sp.

Plate II, figure 17.

Shell large, length 33 mm, bredth 15 mm, convexity very moderate, but slightly increased between the umbones and the posterior extremity. Hinge straight and long. The ventral margin arcuate and it extends uniformly to the longitudiual extremities of the shell so that the anterior and posterior margis are short obligue truncations. Pallial line and muscle scars not visable. Beaks not projecting, low, and placed far anterior. Only one specimen found.

South Saint Paul.

Genus Tellinomya.

Neither of the two species referred to this genus have the characteristic hinge teeth clearly preserved, but that is evidently because the sediment or sand was too coarse to preserve a cast of such minute structure.

*Ext 19th Ann. Rep. Minn. Geol. Sur. March 3rd 1392

Tellinomya novicia n. sp.

Plate III, figure 3.

Length about 12 mm, bredth 8 mm, convexity of a single valve 3 mm. The beaks are prominent, curved, situated about one-third the length from the anterior end, and directed a little forward. Between the beak and the ventral margin the convexity is strong but uniform, while anteriorly and in the postero-dorsal direction the convexity is abrupt, giving the cast a triangular appearance. The hinge is about 8 mm long, curved and elevated posteriorally so as to form a concave surface below it. The pallial line is simple and well marked. The anterior muscle scar is large, round and placed midway below the beak, and tangent to the pallial time, which seems here to form a sort of clavicle. Posterior scar not distinct.

Found at South Saint Paul and Dayton's Bluff.

Tellinomya absimilis n. sp.

Plate III, figures 1 and 2.

Length about 20 mm, bredth 10 mm. Beaks anterior, small and curved close down to the hinge. Hinge, posterior to the beaks, is nearly straight and is long; anteriorally it is short and curved down, in continuation with the anterior margin, which is nearly straight above but curved abruptly back below forming an acutely rounded antero-ventral projection. The ventral margin is gently convex for the anterior half, gently concave to the posterior extremity, but in general direction is parallel to the cardinal line. The posterior margin is nearly straight, is well marked off from the ventral and dorsal, and forms an angle of about 110° with the latter. The point of greatest convexity is at the umbones anterior to the strong acutely rounded umbonal ridge which runs obliquely back forming the postero-ventral angle and giving a convex slope to the postero-dorsal and postero-ventral portions of the shell. Below the umbones the shell is strongly and evenly convex. The shell was thin and marked by fine plications which radiate from the umbonal ridge. The dentition is that of a *Tellinomya* but not distinctly preserved.

Highland Park.

GASTEROPODA.

GENUS HOLOPEA.

Holopea cf. obliqua Hall.

Plate III, figure 5.

Compare *Natica* (species undetermined) Hall 1847, Pal. N. Y., vol. 1, p. 42, pl. 10, fig. 4, and *Holopea obliqua* Hall 1847, Pal. N. Y., vol. 1, p. 107, pl. 37, fig. 2.

Small, of about three or four volutions, the last of which forms the main body of the shell. Volutions evenly ventricose above. Sutures well marked. No umbilicus. Surface with ridges of growth which run directly transverse. Apical angle about 115°. Three specimens have been found all of which are imperfect. There is no umbilicus, but in other respects they are exactly like *H. obliqua* Hall with the lower part broken off. In vertical sections of *H. obliqua* Hall from the Stictopora bed of the Trenton in Minnesota, the umbilicus was found to extend through the last or last two volutions only. There seems to be nothing that indicates a distinction between these specimens and *H. obliqua* as found in the Trenton of Minnesota.

South Saint Paul.

Holopea paludiniformis Hall.

Holopea paludiniformis Hall 1847, Pal. N. Y., vol. 1, p. 171, pl. 37, fig. 3.

One specimen indentical with the upper volutions of *H. paludiniformis* is imperfect but differs in no way that can be seen, from specimens that occur in the "Lower Blue Bed" of the Trenton limestone at Minneapolis.

Found at South Saint Paul.

GENUS MURCHISONIA.

Murchisonia cf. *gracilis* Hall.

Plate III, figure 4.

Murchisonia gracilis Hall, 1847. Pal. N. Y., vol. I, p. 181, pl. 39, fig. 4.
Murchisonia gracilis Salter, 1859. Can. Org. Rem., Decade I, pl. 5, fig. 1.
Murchisonia gracilis ? Whitfield, 1882. Geo. Wis., vol. IV, pl. 5, fig. 19.

Several imperfect specimens have been found that approach *M. gracilis* Hall, but that have the whorls less oblique, and also were much larger when perfect than those in the Trenton and Hudson series of Wisconsin and Minnesota. The specimen figured here has been distorted so that the whorls appear too little oblique and the spire too broad. Other specimens show that there were four or five more volutions below and there must have been as many more to form the upper part of the spire. They resemble in every way the figure of *M. gracilis* (Hall) Salter, from the Chazy or Black River limestone at Paquette's Rapids, Canada. But this is larger, with more numerous whorls and a greater apical angle than those of the Trenton of Wisconsin and Minnesota, and it seems to differ in the same way from Hall's figures of Trenton specimens from New York.

Murchisonia cf. *tricarinata* Hall.

A specimen probably belonging to this species was found at Highland Park and was identified by me, but was afterwards destroyed accidentally so that more exact comparison with the typical Trenton species is no longer possible.

GENUS OPHILETA.

Ophileta fausta, n. sp.

Plate III, figures 8 and 9

Coil of about three volutions nearly in the same plane; spire concave, the sides forming an angle of about 45°. The umbilicus is difficult to distinguish from the concave upper surface except by noting the direction of the aperture. The outer surface of each volution is gently convex, and joins to the upper and lower surfaces by acutely rounded angles, the lower one of which is perhaps a little the stronger. The upper and lower surfaces of each coil are about equally convex, and are nearly straight. The inner surface is quite straight, is equal in length to one-fourth the outer surface, and equal to once the outer surface of the volution with which it is in contact. Sutures deep on the cast. Surface smooth but marked by five transverse lines which run a little forward from the suture to the upper outer angle, thence obliquely down and back to the lower outer angle and from there curve a little forward to the contact with the penultimate whorl. Shell probably very thin.

Highland Park.

Genus Platyceras.

Platyceras vetulum n. sp.

Plate IV, figure 1.

Several specimens have been found which appear to belong all to the same species, although they vary in the form of the aperature and convexity of the body whorl, owing partly to distortion. In general the casts show that the shells were small, dextrally coiled, and had the body whorl proportionally very large. The spire or apex is not well preserved in any of the specimens, but was low, scarcely rising above the body whorl, and con sisted of one, possibly two whorls. The apeçature was ovate, narrowest on the side next the spire, and strongly indented by the penultimate whorl. The plane of the aperature is nearly parallel to the axis of the spire.

There is some resemblance in this species to very rapidly expanding shells of the genus *Holopea*. Unfortunately no specimens could be found sufficiently well preserved, and not enough of them, to allow of good generic diagnosis. The figure is of a large specimen.

Found at South Saint Paul.

Genus Pleurotomaria.

Pleutoromaria aiens n. sp.

Plate III, figures 16 and 17.

Shell large, consisting of about four volutions which are rapidly expanding and ventricose. The first volutions on interior casts are evenly rounded, but the last one on large specimens has a broadly rounded carina a little below the middle. Apical angle 120°. Suture deep. Aperture large, indented on the inner side by the penultimate volution. The margin curves back from the suture for nearly one-fourth of the last volution and then forward an equal distance, making a deep, rapidly narrowing fissure, the rounded apex of which forms the longitudinal ridge. The umbilicus is large and opens nearly to the apex. No surface markings except irregular growth lines.

Highland Park and South Saint Paul.

CEPHALOPADA.

Genus Orthoceras.

Orthoceras minnesotense n. sp.

Plate III, figures 11 and 12.

The only specimen is a fragment of the septate portion of the shell. In the length of about 30 mm. the dorsal and ventral sides converge from 30 mm. to 23, and in that length there are included eight septa. The transverse section is oval, probably broadest above. And the siphuncle, which is about five mm. in diameter, is placed five or six millimeters above the lower surface. The septa were strongly convex, and on the cast the sutures are seen to have been curved backward on the sides as shown in the figure. The surface was smooth and the shell very thin.

Found at South Saint Paul.

Orthoceras (?) sp. undet.

Plate III, figure 10.

Compare *O. montrealense* Billings, Canadaian Naturalist, vol. IV, p. 361.

A fragment of the shell showing numerous septa and fine longitudinal striæ and enough only to show what the circumference probably was is all that has been found of this species.

Highland Park.

Orthoceras sp. undet.

Plate III, figures 13 and 14.

This is a fragment probably of the siphuncle of an Orthoceras which shows no diminution in size at either end. The under side is the exact reverse of the side figured. It has probably suffered from compression since becoming fossilized.

From Highland Bark, Saint Paul, Minn.

BRACHIOPODA.

Genus Crania.

?*Crania reversa* n. sp.

Plate III, figures 6 and 7.

A single cast of a shell marked only by very indistinct concentric lines, with a nearly conical outline and centrally placed apex, has been found. Besides the general outline of a *Crania* it has what are probably a pair of large muscle scars, 1.5 mm. in diameter at half way between the apex and the posterior margin and about one mm. apart. Other characters can not be observed, but this appears to be the ventral valve of a *Crania*.

Found at Highland Park.

Genus Lingula.

Lingula morsii N. H. Winchell.

Plate IV, figures 2 and 3.

Lingulepis morsensis N. H. Winchell, Fourth Annual Report of the Geological and Natural History Survey of Minnesota (1876), p. 41, fig. 6, a, b, c.

Lingulepis morsii (Winchell) S. A. Miller (1889), American Geology and Paleontology, p. 352.

A few specimens of this species have been found near Fountain, Fillmore county, at the same exposure from which the type specimens are said to have been collected. They differ somewhat from the original description and figure but are no doubt the same. The shells are cuneate in outline, moderately convex, with an apical angle of about 50 to 60° (26°, Winchell). The surface is smooth, with but slight concentric growth marks, and of the usual green color, although in most specimens a deep iron coloration has taken place. Radiating (not concentric) elevated rounded striæ are present, strongest near the anterior margin.

The specimens figured are from one of the strata (*c.* fig. 9, pl. IV) of the transition at the base of the Trenton (Galena) group, near Fountain Minnesota.

GENUS ORTHIS.

Orthis perveta ? Conrad.

Plate IV, figure 4.

An imperfect specimen only was found, but so far as can be seen it is like those that occur in the Buff limestone of the Galena series, that rests above the shale [See pl. IV, fig. 9, c.] in which this one was preserved.

BRYOZOA.

GENUS PTILODICTYA.

Ptilodictya ? sp. ?

Plate III, figure 15.

The drawing illustrates an iron-stained imprint found at Highland Park. No distinct characters remain on the fossil except the ramose outline, and evidence that it was flattened in one dimension like some of the Bryozoa so abundant in the Trenton series.

PORIFERA (SPONGIA).

GENUS RAUFELLA.

Raufella ? *fucoida* n. sp.

Plate IV, figures 5 and 6.

The figures are of casts found at Fountain, Minnesota, associated with, even containing, fragments of *Lingula morsii* N. H. W. They have some imperfect surface marks which, together with the general form, suggest that they represent Porifera, the walls of which have served to mould sand into internal casts and have since entirely disappeared. The casts are cylindrical and branched at regular intervals like *Raufella filosa* Ulrich and some other sponges of the Trenton series, and very much like an undescribed species very abundant and associated with *Licrophycus ottawaense* Billings in the Fucoid bed.

General Discussion.

The species are, therefore, distributed paleontologically as follows:

MOLLUSCA—	LAMELLIBRANCHIATA—	*Cypricardites,*	4 species.
		Modiolopsis,	7 species.
		Tellinomya,	2 species.
	GASTEROPODA—	*Holopea,*	2 species.
		Murchisonia,	2 species.
		Ophileta,	1 species.
		Platyceras,	1 species.
		Pleurotomaria,	1 species.
	CEPHALOPODA—	*Orthoceras,*	3 species.
MOLLUSCOIDEA—	BRACHIOPODA—	*Crania, ?*	1 species.
		Lingula,	1 species.
		Orthis,	1 species.
	BRYOZOOA—?	donbtful,	1 species.
PORIFERA—	?	cf. *Raufella,*	1 species.
	Total,	14 genera,	28 species.

All the species of the Saint Peter sandstone are very similar to others in the overlying Trenton limestone. In fact, if all had been found in some stratum of the lower part of the Trenton (Galena) series instead of in the Saint Peter formation, their occurrence would not have been thought surprising. The similarity with Trenton species is far greater than the lithologic difference of the two formations had led geologists to expect. But the Saint Peter fauna is only molluscan, i. e., there are wanting in it the Coelenterata, Bryozoa, Crinoidea and Trilobita which are so abundant in the Trenton. These conditions seem to prove that a physical much more than a time break separates the two formations, for the species are but little different while the faunas as a whole are widely different. A comparison with the formation that underlies the Saint Peter, shows an opposite relation. The Shakopee fauna, so far as the writer has found, consists of a few species of Gasteropoda and Cephalopoda. It is like that of the Saint Peter sandstone in being molluscan, but the individual species are different, being of the Upper Calciferous type. It can be argued from these considerations that the Saint Peter is separated from the Shakopee rather by a time gap than by physical changes. The paleontological evidence is not to be exclusively relied upon, since it is drawn from too few specimens and these not all of the very best kind. But the evidence as we have it agrees essentially with that found by stratigraphical and lithological comparison.

PHYSICAL RELATIONS.

There is in general, an upper and lower division of the Saint Peter sandstone, as has often been suggested by writers who have studied the lithologic characters of the formation, and I can see also a faunal difference, although not a wide one. No one has ever found an exact division, however, even in a single locality and a division of the whole formation is not at all practicable. It must be considered for the present, at least, as an undivided unit. The extreme upper portion of the Saint Peter has been described sometimes as a transitional zone, which it really is, but whether it is clearly distinguishable as such from the main formation is not certain. At Fountain, there are such strata which could be arbitrarily separated where the shales begin, (see fig. 9, pl. IV). But these strata are not constant for any considerable distance. There are also transitional shaly strata with intermingled sand grains at the top of the Saint Peter at Minneapolis, which contain only Trenton fossils and belong to the Trenton. Transition strata are usually found but they are not necessarily equivalent those in one locality with those of another.

The Trenton has been everywhere conformably laid upon the Saint Peter sandstone, with usually a short transitional zone between them. Where the Trenton has been eroded away, the Drift, the Cretaceous, or the Carboniferous rests unconformably upon the Saint Peter, as already described above under the head of Geological distribution.

Upon the relation between the Saint Peter and the Shakopee below it geologists are not agreed as they are upon the transition between Saint Peter and Trenton. McGee (31) Keyes (32) and Norton (33) agree in pronouncing the Shakopee inseparable from the Saint Peter and include the former in the latter. They say that the former really passes by degrees into the latter. This theory does not agree with observations made by other writers. Hall in 1852 (9) describes this transition as abrupt. Chamberlin (21) says that brecciated pieces of dolomite occur in places in the lowest stratum of Saint Peter. Irving (22) writes that "between the periods of deposition of the lower Magnesian and the Saint Peter there was a long gap whose record is in the eroded surfaces of the first named formation." Moses Strong (23) held a similar view. Chamberlin, who wrote later (26) corecting the theory that the great inequality at the top of the "Magnesian" was due to erosion, and showing that the undulating surface was really due to folding of the upper part of the "Magnesian" i. e. Shakopee, still does not contradict Hall's statement that the transition is abrupt. I have not observed a real unconformability between the two formations but such may exist, and the contact has been found an abrupt one as often as observed at all. In Iowa no exposed contact has yet been found by me. The Shakopee consists not only of dolomite but of more or less sandy strata and sometimes clay, and it may be that these sandy strata have been considered as a continuation downwards of the Saint Peter, a view that would require first other evidence to prove. It is contradicted really by the paleontological and stratigraphic evidence that we now have.

The Saint Peter folds conformably with the Shakopee, and the contact can be sometimes at least exactly marked because it is an abrupt transition. It is also conformable to the Trenton with a transition of alternating strata or of mixed materials. The Shakopee and Trenton are not however parallel to each other, for as well known the former is much folded while the latter is almost exactly horizontal, the Saint Peter between them being consequently of unequal depth. It was naturally supposed by geologists that the folding of the Shakopee was completed before the deposition of the Saint Peter began and that may still be supposed correct in part but not entirely.

Figure 10, plate 4 is a sketch of an exposed contact of the last member of the Magnesian series (i. e. Shakopee proper) and the base of the Saint Peter formation, as seen along the Illinois Central Ry., at the crossing of the Chicago Milwaukee and Saint Paul Ry., in LaFayette county, Wisconsin, a few miles north of the Illinois-Wisconsin state line. It represests one of the extreme cases of folding seen in the Peccatonica valley and is chiefly interesting in that the two feet of shale which is always found at the top of the Shakopee in that region is preserved beneath the sandstone undiminished except by compression. Had the folding taken place before a considerable depth, 20 feet or more, of sand was deposited, the shale would have fallen from the eminence by its own weight or at least been washed down by the water. The sandstone in this exposure is somewhat confused by compression yet it can be seen that here as at other exposures in the Peccatonica valley the stratification of the Saint Peter is conformable to the Shakopee. The upper surface of the Shakopee i. e. at the contact, is ripple marked.

There are small faults as described in a former paper (see 30., p. 354. fig. 4.) which extend upwards from the base of the Saint Peter formation through the sandstone, about half way up to the Trenton.

These phenomena were considered to be evidence that the Saint Peter was deposited partly before and partly after the folding of the Shakopee. Of this I shall speak again in discussing the origin of the sandstone.

STRATIGRAPHIC POSITION.

The position of the Saint Peter is of course clearly, between the Lower Buff limestone of the Galena (Trenton) series above, and the Shakopee dolomite of the Magnesian series below. It is conformable to both. Paleontologically it is closest united to the Galena (Trenton) series above it. Lithologically it belongs to the "Magnesian" series with the Shakopee, for it stands as the last of that series of sandstones and dolomites, and does not unite with the Galena (Trenton) series which consists of limestones and clays without sandstone. A time break seems to separate the Saint Peter from the Shakopee, while a physical revolution separates it from the Galena series. It thus appears to be a transition formation between the Magnesian series or Upper Cambrian and the Lower Silurian, and it has been so considered (30).

But that the Saint Peter represents the lowest member of the Ordovician (Lower Silurian) as understood by that term in England and in New York, is not unconditionally asserted. In fact, the Shakopee may be proved to be the lowest member of the Ordovician, when more exactly correlated.

CORRELATION.

The period to which the Saint Peter belongs is by far the most easily determined through its relation to the Galena (Trenton) series, which is richly fossiliferous. The Magnesian series also affords a means of determination because fairly fossiliferous. James Hall and J. D. Whitney (8) in 1858 correlated the Saint Peter, in this indirect way, with the Chazy of New York. Hall again in 1862 and in 1863 repeats it, and nearly all geologists have followed his correlation, hence the name Trenton, which belongs typically to a New York formation, has been equally applied to parts of the Trenton (Galena) series that overlie the Saint Peter. The Trenton series of New York and Trenton (Galena) series of the upper Mississippi valley are correlated. There is, nevertheless, diversity of opinion over the question, what part of the Galena (Trenton) series is equivalent to the Trenton formation proper of the New York Trenton series; what part equals the Black River formation; and what the Chazy.

By many geologists, the Galena (Trenton) series is believed to include only the equivalents of the Black River limestone and Trenton limestone proper, the equivalents of the former being called Trenton and that of the latter Galena limestone. The Saint Peter thus remains to be correlated with the Chazy.

This correlation cannot be said to be undoubtedly established, but represents the extent of our knowledge. It is here inserted because it takes the place necessarily of a direct comparison of the Chazy and Saint Peter faunas, both of which are relatively meagre.

The two formations, Shakopee and Oneota, beneath the Saint Peter faunally correlate well with the Upper and Lower Calciferous respectively, which underlie the Chazy proper, and they also correspond in their relation to each other and to the overlying formations.

Like that of New York, the formation called Chazy in Canada seems to hold a stratigraphic position comparable to that of the Saint Peter sandstone, and, as Joseph F. James (34, p. 131) has pointed out, it is in a way a transition between the Chazy proper and the Saint Peter, since it is neither chiefly limestone like the former nor pure sandstone like the latter, and since it lies geographically intermediate.

The Saccharoidal sandstone in Missouri* was believed to be the equivalent of the Saint Peter by Meek, as also by Shumard (loc. cit.), and more particularly by Worthen (12). In fact the Saccharoidal sandstone is lithologically and stratigraphically like the Saint Peter. Mr. Meek found fossils in it, but unfortunately they have never been described. No new evidence has since been added. Charles R. Keyes has recently doubted that the "Saccharoidal" sandstone is the representative of the Saint Peter in Missouri,† the latter being, as he thinks, either absent or represented by a limestone. He gives no reasons for this new departure.

ORIGIN.

Keating, who was surprised, like many other explorers, at the purity of the Saint Peter sandstone, mentions someone's theory "that this sandstone must have been formed by a chemical precipitation and not by mere mechanical deposition." (See 4, p. 330.) Owen, on the contrary, never mentions anything but sedimentary phenomena in his descriptions of the formation. Hall and Whitney (8) adopted the chemical theory to explain the purity, although apparently but once.

The Saint Peter sandstone is a mechanical sediment and consists of quartz grains such as come from the erosion and decomposition of acidic eruptive rocks (see Chamberlin, 26). Its structure is that of a mechanical sediment. It contains marine fossils. One must therefore explain the purity of the stone in some other way than that which explains the purity in salt and gypsum deposits. But no explanation offers itself readily.

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* See Geological Survey of Missouri, 1st Ann. Rep. (1853) pp. 117 and 197; 2nd An. Rep. (1854) pp. 105, 145 and 160.

† Missouri Geological Survey, vol. 4, pp. 30. 35 and 38.

In the first place, with the exception of the very small percentage of kaolin the impurities distributed through the Saint Peter sandstone can be and evidently should be considered as recent infiltrations. Therefore the stone was once an almost absolutely pure quartz. In the second place, there are fossil casts in the white sandstone; these must have been produced by calcareous shells, although the shells themselves have been dissolved away so thoroughly as to leave no stain nor trace of their substance. Still other fossils are moulds of former internal casts as already described. The moulds are now full of loose sand, which together with soluble materials, probably, for the most part, calcium carbonate, formerly composed the internal casts from which the moulds are preserved. The amount of quartz sand as compared with the now missing soluble materials, seems to be less than half the content of the moulds. The question suggests itself: Could the strata of the Saint Peter have been originally one-half calcium carbonate? Was the formation originally a calcareous sandy mixture, which later became pure quartz by the chemical action of water?

The Saint Peter strata constitute a sandstone in the highest degree porous and water flows through it readily, so that the very best circumstances for infiltration and exfiltration are now afforded by it. It could have been for long periods a perfect underground waterway. It is, in fact, situated next under a series of clay, marl, and limestone formations that are more impervious to water, while beneath it are sandstones and somewhat porous dolomites through which water could pass somewhat readily. The exposed, eroded, and glaciated border of these formations is at the same time their more elevated portion, so that water sinking into any of them would be carried deeper as it coursed in the direction of the stratification. The water in the Saint Peter would be held back by the impervious strata above it, while that in the strata beneath could break upwards through the dolomites and sands into the Saint Peter, which latter thus would be the main underground waterway. This may explain why the sandstone is now so pure, for much calcium carbonate and other constituents could have been carried from the formation by coursing waters.

Such considerations may be used to explain other phenomena as well. It has been shown that the folding of the Shakopee took place at last partly after the sandstone was deposited upon it. (See fig. 10, pl. 4.) The folding is similar to that produced by lateral pressure, except that for some reason the top and not the base of the Magnesian series is involved in it. The Shakopee is very strongly arched here and there and the top of the Oneota likewise, but before the base of the latter is reached the undulation disappears, except in one or two localities, near the city of Saint Peter, Minnesota, for example, and there the underlying Jordan sandstone is pure like typical Saint Peter. The Saint Lawrence formation is not seen to be folded.

In view of the facts as given above, I am constrained to set forth a theory, without, however, considering it as conclusively proved, that the purity of the Saint Peter sandstone, the paucity of its fossils and its variable depth are all due to the effect of percolating waters and were not original characters, and, further, that the supposed unconformability at its base may have been produced solely in this manner. That is, that the Saint Peter has simply had all soluble material washed out of it, that it is thus reduced in thickness, and that the now dolomitic formations immediately beneath have been attacked in a similar manner and reduced—the whole process causing a shifting of the sand sufficient to produce inequalities in its thickness.

The great mass of Silurian and Devonian rocks resting upon the Saint Peter have not been reduced in that manner, nor to the same extent, but have preserved an unbending crust, while the Middle Cambrian sandstones below the Oneota formation remained likewise rigid. Inequalities produced during the reduction of the Saint Peter and Magnesian series also must have caused shifting and readjustment, and naturally these would culminate intermediately between the firm overlying and underlying formations. that is, in the formations that were being most reduced. This may explain why the folding begins midway in the Oneota, culminates at the base of the Saint Peter, and ends below the top of the same.

Heretofore geologists have considered the Saint Peter sandstone as originally deposited in an almost chemically pure condition. One argument against this view lies in the peculiar preservation of its fossils. Again a fair degree of purity is generally found, and all the exposed portions of the formation alike exhibit the conditions necessary for the theoretical origin that has been pointed out. Still it remains that this formation is unique among the Mississippi valley sandstones of Eopaleozoic time.

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November 13, 1892.

[*Paper E.*]

THE RUM RIVER VALLEY AS A BOTANICAL DISTRICT.

E. P. Sheldon.

The Rum river, with its tributaries, drains the surface area of Mille Lacs, Isanti and Anoka counties. Besides this, portions of Crow Wing and Aitkin contributory to Mille Lacs lake, and the eastern edge of Morrison, Benton and Sherburne counties are in its drainage basin. The valley is thus seen to occupy a narrow strip lying between the Mississippi drainage on the west and the St. Croix on the east.

Within this narrow belt the most varied conditions for plant growth are offered. It is to be noted that this section is between that contributory area on the north and east from which we would most naturally expect the entrance of plants usually found occurring wherever large coniferous belts are extant; and the prairie-plant-contributing area on the south and west, from whence we would expect the great host of prairie composites, pulses, grasses, etc.

Viewed in this light a study of the plant immigrants now seeking a foothold in the valley becomes as interesting as a review of the endemic plants. But we must remember that in a very recent time in the history of our continent the plants now considered endemic were emigrants from the

PLATE II

1, 2 and 3. *Cypricardites* (*Vanuxemia*) *fragosus* n. sp. (1) The right valve of a large specimen. (2) Anterior muscle scar and cardinal teeth of a left valve. (3) The concave cast of the anterior portion of a specimen showing the deep muscle scars, the articulation of the cardinal teeth and a section cutting off the anterior ear and the umbones.

4 and 5. *Cypricardites dignus* n. sp. (4) Right valve of the largest specimen, and (5) left valve of another showing a little variation in form.

6. *Cypricardites* (?) *finitimus* n, sp.

7. *Cypricardites descriptus* n. sp.

8. *Modiolopsis contigua* n. sp. The upper anterior margin is imperfect.

9. *Modiolopsis affinis* n. sp.

10, 11 and 12. *Modiolopsis gregalis* n. sp. (10) Left valve of an average sized specimen and (11) (12) cross sections of another specimen at one-fourth and two-thirds the distance from the anterior end respectively.

13, 14, 15 and 16. *Modiolopsis litoralis* n. sp. (13) Cast of an average specimen; (14) (15) (16) sections at three-fourths, one-half and one-third the distance from the anterior end.

17. *Modiolopsis senecta* n. sp. Figure of the only specimen seen.

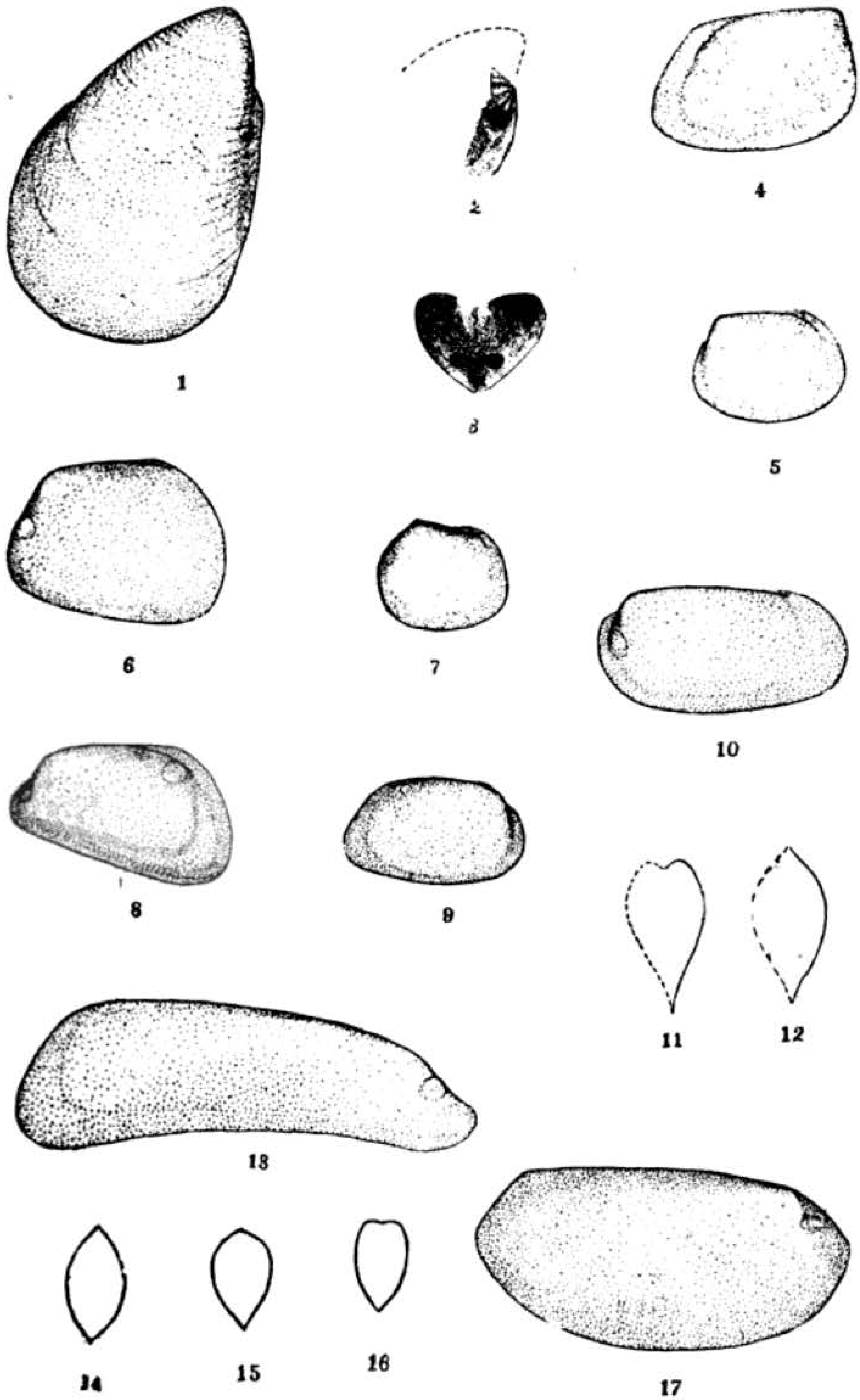
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PLATE III

1 and 2. *Tellinomya absimilis* n. sp.

3. *Tellinomya novicia* n. sp.

4. *Murchisonia gracilis* Hall.

5. *Holopea obliqua* Hall.

6 and 7. *Crania ? reversa* n. sp.

8 and 9. *Ophileta fausta* n. sp. (8) Outer surface of part of the last volution showing the direction of the transverse striæ, and a transverse section of the same specimen. (9) Coil of an imperfect cast.

10. *Orthoceras* (?) sp. undet. Cast of a fragment of the shell and reconstructed circumference.

11 and 12. *Orthoceras minnesotense* n. sp. (1) View from the left side and (12) from the smaller end of the fragment.

13 and 14. Siphuncle of an *Orthoceras* with a transverse section of the same.

15. Bryozoon (*Ptilodictya ?*).

16 and 17. *Pleurotomaria aiens* n. sp. (16) View showing the deep notch in the aperture and (17) apical view of the same specimen.

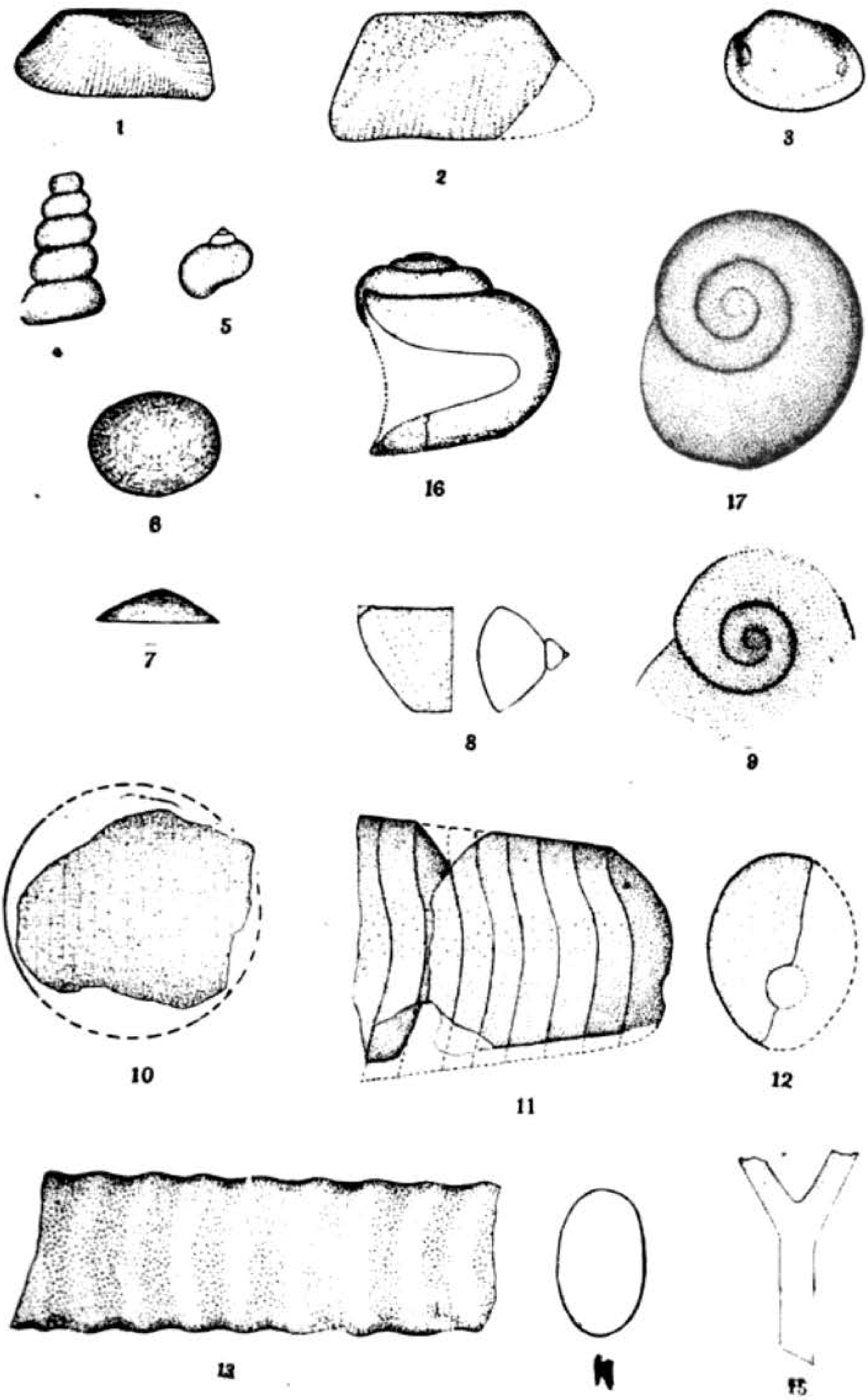
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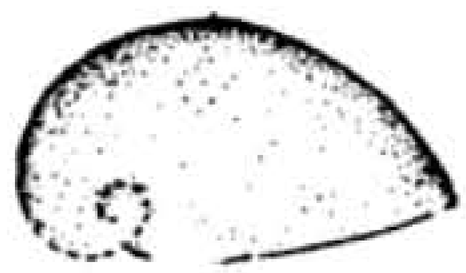
PLATE IV

1. *Platyceras ? vetulum* n. sp. Apical view.
2 and 3. *Lingula morsii* N. H. Winchell. Outline of a cast (2) and of a shell (3). Both specimens are under the average size.
4. *Orthis* cf. *perveta* Conrad. From an imperfect cast of a ventral valve.
5 and 6. *Raufella fucoida* n. sp.
7. *Modiolopsis fountainensis* n. sp. Cast of right valve.
8. *Modiolopsis postica* n. sp.
9. Transition from Saint Peter to Trenton near Fountain.
   a. Coarse sand and small ferruginous pebbles and argillaceous shale.
   b. Coarse light yellow sand; 3 feet 6 inches, variable.
   c. Argilaceous shale, mixed with sand and lime at the top and bottom; 4 feet.
   d. Coarse sand.
   e. Firmer ferruginous laminæ.

The formations above and below these strata are characteristic Trenton and Saint Peter.

10. Contact of Shakopee and Saint Peter formations near Pickett Station, Wisconsin.
   a. Saint Peter.
   b. Green shale laminæ.
   c. Dolomite, much folded, exposed in elevation about 20 feet.
   a b c. Illinois Central railway track.



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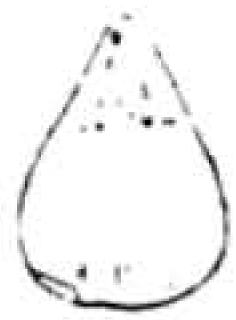

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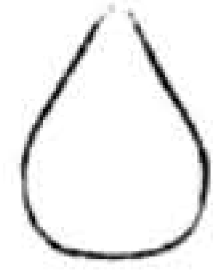

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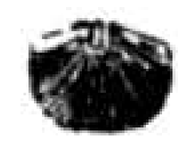

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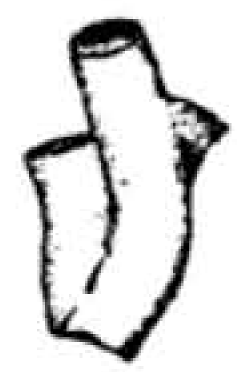

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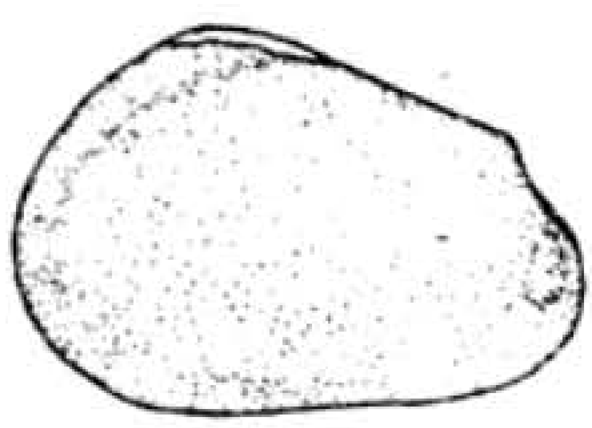

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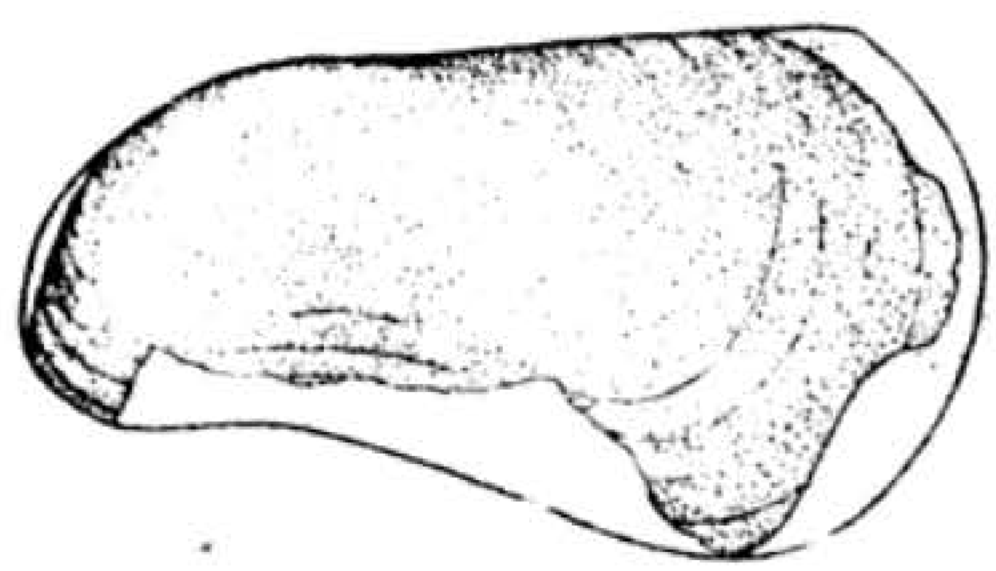

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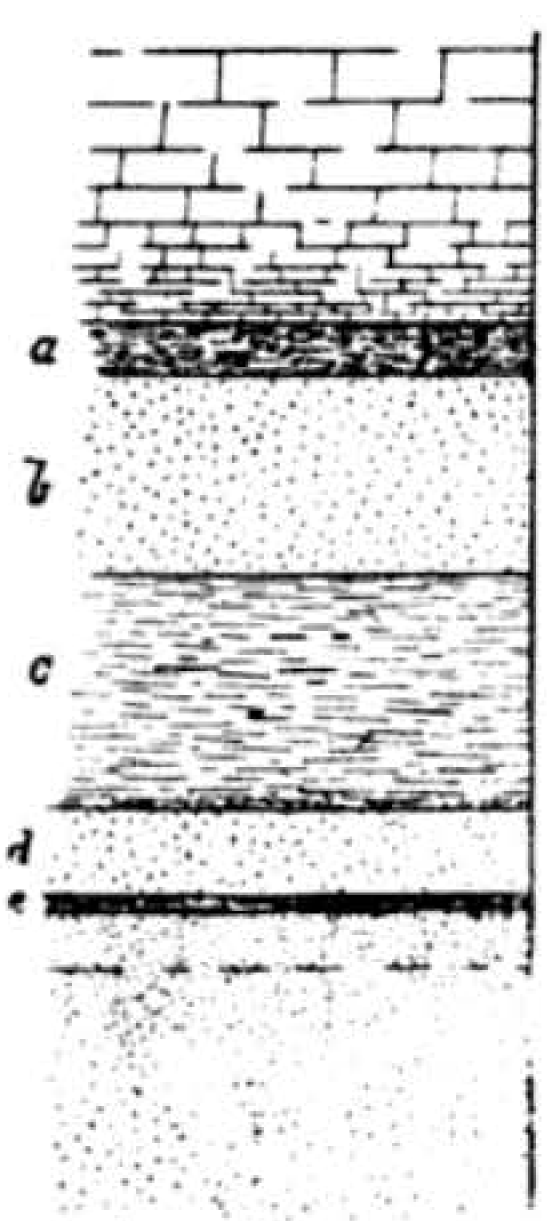

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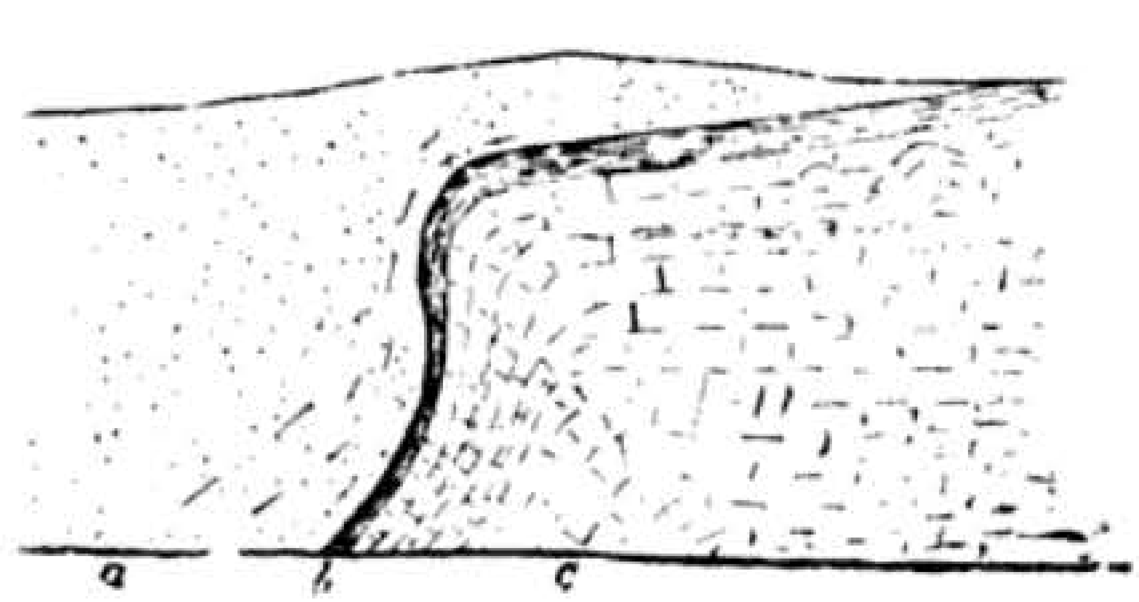

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