T H E S I S

THE DIFFERENTIATION OF RACES IN THE PALEOZOIC BRACHIOPOD LEPTAENA RHOMBOIDALIS WILCKENS.

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TABLE OF CONTENTS.

THE GEOLOGIC RACES (continued) Page

TABLE OF PLATES.

FOREWORD.

This study of the races of the Paleozoic brachipod, Leptaena rhomboidalis Wilckens, was undertaken at the suggestion of Professor H. W. Shimer as a problem well suited to illustrate methods of paleontological research. Work was begun on the specimens in the collection of the Geological Department and was pursued more or less continuously during spare time from October to December of last year. Then, after I had gained something of an insight into the problem at hand, it was continued, through the kindness of Professor P. E. Raymond, by the aid of specimens in the much more extensive collections in the Museum of Comparative Zoology of Harvard University. When, in February of this year, the subject of a thesis was to be decided upon, Professor Sedgwick suggested that this work be continued and suitably written up in fulfillment of the thesis requirement, and signified his willingness to accept from a student in the Department of Biology work done on the biology of the past.

I am, therefore, duly grateful to Professor Sedgwick for permission to continue that which must soon have been set aside, and feel especially appreci-

ative of the encouragement which he has so frequently given. To Professor Raymond of Harvard University I am under great obligations, both for courtesies in his laboratory and for access to old and rare publications in the Museum Library, without which I should have been severely handicapped. And lastly, I desire especially to express my gratitude and feeling of indebtedness to Professor Shimer, not only for his assistance and guidance in the present work, but more for the appreciation of fossil life which he has given me.

GENERAL DISCUSSION.

The ancient class Brachiopoda consists of bivalved animals with inequivalved, equilateral shells, often attached to foreign objects by a posterior prolongation of the body, the pedicle, or cemented ventrally. The shell and general appearance notwithstanding, brachiopods are not mollusks; but are more primitive in general organization, being most closely allied with the Bryozoa, minute encrusting colonial animals, with which they form the phylum Molluscoidea.

They were, and the few survivors still are, exclusively marine, and often formed beds of extensive area in favorable Paleozoic seas. They were present in the lowest Cambrian, they achieved their acme in the course of the Paleozoic, and, numerically considered, have been in a decline ever since. Though the one hundred and sixty living species now known are not often considered by the general student of present-day life, many of the seven thousand or more fossil species have proved to be of the utmost importance to stratigraphers and more have been carefully studied by paleozoölogists.

Leptaena rhomboidalis Wilckens, the species considered in the present paper, is an articulated brachiopod (i. e., provided with interlocking teeth and sockets at the hinge-line), and has the pedicle opening restricted to the ventral valve and to the period of early growth. As is the case, with but one exception, in the sub-family in which Leptaena is placed, the ventral or pedicle valve is more or less convex and the dorsal or brachial valve is concave. Shells of the species range in shape from quadrilateral, where the anterior margin is parallel to the posterior margin (the hinge-line), and the sides are nearly parallel; through other forms where the anterior margin is rounded and the sides diverge toward the hinge-line; to extreme forms in which the hinge-line, always straight, is enormously extended beyond the breadth of the shell and causes it to assume a spread-wing appearance.

The most salient external characters are:

I. Undulations or corrugations in the shell substance concentric about the beak;

II. A more or less abrupt downward deflection of the anterior margin of the convex, pedicle valve, to which, of course, the brachial valve must also conform; and

III. Striae which radiate from the region of the beak.

It is these three external characters, together with the shape, which have been principally considered in differentiating the geologic races.

The species, as ordinarily defined, is one of wide geographical distribution, and of extraordinary geological persistence (from the Trenton formation of the Ordovician period to the Waverly of the Mississippian), and, due to its common occurrence and early recognition in 1769 by Wilckens, possesses a bibliography and synonymy equalled in extensiveness by few forms, living or dead.

In the middle Ordovician, when L. rhomboidalis is first known to appear, it occurs sparingly in the Trenton deposits of New York, and as occasional or imperfect specimens, in rocks of nearly equivalent age from several other regions. In the upper Ordovician, it occurs abundantly in the Richmond of the Ohio River valley and is reported from the Lyckholm and Borkholm of Esthonia and from the sandstones of the Caradoc in Wales. In the Silurian period, the shell is common in eastern North America, in England, the Continent, Sweden, Russia, Gotland. Finally, during the Devonian and early Missis-

sippian, the species attains its greatest dispersion and is then, according to Schuchert, almost of world-wide distribution.

While several genera of the Brachiopoda as Lingula (Cambrian to the Present!) and Rhynchonella (Ordovician to the Eocene) have, as genera, persisted from early Paleozoic to Cenozoic times, no species, as such, ever persisted so doggedly as Leptaena rhomboidalis (Ordovician to the Mississippian). In North America, of three hundred nineteen Ordovician species of brachiopods, but five, including L. rhomboidalis, passed into Silurian times and none of these originated in the Cambrian. Of three hundred eleven Silurian species, but four passed into Devonian times, and of these L. rhomboidalis, alone, originated in a pre-Silurian formation. Of six hundred sixty-three Devonian species, but eleven passed into the Mississippian, of which L. rhomboidalis, again, could alone boast of a pre-Devonian origin. Leptaena rhomboidalis (the L. analoga of Phillips) became extinct rather early in the Mississippian period, a veritable Methuselah of the Brachiopods; and it is noteworthy in continuing the comparison that none of the four hundred seventy-eight Carboniferous species were able to survive the rigorous transition to the Mesozoic. (Data compiled

CHRONOLOGIC CLASSIFICATION

of

PALEOZOIC TIME.

Eras	Periods	Subdivisions
Carboniferous	Upper Carboniferous	
	Middle Carboniferous	Waverly
	Lower Carboniferous	Kinderhook
Devonian	Upper Devonian	Chatauquan Senecan
	Middle Devonian	Erian Onondaga (Cornif.)
	Lower Devonian	Oriskanian Helderbergian
Silurian	Upper Silurian	Cayugan
	Middle Silurian	Niagaran
	Lower Silurian	Oswegan
Ordovician	Upper Ordovician	Cincinnatian Richmond
	Middle Ordovician	Mohawkian Trenton
	Lower Ordivician	Canadian
Cambrian		

from Schuchert's Bibliography of 1897 .)

As might be expected in a species of so venerable an existence, variation among individuals of the same geologic age and the differentiation of individuals of different ages is relatively slight; else the species would have quickly ceased to exist beyond question. That there is some differentiation, however, quite naturally led to a number of specific names, which were usually ignored or else misapplied by later geologists. On the other hand, the variation in individuals from the same beds was sometimes such as to allow many to uphold the union of forms under Wilcken's species.

Many feel, however, that this latter view has been carried altogether too far. It would seem to dull the perceptions of the field-worker to be able to dispose of nearly all deflected and corrugated Leptaenas, from whatever stratum, as L. rhomboidalis. It would seem, also, to invite a habit of approximation and of unwarranted generalization, both of which, in my opinion, lead to more disastrous results in science than the evil of hair-splitting. It appears quite as justifiable, too, to consider some of the geologic races as species which often tend toward individual variation, and it must be appreciated that many of the so-called intermediate forms are <u>not</u> intermediate geologically

or in a true sense; but only aberrant forms, varying about the type of a particular formation, which simulate the typical form of some other formation, distant by thousands or perhaps millions of years.

A recent reprint of an address by the President of the Paleontological Society, R. Ruedemann, at Albany, December, 1916, entitled "The Paleontology of Arrested Evolution," contains a discussion of the persistence of species, in which the following pertinent and antithetical views of L. rhomboidalis are expressed:

> "Among the brachiopods such types as Atrypa reticularis, which ranges through the Silurian and Devonian throughout the world, and Leptaena rhomboidalis, which ranges from the Ordovician (Trenton) into the Lower Carboniferous (Waverly) in America and Europe, come here readily to mind. Also the coral Halysites catenulatus . . . . . Some of these, as Halysites, belong under the heading of persistent sessile forms; the others, as A. reticularis and L. rhomboidalis, are clearly forms of extreme robustness and fertility but slight variability.
>
> "That the persistence of these species is more or less relative was interestingly brought out in a discussion at the New Haven meeting (1912) of the Paleontological Society, when Prof. H. S. Williams mentioned L. rhomboidalis as a form that is persistent because it is a form of great plasticity and very variable in every locality and horizon where it occurs; therefore, he believes it has not been separated although its differences are as great as those of several genera, like Leptostrophia and Stropheodonta. Dr. E. O. Ulrich asserted that it is not so variable in each place, there being but little variation of

> individuals; but that it is made up of a multitude of species of different horizons that can be distinguished. Dr. A. G. Foerste has, indeed, distinguished some of these species. The fact that Leptaena rhomboidalis has so long been left undivided by paleontologists who are ever ready to distinguish species would still indicate that it represents a long-existing compact group of little changing forms of a relatively persistent type."

That L. rhomboidalis is a species of extreme robustness and fertility can scarcely be denied, and much of the difference of opinion in regard to variability, I suggest, is due to a difference in definition. In so far as L. rhomboidalis, throughout its range, is always possessed of concentric corrugations, of radiating striae, of marginal deflection, and can readily be recognized, it does represent "a long-existing compact group of little changing forms." Yet in as much as the concentric corrugations, the radial striae, the deflection, the shape, and other characters undergo change from time to time in the shell's history, there <u>is</u> variation.

Personally, I should scarcely consider it, with Professor Williams, a form of great plasticity, for I think the changes in the shell are astoundingly slight for an existence which must have been upwards of twenty-five millions of years. There was, of course, functional plasticity or adaptability, which is little more

than another way of expressing "extreme robustness."

Results obtained by measuring and examining small series of several of the races from known localities lead me to believe that in some instances, at least, a considerable individual variation in certain characters obtains. The general appearance, shell texture, and the like are usually closely similar in such series, due largely, in my opinion, to the identical conditions of fossilization.

A partial solution of the problem undoubtedly lies in the multiplicity of geologic races. That helps considerably to explain "the fact that L. rhomboidalis has so long been left undivided by paleontologists who are ever ready to distinguish species." With this multiplicity of races, the abundance of material, and the immensity of the geologic time involved, the whole question, indeed, becomes exceedingly complex and particularly liable to confusion.

Up to the present time, to my knowledge, no attempt has been made to examine and correlate all the reported forms on the basis of their stratigraphical occurrence and of their distinctness, and this has become one of the main purposes of the investigations reported in the present paper, though mention is made of such unnamed forms as give promise of specificity.

It had been hoped to develop the subject somewhat on the basis of postulated relationship; but this was early abandoned in view of the uneven merit of the evidence. It was obvious, too, that the status of L. rhomboidalis was not sufficiently determined to warrant speculation and that the time was not yet when, because of its wide dispersion, abundance, and preservation, it could do great service in demonstrating the paths of migration and the intercommunication of ocean basins. The necessity, therefore, of dealing much with technical descriptions, that the way for future work might be more clear, early determined the division of this paper into the present "General Discussion," and the following "Account of the Geologic Races, Their Occurrence and Distinctness."

TABLE OF THE GENERIC SYNONYMS

of LEPTAENA RHOMBOIDALIS.

1769 Conchita (rhomboidalis) WILCKENS. Nachricht von seltenen Versteinerungen p. 79, pl. VIII, fig. 43, 44.

1821 Anomites (rhomboidalis) WAHLENBERG. Nova Act Soc. Sci. Upsalae, vol. VIII, p. 65.

1823 Producta (depressa) SOWERBY. Mineral Conchology, p. 86, pl. CCCCLIX, fig. 3.

1828 Leptaena (rugosa) DALMAN. Uppställning och Beskrifning af de i Sverige funne Terebratuliter; Kongl. Veternskaps-Acad. Handlingar. pp. 94-96, 106, 107. pl1.

1837 Orthis (rugosa) von BUCH. Ueber Delthyris oder Spirifer und Orthis p. 30.

1841 Strophomena CONRAD. Fifth Ann. Rep't. N. Y. Geol. Survey.

1844 Leptagonia McCOY. Synopsis Carb. Fossils. Ireland.

1877 Plectambonites DALL. Bull. No. 8, U. S. Nat. Mus.

HISTORY OF THE GENUS LEPTAENA with especial REFERENCE to LEPTAENA RHOMBOIDALIS WILCKENS.

Though Christian Friedrich Wilckens, in 1769, was the first to name, describe, and figure the brachiopod now universally known as L. rhomboidalis Wilckens, only the specific name has actually survived from his designation of two specimens, Conchitas rhomboidales anomios inequilateros; for Conchita, as a generic name, was rendered unavailable by Karl von Linné's use of Conchites (Mus. Tess., p. 88, 1753) to refer to a fossil brachiopod, now indeterminable, and the latter part, "anomios inequilateros," is not only unnecessary, with our present knowledge and scheme of classification, but is a violation of the rule of binomial nomenclature.

In 1821, when Wahlenberg discussed the species, he properly retained Wilckens' specific name, but substituted Anomites for Conchita. That term, however, had been previously used by Martin (Petrif. Derb., 1809) as a synonym for the older generic name, Terebratula. Neither Conchita nor Anomites were, therefore, available.

In 1823 Sowerby, in his Mineral Conchology, described a Silurian form of England as Producta depressa, and Producta might then have become the name of the

genus containing L. rhomboidalis and its allies, had he not used it some ten years previous (Sowerby, Min. Conch., I, 1814, p. 153) with reference to a quite different species.

Hisinger, in 1826, (Acta. Acad. Sci. Holm., p. 333) described Producta rugosa(= L. rhomboidalis), but Dalman, in 1828 (Kongl. Vetenrskaps-Academiens Handlingar, för ar 1827, pp. 94-96), in discussing Producta rugosa HISINGER, first conferred the present generic name Leptaena, and Producta rugosa HIS. (synonym of L. rhomboidalis) thus became the genotype of the genus Leptaena. In the same paper, unfortunately, in addition to another true Leptaena (L. depressa Sowerby), two other species not co-generic with Producta rugosa were also included in the genus; namely, L. englypha (now Strophonella HALL, 1879) and L. transversalis (now Plectambonites PANDER, 1830). In general, however, for the next thirty years, the correct usage largely obtained.

Yet, in 1837, von Buch (Ueber Delthyris oder Spirifer and Orthis, p. 30) wrongly applied Orthis to what is now the genus Leptaena, and McCoy, laboring under a misapprehension, in 1844 (Synopsis Carb. Foss. Ireland, p. 116), proposed the new term Leptagonia.

And next, through the efforts to systemize the nomenclature, Leptaena became involved in an intricate

tangle with Strophomena (RAFINESQUE, 1820) DeBLAINVILLE, 1825. Conrad, in 1841 (Fifth Ann. Rep't, N. Y. Geol. Survey) and Vanuxem, in 1842 (Geol. N. Y. Rep't, 3rd Dist., p. 79), both used Strophomena in this sense. Then Hall, in Paleont. of N. Y., III, p. 175, reported that specimens of L. rhomboidalis from Rafinesque's collection in the possession of Mr. Charles D. Poulson of Philadelphia, labelled Strophomena rugosa in the handwriting of Rafinesque himself, were the only examples of "Strophomena" known from that source, and raised the question whether, since Rafinesque's genotype was only known on DeBlainville's say-so, L. rhomboidalis should not therefore become the genotype of Strophomena. Davidson, in England, somewhat later, defined the genus as including forms with normal convexity of valves (Rafinesquina, HALL, 1892), with reversed convexity (genotype= Strophomena rugosa), or with the typical corrugations and deflections of L. rhomboidalis and its allies, and long upheld his view.

Finally, although great difference of opinion at first existed, Strophomena rhomboidalis was restored to its proper genus Leptaena, and those forms which had been extensively known as Leptaena, from Dalman's fourth form (L. transversalis), were placed in Pander's genus Plectambonites.

With the present usage, Leptaena now resembles most closely the genus Rafinesquina, a further division of the old genus Strophomena, and there are a few species, as Rafinesquina (Leptaena) deltoidea CONRAD, L. unicostata MEEK and WORTHEN, and others, which are intermediate in character. Moreover, concentrically wrinkled species in the genera Strophomena, Strophonella, and Stropheodenta do occur. This is especially unfortunate, since so much importance is usually placed on the external characters of corrugation and deflection in Leptaena, and undoubtedly does some injury to the status of the genus.

A DESCRIPTION AND DISCUSSION of the REPORTED GEOLOGIC RACES as THEY OCCUR in SUCCESSIVE STRATA.

Ordovician Period.

Shells belonging to the genus Leptaena have been reported from North America in the Chazy limestone (Lower Ordovician) of New York, but have never been referred to L. rhomboidalis or to any of its sub-species. The name L. incrassata was conferred by Hall in 1849 (Pal. N. Y., I, p. 17, pl. 4) upon this species, which has since been found to range up into the Black River (Middle Ordovician).

The L. charlottae of Winchell and Schuchert (Amer. Geol., 9, Apr. 1, 1892) is another and later Leptaena (Black River [Decorah] of Minneapolis and St. Paul, Minnesota) which also has not been included among the extensive synonymry of L. rhomboidalis. It is interesting to note that distinct concentric wrinkles are not yet developed and that the radial striae are apparently intermediate between the marked alternation in size in Rafinesquinas and the greater uniformity and evenness in Leptaenas. The following characterization will give a suggestion as to the appearance of this species, rather better, perhaps, than a reproduction of the very poor figures of plate 32, volume 3, of the

Middle Ordovician.

Minnesota Geological Survey, 1893.

L. charlottae is a small, transversely semi-oval Leptaena. The surface is marked with fine, closely crowded, alternating striae as in Rafinesquina alternata, crossed by exceedingly delicate concentric lines, and bears on the central flat disk of each valve more or less continuous zig-zag wrinkles.

Leptaena rhomboidalis is considered first to appear in this country as occasional, stunted, or imperfect specimens in deposits of Trenton age. I have, as yet, no reference to an earlier occurrence or, indeed, to one of exact equivalence in Europe or elsewhere. Yet there is nothing known at present, I believe, which would warrant a postulated birthplace in this country, if a common origin for all the forms is to be postulated at all. No attempt has been made by me to study the two small species briefly mentioned above, much less to examine Rafinesquina and the allied genera for those species of questionable affinity which might prove to be of great significance. It would probably be easier, in determining the relationship of these early Leptaenas, to

Trenton, Ordovician.

examine all the corrugated and deflected brachiopods of Lower and Middle Ordovician strata, without reference to genus, if one could.

In Part VI, Vol. I, page 108, of the Natural History of New York, James Hall, in 1847, makes the first mention of the Trenton form of L. rhomboidalis in this country. Since a form from the Caradoc of Wales (Upper Ordovician) had, some eight years previous, been figured and described in Murchison's Silurian System by J. deC. Sowerby, Hall blindly reported his shells as L. tenuistriata Sowerby, a form which they seem in no way to have resembled. He says:

> "This species of Mr. Sowerby to which ours bears a close analogy is generally regarded as identical with L. depressa; but I am by no means satisfied that it is not really different. In all the specimens which I have seen the shell has a different aspect, is not so rounded, and is less regularly wrinkled. I have not been able to see the internal structure which will eventually decide the difference between the two shells. . . . .
>
> "Position and Locality.--This species, though very rare in most localities where the other forms of this genus are found, is sometimes seen in other associations near the higher part of the limestone. It is unknown to me in the Hudson River group, though at the west it is found in a similar position. It occurs at Adams (Jefferson County); near Turin (Lewis County) and at Middleville. Among its western localities, Cincinnati and Oxford, Ohio, Maysville, Kentucky, and Madison, Indiana, are the most important."

Trenton, Ordovician.

The general appearance of the specimens figured in Plate XXXI strongly suggests the Upper Ordovician form, L. richmondensis FOERSTE, which will be fully discussed later, and the western Hudson River localities are in the very region which furnished the type specimens of that species.

Recently, Rudolph Ruedemann (N. Y. Museum Bull. No. 24) has reported the occurrence of "L. rhomboidalis" from the Trenton Conglomerate of Rysedorph Hill, and in his account, refers to Hall's description of 1847. Up to the present time, unfortunately, his specimens have not been available for study, as recent changes in the disposition of the geological material in the N. Y. State Collection at Albany have rendered them inaccessible.

Under the circumstances, then, the most that can be said is that, to me, "L. rhomboidalis" from the Trenton of America seems most closely related to L. richmondensis FOERSTE (See page 29), and should probably be regarded either as stunted specimens or as a variety of that species.

LEPTAENA TENUISTRIATA SOWERBY ?

Uppermost Mohawkian, Middle Ordovician.

For more than fifty years attempts to correlate American Ordovician forms of L. rhomboidalis with Sowerby's L. tenuistriata have been made. The most recent is that of A. G. Foerste (Denison Univ. Scient. Lab. Bull., June, 1910), who reports finding a single pedicle valve which approximates the appearance of Sowerby's form in the Saltillo bed at Clifton, Tenn.

The shell is quadrate with the concentric wrinkles approaching the hinge-line nearly at right angles and with no conspicuous extension of the shell. The main body of the pedicle valve is comparatively flat, the geniculate border bending abruptly downward. The striae (14 in 4 mm.) are sharp and are separated by grooves equal in width to the striae. The shell, with a length of 11.5 mm. and a width of 18 mm. is relatively shorter and broader than in the figure of the type specimen, and Foerste only says that while not identical, it approaches more closely the form than the distinct Ordovician species L. richmondensis.

Obviously, in a shell of so variable a nature, too much significance can not be placed upon the character-

Uppermost Mohawkian, Middle Ordovician.

istics of a single valve, and since Dr. Foerste has not reported further specimens, my opinion still is that the occurrence of Sowerby's species, L. tenuistriata, in America has not yet been demonstrated.

Table of Sub-Divisions.

Lower Cincinnatian	Utica	Fulton
		Nicholas
	Cynthiana	Greendale
		Perryville
Upper Mohawkian	Lexington	Paris
		Wilmore
		Logana
		Curdsville=Saltillo

From D. U. S. L. Bull., 1910.

LEPTAENA GIBBOSA JAMES.

Eden, Upper Ordovician.

This species, described by James in the Cincinnati Quarterly Journal of Science, Vols. 1 and 2, 1874-5, is semi-oval in shape, with the cardinal line extended to or somewhat beyond the width of the shell further forward, and is deflected at the extremities, with the lateral and front margins regularly rounded. The width of a specimen of medium size, at the hinge-line, is 29 mm.; the length, 19 mm. Striae are very narrow and inconspicuous (20--26 in 5 mm. at deflection), with the exception of those in the median line, which are regularly more pronounced.

The ventral valve is slightly convex in the umbonal region; but at a third or a half of the distance from the beak to the anterior margin, it curves suddenly upward, rounds off, and then is abruptly deflected downward, forming a high rounded ridge which gives to the shell a decidedly gibbous form. From six to eight slight wrinkles can be observed on the umbonal region.

The dorsal valve is gently concave to about the middle, where it makes a sudden curve to conform to the shape of the other valve. The two valves are so closely compressed as to leave scarcely any visceral space.

Eden, Upper Ordovician.

Specimens of this shell occur in the Economy member of the Eden.

In general, the shell of L. gibbosa is much thinner, the concentric wrinkles fainter, the striae finer, and the umbone less pronounced than is the case in the more or less closely associated Richmond form, L. richmondensis (See page 29).

L. GIBBOSA var. INVENUSTA FOERSTE.

Foerste in the Denison University Scientific Laboratory Bulletin, Vol. XIV, has erected this variety on the following basis:

> "Width along hinge-line about thirty millimeters, the postero-lateral parts of the shell being broken away, the width is an estimate. Fourteen millimeters from the beak, the anterior part of the pedicle valve is geniculately deflected almost vertically for a distance of six millimeters. The general surface of the valve is gently convex. The concentric wrinkles characteristic of this genus are almost obsolete, being faint but close together. About fifteen radiating striae occur in five millimeters along the anterior margin and the middle one is slightly more prominent. The remainder are uniform and separated by very narrow spaces.
>
> "Compared with L. gibbosa JAMES, the shell material of each valve is thicker, the striae are more nearly uniform in size, and there is no concentric depression immediately posterior to the geniculate border, which is shorter.

Eden, Upper Ordovician.

> Moreover in L. gibbosa, the spaces between striae are relatively wider, especially along the the median parts of the pedicle valve."

The occurrence is in slightly lower strata than the species itself, perhaps in an upward extension of the Fulton horizon.

Plate I.

L. gibbosa var. invenusta Foerste. (See page 24.)

Eden, Upper Ordovician.

(Denison University Scientific Laboratory Bulletin, Vol. XIV, Plate I, Fig. 5 B.)

Lower Cincinnatian.

L. gibbosa appears to be the distinct form of the early Cincinnatian; but with regard to the variety "invenusta," it seems questionable whether it is of much value to any save so specialized a field-worker as its author.

Leptaena unicostata MEEK and WORTHEN from the Lorraine and Richmond of Illinois and farther northwest has, for some time, been separated from the L. rhomboidalis group. Here the median striation is much more conspicuous, and the concentric wrinkles are less conspicuous (often to the extent of entire absence) than in L. gibbosa and the absence of a strong concentric, curved elevation at geniculation is a noteworthy characteristic. FOERSTE.

LEPTAENA TENUISTRIATA, SOWERBY.

Caradoc of Wales.

> "Leptaena tenuistriata. Semi-cylindrical, closely striated, top of upper valve with twelve or more concentric rugae, convex, sides expanded. A shell much resembling L. depressa (=L. rhomboidalis) and about same size, but ornamented with much closer striae and of a thinner substance. Can this be the L. depressa of Swedish authors, and may our L. depressa be their L. rugosa?
>
> "Loc.---Marloes Bay; Narbeth, Pembrokeshire; also at Gaerfawr in the Caradoc sandstone of Montgomeryshire."

The foregoing characterization by James deC. Sowerby, in Murchison's Silurian System (1839), is the first description of an Ordovician form of L. rhomboidalis. This form is of especial interest, since Sowerby's name has been so persistently misused in this country to refer to shells with no point of resemblance to the type save geologic occurrence.

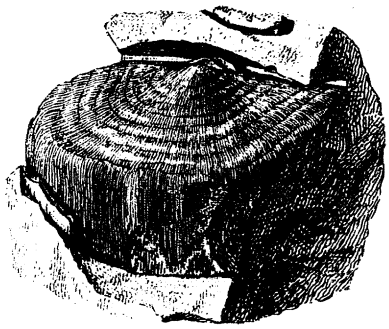
It is almost needless again to state that L. tenuistriata apparently does not occur in North America (see page 21, however), and I have no information as to its abundance in the Welsh localities. No specimens, moreover, have been found in the collection of the Museum of Comparative Zoology of Harvard University.

Twenhofel in Part 2 of the report on the Shaler

Caradoc of Wales.

Memorial Expedition to the Baltic Provinces (Bull. M. C. Z., Vol. LVI, No. 4, 1916) records the occurrence of "Strophomena" tenuistriata SOWERBY from the Lyckholm of Esthonia; but states, in a personal communication, that it was included on the authority of others.

Plate II.



The L. tenuistriata of Sowerby.

(See page 27.)

Caradoc, Ordovician of Wales.

(Murchison's Silurian System. Plate 22, Fig. 2 A.)

LEPTAENA RICHMONDENSIS FOERSTE.

Richmond, Upper Cincinnatian.

This species, first proposed by Foerste in "Preliminary Notes on Cincinnatian Fossils," Vol. XIV of the Denison Univ. Scientific Laboratory Bulletin, is unquestionably one of the most distinct and satisfactory races of L. rhomboidalis.

The shell is broad; the ventral valve is comparatively flat; and the geniculated portion, in most specimens, is neither bent abruptly nor very far prolonged. The concentric wrinkles, though distinct, are not numerous (5--8), are more or less discontinuous, and become less deep toward the beak. The striae (15--16 per 5 mm. at geniculation) are broad, with narrow intervening grooves, and resemble "pieces of cord in close juxtaposition." In many specimens, the anterior margin is slightly cleft or depressed in the median line.

The following measurements of typical specimens have been made:

Description of Specimens	Striae per 5 mm. at Geniculation	Breadth at Hinge	Length of Disk	Undulations
M.C.Z. Blue Limestone Oxford, Ohio.	16	24 mm.	13 mm.	6
	16	25 "	12 "	5

Richmond, Upper Cincinnatian.

Specimens	Striae	Breadth	Length	Undulations
Dyer Collection	16	31 mm.	19 mm.	4-6
M.C.Z.	16	28 "	17 "	6
Moore's Hill, Ind.	14	32 "	18 "	7
	13	35 "	17 "	5
M. I. T. No 2926 Madison Ind.	16	25 "	17 "	7

The species was figured by Meek as Strophomena (Leptaena) rhomboidalis var. tenuistriata, in part 2 of the Paleontology of Ohio, and by Hall as L. tenuistriata in Part VI, Vol. 1, Nat. Hist. of New York, 1847, and in the Pal. of N. Y., VIII, Pt. 1, 1892.

The typical form, as found by Foerste, ranged from the middle part of the Waynesville bed to the upper part of the Whitewater. In the Arnheim bed, however, a variety (L. richmondensis precursor Foerste) is said to occur, which has the top of the pedicle valve more convex, the anterior deflection less pronounced, and the concentric wrinkles less conspicuous.

In connection with his intensive study of the Richmond fauna, Dr. Foerste (Ohio Naturalist, Vol. XII, Jan., 1912, and Denison University Scient. Lab. Bull., Vol. XVII) has given considerable attention to the association of Dinorthis carleyi and Rhynchotrema capax with L.

richmondensis, with a view to determining the probable source of these forms, from which they suddenly migrated to Cincinnatian seas.

In the D. U. S. L. Bull., Vol. XVII, he says--

> "In determining the source of L. richmondensis geographically, it should be noted that it is associated in the Arnheim with Dinorthis -- and Rhynchotrema, and was apparently brought in from the same source which furnished these species, arriving a relatively short time before the latter. Then in the Waynesville member, Leptaena richmondensis again makes its appearance before Dinorthis carleyi, the latter arriving at the lower Herbertella insculpta horizon at the base of the Blanchester. Rhynchotrema dentata is seen farther up in the Blanchester division. . . . . .
>
> "Since none of this species (L. richmondensis) occur in the Mississippi valley, they do not appear to have entered Cincinnatian areas from the west. Since these three are unknown in the long stretch from Drummond Island to N. Y. state, they do not appear to have come in from the north. Rhynchotrema neenah from Wisconsin and Illinois is not sufficiently similar to R. dentata to indicate origin of this species from the north-west. Connection with the St. Lawrence valley and the east appears to be shut off by shaly and sandy Richmond deposits, practically unfossiliferous. This leaves a southern origin for that part of the Arnheim fauna here under discussion, notwithstanding that the nearest relative to Dinorthis carleyi is Dinorthis retrorsa of Wales."

However subject to errors of judgment and however disappointing the conclusions may be, it is surely to

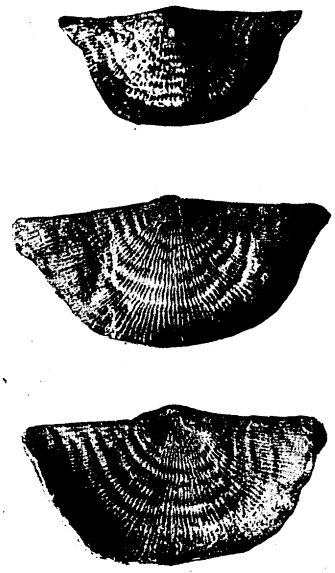
be hoped that such interpretations of the rise and migrations of "L. rhomboidalis" shall more and more frequently be made.

Table of Sub-divisions of Richmond Strata.

Richmond	Laughery	Elkhorn
		Whitewater
		Saluda
		Liberty
		Waynesville
		Blanchester
		Clarksville
		Fort Ancient
	Arnheim	Arnheim
		Oregonia
		Sunset

From Ohio Naturalist, Vol. XII, No. 3.

Plate III.



L. richmondensis precursor Foerste. (See page 30.)
Pedicle valve.
Lower Richmond.

L. richmondensis precursor Foerste. (See page 29.)
Pedicle and brachial valve.
(Bulletin Scient. Lab. of Denison University, Vol. XVII, Plate I, Page 141, Figs. 6 A, 6 B, and 6 C.)

LEPTAENA QUADRILATERA SHALER.

Gamachian, Ordovician-Silurian.

Shaler, in 1865 (Bull. M. C. Z., Vol. I, No. 3), described a shell of the L. rhomboidalis type from Anticosti, which was broadly semi-oval in general outline, and in which the undeflected portion of the ventral valve was retangular (the breadth equalling twice the length), somewhat convex and broadly rounded at the umbo, with distinct, fine, evenly-spaced, radiating striae, and about six concentric undulations. The dorsal valve was nearly flat and often with a mesial sinus.

He says-

> "This species may prove identical with the form from the Niagara group of New York, but there are several constant differences."

With regard to size, I find that most of the material which he brought back is composed of relatively small and uniform shells. The following measurements have been made:--

Description of Specimens	Striae per 5mm. at Deflection	Breadth at Hinge	Length of Disk	Undulations
M.C.Z. Shaler's Collection	20	22 mm.	14 mm	—
	18	18 "	12	—
Ellis Bay, Anticosti.	17	21 "	14	—
	19	22 "	13	—

Gamachian of Anticosti Island.

Specimens	Striae	Breadth	Length	Undulations
M.C.Z.	20	20 mm.	13 mm.	—
Shaler's Collection	21	18 "	12 "	8
	20	—	10 "	6
Ellis Bay, Anticosti.	19	—	—	8
	20	21 "	10 "	6
	20	20 "	12 "	7

According to Twenhofel (personal communication), the material with which I have had to deal most probably comes from zone 4 of the Ellis Bay formation, a horizon not easily correlated with others in this country. In "The Anticosti Island Faunas" (Canadian Dep't of Mines, Mus. Bull., No. 3), he says--

> "The faunas of the Ellis Bay formation are partly derivative from those of the previous formations, partly indigenous, and partly migrants from European seas. Most of the species consist of forms not elsewhere known in America, or not in a horizon so low as this. That there is a decided Richmond aspect is clearly evident; but the assemblage is not identifiable with that of any interior deposit. This suggests that the interior was free from marine waters, or that all paths permitting migration to the interior were closed."

Whatever the source of the Ellis Bay form, the general faunal characteristics uphold, then, the view that it is not closely related to the preceding Richmond form. With its compact shape and abrupt deflection,

L. quadrilatera is moreover the first distinct suggestion, on this continent, of the L. rhomboidalis stock which was to exist in the Silurian.

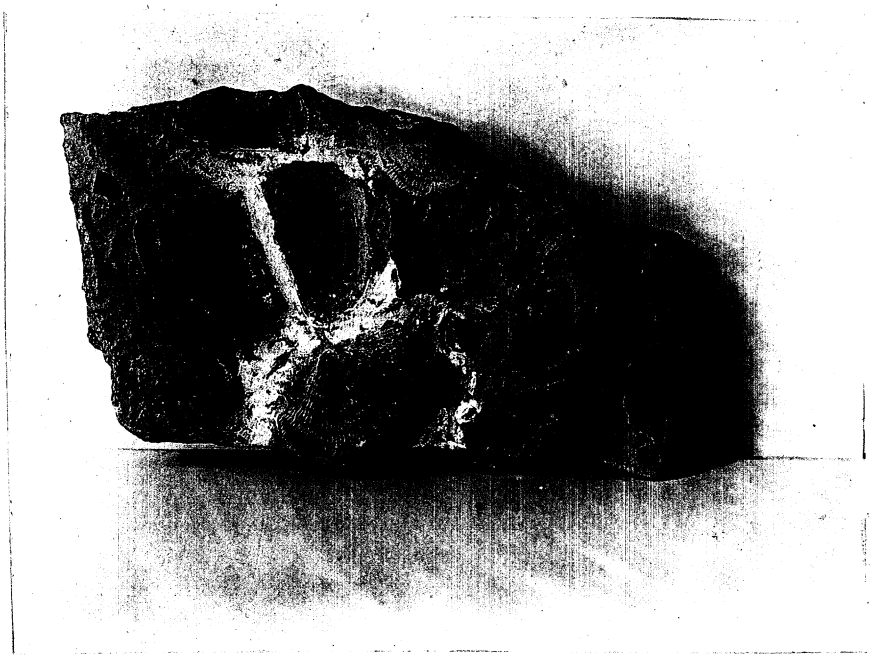
According to Dr. Twenhofel there is some variation in the specimens from various horizons of the Anticosti section; but from his descriptions it is difficult for one to obtain an adequate idea of the variation. He considers the largest specimens from the Ellis Bay similar to some of the normal Richmond forms, except (!) for more abrupt deflection and more striae per millimeter; and those of the Gun River formation (Silurian) to the shells from Gotland (Münthe's "marl shales with lenses and bands of limestone"). Though one or two very large Anticosti specimens (horizon unknown) I have seen, do possess the general form of the Gotland specimens, I have never felt warranted in pressing the comparison very far.

In conclusion, it seems that the forms from all horizons of Anticosti should be more thoroughly studied before L. quadrilatera be reinstated as a distinct species, though I am at present personally inclined to regard it as such.

Gamachian of Anticosti Island.

Three Anticosti species of Leptaena with which I am not acquainted are L. julia BILLINGS (Jupiter River), and L. nitens BILLINGS, and L. reticulata SHALER (both of the Richmond [Charle ton] and Gamachian [Ellis Bay]).

plate IV.



Slab of limestone from Anticosti, showing both dorsal and ventral aspects of the included shells. (See page 33.)

Gamachian of Anticosti.

Shaler Expedition.

SILURIAN PERIOD.

The classic description by Wilckens of L. rhomboidalis in 1768 is believed to be of so much historical interest and so inaccessible to most students that it, with the figures, is reproduced in the following pages, together with an English translation. For reasons which will presently appear, Wilcken's form is here considered to have been of Silurian age and hence entitled to the place of honor in this section.

Nachricht // von seltenen // Versteinerungen, //
vornemlich // des Thier-Reiches, //
welche // bisher noch nicht genau genug
beschrieben // und erklaret worden, //
mit kupfern.//

In drey Sendschreiben // an // seine
Gönner und Freunde // abgefasset//
von//
Christian Friedrich Wilckens //
Inspectore der Cotbusischen Dioces und //
Pastore Primario

Berlin und Stralsund
bey Gottlieb August Lange
1769.

Drittes Sendschreiben // an den // Hoherwürdigen und Hockgelahrten // Herrn // Herrn Johann Burchard // Gentznar // Pastorem Primarium und Propst bey der // Hauptkirche zu Stargard im Mechklenburgischen.

Hochehrwürdiger Gönner und Freund!

. . . . . .

(P. 77).

Noch nehme ich mir die Freyheit Ihnen ein paar Anomiten von besonderer Gestalt zur Beurtheilung vorzulegen. Der erste ist . . . . . .

(P. 78).

Und eben so wenig weisz ich Ihnen von dem andern, dessen ich jetzt gedenken will, etwas bey den Schriftstellern nachzuweisen.

Ich besitze zwei etwas verschiedene Exemplare, aber nur allein die grőszern Muschelhälften. Beyde haben eine gedoppelte Zeichnung erfodert, um Ihnen ihre Gestalt und natürliche oder bauchigte Grősze sehen zu lassen. Und weil denn auch hier eine Beschriebung

nicht ganz überflüssig seyn kann; so fange ich es mit der in der XLIII ten Figur bey A und B vorgestelten zu erst an.

Die noch natürliche aschgraue sehr dünne und mit einem gelben dichten kalksteine ausgefüllte Schale ist in diesem Exemplar, die beyden ungleichen Seitenflügel a und b mitgerechnet, einen starken Zoll breit. Vom spitzengeraden Schlosse angehen etwa eilf bis zwölf starke halbcirkel förmige dicht und zart in der Länge gestreifte Runzeln, die immer stärken werden, über dem etwas gewölbten halben Leib der Muschelweg. Ich sage den halben Leib; denn von diesem runzlichten Theil, der einem halben Zoll an Länge Beträge, und besonders von der letzen stärksten Runzel c--d gehet die andere Hälfte des Leibes unter einem fast rechten Winkel umgebogen mit einem mahl unter sich weg, und ist daselbst mit ihrer flachern zart in der Länge gestreiften Schale ebenfals noch einem halben Zoll lang. Die XLIII te Figur B wird dieses deutlich machen.

Das andere Exemplar dieses Anomiten, wozu die Figur XLIV A. B. gehöret, ist in der Hauptsache seinem eben gemeldeten Compagnon ganz ähnlich. Der Unterschied ist blosz dieser, dasz die natürliche Muschel-

schale hier weisz silberfarben ist, und dasz man wenigstens den einen Seiten-flügel nicht nur länger als bey dem vorhergehenden, sondern auch so gerunzelt, wie der halbe Leib selbst ist, sehen kann. In der Mitte dieser ersten Leibeshälfte habe ich etwa neun bis zehn Runzeln gezehlet. Bis ich einen geschicktern Namen für beyde Exemplare von Ihnen horen werde, will ich sie Conchitas Rhomboidales anomios inequilateros nennen. Vielleicht wissen Sie mir aber auch wohlgar das dazu gehörige Original nachzuweisen.

Da Stargard in Pommern mir dieses Petrefact hergegeben hat, sowunsche ich, dasz Stargard in Mecklenburgischen Ihnen auch schon dergleichen abgeliefert haben möge.

Yetzo aber erinnere ich mich, dasz kein Brief allzulange seyn müsse, ...

Dero

ganz ergebenster Freund

und Diener

C. F. W.

C. den 3 ten Aug.

1768.

An Account // of rare // Fossils // especially // of the Animal Kingdom // which // up to the present time have not been sufficiently accurately described and discussed // with plates.

In three Circular Letters to his Patron and Friend by Christian Friedrich Wilckens. Superintendent of the Diocese of Cottbus // and Head Pastor.

Berlin and Stralsund

[Printed] by Gottlieb August Lange 1769.

Third Letter // to the // very Reverend and Learned //
Johann Burchard Gentzmar
First Pastor and Provost at the Cathedral
at Stargard in Mecklenburg-Strelitz.

Very reverend Patron and Friend---

. . . . . .

(page. 77).

I take the further liberty of bringing to your attention a pair of Anomiten ( ) of peculiar form. The first is . . . . . I, at least, have not come across any figure or description of this Anomiten.

(page 78).

And just as little can I show you by [previous] authors on the other, of which I will now make mention.

I possess two somewhat different examples, but only [in both cases] the larger valve. Both have required two cuts in order to show you fully their shape and natural gibbose form. And since a description here, too, can not be wholly superfluous; I begin at first with A and B in the forty-third figure.

The very thin, natural-looking, ash-gray shell,

filled with a compact yellow limestone, is, in this specimen, a good inch wide, including the two unequal side-extensions "a" and "b." From the very straight hinge-line, some eleven or twelve strong, semi-circular wrinkles, which become more and more pronounced and are marked by close, fine, longitudinal striae, occur on the somewhat convex half of the valve. I say half; for from this wrinkled part, which is an half inch in length, and especially from the last and strongest wrinkle "c--d," the other half bends down abruptly almost at right angles to itself, and is there with its flatter, finely striated shell also another half inch in length. The forth-third figure B will make this plain.

The other specimen of this Anomiten, to which figures A and B XLIV belong, is in general closely similar to its companion, described above. The difference is merely this; that the shell is in this instance silvery white and that one can see one of the hinge-extensions to be not only longer than in the preceding, but also wrinkled just as is the convex half, itself. In the middle of this first part I counted nine or ten wrinkles. Until I shall hear of a more

suitable name for the two specimens from you, I shall call them Conchitas Rhomboidales anomios inequilateros. Perhaps you can show me, however, the original account of it.

Since Stargard in Pomerania furnished me with this fossil, I hope that Stargard in Mechlenburg-Strelitz may also have already furnished you some of the same.

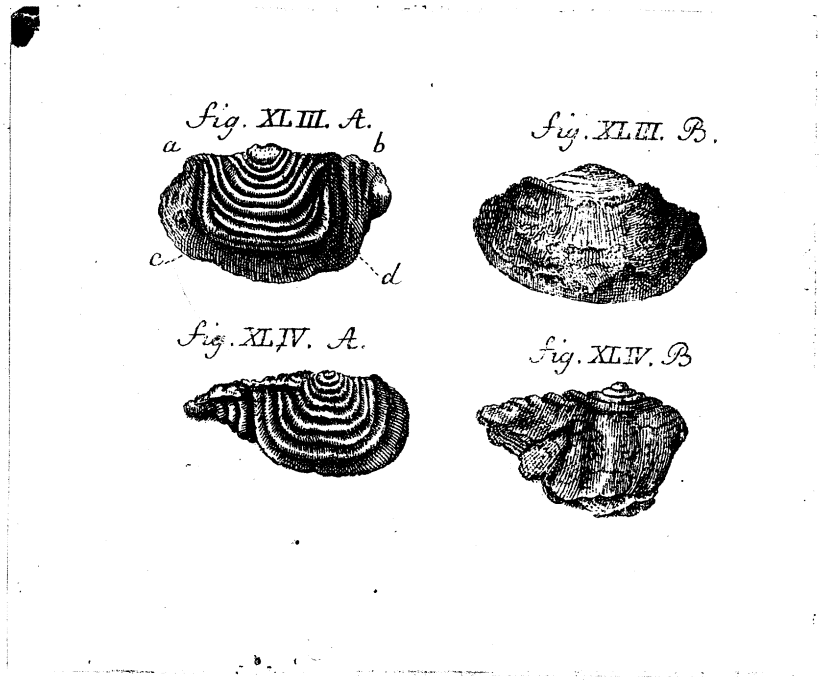
But now I remember that no letter should be too long, etc., etc., ...

Your humble friend and servant,

C. the 3rd August, C. F. W.

1768.

Plate V.



First known illustration of a Leptaena, the Conchitas rhomboidalis anomios in equilateros of Wilckens. References to figures in the text. (See pages 37 - 39.)

(C. F. Wilckens, 1769, Nachricht von seltenen Versteinerungen, Tab. VIII, Figures XLIII (A and B), XLIV (A and B).)

Silurian of Europe.

Fortunately, Wilckens saw fit to mention the region which furnished his specimens -- Stargard in Pomerania -- and as a locality where they might occur -- Stargard in Mecklenburg-Strelitz. Now, as far as I can determine, this band of territory bordering on the south-western shore of the Baltic has exposures largely of Tertiary, and none of Paleozoic, age. Almost beyond question, then, Wilckens' specimens of this Paleozoic brachiopod were culled from the glacial drift, which is known to have swept down from the northeast (Gotland) and still to exist as boulders scattered over the country side in eastern Prussia. That they were so badly weathered as the figures indicate would then be the logical expectation. That they may easily have been specimens from Gotland can further be deduced from a knowledge of the paths of glaciation, and from the suggestive appearance of the fossils themselves, one "asch. graue mit einem gelben dichten Kalksteine ausgefüllt" and the other "weisz silberfarben." A hundred or more specimens from that source which I have examined have held closely to the same appearance.

On the strength of this circumstantial evidence, since more direct can probably never be procured, I

propose therefore to regard Leptaena rhomboidalis as the type of Gotland form.

The next mention of this shell was in 1781 by A. Hüpsch in his Natürgeschichte des Niederdeutschlands, Volume I, page 15, pl. 1, fig. 7 & 8. This work has not been available and it has been assumed that, for the present purpose, probably nothing of interest is contained.

Then in 1821, Georgio Wahlenberg, in Nova Acta Upsaliensis, Vol. VIII, p. 65, definitely transfers Wilckens' specific name "rhomboidalis" to specimens from the island of Gotland.

He says--

> "7) Anomites rhomboidalis valvulis subquadratis radiatim striatis concentrice undulatis extrorsumque gibbosis, latere cardinis rectilineo latitudinem testae excedente. Wilcken Verstein, pl. 8, f. 43 A et 44 A. A.Hüpsch Naturg. p. 15, pl. 1, f. 7 et 8. Copiose inveniuntur tum in Gothlandiae et Dalecarliae calce exemplaria integra, tum in Westrogothiae shisto superiore pallido impressiones variae affinitate et magnitudine ad sequentum speciem proxime accedit; saepius duo pollices latus est.---"

Silurian of Europe.

Having previously determined pretty much to my own satisfaction that Wilckens' name was not pre-empted, I feel that Wahlenberg is here using L. rhomboidalis in its most correct sense; i.e. to refer to Gotland specimens.

The next Silurian form to be described was Producta depressa of Sowerby (Sowerby's Genera, and Sowerby's Mineral Conchology of Great Britain, 1823). The locality was given as the Dudley; i.e., Wenlock, Limestone of England, and the specific characters are as follows:

> "Nearly semi-circular, depressed, corrugated, longitudinally striated; upper portion convex near the beak, concave near the margin, front abruptly descending."

If these terms be somewhat general, Sowerby's plate (seen by me only in the later French edition) does away with any obscurity; for they are good Gotland forms, except only for the shorter deflected margin. Moreover, specimens from the Wenlock examined by me are practically undistinguishable from Gotland specimens, in every particular. This means that L. depressa is an exact synonym for the older L. rhomboidalis; but what is of

more interest, that in lower and middle Silurian times, the seas of both Britain and Gotland contained exactly the same form of L. rhomboidalis, as, of course, might be expected.

Hisinger, in 1826 (Acta. Acad. Sci. Holm., p. 333), proposed still another name, Producta rugosa, for a Silurian rhomboidalis from Gotland, which differed in certain respects from L. depressa, or, as seems more proper, L. rhomboidalis. His description has not been seen, but presumably the account by Dalman, which is here reproduced, is but an elaboration. This latter work is of great interest, since it not only contains descriptions of both L. rugosa and depressa, but also founds the genus Leptaena (see page 14).

UPPSTÄLLNING

OCH

BESKRIFNING

AF DE

I SVERIGE FUNNE

T E R E B R A T U L I T E R;

AF

J. W. DALMAN.

---o---

(Ur Kongl. Vet. Acad. Handlingar 1827).

STOCKHOLM,

Tryckt Hos P. A. Norstedt & Söner,

1828.

I. LEPTÆNA.

I. LEPTÆNA rugosa.

Tab. I. fig. I.

L. testa longitudinaliter striata, margine abrupte deflexo ampliatoque; disco plano semicirculari rugis concentricis rudibus.

°Producta rugosa HISINGER in Act. R. Ac. Sc. Holm. 1826, p. 333.

°Anomites rhomboidalis WAHLENBERG in Act. R. Soc. Upsal. Vol. VIII. pag. 65, n. 7. (cum L. depressa commixta.)

Locus: in calce Gottlandiæ ; in calce obscure cinerea Ostrogothiæ ad Borenshult; --- in Schisto superiore albo montium Vestrogothiæ , e. gr. in Mösseberg ad Betstorp, in Ålleberg, et in Fårdalaberget supra Kaflås.

Longit. 24 millim. latitud. 44 millim.

Species magnitudine forma atque sculptura nimis affinis Lept. depressæ, sed diversa disci rugis concentricis paucioribus (10--13) et multo crassioribus, præsertim vero margine apicali disci rotundato, nec ut in L. depressa truncato, unde totus discus semiorbicularis, cum in L. depressa revera rhomboidalis.

Striæ longitudinales subtiles, ejusdem fortitudinis et figuræ . Basis recta, latissima, angulis lateralibus plus minus productis, acutangulis. Margo abrupte deflexus, ruga

elevatiore a disco distinctus, omnino ut in L. depressa.

Observatu dignum videatur in schisto superiore montium Vestrogothiæ hujus speciei exemplaria numerosa esse obvia, nullum vero L. depressœ , unde distinctas esse species confirmatur.

2. LEPTÆNA depressa.

Tab. I. fig. 2.

L. testa longitudinaliter striata, margine abrupte deflexo ampliatoque; disco rhomboidali rugulis concentricis.

°Producta depressa SOWERBY Miner. Conchol. pag. 86. Tab. 459, fig. 3. (Figura minus bona.)

° --- --- Sow. Genera of foss. and recent. Shells. Gen. Producta, fig. 2.

° HISINGER in Act. R. Ac. Sc. Holm. anno 1826.

°Anomites rhomboidalis WAHLENBERG in Act. R. Soc. Upsal. Vol. VIII. p. 65, n. 7. (cum L. rugosa commixta.)

Locus: In Gottlandia, vulgatissima.

Longit 24 m. m., latit. 38 m. m.; -- crassit. ad testæ basin 3 m. m.; margo deflexus 16 -- 18 m. m. attinet.

Ocurrunt specimina margine plus minus ampliato, angulis marginis cardinalis plus minus productis, rugis concentricis, versus testæ basin plus minus curvatis, et. s. p. --- Variat etiam hæc species margine antico subrecto[28]), vel trisinuoso[29]).

Testæ margo cardinalis rectilineus, latissimus, angulis aliquantum productis acutangulis. Discus utrinque planus,

---

[28]) Ut in figur. Sow. Min. Conchol. l. c.

[29]) Ut in fig. Sow. Gen. l. c.

subrhomboidalis, rugis concentricis numerosis (circiter 13--15), sed parum elevatis,, exteriorem si excipias crassiorem, quæ limitem marginis deflexi et ampliati efficit. --- Striæ radinates numerosissimæ et confertissimæ , crassitudine et sculptura æquales, testæ et basin et marginem extimum attingentes. Rugæ transversales vero in margine deflexo haud continuatæ .

Plate VI.

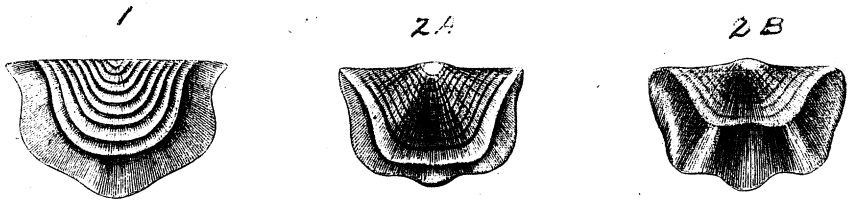


Figure 1. Leptaena rugosa Hisinger.

(See page 41 B.)

Figure 2 (A and B). L. depressa Sowerby.

(See pages 41 - 45.)

(Dalman, Kong. Vetenskaps. -- Acad. Handlingar,
Tab. 1, Figures 1, 2 A, and 2 B.)

Silurian of Europe.

Neither of these descriptions agree in all respects with the specimens from Gotland which I have seen, particularly with reference to the number of undulations, which is less in both forms than the number Dalman states, and more in agreement with Wilckens. A considerable variation among individuals in this respect occurs, however, many specimens of the so-called depressa possessing from 10--12 undulations, or again, practically none, with merely a few slight wrinkles indicated at the hinge line. A trilobation of the deflected margin (as indicated in Dalman's plate) is of very frequent occurrence, both in Gotland and in the Wenlock of England, and is of the more interest since nothing of the kind has ever been observed in American specimens.

Description of Specimens	Striae per 5mm. at Deflection	Breadth at Hinge	Length of Disk	Undulations
M. C. Z.	14	40 mm.	19 mm	Indistinct
Marl shales Fröjel Gotland. Coll. Twenhofel	14	38 "	19 "	8
	15	30 "	18 "	9
	13	30 "	18 "	8
	14	28 "	16 "	8
	15	29 "	19 "	7
	13	29 "	16 "	5
	12	28 "	16 "	Discontinuous
	14	28 "	16 "	10

Silurian of Europe.

Specimens	Striae	Breadth	Length	Undulations
M. C. Z. Wisby, Gotland. DeKoninckx Collection	11	24 mm.	16 mm	9
	13	32 "	20 "	10
	15	30 "	18 "	10
	14	22 "	17 "	8

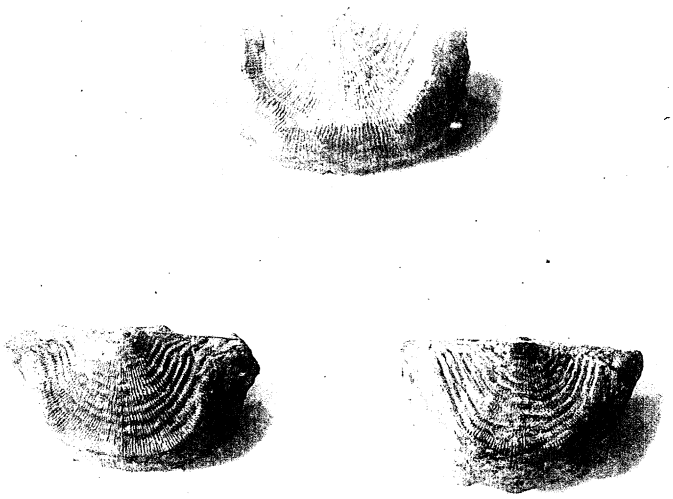
In all of these specimens, the undulation at deflection is most pronounced.

To my mind, Hisinger's species, L. rugosa, is of doubtful distinctness. Apparently it is an aberrant form, occasionally occurring more or less in the companionship of the more typical, with characteristics which intergrade. Certain specimens from Dr. DeKoninck's collection, and labelled by him, have a more rounded disk, fewer and stronger undulations, and a different form than "L. depressa," to be sure; yet careful study only serves to strengthen the opinion expressed above.

It would seem, then, that of three different specific names, used to denote Silurian forms, two (L. rhomboidalis and L. depressa) are unquestionably synon-

ymous, and the third (L. rugosa) is probably synonymous with the other two.

Plate VII.



Sowerby

L. depressa of Dalman. (See pages 41 A to 45).

Upper specimen showing absence of definite concentric undulations. Gotland, Twenhofel, Collector.

Lower left, a normal specimen of same species from same locality. Frojel Brickyard. Gotland.

Lower right, specimen of the same species from the Wenlock of England.

Silurian of America.

We now come to the difficult question: Do the American forms resemble the true L. rhomboidalis of Europe closely enough to be included legitimately in that species? This question is, so far as I am concerned, far from being answered. My feeling is, however, that points of dissimilarity tend to outweigh points of similarity, and I am positive that no general correlation of American Silurian forms can rightly be made with the L. rhomboidalis of Europe.

Hall and others, in this country, have had their L. depressa, L. rugosa, and their L. rhomboidalis, to be sure. That is why so much pains has been taken in this paper in dealing with the precedents which have arisen from previous European usage, and why so little has yet been done with American forms. If the answer to the above query be no, then at least one entirely new specific name will have to be proposed. But, whether the answer be yes or no, it would seem that this bit of antiquarianism has been of some avail.

Silurian of Anticosti.

Reference has previously been made (page 33) to the forms of Anticosti, especially from the earlier horizons. It has been thought advisable to describe briefly the larger shells from the later (Silurian) horizons, because of certain marked differences.

In these, the disk of the pedicle valve is nearly semicircular and hence less broad in proportion to length than in the sub-semicircular Gotland forms, which they do somewhat resemble. The concentric wrinkles are very pronounced, rounded, continuous, and constantly few in number (4 to 6), with none of the fluctuations observable in Gotland material. The striae are coarse (9-10 in 5 mm. at geniculation), very distinct, and with interspaces equal in width to the striae. The deflection is abrupt and moderately deep (10 or more mm.) for shells of their size (breadth of disk 20 mm., of ventral valve 30 mm.; length of disk 12 mm.)

Lower Silurian of New York.

Certain shells from the lower Silurian of the eastern United States, as figured and described by various authors, seem in general to have the compact, semi-circular form, the few, distinct corrugations, and the pronounced striae, typified by the Anticosti specimens, yet they are never as perfect nor of as normal an appearance as the latter. (See pl. 20, Weller, Pal. N. J., Vol. III)

Hall (Nat. Hist. N. Y., Pt. 6, Pal., Vol. 2, 1852), in discussing the Clinton forms, says that he finds even these imperfectly developed and distinctly inferior to the succeeding Niagara specimens.

Middle Silurian of New York.

The "L. rhomboidalis" of the Niagaran Group does not appear to consist of a single type, but of at least two strains.

One is evidently a vigorous form arising from the stock of the preceding Clinton and Lower Silurian rocks. The shells are semi-oval or semicircular with the hinge often somewhat produced into ears, with strong concentric undulations (6-8), abrupt deflection, and prominent striae. (See N. H. of N. Y., Part VI, Pal., Vol. 2, pl. 53)

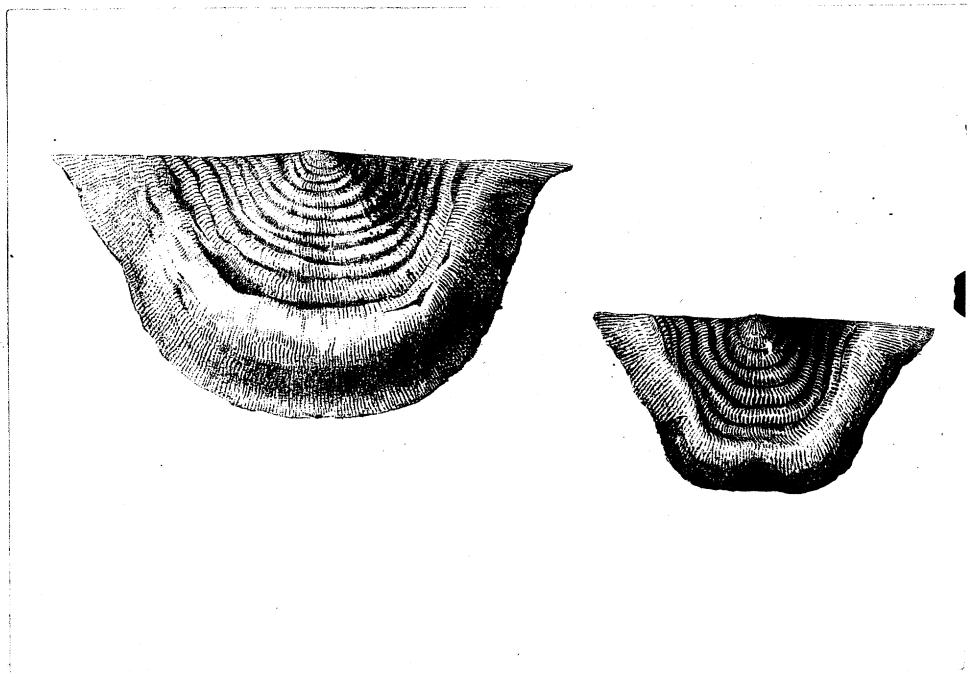
Middle Silurian of New York.

The other is typified by shells of very large size, extreme broadness, and a greatly increased number of undulations, which are distinct but less prominent and accentuated than in the preceding. Several specimens from Rochester, N. Y., occur in the collection at Harvard. The increase in wrinkles is significant, for it is the earliest presentiment of the highly undulated forms of the Devonian and Mississippian, of which I know; and the enormous size and great breadth are departures from what had gone before.

Specimens	Striae per 5mm. at Deflection	Breadth at Hinge	Length of Disk	Undulations
M.C.Z. Niagara Group.	10 - 11	60 mm	26 mm	14 +
Rochester N.Y.	12 - 13	52 "	24 "	16 +

Only with access to very large local series, as in the New York State Collections, could these Middle Silurian forms adequately be treated; and it is earnestly to be hoped that such a study may eventually be undertaken.

Plate VIII.



Niagaran shells figured by Hall, in 1852, as L. depressa. (See page 47.)

(Paleont. of N. Y.; Vol. II, Pl. 53, Fig. 6 F and 6 E.)

DEVONIAN PERIOD.

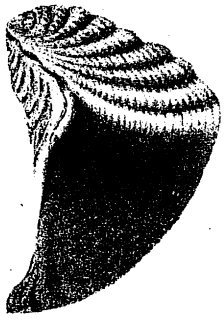
Helderbergian of the Lower Devonian.

In the New York strata, several forms of "Leptaena rhomboidalis" here occur, of which it is impossible to determine the distinctness without careful observations on their occurrence in the field.

First, if material in the Technology collection be correctly labelled, shells occur which closely resemble the auriculated Niagaran form with few wrinkles, previously mentioned; and I see no reason why that race could not have persisted.

The Delthyris shaly specimens constitute a second distinctive type. In these, the wrinkled disk of the pedicle valve is extremely convex and the very long deflected portion curves noticeably under the disk in continuation of the convex profile. The undulations are strongly elevated, continuous, circular, distributed over the entire disk, and are from nine to ten in number. The striae are sharp, even, and occur eleven in five mm. at deflection.

Plate IX.



Profile view of a strongly geniculated specimen, showing the contour of the two valves. (See page 49.)

Lower Helderberg, Albany and Schoharie Co., N. Y.

(Nat. Hist. of N. Y.; Part I, Vol. VIII, Plate VIII, Fig. 21.)

Lower Devonian.

In the 10th Report N. Y. State Cabinet Nat. Hist., 1857, p. 55, James Hall described and named a gibbose variety of the Oriskany sandstone of New York and Maryland. Much more recently (1903) it has been reported from New Jersey by Weller: The pedicle valve is said to be very convex or ventricose and because of this convexity to be scarcely geniculate in front. The wrinkles are broad and pronounced. The brachial valve is very concave and very coarsely marked. Not having seen this form -- Leptaena rhomboidalis var. ventricosa Hall,-- I am unable to determine its relationship with the convex Delthyris shaly form. In view of the large number of accompanying ventricose species (Platyceras ventricosum, Diaphorostoma ventricosa, Renssaellaria subglobosa, etc., etc.,) it would seem that the Oriskanian habitat exerted a profound influence upon some of its fauna.

A fourth type, perhaps, consists of specimens in which the disk is lengthened anteriorly and covered with from 12-14 evenly undulating wrinkles and less distinct striae. A fine series of these forms is described by Weller in the Paleont. of N. J., Vol. III. In the Coeymans limestone, where they are not common, the

Lower Devonian.

specimens are compact and may be 24 mm. wide, and 17 mm. long. These seem to lead to Conrad's form.

Middle Devonian.

Conrad (5th Annual Rep't N. Y. Survey, 1841, p. 54), described a form, occurring at Schoharie, Horizon 20, with profound concentric grooves and crowded radiating striae, which differed "from L. rugosa in its simple convexity and more numerous undulations;" and proposed the name L. undulosa. Unfortunately, from his description, it does not seem possible positively to identify his species, which might be the Delthryis form or, more probably, the anteriorly elongated one. Since Vanuxem, however (in Nat. Hist. N. Y., Geol. 3rd District, page 139, fig. 3), specifically refers L. undulatus to the latter, Conrad's specimens are so referred. Of the two races, occurring in the Corniferous, according to Vanuxem, one, the undulated Leptaena, differs particularly in having even as many as eighteen ridges on the disk.

I do not find this number at all constant, though it is regularly more than ten or twelve; but the wrinkles do possess a well-defined character. In addito the greater length in proportion to the breadth of the disk, these ridges are sharply edged, particularly at

Middle Devonian.

geniculation, and the anterior slope of each wrinkle is longer and more gradual than the corresponding posterior one.

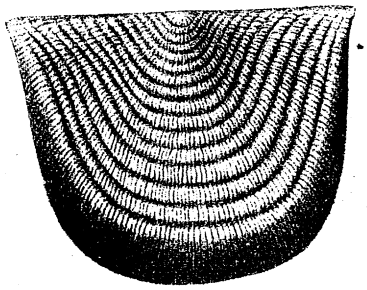
Delthyris shaly form.

Specimens	Breadth at Hinge	Length of Disk	Striae per 5mm at Deflection	Undulations
M.C.Z. Delthyris Schoharie N.Y.	28 mm	20 mm	11	9
	30 mm	20 mm	10	9
	40 mm	22 mm	9	10

L. undulosa of the Corniferous.

Specimens	Breadth	Length	Striae	Undulations
Onondaga Waterville N.Y.	28 mm	21 mm	14	—
	30 mm.	20 "	16	—
Onondaga Marshall N.Y.	26 mm.	18 mm	15	—
	25 mm	17 "	14	—

plate X.



Exterior of a pedicle valve, anteriorly elongate, with very numerous undulations.

The L. undulosa of Conrad (L. undulata of Vanuxem), from the Carboniferous limestone of Western New York.

(See page 51.)

(Natural History of N. Y.; Part I, Vol. VIII, Plate VIII, Figure 29.)

MISSISSIPPIAN PERIOD.

Waverly.

With the passing of the Waverlian seas, brachiopods of the L. rhomboidalis type became extinct throughout the world. It is in vain, however, that one looks for a last extravagant expression of the "élan vital." Conservative through life, they are conservative at death.

Leptaena analoga Phillips.

In 1836, in his Geology of Yorkshire, Phillips was the first to describe a Leptaena from the Mountain Limestone, which he believed might be really different from L. depressa. In it, the corrugations were much more numerous and less even, the striae less equal, and "the whole less neat." The Mississippian form has ever since been extensively known, both in England and on the Continent, as L. analoga Phillips.

Though Waverlian specimens of "L. rhomboidalis" have been repeatedly reported in this country, Weller, in 1914, in his Mississippian Brachiopoda, was the first to refer these to Phillips' name. He describes specimens from the Kinderhook and Lower Burlington much more

in detail than they can be treated here.

The shell is of medium size or larger, sub-trapezoidal in outline, the greatest width at the hinge. Dimensions of a nearly perfect specimen were: length, 25 mm.; breadth at hinge, 40 mm.

The pedicle valve is depressed convex at the umbo; flattened anteriorly toward the margin of wrinkled disk, where it is abruptly geniculate, the deflected portion variable in length with age. The geniculate border is often distinctly raised, especially in the median line. A shallow mesial sinus in the deflected portion may give it a sinuous appearance. The brachial valve possesses no especially distinctive characteristics.

The surface markings of both valves consist in a series (15-20) of conspicuous undulating corrugations, covering the entire surface of the disk, which are often discontinuous and anastomosing and are crossed by fine, rounded, radiating striae (18-20 in 5 mm. at deflection). Weller.

Phillips' figure of this species was a product of his own pen, and though pleasing enough in appearance, is very general in its characters; and Weller was careful to state that he had had to establish the apparent

identity on the basis of the later figure of Davidson. Though several other Carboniferous species have been described in England, Weller seems to have been correct in his correlation.

Leptaena convexa Weller.

Certain forms from the Kinderhook have seemed distinctive enough to Weller to warrant a new species name, L. convexa. He says of these:

> "This species differs from L. analoga in the absence of the distinctly flattened posterior region which passes into the anterior and antero-lateral border by an abrupt geniculate deflection of the valves; for, instead of this, the valves are more regularly curved throughout, the surface curving somewhat more rapidly towards the margin instead of being deflected. Upon this species, the fine radiating costae are also more strongly and more regularly developed, although no broader; the concentric corrugations are less deeply impressed and a little less regular in their development, and the fine concentric markings are more conspicuous. In their occurrence, the two species are not associated together in the same fauna, and the present species is less commonly seen than is L. analoga."

The type of convexity above described is exactly analogous with that of the Delthyris shaly form.

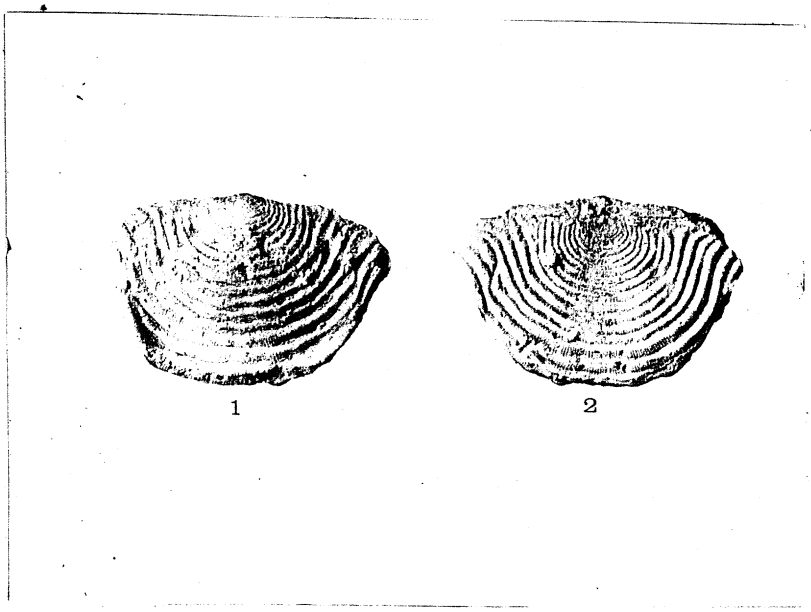
A powerful commentary upon the treatment which the races of L. rhomboidalis have in the past received, lies

Waverly.

in Weller's own remarks on specimens of this species, in 1901 (Kinderhook Faunal Studies, Acad. Sci., St. Louis, Vol. XI).

> "Needs no comment, being similar to those occurring elsewhere." "Not abundant. Does not differ essentially from the ordinary form of this cosmopolitan species."

Plate XI.



1 2

Pedicle and brachial valves of a nearly complete specimen of L. analoga Phillips. (See page 53.)

Walker Museum, University of Chicago, No. 4696.

Fern Glen formation,

Kinswick, Missouri.

(Ill. State Geol. Survey. Miss. Brachiopoda, Plate II, Fig. 1 & 2.)

CONCLUSIONS.

1. The use of the name Leptaena rhomboidalis Wilckens to refer to all shells of a certain general type is unsound and has been the outgrowth of careless observation.

2. Shells of this L. rhomboidalis type, when they have been thoroughly and intelligently studied, have usually been found to be capable of classification into many distinct races.

3. Sources of difficulty which have delayed such classification are:

    a. Individual variation.

    b. Environmental effects.

    c. The magnitude of the geologic time involved.

    d. Careless and misleading statements existing in the very extensive literature.

4. Such classification is of great importance; not for species' sake, but for the invaluable aid to generalization and to theory, which an accurate knowledge of so long-enduring, cosmopolitan a group could not fail to give.

5. Since the present paper has aimed, primarily, to dis-

cuss those races already reported, and, secondarily, to indicate such forms in this country as are suspected of racial distinctness, the real classification, the exhaustive study, and the subsequent erection of new species rests largely with future workers.

BIBLIOGRAPHY.

NOTE.---The following are the most important of the many references consulted and represent but a small portion of the enormous bibliography of this group. Whenever more detailed references are desired, consult:

DAVIDSON, Brit. Foss. Brach., Vol. II, 1859.
(for early English and European accounts.)

SCHUCHERT, Syn. Amer. Foss. Brach., Bull. U. S. Geol. Survey, 1897.
(American forms, principally.)

BASSLER, Bib. of Ord. and Sil. Fossils, Bull. Nat. Mus., 1916.
(very complete and up-to-date.)

1769 Conchita rhomboidalis WILCKENS. Nachricht von seltenen Versteinerungen. p. 79, pl. VIII, fig. 43, 44.

1781 A. HÜPSCH Natürgeschichte des Niederdeutschlands, Vol. I, p. 15; pl. 1, fig. 7 & 8.

1821 Anomites rhomboidalis, G. WAHLENBERG. Nova Act. Soc. Sci. Upsalae, Vol. VIII, p. 65.

1823 Producta depressa. J. SOWERBY. Mineral Conchology, p. 86, pl. CCCCLIX, fig. 3.

1826 Producta rugosa. HISINGER. Acta Acad. Sci. Holm., p. 333.

1828 Leptaena rugosa and L. depressa J. W. DALMAN. Kong. Veternskaps-Acad. Handlinger, pp. 94-96, 106, 107; pl. I.

1836 Leptaena analoga PHILLIPS
Geol. of Yorkshire, p. 215, pl. VII, fig. 10.

1837 Leptaena rugosa HISINGER
Lethaea Suecica, p. 69, pl. XX, fig. 2 and 3.

1839 Leptaena tenuistriata and L. depressa.
J. DeC. SOWERBY. In Murchison's Silurian System, pp. 623, 636, etc., etc., pl. XII, fig. 2, and pl. XXII.

1841 Strophomena undulosa CONRAD
5th Annual Report, N. Y. Geol. Survey, p. 54.

1842 Strophomena undulata VANUXEM
Geology of N. Y.; Rep't. of 3rd District, p. 139, with fig.

1844 Leptagonia McCOY Synopsis of the Carboniferous Fossils.
Several forms not elsewhere mentioned are here discussed.

1847 L. tenuistriata (of the Trenton) HALL. Pal. N. Y., Vol. I, p. 108, pl. XXXI A.

1852 HALL Pal. N. Y., Vol. II, pp. 62, 257, pl. XXI, fig. 3; pl. LIII, fig. 6.

1857 Strophomena depressa var. ventricosa HALL 10th Rep't. N. Y. State Cab. Nat. Hist., p. 55.

1859 Strophomena rugosa var. ventricosa HALL Pal. N. Y. III, p. 417, pl. 94, fig. 2 & 3.

1859 DAVIDSON Brit. Foss. Brach. (see above)

1865 L. quadrilatera SHALER Bull. M. C. Z. No. 4, p. 65.

1874 L. gibbosa JAMES Cincinnati Quart. Jour. Sci., I, p. 333.

1875 Strophomena tenuistriata (=L. richmondensis Foerste) MILLER Ibidem, II, p. 55.

1892 HALL and CLARK. Genera of Paleozoic Brachiopoda, N. H. of N. Y., Pt. I, Pal., Vol. VIII, p. 276.

1897 SCHUCHERT Amer. Foss. Brach. (See above.)

1902 WELLER Geol. Survey of N. J. Pal. Vol. III, Paleozoic Faunas.

1909 L. richmondensis and L. gibbosa invenusta A. G. FOERSTE Denison Univ. Scient. Lab. Bull., Vol. 14.

1910 L. tenuistriata ? FOERSTE D. U. S. L. Bull., June.

1912 L. richmondensis FOERSTE D. U. S. L. Bull., Vol. 17.

1916 BASSLER. Bibliography of Ord. and Sil. Fossils. Nat. Museum. (See above).